Condensed Abstracts of the Technical Papers to be Presented at the

58th ANNUAL TECHNICAL MEETING OF THE INDIAN INSTITUTE OF METALS

Trivandrum
November 17-19, 2004
## Contents

*Name of the Sessions / Topics*  

<table>
<thead>
<tr>
<th>Name of the Sessions / Topics</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron Steel – I, II and III</td>
<td>A3</td>
</tr>
<tr>
<td>Process Modelling &amp; Automation</td>
<td>A13</td>
</tr>
<tr>
<td>Secondary Processing (Ferrous)</td>
<td>A16</td>
</tr>
<tr>
<td>Emerging Technologies</td>
<td>A20</td>
</tr>
<tr>
<td>Non-ferrous Extraction</td>
<td>A23</td>
</tr>
<tr>
<td>Non-ferrous Alloys</td>
<td>A28</td>
</tr>
<tr>
<td>Secondary Processing (Non-ferrous)</td>
<td>A34</td>
</tr>
<tr>
<td>Aerospace Materials</td>
<td>A37</td>
</tr>
<tr>
<td>Microstructural Engineering - I and II</td>
<td>A41</td>
</tr>
<tr>
<td>Mechanical Behaviour - I and II</td>
<td>A47</td>
</tr>
<tr>
<td>Modelling &amp; Simulation</td>
<td>A54</td>
</tr>
<tr>
<td>Advanced Materials &amp; Processes - I and II</td>
<td>A57</td>
</tr>
<tr>
<td>Composites</td>
<td>A65</td>
</tr>
<tr>
<td>Corrosion &amp; Surface Engineering</td>
<td>A68</td>
</tr>
<tr>
<td>Environment &amp; Recycling</td>
<td>A72</td>
</tr>
</tbody>
</table>
VISION 2020 OF INDIAN STEEL INDUSTRY – POTENTIALS AND STRATEGIES (Lead Lecture)

S.K. Gupta
Jindal Vijayanagar Steel Limited
Vidyanagar – 583275, Karnataka
Email: gupta_sk@satyam.net.in

Vision 2020 triggers the pursuit of India to become a developed nation. At below 400 kg per capita steel consumption no country gets an entry there. From a base of 32 kg, the mission seems to be impossible. But many nations had consistently doubled their steel production and demand for decades. The paper attempts to provide a path breaking blueprint.

AN OVERVIEW OF THE STAINLESS STEEL INDUSTRY (INDIA/INTERNATIONAL) AND ITS GROWTH TRENDS AND POTENTIAL (Lead Lecture)

Mrinmoy Roy
Executive Director
Salem Steel Plant, Salem

The Twentieth century alloy - as it is popularly referred to, Stainless Steel made its entry into the world of alloys just under a hundred years. The versatility of Stainless Steel lends itself to a wide spectrum of uses ranging from kitchenware to creative expressions in architecture- from injection needless to nuclear reactors.

DEVELOPMENT OF PROCESS TECHNOLOGY FOR PRODUCTION OF ALLOYED PIG IRON IN BLAST FURNACE USING CHROMITE OVERBURDEN

*MECON Limited, Ranchi, **Director, Jindal Stainless Limited, Hisar, #KIWL, Barbil, Orissa
Email: metwing@mecon.co.in

Industrial trial for production of Ni-Cr bearing pig iron was conducted in blast furnace of IKIWL, Barbil using 25% to 50% chromite overburden sinter in the burden. During three days trial 250 tonnes of alloyed pig iron having Ni in the range of 0.39-0.9% has been produced successfully first time in the country using the waste from chromite mines.

PACKED BED REDUCTION OF IRON ORE-GRAFITE COMPOSITE PELLETS

G.M. Chowdhury, G.G. Roy and V.K. Mishra
Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Kharagpur-721 302
E-mail: groy@metal.iiitkgp.ernet.in

To simulate the reduction of ore, coal composite pellets in actual shaft type furnace under reactive atmosphere, preliminary experiments were conducted in a tailor made thermo-gravimetric packed bed reactor under inert argon atmosphere in the temperature range 800°C to 1100°C. The lower activation energy estimated (30.3 kJ mol⁻¹) for the reduction process suggests that the reduction in packed bed reactor may greatly be influenced by heat transfer.

DEVELOPMENT OF SELF-FLOW CASTABLE FOR SUSTAINING HIGH BLAST TEMPERATURES AT BLAST FURNACES

*RDCIS, SAIL, Ranchi-834002
**Bokaro Steel Plant, SAIL, Bokaro-827001
E-mail: bko_rdcishsl@sancharnet.in

To improve performance and reduce refractory failures (red hot spots) of tuyere stocks, conventional castable has been replaced by self-flow low cement castables. The self flow characteristic ensures no voids and flaws during casting. It has high resistance to wear against passage of hot air. A high hot blast temperature of 1030°C could be withstood with the modified tuyeres stock assembly.

IMPROVEMENT IN PERFORMANCE OF COKE SCREEN AT COKE SORTING PLANT OF RSP

*RDCIS, SAIL, Ranchi-834002
**Rourkela Steel Plant, SAIL, Rourkela-769001
E-mail: mt@sail-rdcis.com

Size analysis of coke samples showed improvement in screening of nut and breeze coke size fraction (-25 mm) in BF coke. With earlier screen the percentage of nut and breeze coke size fractions in BF coke was 3.9-9.3%, where the same is found to be 1.8-2.7% with the new screen material. Also the size measurement of screen hole carried out after 3-4 months of use has indicated no increase in the size of hole. This is due to the improved wear and corrosion resistant properties of the new steel.
CONTROLLING THERMAL REGIME 
OF COKE OVENS – A NEW METHOD 
S. Mazumdar*, P. Mazumdar** and M.S. 
Sengupta* 
*RDCIS, SAIL, Ranchi, 
E-mail: rdcisdsp@sail-rdcis.com 
** Durgapur Steel Plant, SAIL, Durgapur-713203 
In the carbonization process; demand-oriented heat flow is of paramount importance to conserve energy, ensure coke quality, reduce pollution and increase service life of Coke Ovens. Conventional ways of heating control does not fulfil the above requirements. In view of this, supervisory control and data acquisition system introduced in Coke Oven Battery # 1, DSP. The system has been successfully implemented and is in regular use for controlling the heating regime.

PRODUCTION OF QUALITY BURNT 
DOLOMITE THROUGH ROTARY 
KILNS 
Gyanesh Jha, S. Roychowdhury, R.K. 
Mukherjee and R.C. Shrivastava 
SAIL, Bhilai Steel Plant 
Bhilai – 490001 
Burnt dolomite is used for fettling of Twin Hearth Furnaces (THF) of Steel Melting Shop –I of Bhilai Steel Plant. This paper deals with the production of burnt dolomite in Rotary Kilns and steps taken to improve the quality of burnt dolomite, which has led to minimizing the procurement of Dead Burnt Magnasite thereby improving the profitability of Bhilai Steel Plant. A saving of Rs. 7.34 Crores per annum by way of reduction in procurement of costly Dead Burnt Magnasite and reduction in refractory consumption is anticipated. Also an increase in production of burnt dolomite by 20% could be achieved.

PROCESS IMPROVEMENT MEASURES 
AT PELLET PLANT OF JINDAL 
VIJAYANAGAR STEEL LIMITED 
D.L. Saralaya, Suresh Kumar and M.Prabhu 
Jindal Vijayanagar Steel Limited, Vidyaganj – 583275 
E-mail: shyam.sunder@jvsl.com 
Performance improvement measures in operation maintenance and introduction of innovation like use of high ultra fine raw material coupled with high aluminous characteristics, use of organic binders and the hyper activation of bentonite to bring about reduction in gangue content, Corex sludge addition as carbon bearing material along with BOF sludge, etc, JVSL has surpassed its rated capacity of 3 mtpa and has produced 3.25 mt in 2003-04 with improved quality and reduced operational cost. This plant has been upgraded to 4.2 mtpa in May 2004.

IMPROVEMENT IN IRON ORE 
PELLETS QUALITY 
D. Srinivas, T. Uma Devi, M. Prabhu and 
S.S. Gupta 
Jindal Vijayanagar Steel Limited, Vidyaganj – 583275 
E-mail: shyam.sunder@jvsl.com 
With increasing level of alumina in iron ore fines feed for pelletisation process, critical properties like reduction degradation index has been deteriorating. Pellet size was optimised and + 10 – 12 mm fraction was increased by control of pelleting process and screening. Further, pilot scale studies with different basicities of pellets have shown that increase of basicity to 1.2 from present level of 0.5 would significantly improve pellet quality.

OPTIMISATION OF COAL BLEND FOR 
COREX 
P. Prachethan Kumar, T.K. Naha and S.S. 
Gupta 
Jindal Vijayanagar Steel Limited, Vidyaganj – 583275 
E-mail: shyam.sunder@jvsl.com 
COREX process has been developed as an alternative to Blast Furnace and it uses non-coking coal unlike coke in blast furnace as a fuel. Based on the use of several coals in COREX at JVSL, it was established that coals with superior Char Strength after Reaction and Char Reactivity Index resulted in improved performance of COREX. With this experience, the specifications of coals for COREX have been revised, an optimum coal blend has been developed which has helped JVSL to surpass rated capacity of COREX.

STRENGTHENING OF BLAST 
FURNACE REFRACTORY LINING 
THROUGH TAR-PUMPING 
G. Rajadhas, Kurre, S. Ahmed and S.K. Ghosh 
Bhilai Steel Plant, Bhilai 
Bhilai – 490001 
In Blast Furnaces of Bhilai Steel Plant problem of intense gas burning around the tap hole area, increased heat loss from the upper-hearth bottom coolers and hearth coolers were encountered. There was also sharp rise in body temperature of one furnace around the bosh. To counter these problems a system of Tar pumping into the refractory mass has been developed and implemented successfully. This paper details the scheme.
EVALUATION OF ORGANIC BINDER IN IRON ORE PELLETIZATION

S.S. Deginal*, K. Suresh Kumar**, P.L.N. Reddy* and K.L. Bhat*
* Department of Metallurgical and Materials Engineering, National Institute of Technology Karnataka, Surathkal.
** Deputy General Manager, Pellet plant, Jindal Vijayanagar Steel Limited, Vijayanagar – 583275.
E-mail: klnbhat@nitk.ac.in

Iron ore pellets with organic binders were produced with the dosage of 150 g/ton and 190 g/ton by replacing bentonite completely in laboratory and partially in plant scale. The metallurgical properties were assessed. Factors such as particle size, moisture and mixing time have considerable influence on the process and quality parameters.

MEASURES FOR MAINTAINING THE HEALTH OF THE BATTERY DURING COAL CRISIS AT BHILAI STEEL PLANT

Bhilai Steel Plant, Bhilai– 490001
E-mail: jagdishsingh@sail-bhilaisteel.com

Oven pushing rate was reduced significantly to as low as 55 ovens per day per Battery in BSP, due to severe coal crisis. This paper highlights the various measures adopted and the technological discipline adhered to which help to sustain the crisis and maintain the health of battery and coke quality at a fairly stable level.

AN EXPERIENCE IN ANCIENT IRON MAKING

P.K. Biswas and A.K. Vaish
National Metallurgical Laboratory, Jamshedpur 831 007
E-mail: AKV@nmlindia.org

Iron was being produced by smelting low grade ore in clay made furnaces using traditional charcoal as reductant before blast furnace era. The British failed to duplicate the process, which was rather an art than a science. The authors studied the iron making process in detail with respect to design and process parameters by the age old method at tribal site of Bishunpur, Gumla District and at NML to comprehend the process in metallurgical parlance. Some developmental work was also attempted.

THE CONCEPT OF BASICITY IN GLASS MAKING AND PROCESS METALLURGY

Sumit Pal, Hem Shanker Ray and Pranab Choudhury
CGIRI, Kolkata – 700 032
E-mail: sumitpal_2000@yahoo.co.uk

In this presentation the role of Optical Basicity (OB) is briefly reviewed in the context of electrical, optical and thermodynamic properties of glass systems. The concept of OB appears to be equally important in describing the behavior of both glasses and slags provided correct values of OB are taken.

ORE MICROSCOPY AND ITS RELEVANCE FOR SELECTION OF A SUITABLE BENEFICIATION METHOD FOR PROCESSING OF HIGH ALUMINA IRON ORES

Vinod Kumar*, G.N. Jadhav** and N.K. Khosla#
* Department of Earth Sciences, IIT Bombay, Mumbai–400076.
E-mail: vinod_nfp@iitb.ac.in
** Department of Earth Sciences, IIT Bombay, Mumbai–400076.
# Department of Metallurgical Engineering, IIT Bombay, Mumbai–400076.
E-mail: nkk@met.iitb.ac.in

This paper reviews the concentration operations currently employed at Noamundi mines, Jharkhand, India and shows how ore microscopy may prove useful in understanding the efficacy of various concentration methods for beneficiation of high alumina iron ores. Beneficiation studies involving classification (hydrocyclone), gravity separation (tabling and multi gravity separator), wet high intensity magnetic separation (Jones type WHIMS and Eriez WHIMS) have been carried out and the mineral concentration results have been correlated to the ore microscopy studies and detailed results are presented in the paper.

DEPHOSPHORIZATION OF STEELMAKING SLAG

P.N. Chaudhary, J. Pal, D.P. Singh, M. Singh and S. Ghosh
National Metallurgical Laboratory, Jamshedpur-831007
E-mail: pnc@nmlindia.org

Amongst the different methods tried for phosphorus removal, chemical process has been considered most suitable because it utilizes the energy content of the slag. Initial tests have been conducted using carbon as a reductant. The results have shown 70-75% recovery of metallic values from slag whereas phosphorous removal varied in the range of 65-95%. In all the tests, P content of recovered metal is very high (1.5-2.5%) indicating that certain percentage of P comes to the metal phase.
USE OF HOT METAL IN ELECTRIC ARC FURNACE FOR PRODUCTION IN STEEL

M.S. Khan*, S.N. Sinha ** and M.D. Maheshwari*
Tata steel Jamshedpur
**Department of met Engg. & Material science
E-mail: mkagrawal _nit@yahoo.co.in

Electric Arc furnace has come up as a viable competitor to BOF in the production of tonnage steel for flat products for automobile industries, through various developments in technology, including use of virgin input materials like DRI, hot metal, pig iron and iron carbide. This paper reviews the uses of hot metal in various steel plants of the world, and presents the results obtained at Usha Martin Industries Ltd., Jamshedpur.

MANAGING COAL & COKE CRISIS AND ENHANCING BLAST FURNACE PERFORMANCE IN BHILAI STEEL PLANT

Kaushik Basu, Shankar Dutta, S.K. Ghosh and S. Ahamad
Bhilai Steel Plant, Bhilai– 490001
E-mail: jagdishsingh@sail-bhilaisteel.com

Bhilai Steel Plant encountered a severe shortfall in coke production owing to coal crisis. Several innovative measures were taken to reduce coke rate and maintain optimum level of production under the prevailing circumstances. The paper highlights these details.

ENHANCEMENT OF PERFORMANCE OF BF # 3 IN BHILAI STEEL PLANT

Shankar Dutta, Kaushik Basu, N.K. Das, G.K. Adil and Sulaiman Ahmad
Bhilai Steel Plant, Bhilai
E-mail: drranjanhaldhar@sail-bhilaisteel.com

Blast Furnaces of Bhilai Steel Plant are heading towards a production of 7.0 million tonne of hot metal by the year 2011-12 with all seven Blast furnaces in operation. It is very much necessary to go for up-gradation & modernizations of all the Blast Furnaces. This paper highlights on how the up-gradation and modernization in Blast Furnace # 3 helps to achieve a productivity (w/v) level of 2.4 T/M3/THM.

AN EXPERIMENT WITH SPONGE IRON IN BLAST FURNACE

Bhilai Steel Plant, Bhilai – 490001
E-mail: drranjanhaldhar@sail-bhilaisteel.com

Sponge Iron, though extensively used in Steel making can be used in Blast Furnaces as well. At Bhilai Steel Plant, a trial was conducted with the usage of Sponge Iron in one of its small Blast Furnaces (1033 m3 useful volume). The ferrous burden constituted Iron Ore, Sinter and Sponge Iron. A coke saving of 15 kg/thm was achieved with an equivalent production rise of 32 t/day at a Sponge Iron consumption of 92 kg/thm.

STUDIES ON FLOTATION OF BHEL AT AND COAL FINES

Asha Immanuel Raju
Chemical Engineering Department
Andhra University,
Visakhapatnam - 530 003
Email: immy_chair@yahoo.com,
immy_chair@rediffmail.com

The present study deals with the development of a method for flotation of coal at Bhelatand washery. The optimum values of various operating variable which greatly influence the flotation process on coal were determined. Flotation performance was evaluated with respect to frother dosage, collector dosage, impeller speed on different feed size coal.

MANAGING BLAST FURNACE OPERATION DURING COKE CRISIS PERIOD

P.K. Sinha, S.K. Dubey , S. Balaji and V. Dalmatov
Durgapur Steel Plant, Durgapur - 713203
E-mail: dgp_mddsp@sancharnet.in

Due to blanking of tuyeres all temperatures of the Bosh area started coming down to as low as 45- 50°C from a level of 150-200°C showing a considerable build up in Bosh. After one month the blank tuyeres in all the three furnaces are rotated to minimise the damage. Tuyeres are being opened in the furnaces as the Coal / Coke position has started improving. Production level has started touching and crossing 6,000 tons mark slowly.
IT ENABLED QUALITY MANAGEMENT THROUGH INTEGRATED PRODUCTION PLANNING AND CONTROL SYSTEM AT DURGAPUR STEEL PLANT

Sinter Plant, Durgapur Steel Plant, SAIL, Durgapur - 713203
E-mail: dgp_mddsp@sancharnet.in

Durgapur Steel Plant has developed an Integrated Computerised Production, Planning and Control (PPC) System. The system activity starts with receipts of orders electronically from our Central Marketing Organisation (CMO) through the intra-network “SAILNET.” Once the order is received and accepted, the process of planning and scheduling starts and production takes place. Benefits of this system are discussed.

IMPROVEMENT IN PRODUCTIVITY OF SINTER PLANTS, DSP

A.K. Ray*, B. Choudhary*, A.C Nigam*, L. Mahato* and S.A. Balaji**
* Sinter Plant, Durgapur Steel Plant, SAIL, Durgapur - 713203
** RDCIS (Durgapur), Centre, SAIL, Durgapur - 713203
E-mail: dgp_mddsp@sancharnet.in

Durgapur Steel Plant has 3 sinter machines, SP#1 having 2 machines of area 142.7 m² each and suction of 300 – 350 mmWC and SP#2 having modern machine of area 180 m² and suction of 1400 mmWC. This paper discusses the various measures implemented in both SP#1 & SP#2 for improving the productivity of sinter machine.

GOOD BALLING – A PREREQUISITE IN THE ART OF QUALITY SINTER PRODUCTION

Murlimohan, V.K.C. Shekar and S.K. Basar
Sintering Plant – 3, Sinter Bhawan, Bhilai Steel Plant, Bhilai - 490001.
E-mail: kharulsbasar@sail-bhilaisteel.com, basar_s@yahoo.com

In the latest Sinter Plant-3 of Bhilai Steel Plant, a unique trial was conducted to find out the equations which can be helpful for finding the optimum speed of mixing cum noudilising drum (MND) at which best balling can be obtained. Based on generated data, a linear equation was derived by which speed of MND is continuously regulated for getting maximum balling. It helps in drastic reduction of permeability fluctuation resulting higher productivity with in consistent quality.

ENHANCING THE PERFORMANCE OF THE BELL FURNACES OF BSP – A REVIEW

R.R. Nagare
Blast Furnace, Bhilai Steel Plant, Bhilai
E-mail: sulaimanahmed@sail-bhilaisteel.com

Bhilai has three smaller Blast Furnaces of 1033 cuM volume having conventional two bell system and with rotary charging unit facility in BF # 3. Stock house conveyerisation and top equipments monitoring modified with PLC control system. The productivity was increased from 1.2 to 1.8 T/Cu.m/day till year 2000. Further improvement started after implementation of several ideas and innovations; Benchmarking performance of BF#1 was achieved due to less downtime, use of BLT type, Charging pattern, mixing of non-coke material, better screening of coke by frequency control. BF # 3 productivity and coke rate improved further due to tar Injection & Oxygen enrichment facility provided.

IMPLEMENTATION OF ISO-9002 QUALITY ASSURANCE SYSTEM IN A SPONGE IRON PLANT

Smitha Raithatha
Dept. of Metallurgical Engineering
Govt. Engineering College, Raipur
E-mail: Shrivastavapk54@rediffmail.com

Sponge iron industries are fast becoming a key player in the Indian steel sector. However, there is not much awareness about quality or quality requirements in this industry at present. This industry has to commit itself to quality and optimise its operations and practices, which can be done by subscribing to a Q.A.S as ISO-9002. In this paper an attempt has been made to highlight the procedure for getting ISO-9002 certification for a sponge iron plant.

UTILISATION OF IRON ORE FINES GENERATED IN BHILAI STEEL PLANT

R.K. Agarwal and R Haldar
Bhilai Steel Plant
E-mail: drranjanhaldhar@sail-bhilaisteel.com

In Bhilai Steel plant, more than 8 million tones of non-usable iron ore fines have been dumped leading to large scale degradation of agricultural land, deforestation, air and water pollution. Present study suggests some innovative ways of agglomeration and utilization of these wastes. These low-grade iron ore agglomerates can be used directly in furnaces and Converters as coolant.

IMPLEMENATION OF ISO-9002 QUALITY ASSURANCE SYSTEM IN A SPONGE IRON PLANT
DEVELOPMENT OF SPECIAL STEEL ROLLING IN BHILAI STEEL PLANT

N.K. Prasad and R Haldar
Bhilai Steel Plant, Bhilai
Email: drranjanhaldhar@sail-bhilaisteel.com

Bhilai Steel Plant has successfully developed and commercially adopted processes namely, Accelerated Cooling which eliminates normalizing process, Temperature Control Rolling (TCR) and Normalizing Rolling (NR) impart unique combination of high strength toughness and weldability, Isothermal Treatment of Slabs improved the acceptance of thicker plates on ultrasonic testing.

CONTRIBUTION OF BOKARO STEEL PLANT IN THE DEVELOPMENT OF HIGH STRENGTH MICRO ALLOYED STEELS FOR DEFENCE, STRUCTURAL AND AUTOMOBILE INDUSTRY

M. Mandal, D. Chatterjee, M.M.S. Sodhi, R.S. Chowdhary and S. Ghosh*
R & C Laboratory, Bokaro Steel Plant, Bokaro Steel City, Jharkhand-827011
Email: mandal_mrinmoy@rediffmail.com

With the introduction of state of the art Vertical Bending Type Concast unit along with Secondary Refining facilities, Bokaro Steel Plant took up regular production of micro alloyed steel in the E34, E38, BSK 46, SAILMA,IS 8500 Fe540B, API 5L X52/60/65, E-460/500/550, DMR249A, HSCR-26/35 grades. Clean steel produced through BOF- SRU-CC route having better bend properties and a clean surface was accepted by the customer.

PRODUCTION OF CANNON TUBE STEEL THROUGH EAF – LF/VD – ESR PROCESS

Ashutosh Kumar and R.N. Jha
Metal and Steel Factory, Ishapore, 24 Parganas (N), WB – 743144

Cannon tube steel is used for cannon tube manufacture for tank. Previously the production of cannon tube steel was made by using EAF steel making. There was huge rejection in this route and also shorter life of the product. EAF - LF/VD – ESR route has been taken into practice to produce cannon tube steel where the rejection became extremely less & subsequently increased life cycle.

IMPROVEMENT IN THE PERFORMANCE OF EDD QUALITY STEEL AT BOKARO STEEL PLANT WITH THE HELP OF MODIFIED STEEL MAKING AND ROLLING PRACTICES

B. S. Minz, M. Mandal, M.M.S. Sodhi, S. Ghosh and P. N. Tripathy*
Bokaro Steel Plant, Jharkhand-827011
E-mail: mandal_mrinmoy@rediffmail.com

In order to increase the market share of EDD steel (both HR & CR) for the automobile and cold reducer segment quality of EDD steel (C=0.04%) has changed a lot and demand for high elongation along with high formability is required after cold rolling and annealing. Currently with the efficient practice of combined blowing technology (CBT) in SMS-2 along with steel refining unit, slab casters, walking beam type slab reheating furnace, modernized finishing stand and run out table with laminar jet cooling has made it possible for BSP to fulfill most of the Indian demand of high formable extra deep drawing quality steel for automobile industry.

PHOSPHORUS IN IRON & STEEL

P. K. Tripathy, B. Bhattacharya and A. K. Das
Tata Steel, Jamshedpur –831001
Email: ptripathy@tatasteel.com

This paper deals with measures of producing low phosphorus steel modification of slag chemistry and slag volume, use of six hole lance, bottom stirring during the blow, optimization of slag chilling process near the blow end etc. The influence of phosphorus on steel quality, the useful effects of phosphorus and its applications in some special grades of steel, e.g. high strength steels for automobile industries is presented.

INFLUENCE OF BLOW PRACTICES ON EFFECTIVENESS OF SLAG SPLASHING IN BOF VESSELS: A CASE STUDY OF VISAKHAPATNAM STEEL PLANT

*Steel Melt shop, Visakhapatnam Steel Plant, Visakhapatnam-530031
**Quality assurance and Technology Development, Visakhapatnam steel plant
†Department of Materials and Metallurgical Engineering, IIT-Kanpur, Kanpur 208016

The retained slag after tapping is sprayed on to vessel lining by blowing nitrogen. slag samples, with and without reblow, have been analyzed by XRF and examined under SEM. Tuning of blow practices to end at good turn down chemistry of and fluidity of slag has improved slag splashing and thereby BOF vessel lining life.
PRODUCTION OF BALL BEARING STEEL THROUGH EAF-CC ROUTE

M.M. Mahato*, A.K. Das* and S.N. Sinha.**
*Tayo Rolls Limited. Gamaria, Jamshedpur
**Dept. of Met. Engg. & Material Science, N.I.T. Jamshedpur

Sound quality Ball Bearing steel production can be achieved through E.A.F-C.C route economically and efficiently. It can produce lesser amount of inclusions in steel. The morphology of inclusion can be changed so that its removal becomes easy and convenient. Sulphur segregation in the billet is uniformly distributed which reduces the number of rejection significantly. By this route it is possible to produce Ball bearing steel of a narrow range of sulphur and phosphorous upto the level of 0.010%.

SUCCESSFUL MAKING OF IS: 2879 STEEL GRADE AT VSP

Visakhapatnam Steel Plant, Visakhapatnam-530031
E-mail: rama_ak@rediffmail.com

Generally the rimming steel having very low carbon content can’t be cast through continuous casting. The challenge is to develop a suitable concast process to make IS: 2879 grade steel. This involves modification of process for making EQ grade at VSP. This paper describes the journey towards successful making of this grade with available resources to kill the steel with aluminium of <0.012% with alternate de-oxidizers.

PRODUCTION OF QUALITY STEELS USING TUNDISH METALLURGY TECHNIQUES

Subhabrata Sen Gupta
M.N. Dastur & Company Pvt. Ltd, Kolkata
Email: labcm7@dasturco.co.in

The modern tundish has become an efficient metallurgical reactor, through improvements in flow modification devices, development of ceramic filters, inert gas stirring, use of synthetic slags etc. Major control functions possible in the tundish today include control of fluid flow, oxidation prevention, improvement in cleanliness, inclusion morphology control, fine tuning of composition and control of superheat. Such refinements and controls lead to better steel quality, increased yield of prime material through lower rejections and grade diversions improving overall cost effectiveness. These techniques can also be employed for production of ultraclean and defect-free steels.

PORE EVOLUTION DURING SINTERING OF Fe-2Cu-0.9C ALLOYS

M. Das, A. K. Jain, A. Dutt, V. Tripathi, A. Upadhyaya
Department of Materials and Metallurgical Engineering, IIT-Kanpur, Kanpur -208016
Email: anishu@iitk.ac.in

To achieve high dimensional precision in P/M steels, typically the composition and sintering parameters are so adjusted so as to have very little dimensional change during sintering. This paper discusses the sintering behavior of Fe-2Cu-0.9C alloys. Fe-Cu system is transient liquid phase sintered when Cu content is less than 9 mass %. Thus, ‘secondary’ pores are created. To control or compensate compact swelling, controlled addition of carbon is done which increases the strength of sintered Fe. Despite having the same porosity level, the nature of pores in sintered condition is very different than those in the as-pressed steels. This study examines the effect of sintering temperature on the pore morphology and mechanical properties of sintered Fe-Cu-C steels.

WORKING EXPERIENCE OF DESULPHURISATION PRACTICE IN BOKARO STEEL REFINING UNITS

BSP, SAIL, Bokaro-827001
E-mail: bko_rdcishsl@sancharnet.in

In order to meet the desired properties of the end product and for efficient calcium treatment for castability and inclusion shape modification, it is essential to bring down ‘Sulphur’ < 0.010%. Understanding of the thermodynamics and kinetics of the slag metal interface at a basic and reducing atmosphere and the practice adopted at the ladle furnace has been corroborated. Measures taken have helped the plant to achieve its objective of low sulphur steel production.

 AUXILIARY FUEL INJECTION IN SAIL BLAST FURNACES – PRESENT STATUS, POTENTIAL AND FUTURE PLANS

B. Kedia, M.K. Lal, S. Chakrabarty and D. Mishra
Centre for Engineering & Technology, SAIL, Ranchi – 834 002

This paper deals with the present status, potential and future plans for auxiliary fuel injection in SAIL Blast Furnaces. The paper also deals with plans during next 8 years for higher oxygen enrichment of blast, improvement in cooling systems, improvement in raw materials quality etc. to enhance Blast Furnace potential to accept higher auxiliary fuel injections.
PROCESS DEVELOPMENT FOR PRODUCTION OF LOW NITROGEN STEELS THROUGH ELECTRIC ARC FURNACE

SAIL, Durgapur - 713208

With specifications calling for 60 ppm and below nitrogen in steel, studies were carried out for controlling nitrogen pick up. Accordingly, adoption of foamy slag practice, increasing DRI amount, no de-oxidation in EAF, lime stone cum slag mixture usage during tapping followed by reduced treatment time and aluminium contents in LF/VAD units and applying argon shrouding during teeming resulted in achieving low nitrogen contents in steels produced through EAF.

STABILIZATION OF COAL DUST INJECTION IN BF#6 AT BHILAI STEEL PLANT

R.N. Srivastava, Ajay, R.N. Singh, Shanker Dutta and Sulaiman Ahmed
*RDCIS, SAIL, Ranchi-834002
E-mail: rdcisbsp@sail-bhilaisteel.com
** Blast Furnace Department, Bhilai Steel Plant, SAIL, Bhilai-490001

Through trials optimum coal injection rate was established. Keeping conducive blast parameters and slag chemistry, burden distribution was adjusted to suppress peripheral flow and accelerate central flow. To facilitate coal combustion and to arrest heat flux in bosh region, blow pipes with double lances were developed; sector charging of LD slag was introduced and bosh cooling was enhanced.

REDUCTION IN COKE RATE OF BLAST FURNACE NO.3, DSP THROUGH ADOPTION OF LAYER CHARGING

*RDCIS, SAIL, Ranchi-834002
**Blast Furnace Department, Durgapur Steel Plant, SAIL, Durgapur-713203, West Bengal

Charging of ferrous burden and coke in separate layers in blast furnace results in improved gas utilisation, stable furnace operation and decreased coke rate. A two weeks trial of layer charging in blast furnace no.3 of DSP resulted in saving of 3.7% in coke rate and improvement in productivity of 2.5% as compared to mixed type of charging in base period.

USE OF UNDER BURDEN AND VERTICAL PROBES IN BF#5, BSL TO IMPROVE GAS UTILISATION THROUGH BURDEN DISTRIBUTION

U.K. Banerjee, S. Pal and A. Mukhopadhyay
*RDCIS, SAIL, Ranchi-834002
**Bokaro Steel Plant, SAIL, Bokaro-827001
E-mail: bko_rdcisbsl@sancharnet.in

Based on the UBP and VP measurements, the burden distribution has been carried out by adjusting the BLT matrix position. The gas utilization efficiency, ETA CO [i.e. (%CO/ %CO2 + %CO)* 100] over the furnace height from the SL0 position to almost the root of the cohesive zone has been determined. Formation of holding zones at ETA CO of 40/ 45% (Low temperature thermal Reserve Zone, LTRZ) and 30% (Thermal Reserve Zone TRZ) have been observed. Longer length of the TRZ impairs gas movement through the centre of the furnace.

IMPROVEMENT IN SINTER QUALITY AND PRODUCTIVITY OF SINTER PLANT #3, BHILAI STEEL PLANT THROUGH AIR VOLUME CONTROL ALONG THE SINTER MACHINE

*RDCIS, SAIL, Ranchi-834002
E-mail: gmdmurthy@sail-bhilaisteel.com
**Sintering Plant #3 Department, Bhilai Steel Plant, SAIL, Bhilai-490001

Plant scale trials were conducted to improve the yield of top layer sinter by increasing heat holding time through throttling of preferential wind boxes. Ignition temperature was optimised and residence time of sinter mix was increased by controlling rotational speed of MND. These resulted in achieving 1.3t/m2/hr sinter productivity with consistent quality.

AUGMENTATION OF THE SYSTEM FOR LIME ADDITION TO IMPROVE PERFORMANCE OF SP#2, DSP

*RDCIS SAIL, Ranchi-834002
E-mail: dsp_rdcis@sancharnet.in
**Durgapur Steel Plant, SAIL, Durgapur-713203

Lime has been recognized as one of the strongest intensifier of sintering process. Addition of lime fines improves the process.
granulation, improves the vertical sintering speed and results in overall increase in productivity. This paper describes the work done in augmenting the system for lime addition in SP#2, DSP utilizing the fines generated in New Lime Calcination Plant. The industrial trial resulted in increase in SP#2 productivity from 1.25 to 1.45 t/m²/hr.

**USE OF DRI AS PARTIAL SUBSTITUTE OF SCRAP IN BOF AT ROURKELA STEEL PLANT**


*RDCIS, SAIL, Ranchi-834002
E-mail: psm@sail-rdcis.com
**Steel Melt Shop-II, Rourkela Steel Plant, SAIL, Rourkela-769011

Rourkela Steel Plant is facing acute shortage of scrap both w.r.t. quality and quantity. RSP and RDCIS jointly undertook a study to identify appropriate substitute to scrap and establish methodology for its regular use in 150T BOF. Total 15 (Fifteen) trials were carried out with 100T DRI (Direct Reduced Iron) as partial replacement of scrap up to 35%. Technology for its use upto 45 kg/tcs of DRI has been established. The paper explains in detail the methodology of usage, results achieved, problems likely to be encountered and measures to overcome them for regular use of DRI in BOF.

**EFFECTIVE USE OF RECYCLED LD SLAG IN BOF STEELMAKING**


*RDCIS, SAIL, Ranchi-834002
E-mail: rdcisdsp@sail-rdcis.com
**Durgapur Steel Plant, SAIL, Durgapur-713203.

Use of recycled BOF slag at the start of blow helps in early slag formation and improves refining because of its prefused nature and free lime content. The paper describes the various steps taken on use of BOF slag in converter at DSP, Durgapur. Slag usage @ 10-15 kg/tcs resulted in saving of flux by 6 - 7 kg/tcs.

**DEVELOPMENT OF HOT PRESSED MAGNESIA-CARBON ZONAL LINING IN 150T LF-CC LADLE TO INCREASE LIFE TO 100 HEATS AT ROURKELA STEEL PLANT**

Swapan Kumar Garai*, Pulak Barua*, Nirmal Kanti Ghosh*, Purimeta Chintaiah*, Manish Kujur*, Nayan Pal** and Bijay Kumar Karan**

*RDCIS, SAIL, Ranchi-834002
E-mail: rt@rdcis-sail.com and dpc@rdcis-sail.com
**Rourkela Steel Plant, SAIL, Rourkela-769011

In Rourkela Steel Plant an average steel ladle lining life of 47 heats was obtained in 2003-04. Wear profile of few campaigns were studied and based on wear profile a zonal lining design was developed using three different quality hot pressed MgO-C bricks developed and manufactured in brick plant of RSP for working lining of 150 T ladles. One set of developed zonal lining installed in Ladle No. 1 in SMS-2 in January 2004. The ladle achieved a life of 106 heats with slag zone straight life of 57 heats which is highest among four integrated SAIL plants.

**LIFE ENHANCEMENT AND COST REDUCTION OF STEEL LADLES BY IMPROVING MATERIAL AND DESIGN OF REFRACTORIES AT SMS-II, BSP**


*RDCIS, SAIL, Ranchi-834002
E-mail: rl@sail-rdcis.com
**Bhilai Steel Plant, SAIL, Bhilai-490001

Ladle lining life at BSP was around 40 heats where 18-20 heats were taken through VAD/ LF – RH route. Slag zones of these ladles were changed after 8-10 heats. Inhouse brick production with modifications in granulometry, carbon content, introduction of plasticiser and change in shape of bricks have improved the brick properties and enhanced the average lining life to 60 heats which includes 25-28 secondary heats.
IMPROVEMENT IN BOF LIFE BY DEVELOPMENT OF NEW LINING DESIGN IN SMS-1, RSP


*R&D Centre for Iron & Steel, SAIL, Ranchi - 834002
E-mail: rkl_rdcisrrsp@sancharnet.in
**Rourkela Steel Plant, SAIL, Rourkela - 769011

The average BOF lining life in SMS-1 was low due to adverse input conditions, making of special grades of steel, less number of blows etc. New lining design was developed based on studies of wear patterns of past campaigns. A well directed action with respect to slag passivation, modification and splashing/coating was undertaken. Zonal lining of barrel area with higher carbon containing bricks improved the slag adherence. The modification in lining practice, slag splashing/coating and change in addition practices provided rewarding results with life improved beyond 850 heats, which is a record for the shop.

UPGRADATION OF OPERATIONAL EFFICIENCY FOR ENHANCED PRODUCTIVITY AT STEEL MELT SHOP, ESSAR STEEL


*Steel Making Plant, Essar Steel Ltd,
**Technology Cell, Essar Steel Ltd, Gujrat-394270
E-mail: stiwary@essar.com

Steel makers throughout the world look for ways to lower their cost of operations in the face of stronger global competition. This paper discusses the journey of Steel Melt Shop, Essar Steel from a rated capacity of 1.6 to 2.4 MTPA and thereafter. It discusses the operating philosophy and the innovative upgrades carried out in house at Essar Steel in line with the latest advances of melt shop technology.

QUALITY ORIENTED MAINTENANCE APPROACH AT CONTINUOUS CASTING PLANT, ESSAR STEEL

D. Mojumdar*, Mitesh Shah**, R. Sangwai**, P. Chaudhuri*, A.Ghoshal* and Anil Kumar*

*Steel Making Plant, Essar Steel Ltd, "Continuous Casting Plant, Essar Steel Ltd,
**Technology Cell, Essar Steel Ltd, Gujrat-394270
E-mail: stiwary@essar.com

The capability of a continuous casting plant with regard to the economical production of different grades as well as meeting stringent quality requirements is largely determined by the capability to integrate the manufacturing practices with efficient maintenance practices. In its pursuit, Continuous Casting Plant, Essar Steel has adopted a consolidated “Quality Oriented Maintenance Approach”. This paper reviews the maintenance philosophy adopted and implemented at the plant to achieve a world-class quality.

CRANKSHAFT QUALITY STEEL MAKING AT ALLOY STEELS PLANT, DURGAPUR

S.K. Kar, S.K. Samanta and N. Pal

Research and control Laboratory, Alloy Steel Plant, Durgapur- 713208

Crank shaft quality application demands for a very clean steel. The paper in a nutshell demonstrates the requirements of Crank Shaft Quality material, basic theory of production and capability of Alloy Steels Plant in exploiting and assimilating secondary metallurgical technology in production of C.S.Q material.

PRODUCTIVITY ENHANCEMENT AT CONTINUOUS CASTER


Jindal Vijayanagar Steel Limited, Toranagallu, Karnataka
E-mail: shyam.sunder@jvsl.com

Capacity of BOF shop at JVSL has been enhanced from 1.6 mtpa to 2.5 mtpa without any major investment. Basic emphasis was put to increase the productivity rate by increasing the throughput from an average 2.4 tonnes/min to 2.8 tonnes/min by readjusting the machine K-factor and casting all slab width section at maximum speed. Reduction in machine turnaround time, increase in sequence length, abnormalities rate less than 0.01 % and reduction in process losses has improved the productivity rate with an average yield of 98.4 %. Further, additional facilities like Online Auto Mould width change and Tube changer have been incorporated to increase the machine utilization.

PROBLEM OF SHRINKAGE AND COLD LAPS IN FOUNDRY

A.K. Misra

Vizag Steel Plant, Vizagapatanam - 530 032

A case study was undertaken at Foundry of Vizag Steel Plant where defects in casting such as slag holes, gas holes, blow holes, shrinkage and cold laps were found in some castings. By diagnosis of manufacturing process and observation it was found that by keeping pouring bush full during pouring having proper bush size, a non-pressurized gating system, melt cold and pour hot and pouring temperature around 1390 °C we can reduce casting defects, mainly shrinkage and cold laps.
OPERATING EXPERIENCE OF QUALITY STEEL MAKING IN TWIN HEARTH FURNACES

S.K. Roy and S.N. Singh
Bhilai Steel Plant, Bhilai
E-mail: jagdishsingh@sail-bhilaisteel.com

In the existing market, it is imperative to produce quality steel with lower cost. Contrary to the existing trend of slag free tapping, in Twin Hearth Technology, tapping is done with considerable slag carry-over. By developing a typical synthetic slag from the waste of Lime Plant and adopting slag-aided de-oxidation practice, it has been possible to ensure consistent quality as well as cost effectiveness in the bulk steel produced from Twin-hearth furnaces.

ALKALI PROBLEMS IN BLAST FURNACES OF ROURKELA STEEL PLANT

A.L. Kundu and H.S. Prakash
Rourkela Steel Plant, SAIL, Rourkela-769 011

Alkali is considered to be a major concern for sustaining stable and smooth operation of a blast furnace. Alkali enters the blast furnace through input materials e.g. coke, sinter, fluxes, iron and Mn ores and coming out through the slag, flue dust and sludge. But, there is always some alkali, accumulation inside the furnace which is not desirable. An attempt has been made to calculate the alkali balance and remedial measures have been suggested to reduce its input alkali and minimize the accumulation inside the blast furnace.

COMMERCIAL PRODUCTION OF LPG GRADE STEEL WITH SUPERIOR QUALITY AND IMPROVED YIELD AT ROURKELA STEEL PLANT

Devasish Mishra* and U.C. Patra**
R&C LAB, Rourkela Steel Plant, SAIL, Rourkela-769 011

Rourkela steel plant in its quest for excellence and for achieving the ever demanding LPG market has successfully commercialized the production of deep drawing. This paper describes in detail about the technological modifications that were carried out for getting defects –free high quality deep drawing LPG coils along with close dimensional tolerance.

EFFORTS FOR MAKING QUALITY STEELS AT SMS-II OF ROURKELA STEEL PLANT, ROURKELA

*RDCS, SAIL, Ranchi-834 002
E-mail: rkl_rdcisrsp@sancharnet.in
** Rourkela Steel Plant, SAIL, Rourkela-769 011

The new steel melting shop of Rourkela Steel Plant is engaged in the production of flat products conforming to different sectors like automobile, line pipe, electrical etc. Extensive process modifications during ladle refining as well as casting have been carried out for the above grades of steels. Measures developed resulted in achieving carbon < 50 ppm.

A STUDY ON HOT METAL TEMPERATURE DROP AT VARIOUS STAGES AND MEASURES FOR ITS IMPROVEMENT AT RSP

A.L. Kundu, D. Chottopadhyay, M.K. Pradhan and S.N. Roy
Rourkela Steel Plant, SAIL, Rourkela-769 011

Significance of hot metal temperature is well known to iron and steel makers. All blast furnace operators desire to maximize hot metal and slag temperatures for smooth drainage and flow at a shortest time. Hot metal temperature drop from blast furnace cast house to steel melting shop no. II has been very high. A study was undertaken to find out the extent of drop in hot metal temperature at various stages and necessary measures have been taken for its improvement.

PROCESS MODELLING & AUTOMATION

AUTOMATION OF MOULD COOLING SHOWER FOR CONSERVATION OF WATER AND INCREASING MOULD LIFE

Shobh Nath Singh and Chaitanya Misra
SMS-1, BSP, Bhilai –490001
Email: snsingh@sail-bhilaisteel.com

The automation of Mould Cooling Shower was designed to conserve water and increase mould life through controlled cooling. For providing effective mould coating (containing natural graphite and water), the temperature of mould after cooling in shower must be between 80°C to 100°C. This modification has resulted in steep reduction in mould consumption and mould-stickers.
STRATEGIES FOR DEVELOPMENT OF PROCESS CONTROL MODELS FOR HOT METAL DESULFURATION: CONVENTIONAL AND AI APPROACHES

A. Dey*, R.K. Lingamaneni*, B. Deo* and R. Boom**

*Department of Materials and Metallurgical Engineering, IIT- Kanpur
E-mail: arghya@, bdeo@iitk.ac.in
**CORUS, R&DT, Ijmuiden, Netherlands,
E-mail: rob.boom@corusgroup.com

Control models are developed on the basis of plant data for hot metal desulphurization by using both conventional approach and also artificial intelligence approaches (AI) including artificial neural nets genetic algorithm and fuzzy rule based experts system. A combination of conventional and AI approaches provides a better model for process control on the shop floor.

EFFICACY OF ADVANCED VARIABLE SELECTION AND REGRESSION TECHNIQUES FOR ANALYSIS OF BOF DATA

Satish Kumar*, Mohd. Asif Khan**, Ajay Kumar Shukla*, K. Srinivas*, P.Nageshwar Rao* and Brahma Deo*

*Department of Materials and Metallurgical Engineering, IIT -Kanpur
**Department of Materials and Metallurgical Engineering, IIT Madras
*Steelmaking Division, Visakhapatnam Steel Plant, Visakhapatnam-530031
Email: {satis@, akshuk@, bdeo@} iitk.ac.in

Operational data of BOF is analyzed by conventional multivariate analysis using eigen functions to plot Scree curve, the advanced Mahalanobis Taguchi System (MTS), and the approach of heat and mass balance. Efficacy of different techniques is compared. The selected variables are then used to develop artificial neural network (ANN) models for prediction of temperature of steel at tap.

PREDICTION OF YIELD STRENGTH OF HOT ROLLED MICROALLOYED STEELS USING ARTIFICIAL NEURAL NETWORK

Adity Ganguly, M.C. Sadhu and A. K. Das
Tata Steel, Jamshedpur –831001
Email: adity.ganguly@tatasteel.com

Based on back-propagation Artificial Neural Network (ANN), a yield strength prediction model for micro alloyed grades rolled at Hot Strip Mill of Tata Steel has been developed. Network architecture, such as number of hidden layers, learning rate etc. were decided using one-dimensional optimization algorithm. A data set of 1050 coils was used for training the model. The final prediction root mean square error of the model is 0.041 Avg. The model is being used for designing new chemistries and modifying chemistry or process parameters at hot strip mill for micro alloyed grades.

HEAT TRANSFER ANALYSIS OF DRY SLAG FORMATION AND LANCE SKULLING IN BOF VESSELS

M. Malathi and B. Deo
Department of Materials and Metallurgical Engineering
IIT-Kanpur 208016
E-mail: bdeo@iitk.ac.in

Heat transfer to lance inside the BOF takes place by conduction, convection and radiation inside the vessel and also by radiation from the hot spots formed in the jet impact zone. Heat transfer analysis is carried out to predict the dry slag formation period with the help of plant measurements on lance water temperature during different stages of blow.

MAPPING OF LADLE FURNACE PERFORMANCE AND ITS COMPARATIVE EVALUATION

Pradip K Thakur
CET/SAIL Ranchi

The salient features of Ladle Furnace processing includes ladle refractories stirring power, power input, Electrodes and power consumption, Carbon pick up, Gas content, Slagging and alloy addition practice. The paper highlights the various measures to be taken to evaluate LF performance and compare the same with standard equipment for cost control and operational improvement.

DESIGN AND DEVELOPMENT OF AN IMPROVED EDGE CONTROL SYSTEM WITH RELIABLE HIGH FREQUENCY POWER SOURCE


*Cold Rolling Mill, Bokaro Steel Plant SAIL, Bokaro Steel City- 827011
** RDCIS, SAIL, Ranchi-834002
E-mail: bko_rdcishsl@sancharnet.in

Precise edge control is important to avoid side tracking and having better edge finishing during cold rolling and processing of a coil. Through in-house design and development of a novel and cost-effective improved edge control system with reliable
high frequency power source using voltage regulator, transistorized oscillator and illumination system with better cooling efficiency, it has been possible to reduce side tracking by 75% and electrical delays by 10% resulting in savings to the tune of Rs. 54 lakh and solving the problem of non-availability of spares.

**MODELING OF LIQUID FLOW IN THE LOWER PART OF A BLAST FURNACE**

V. Singh* and G.S. Gupta**
Department of Metallurgy, Indian Institute of Science, Bangalore-560012
**E-mail: govind@met.iisc.ernet.in
*E-mail: vikrant@platinum.metalrg.iisc.ernet.in

In the dropping zone of a blast furnace, gas flows counter-current as well as cross-current to the descending molten metal and slag. The low liquid flux rate is modeled using a force balance approach, because of its discrete nature. The gas flow has been modeled using standard Navier-Stoke equations along with k-å model. Simulation results for the liquid distribution at the bottom of the bed are compared with published results.

**COLD MODEL STUDY OF PRESSURE HYSTERESIS IN THE DROPPING ZONE OF A BLAST FURNACE**

S. Sarkar and G.S. Gupta*
Department of Metallurgy, Indian Institute of Science, Bangalore-560012
*E-mail: govind@met.iisc.ernet.in

Raceway is an important zone in iron making blast furnace as it influences the aerodynamics of the furnace and smelting process. The effect of raceway hysteresis on gas flow, using a cold model, has been studied. Pressure hysteresis has been observed in some parts of the model. Experimental results are reported here and have been compared with theory. A good agreement has been found between the two.

**DEVELOPMENT OF FLOW MODIFIERS FOR HIGHER TUNDISH SEQUENCES**

*RDCIS, SAIL, Ranchi-834002
E-mail: cast@sail-rdcis.com
**Bhilai Steel Plant, SAIL, Bhilai – 490001

Improvement of tundish sequence length is desired by all steelmakers. To achieve this goal, design of tundish turbulence inhibition pad was carried out using physical modelling techniques. The flow modifier was used at the 3-strand bloom tundish of Bhilai Steel Plant. It has shown advantages in terms of high sequence size, lower tundish reoxidation and better steel properties. Regular use has resulted in improved plant performance.

**FLUID FLOW PATTERN IN COLD MODEL OF SLAB CASTER MOULD – A PIV MEASUREMENT**

RDCIS, SAIL, Ranchi-834002
Email: clg@sail-rdcis.com

The fluid flow in a 0.4 scale water model of a slab caster mould is investigated by Particle Image Velocimetry (PIV) system. The length of the set-up has been decided in such a way that physical bottom of set-up does not affect the flow pattern in the mould. The experimental measurements shows in general double roll flow pattern in the mould. However, flow pattern is a strong function of flow rate and SEN submergence depth. The meniscus oscillation increases with increase in flow rate and decrease in SEN submergence depth.

**OPTIMISATION OF HOT METAL DESULPHURISATION REAGENT CONSUMPTION**

D.S. Vinoo, I.A.K. Prakash and S.S. Gupta
Jindal Vijayanagar Steel Limited, Vidyanagar – 583275
E-mail: shyam.sunder@jvsl.com

The performance analysis of desulphurisation hot metal with calcium carbide based reagent shows that degree of desulphurisation and hot metal temperature had significant impact on the consumption of reagent. Optimum consumption of desulphurisation reagent is achieved by maintaining hot metal temperature above 1360°C and degree of desulphurisation less than 80%. A computer based model has been developed to guide the operator to ensure optimum consumption of desulphurisation reagent.

**MODEL FOR PREDICTION OF STEEL TEMPERATURE IN BOF-CCP PROCESS**

D. Satish, I.A.K. Prakash and S.S. Gupta
Jindal Vjayanagar Steel Limited, Vidyanagar – 583275
E-mail: shyam.sunder@jvsl.com

In order to control superheat of steel being supplied to continuous casting machine a simplified real time model has been developed to predict steel temperature at different locations starting from tapping from converter, Argon Rinsing Station, Ladle Heating Furnace and transportation of ladle from LHF to CCP. The model has been developed with minimum number of inputs to ensure operator friendliness. The model predication is within ± 5°C for more than 90 % of the heats.
MODELING OF TEMPERATURE PROFILE OF HOT CHARGED SLABS IN HOT STRIP MILL RE-HEATING FURNACE

S. Manjini and R.K. Sharma
Jindal Vijayanagar Steel Limited, Vidyanagar – 583275.
E-mail: shyam.sunder@jvsl.com

A mathematical model has been developed to obtain the temperature profile of the slab at any instance in the re-heating furnace at Jindal Vijayanagar Steel Limited. The direct hot charged slabs attained uniform re-heating temperature ahead of the soaking zone in the case of fixed re-heating time study. The re-heating time required to achieve the desired slab exit temperature for hot charged slabs were found to be less than 2 hours 15 minutes which increases the throughput of the re-heating furnace from the designed capacity of 250 t/h to more than 300 t/h.

AN INSIGHT INTO ENERGY SAVING MEASURES IN AN INTEGRATED STEEL PLANT

A.K. Vaish, S.D. Singh, R.K. Minz and D. Bandyopadhyay
National Metallurgical Laboratory - Jamshedpur-831007
E-mail: AKV@nmlindia.org

The manufacture of steel involves the huge amount of energy in an integrated steel plant. The cost and productivity of steel making process largely depends on the quality and consistency of hot metal produced by the blast furnace and its subsequent refining. The present communication deals with various energy saving measures during iron and steel making process in an integrated steel plant.

USAGE OF PROCESS MODEL TO OPTIMIZE SINTER PLANT OPERATION

Dieter Bettinger, Bernhard Schürz, Klaus Stohl and Sudip Sen
VOEST-ALPINE Industrieanlagenbau GmbH
P.O. Box 4, 4031 Linz, Austria
E-mail: Bernhard.Schuerz@vai.at

In order to ensure smooth and cost effective sinter plant operation VAI expanded and improved its proven, powerful sinter plant automation package consisting of Technological Control Systems (running on PLCs) and of online mathematical process models (running on PCs). The Paper gives a good overview of the system functionally.

GRAPHICAL ANALYSIS OF BLAST FURNACE OPERATION

R.N. Ray, Anupam Banejee and S. Pramanik*
Dept. of Metallurgical Engineering, NIT, Durgapur
*Blast Furnace, Durgapur Steel plant, Durgapur - 713203
E-mail: rnray_mete@yahoo.co.in

The understanding of blast furnace operation can be helped greatly by exploring relationship between (O/Fe) and (O/C) (operating diagram). In constructing the operating diagram line we have considered stoichiometry and enthalpy demand for known inputs and outputs. The conclusions are drawn from the deviation of operating line from ideal one in regard to CO/CO₂ ratio and coke rate.

SECONDARY PROCESSING

CHARACTERIZING HETEROGENEOUS DEFORMATION IN OPEN DIE EXTRUSION OF AISI 1020 STEELS

K. Srinivasan* and P. Venugopal**
* Dept. of Metallurgical and Materials Engg., N.I.T.K., Surathkal
** Metal Forming Lab, I.I.T., Madras, Chennai
Email: ksrini@nitk.ac.in

Metal forming processes involve heterogeneous deformation wherein shear strain rates are not zero. Open die extrusion is no exception. But it is found to be very less compared to conventional extrusion. This heterogeneity is characterised and studied by simple hardness measurements in the deformation zone of the extrude. This hardness is related to strain and stress by constitutive equations which have been established by simple asymmetric compression test. Therefore any local variations can be inferred. The tests were carried out at room temperature in a 100 ton Hydraulic Press at a strain rate of 0.07 s⁻¹. The lubricant used was Molybdenum disulphide.

STABILITY OF STRIPS ON LONG RUNOUT TABLES: MODIFICATIONS AT BOKARO HSM

Alok Verma, N. K Gautam and A. S Mathur
Hot Strip Mill, Bokaro Steel Plant, SAIL
Jharkhand-827011

Stability of strips on very long runout tables with down coilers has been a problem in hot strip mills which utilize the ROT for extensive air and water cooling. The problem was studied with video filming. Mechanical design of coiler strip switches was changed and PLC software of guide operating scheme was modified to increase the stability of strip, leading to cobbles free operation and increase in productivity at Bokaro steel plant.
IMPROVEMENT IN SHAPE OF COLD ROLLED STEEL STRIPS WITH STEPLESS CONTROL SYSTEM OF HYDRAULIC ACTUATORS
A.K. Marik, P.C. Bhownik*, Rakesh*, D. Sengupta and K. Nafde*
RDCIS, SAIL, Ranchi-834002
* Bokaro Steel Limited, SAIL
Email: broy@sail-rcdis.com

In order to meet the customer’s requirement and improved cold rolled (CR) strip shape, the modified roll balancing system with stepless control has been designed and installed at last stand of TCM-I and SPM-I to correct the shape defect as far as possible manually, with the provision for varying of the roll separating force from 0 to 100 bar by the operator. The modified work roll bending system has resulted in improved strip flatness by 20% and helped to correct the edge waviness and centre buckles on the strip.

DEVELOPMENT AND COMMERCIALIZATION OF LOW CARBON CORROSION RESISTANT TMT REBAR/WIRE ROD (Gr. Fe 415) AND DRAWING QUALITY WIRE ROD (SWR 10/14) WITH 0.10% PHOSPHORUS
J. Singh*, D. B. Shrivastava*, S. N. Singh*, T. C. S. Prasad* and B. K. Panigrahi**
*Bhilai Steel Plant
** RDCIS, SAIL, Ranchi-834002
Email: snSingh@sail-bhilaisteel.com

A higher phosphorous (0.10% P) low carbon (0.10% C) has been developed for high strength TMT rebar (Gr. Fe 415) and drawing quality wire rod (SWR 10/14). The TMT rebar (dia. 32 mm) is characterized by exceptionally good Charpy impact toughness (160 Joule at RT, DBTT: -50°C) and weldability. The SWR wire rod (dia. 8/10 mm) could be drawn to 2.0 mm and 2.6 mm dia. Wire by batch and continuous processes respectively and used as fence wire. Phosphorous addition improved atmospheric corrosion resistance due to presence of phosphorous in the exposed surface of wire.

IMPROVEMENT IN COLD HEADABILITY BY OPTIMIZING POST ROLLING COOLING STRATEGY
Atanu Banerjee, Arunangshu Halder, Sudipto Sarkar, Indranil Chakraborty and M. D. Maheshwari *
Tata Steel, Jamshedpur –831001
E-mail: mmaheshw@lot.tatasteel.com

Cold heading is the most critical operation in fastener manufacturing. In cold forging, head of a bolt undergoes 80% upsetting causing splitting from the base of surface defect. Sub-critical surface defect can become super critical if strength of the material is high. The present paper discusses cause of failure during cold heading operation, effect of cooling parameters on laying head temperature and phase transformation, change of water box cooling parameters and laying head temperature to improve cold headability.

PRODUCTION OF WIDE PLATES IN HIGH PURITY STAINLESS STEEL MDN 304L (REFINED)
S.N. Jha
Mishra Dhatu Nigam Limited, Hyderabad
E-mail: spralloy@hd1.vsnl.net.in

MDN 304L (Refined) is high purity stainless steels where elements like carbon, silicon, phosphorus and boron levels have been controlled at very low levels. The steel is characterized by high degree of cleanliness, narrow band of chemistry, high degree of structural integrity and predictable response to heat treatment. The manufacturing technology has been established using commercial Electric Arc Melting, Vacuum Induction Refining and Electro slag Remelting. MDN 304 is free from intergranual corrosion because of extremely low levels of carbon, silicon, phosphorus, sulphur, and non-metallic inclusions.

IMPROVEMENTS AND INNOVATIONS IN ROLL TECHNOLOGY FOR PREVENTION OF ROLL FAILURES
Umesh Singh
Tata Steel, Jamshedpur –831001

Roll failures can be avoided through proper design of the specifications and physical dimensions, roll pass design, maintenance and usage. The Paper describes several such preventive measures against roll failures in the Flat and Long Product Mills of Tata Steel which have contributed towards reducing roll consumption over the years.

AN INVESTIGATION INTO THE WELD BREAKAGES IN COLD ROLLED STRIPS AT HOT DIP GALVANISING LINE OF BOKARO STEEL PLANT
M. Singh, S. Srikanth*, A.K. Mukherjee and K. Nafde
Bokaro Steel Plant, Bokaro-827001
Email: manojsingh1958@rediff.com

An assessment of the welding machine for reconditioning and upgradation indicated that the changeover from ignitron contactors to solid state thyristors for phase shift current control, the adoption of microprocessor-controlled selection and implementation of pre-programmed weld schedules for different gauges and the retrofitting of a knurl dressing system are most
advantageous and imperative for achieving a sound, improved and consistent weld quality in HDGL.

QUALITY IMPROVEMENTS OF FORGED CRM WORK – ROLLS

A.K. Verma
Forged Roll Division, Götterman-Peipers (India) Ltd., Kolkata (W.B.)
Email: gpil@giasecl01.vsnl.net.in

The increasing requirement for critical surface finish and texture of flat rolled product, mill productivity and roll shop efficiency demands the manufacture of quality CRM work rolls of high wear resistance in modern cold rolling mills. The paper describes the advancements made in the steel melting, forging, heat treatments and quality control measures taken for the quality improvements of the forged work rolls which are based on experience with rolls manufacturing since last 3 decades.

COMPARATIVE EVALUATION OF THERMO-MECHANICALLY TREATED MICRO-ALLOYED STEELS CONTAINING NIOBIUM AND OR VANADIUM

*RDCIS, SAIL, Ranchi-834002
E-mail: array@sail-rdcis.com
**Bhilai Steel Plant, Bhilai-490001

Theoretically calculated Tnr, r3 and Bs temperatures help to explain the microstructure, and mechanical properties of the steels. 0.04% Nb steel and 0.04 % Nb 0.035% V steel have good tensile and impact properties. These two steels have theoretical Tnr and r3 temperature as 966.76, 1007.66°C and 740.30°C, 744.4°C respectively. Present results show that optimum Al, minimum banded structure, fine ferrite grain size (8-9 micron) and rolling below Tnr will lead to better properties in Nb, V microalloyed steels.

IMPROVEMENT IN PRODUCTIVITY AND SURFACE QUALITY OF CONTINUOUSLY ANNEALED COILS

*RDCIS, SAIL, Ranchi-834002
E-Mail: fr@sail-rdcis.com
**Rourkela Steel Plant, Rourkela-769 011, Orissa

Increase of line speed resulted in improved productivity of continuously annealed coils at CRM, RSP by 27%. Increased heat input to furnace and modifications of annealing cycle had resulted in increased line speed. The Surface Reflectance of annealed coils was increased from 75 to 90% by introduction of high pressure rinsing system and use of a superior cleaning agent.

STUDY ON CAUSES AND PREVENTION OF HOT STRIP MILL BACKUP ROLL SPALLING

K.K. Singh, C. Mandal, R.S. Verma, P.C. Das and S. Chakraborty
RDCIS, SAIL, Ranchi – 834002
E-mail: emt@sail-rdcis.com

The reasons of frequent incidence of spalling of backup rolls of Hot Strip Mill of Bokaro Steel Plant have been analysed. The remedial measures evolved include shortening of campaign length and maintaining an optimum dressing amount. The use of superior rolls material has been suggested for prolonged campaign length and reduced roll consumption.

MILL STATUS MONITORING AND CONTROL SYSTEM FOR RAIL AND STRUCTURAL MILL

*RDCIS, SAIL, Ranchi-834002
E-Mail: pa@sail-rdcis.com
** Rail & Structural Mill, Bhilai Steel Plant, SAIL, Bhilai-490001
E-Mail: ssverma@sail-bhilaisteel.com

A mill status monitoring system has been designed, developed and commissioned at Rail & Structural Mill of Bhilai Steel Plant using industry standard communication network and PLCs. This system is capable of checking pre-rolling mill readiness, online monitoring of operation mechanisms and controlling through forbiddance in case of abnormality to help in reduction of cobbles.

BASE CAPACITY ENHANCEMENT OF HOOD ANNEALING FURNACES AT CRM, RSP

RDCIS, SAIL, Ranchi – 834002
E-mail: pe@sail-rdcis.com

The base capacity of hood annealing line was increased from 30T to 42 Tons through various design modifications. Earlier the individual bases were used to process only two coils per batch, which can now process three coils. The incorporated design modification has been able to increase the batch charge
weight for hood annealing from 28 Tons (approx.) to 42 Tons (approx.), resulting in increase in productivity of base from 1.36 t/hr to 1.66 t/hr.

DEVELOPMENT OF LOW CARBON STEEL HOT ROLLED STEEL FOR DIRECT FORMING APPLICATIONS

U.B. Jagdale, S.K. Tiwary, Deepak Gupta and A.M. Kulkarni
Essar Steel Ltd. Hazira, Surat, Gujrat-394270
E-mail: stiwary@essar.com

The mechanical properties achieved in the thickness range of 2.9 to 4 mm were in the range of YS –20- 22 Kg/mm², UTS 33-35 Kg/mm² and % El – 45% Minimum along with YS/UTS ratio of 0.6–0.70. Trials were taken at different customers for making lower and upper half compressor shell of refrigerator as well as air conditioner and material has been formed successfully without any difficulties. Now we are supplying the material in bulk for various customers.

TRACKING AND ELIMINATION OF ROLLED IN SCALE DURING HOT ROLLING OF STEEL

K.S. Choudhary, S. Chattopadhyay, Babu Venkatesh and Vichore Mukul
Essar Steel Ltd., Hazira, Surat, Gujrat-394270
E-mail: stiwary@essar.com

The main focus of the study was on the elimination of random scale (RS) occurrence in the extremely surface critical grades like Interstitial Free steels (IF), extra low carbon steels (EDD) and steels designed for greater than 90% reduction during cold rolling. The incremental actions were taken embracing new concepts to reduce the problem. With the help of above initiative it was possible to reduce the RIS problem thereby decreasing the quality rejection at Mill as well as at Customer’s end.

CONTROL OF EDGE DEFECTS IN COLD ROLLING GRADES DUE TO ALUMINUM MARKING ON SLABS AT ESSAR STEEL LTD.

Deepak Gupta and A. M. Kulkarni
Essar Steel Ltd., Hazira, Surat, Gujrat-394270
E-mail: stiwary@essar.com

A large number of coils were observed at the service centre and a very strong locational co-relation emerged as these defects were observed to occur in coils at a location which corresponds to the aluminium marking on the slabs. Close examination revealed that burrs were formed at the edges and some of these burrs were rolled on the surface of the coil. These rolled-in-burrs get chipped off and leave edge cuts on the surface of the coils. Trials were conducted with the above parameters and this resulted in elimination of the edge defects in cold rolling grades.

ROLL FAILURES IN HOT STRIP MILLS – AN ASSESSMENT

Tanmay Bhattacharyya, Sudipto Sarkar, S Bhaskar, J C Pandey and M D Maheshwari
Tata Steel, Jamshedpur – 831007
E-mail: mmaheshw@lot.tatasteel.com

Recently number of roll failures ascended in the roughing mill and the first two stands of the finishing mills of hot strip mill of the authors’ works. For roughing mill the rolls failed predominantly due to overload. For finishing mills, failures were caused by thermal shock, left over small cracks etc. However, some roll manufacturing abnormalities (e.g. bond abnormality, improper nodularization of core) were significantly identified. This paper details the indepth study carried out to understand the reasons for failure.

REDUCING SCALE-LOSS DURING HOT ROLLING

S.P. Shenoy
Steel Plant Specialities, 211, Raikar Chambers, Govandi East, Mumbai – 400 088
E-mail: espon@vsnl.net

Hot rolling involves controlled plastic deformation of heated metals and alloys into desired long or flat products. Mechanism of scaling and decarburisation and the attendant harmful effects are explained. A unique ESPON coating process, developed by an Indian firm, is found to be a economical method to minimize these problems.

HOT SLAB CHARGING IN HOT STRIP MILL - AN EFFECTIVE TOOL FOR PRODUCTIVITY AND ENERGY OPTIMIZATION

Jindal Vijayanagar Steel Limited, Vidyavagar – 583275
E-mail: shyam.sunder@jvsl.com

JVSL has successfully introduced hot charging of slabs from continuous casting machine to reheating furnace of HSM. The percentage of hot charging has increased form 36 to 75% during the 27 months of its operation with the daily charging reaching a level of 95%. This practice has resulted in an increase in the furnace productivity (27 to 60%) and consequent decrease in fuel and power to the extent of 9.5%. This in turn has made it possible for the mill to produce more from one furnace at lower power and fuel rate.
STANDARDISATION OF ROLLING PROCESS FOR FLAT PRODUCTS

Sandeep Hegde* and R.K. Yadava**
*Jindal Vijayanagar Steel Ltd., Vidyanagar – 583275
**MNIT, Jaipur
E-mail: rk Yadava@rediffmail.com

The main goal of the rolling process is to determine the optimum means of producing the best quality rolled products at optimum cost. The optimization criteria of rolling operation may vary depending on product requirement. Based on studies of the rolling operation of Bokaro Steel plant, Bokaro and Jindal Vijayanagar Steel Ltd., Bellary (Karnataka), an attempt has been made for the development of an off-line rolling process to predict the capability for flat products of different grades of steel.

STUDY OF BAKE HARDENABLE OF EXTRA DEEP DRAWING AND INTERSTITIAL FREE STEEL SHEETS SUITABLE FOR AUTO BODY APPLICATION

National Metallurgical Laboratory - Jamshedpur-831007
*Visvesvaraya National Institute of Technology, Nagpur
E-mail: AKV@nmlindia.org

Bake hardenable steel sheets are preferred for auto body panels due to their high forming rates. They exhibit capacity for significant increase in strength through work hardening during part forming and strain aging during paint baking. The bake hardenable of EDD and IF steel sheets have been studied with regard to varying time and temperature conditions during annealing.

VAI STECKLE MILL TECHNOLOGY ECONOMIC AND FLEXIBLE SOLUTIONS FOR HOT-STRIP AND PLATE PRODUCTION

G. Thaller, G. Djumlija and W. Gruber – VAI/ Austria
N. Champion and A. Marples – VAI-UK/U.K.
E-mail: rashida@vai.eu.vai.at

VAI has been involved in nearly all major Steckel mill projects in recent years, for new installations and revamps. This paper provides various Steckel Mill and Plate-Steckel Mill solutions offering a highly attractive process route for steel producers at economic investment for production of carbon, stainless and special steel grades.

A COMPARATIVE STUDY OF MICROSTRUCTURE AND TEXTURE FORMATION IN A (Ti+Nb)- IF STEEL AFTER ULTRA HIGH LEVELS OF COLD ROLLING AND ANNEALING

Rajib Saha and R.K. Ray
Department of Materials and Metallurgical Engineering
IIT- Kanpur, Kanpur-208016
E-mail: rkray@iitk.ac.in

The present investigation deals with texture development after ultra high levels of cold rolling upto 98% followed by annealing in a (Ti+ Nb)- IF steel. The results have indicated that increasing the amount of cold reduction from 90 to 98 percent makes the kinetics of recrystallization sluggish. The textures and microstructures of the steel samples correlate well with cold reduction levels.

OPTIMIZATION OF HEAT TREATMENT OF WHEELS FOR IMPROVED MECHANICAL PROPERTIES AND PRODUCTIVITY

U.S. Biswas, A. Kannan, B. Roy, R.S. Tewari, A. Bhatacharyya and A.K. Mukherjee
Durgapur Steel Plant, Durgapur-713203
E-mail: dgpmddsp@sancharnet.in

Heat treatment of wheels plays a vital role in achieving the desired mechanical properties within the stipulated chemical composition. This required a re-look the entire heat treatment cycle of wheels for improving their mechanical properties including Y.S. to T.S. and fracture toughness on a consistent basis. This paper deals with various studies conducted in this connection and results thereof for BG Coaching wheels.

EMERGING TECHNOLOGIES

EFFECTIVE BORON IN STEEL - SIGNIFICANCE AND ONLINE DETERMINATION

Atanu Banerjee, K.N. Udpa, Sudipto Sarkar, Indranil Chakraborty and M. D. Maheshwari *
Tata Steel, Jamshedpur –831001
Email: mmaheshw@lot.tatasteel.com

Small amount of boron remarkably improves hardenability of steel. Soluble part of the total boron in steel effectively increases the hardenability. Balance of the amount form precipitates and does not contribute to the hardenability of the steel. Existing methods to determine soluble boron content in steel are tedious. The paper describes the trial with optical emission spectroscopy, which determines soluble boron content in steel within the stipulated time of steel making. The results obtained on certified materials using the technique are also presented in the paper.
THEORETICAL AND PRACTICAL ASPECTS OF MgO-C REFRACTORY WEAR IN BOF VESSELS AND TRANSFER LADLES

*Department of Materials and Metallurgical Engineering, IIT-Kanpur, Kanpur-208016
E-mail: arghya@iitk.ac.in, bdeo@iitk.ac.in
**Steelmaking Division, Visakhapatnam Steel Plant, Visakhapatnam-530031.
*Bokaro Steel plant, Bokaro-827001

MgO-C brick samples from 145-ton BOF and 300 ton ladles have been investigated using SEM and EPMA to understand the wear mechanism. A kinetic model is developed to describe the wear rate. Modifications in operating strategy increased the refractory from 900 heats to greater than 2200 in the case of BOF.

SYNTHESIS AND CHARACTERIZATION OF GRAPHITE IN CAST IRONS

K.K. Singh
Department of Foundry Technology, National Institute of Foundry and Forge Technology, Hatia, Ranchi – 834 003
E-mail: kksingh_nifft@yahoo.com

In this study, the nodularity, nodule size and distribution were controlled by proper control of charge materials, nodularizing and inoculation treatments. The grid count method and Area methods were used for measurement of nodule count, size and size distribution of nodules. The estimated nodularity value increased from heat No.I (Gray Iron) to IV (S.G. Iron). The nodule size decreased from heat No.II to IV. The frequencies of fine nodules increased with increase in Heat Nos. It has shown decreased strength and improved ductility with increase in heat no. from II to IV.

DEVELOPMENT OF TITANIUM – HIGH STRENGTH STEEL CLADDDED COMPONENTS BY EXPLOSION CLADDING ROUTE

M .Chatterjee* and B. Hanumanth Rao*
*Mishra Dhatu Nigam Limited Hyderabad.
*Explofab Metals Ltd. Hyderabad.
E-mail: spralloy@hd1.vsnl.net.in

In the present work, a technology for cladding of Grade 2 Titanium (Yield strength 350 MPa) on high strength steel forgings having yield strength of 700–850 MPa have been successfully developed. Best properties are obtained under conditions where intermetallic formation is minimum and when they are formed in small isolated pockets surrounded by ductile matrix. The present paper discusses the cladding methodology as well as the microstructure and properties obtained under different processing conditions.

THE CASTRIP® PROCESS – AN UPDATE ON RECENT EXPERIENCES AT NUCOR CRAWFORDSVILLE

Peter Campbell, Richard Wechsler, Rama Mahapatra and Wal Blejde
Castrip LLC, 2100 Rexford Rd., Suite 420, Charlotte, NC, 28226, U.S.A
Email: Rama.Mahapatra@bluescopesteel.com

Nucor Steel is currently operating world’s first commercial strip casting facility for production of thin plain-carbon steel sheet employing the CASTRIP® twin-roll casting process. To date, the plant has produced in excess of 100,000 tons. This paper will report on the progress at the plant plus next steps in the commercialisation of this breakthrough technology.

LABORATORY STUDIES ON THE WEAR BEHAVIOUR OF STEPPED AUSTEMPERED DUCTILE IRON BALLS IN GRINDING IRON ORE

B. S. Jayaraj, K.R. Udupa and K.L. Bhat
Dept. of Metallurgical and Materials Engg. NITK, Surathkal -575 025

In the present study, an attempt has been made to evaluate the suitability of austempered ductile iron as grinding media material for grinding the iron ore in a ball mill. The wear rate of ADI was compared with En-31 forged steel balls. The wear behaviour of ADI in grinding iron ore is not only dependent on the hardness but also on the microstructure, phase constituents of the ADI material. The wear resistance and the energy consumed by ADI ball were found to be better.

A NOVEL TECHNIQUE FOR FLUORIDE REMOVAL IN THE PICKLING LINE EFFLUENT FOR STAINLESS STEELS

S. Ramachandran and R. Baskar
Dept. of Chemical Engineering
Lecturer Kongu Engineering College, Erode, TN 638 052
Email: jeyramrad@yahoo.com

The rejected mixed acid and wash water from stainless steel pickling lines result in a Fluoride load in the effluent. The Fluoride content of (around 8 ppm) due to the solubility of CaF$_2$ is much higher than the allowable 2 ppm. To mitigate the above problem a novel technique of sludge recycle was tried. The paper discusses the details of this trial.
MIS BEHAVIOUR OF BORON STEELS
C.V. Ramesh Kumar, Mahesh Kulkarni, A.S. Phaneendra* and T.J. Saravanan
Dept. of Qlty Engg., EM Division, BEML, K.G.F.
* Dept. Of Qlty Engg., HP Division, BEMLl, K.G.
Email: maintemdbeml@vsnl.net
This case study throws light on behaviour of cost effective Boron Steel during carburising, where-in the effect of boron on hardenability is unpredictable. This has necessitated in conducting a series of experiments to obtain similar consistent results, which would have been obtained in conventional carburising steels like SAE8620H.

DEVELOPMENT OF FINE PARTICULATE MONITORING SYSTEM FOR LD AND MIXED GAS LINES AT RSP
*RDCIS, SAIL, Ranchi – 834002
**Energy Mgt. Dept. Rourkela Steel Plant, SAIL, Rourkela-769011
To monitor the concentration of dust present in the gas lines, a monitoring probe has been designed and installed by RDCIS in LD and mixed gas lines near to the gas mixer tank. The probe system has special safety features like compressed air ejector, purging facility for probe and discharge of sample gas after dilution to prevent any hazard. The system is being used by Rourkela Steel Plant for monitoring quality of gas. The feed back of the system can help in improvement in performance of gas cleaning equipment in respective shops.

HIGH VELOCITY BURNER FOR LADLE HEATING
D. Zamindar¬, M. Sen¬, M.Choubey¬, P. Karmakar¬ and S. Sen¬
¬RDCIS, SAIL., Ranchi-834002
E-mail: dgp_rdcisbnp@sancharnet.in, gisc@sail-rdcis.com
¬¬IISCO, SAIL., Bumpur- 713325
Ladle heating system of SMS, IISCO is inefficient, mainly due to tube in tube type burner with a very short and lezzy flame. In this work a high velocity burner designed tailor made for IISCO ladles and tested at site. Excellent result achieved with high thrust & long flame touching ladle bottom and heating uniformly.

CHARACTERIZATION OF GALVANIZED SHEETS FROM VARIOUS SOURCES/MANUFACTURERS
Mandipkaur Pabla, Ajay Patel, Bobby Pujara and T.V.N. Murty
Essar steel Ltd., Hazira, Gujrat-394270
E-mail: stiwary@essar.com
The coating of steel or iron with zinc using various processes is called ‘galvanising’. Total 13 corrugated sheets were received and complete characterization was carried out to understand the characteristics of the zinc coating. The coating thickness (m) was found to vary from 10 to 20m for different suppliers. The characterization of the different layers of zinc coating shows presence of different layers viz. Eta, Zeta, Delta and Gamma.

ANNEALING BEHAVIOUR OF COPPER BEARING IF STEELS
R.K. Rana, S.B. Singh and O.N. Mohanty
Department of Metallurgical and Materials Engineering
IIT-Kharagpur, Kharagpur -721302
E-mail: sbs22@metal.iitkgp.ernet.in
The annealing behaviour of Cu-containing IF steel (IF-Cu) has been studied using Thermo Electric Power (TEP), electrical resistivity, hardness measurements and optical metallography. The TEP value of the cold worked material increased upon annealing due to annihilation of dislocations. TEP, resistivity and hardness values of IF steels showed sharp change during the first few minutes of annealing. This leads to the conclusion that most of the hardness drop of cold worked IF steels during annealing is due to recovery only and not due to recrystallisation.

STUDIES ON LASER ASSISTED FABRICATION OF AISI 316L STAINLESS STEEL
J. Dutta Majumdar*, S. M. Ganeshan*, I. Manna* and Lin Li*
*Department of Metallurgical and Materials Engineering, IIT-Kharagpur, Kharagpur, - 721302
*Department of Mechanical, Aerospace and Manufacturing Engineering, LPRC, UMIST, P. O. BOX 88, Manchester M60 1QD, UK
E-mail: jyotsna@metal.iitkgp.ernet.in
The present study concerns laser assisted fabrication of 316L stainless steel by melting the feedstock powder using a Laser-line diode laser (maximum power of 1.5 kW) and layer by layer deposition of the melt on a substrate. The physical and microstructural characteristics of the fabricated component were studied. Significant improvements in mechanical and electrochemical properties were achieved as compared to the conventionally available one.
MECHATRONIC SYSTEMS FOR QUALITY OPTIMISATION IN STEEL PRODUCTION AND RESEARCH

Michael Traugott,
Vatron - voestalpine mechatronics GmbH
Voestalpine str. 3, A-4031 Linz / Austria
E-mail: Michael.Traugott@vatron.com

Combining expertise in the fields of mechanics, electrotechnics, sensorics, computer science, instrumentation and testing technology, this presentation will focus on customized measuring and control systems along the complete production range of steelmaking and processing industries. The vatron team has developed about 60 different mechatronic systems that have proven their industrial durability in more than 150 worldwide references. The presentation will cover the experiences collected at Voestalpine Stahl production sites. Some of these most production critical and advanced systems will be described, their advantages pinpointed and applications discussed.

DEVELOPMENT OF SEMI PROCESSED ELECTRICAL STEEL AT M/S UTTAM GALVA STEEL LIMITED

* M/s Uttam Galva Steels Limited, Donvat
** RDCIS, SAIL, Ranchi
E-mail: rnm.works@uttamgalva.com

The present paper discusses the development of Semi Processed Electrical Steel with low silicon (0.25% and 0.60%) and lower core-loss (<6 W/kg and <4.5 W/kg respectively) for Fractional and low horsepower motors. At UGSL attempts were made to achieve the lower core loss value through selection of Chemical composition range, hot rolling and cold rolling parameters. Control was exercised during Bell Annealing and Skin pass.

DEVELOPMENT OF SUPER EDD AND IF STEEL WITH HIGH AVERAGE PLASTIC ANISOTROPY AT M/S UTTAM GALVA

* M/s Uttam Galva Steels Limited, Donvat
** RDCIS, SAIL, Ranchi
E-mail: rnm.works@uttamgalva.com

The present paper discusses the role of hot band microstructure and subsequent processing parameters on the final r-value of the cold-rolled EDD/IF steel for undergoing Critical deformation. The typical final anisotropy value achieved in the IF grade is 2.1 and EDD grade was between 1.7–1.9. With such excellent combination of properties, several critical components were formed for automotive and General Engineering application.

IMPROVEMENT IN VAR-HEAT-SHIELD-LIFE THROUGH INNOVATIVE MONOLITHIC ZONAL REFRACTORY LINING

R.B. Gupta, D. Upadhyay and S.K. Vadher
Rourkela Steel Plant, SAIL, Rourkela-769 011

After adopting continuous casting route of steel production, the treatment time and holding time of ladle increased many fold at VAR Secondary station. This has resulted in poor life of VAR-Refractory heat shield. To overcome this, many lining patterns with different kind of refractory materials were used and VAR heat shield life could be increased many fold. This paper depicts all such developments.

NON-FERROUS EXTRACTION

BULK SULPHIDE PRECIPITATION FROM SEA NODULE LEACH LIQUOR AND DISSOLUTION IN CHLORIDE MEDIA

K.K. Sahu and R.K. Jana
Metal Extraction and Forming Division
National Metallurgical Laboratory, Jamshedpur – 831 007
Email: rkjana@nmlindia.org

In order to reduce the volume of leach liquor, size of equipments, cost of capital and energy, it was proposed to adopt bulk sulphide precipitation of the valuable metals from the dilute leach liquor followed by redissolution in chloride media and SX-EW operation. Bulk sulphide was precipitated from manganese nodule leach solution containing 800 ppm Cu, 970 ppm Ni, 67 ppm Co and 150 ppm Zn. Complete precipitation of all metal sulphide was achieved with 5% excess sodium sulphide concentration to the stoichiometric requirement. Various leaching parameters such as acid, sodium chloride, ferric chloride concentrations, temperature etc. have been studied to optimize the leaching conditions for redissolution of bulk sulphide precipitate.

IMPROVEMENT OF COBALT EXTRACTION IN REDUCTION-ROAST AMMONIA LEACHING OF SEA NODULES

T.C. Alex, T.B.Singh and R. K. Jana
Metal Extraction and Forming Division
National Metallurgical Laboratory, Jamshedpur – 831 007
Email: alex@nmlindia.org

Realizing the importance of polymetallic sea nodules as future resource of copper, nickel and cobalt, National Metallurgical
Laboratory, Jamshedpur has developed a process following reduction roast and ammonia leaching route for their extraction. Though copper and nickel extractions from roasted sea nodules in ammonical leaching were well above 90%, the cobalt recovery was only in the range of 50–60%. Studies using pure metal powders have shown that co-precipitation of cobalt with iron and manganese was the main reason for the low cobalt recovery. Attempts have been made to minimise the coprecipitation of cobalt using some additives during leaching. Preliminary results of leaching experiments with different additives showed that some of the additives could control the cobalt coprecipitation very effectively.

ION EXCHANGE PROCESS FOR GALLIUM RECOVERY

M.Ramasami, P.Selvi, M.H.P.Samuel, P.Adaikkalam and G.N.Srinivasan
Central Electrochemical Research Institute, Karaikudi-630 006
Email: cecri_icp@rediffmail.com

An environment friendly separation technique for the recovery of gallium from Bayer Liquors using chelating ion exchange resins is presented. The synthesis of the resin, its adsorption and elution characteristics and the designing of a pilot plant to recover gallium on a 100g/day scale is described.

THE ANODIC DISSOLUTION OF TUNGSTEN

Central ElectroChemical Research Institute, Karaikudi 630006
Email: cecri_icp@rediffmail.com

The recovery of tungsten from tungsten alloy swarf through the anodic dissolution of the scrap in sodium hydroxide solution was investigated. The optimum concentration of the electrolyte and the anode potential for the dissolution of tungsten at 100% efficiency was determined. The effect of rotation on the dissolution of tungsten was also studied.

SOLVENT EXTRACTION OF COPPER FROM AMMONIACAL SOLUTIONS

P.Adaikkalam and G.N. Srinivasan,
Central Electrochemical Research Institute, Karaikudi-630 006
Email: cecri_icp@rediffmail.com

Solvent extraction has an edge over the conventional chemical methods like precipitation for recovery of copper. In this paper, the use of DEHPA (Di ethyl Hexyl Phosphoric Acid) for its recovery from ammoniacal cupric chloride solution is described. The factors affecting the recovery such as pH, extractant concentration, copper concentration, A/O ratio etc. have been studied on laboratory scale and reported.

SOLVENT EXTRACTION OF GALLIUM FROM CHLORIDE SOLUTION USING D2EHPA

M.S. Vinodhkumar P. Adaikkalam and G.N.Srinivasan.
Central Electrochemical Research Institute,
Karaikudi-630 006
Email: cecri_icp@rediffmail.com

Gallium is an important material in the semiconductor industry. Electrolysis is one of the methods to recover gallium from Bayer’s liquor using mercury cathode. Solvent extraction is another alternative technique for the extraction of gallium. The factors affecting the recovery such as pH, extractant concentration, aqueous to organic ratio, gallium concentration and impurities effect have been studied on laboratory scale and reported.

RECOVERY OF HIGH PURE LEAD FROM SCRAP LEAD ACID BATTERIES BY ELECTRO REFINING

P. Ramachandran and V. Nandakumar,
Central Electrochemical Research Institute,
Karaikudi-630 006
Email: cecri_icp@rediffmail.com

Electro refining of lead was investigated for producing high pure lead from the scrap lead-acid batteries. The battery scrap was smelted directly in an electric furnace to lead metal, which was subsequently electrorefined in a fluoroborate medium. The purity level of electrorefined lead was greater than 99.99. Recovery of antimony, energy consumption, monitoring of electrolyte additives and cell voltage rise are discussed.

RECOVERY OF COPPER AS SALT BY CRYSTALLISATION FROM COPPER SPENT SOLUTION OF A COPPER UNIT.

A Agrawal, S Kumari, D Bagchi, V. Kumar and B D Pandey
Metal Extraction and Forming Division National Metallurgical Laboratory, Jamshedpur – 831 007
Email: archana@nmlindia.org

From the point of view of metal recovery and reuse from copper spent electrolyte containing 40-50 g/L Cu, 10-20 g/L Ni, 170-200 g/L H₂SO₄ of a copper plant, a bench scale study on the preparation of metal sulphate from a spent copper solution with/ without following a partial decopperisation step prior to crystallization was done. Copper sulphate crystals with a little nickel contamination (0.7-2.27%) obtained without decopperisation can be recycled back to electro-refinery plant to make up the copper level in electrolyte/ can be used as
chemical. The mixed sulphate crystal obtained after decopperisation could be processed to separate the valuable metals such as Cu and Ni by solvent extraction using reagents such as LIX 84/Cyanex 272, which lead to the development of a process flow sheet, for preparing value added products such as high pure metal salts/metal powders.

**GAS-PHASE SULPHATION OF NICKEL SPENT CATALYST FOR RECOVERY OF NICKEL**

B.B. Kar  
Regional Research laboratory, Bhubaneswar.  
Email: biswabandita@rrlbhu.res.in

The sulphur trioxide roasting of nickel spent catalyst was investigated at temperatures from 500°C to 750°C. The kinetics of the sulphation appeared to be a transport controlled process. A two-step sulphation process was investigated that takes advantage of the rate characteristics. The selectivity is achieved at 700°C with 94% of the nickel recovery.

**UPGRADATION OF INDIAN ILMENITES — PROSPECTS AND PITFALLS**

CVGK Murty, S.Asokan, Amit Chatterjee and B.Muthuraman  
Tata Steel, Titania Business Unit, Chennai  
Email: titaniabusiness@tatasteel.com

While direct consumption share of ilmenite in TiO₂ pigment is declining, consumption of upgraded ilmenite (Synthetic Rutile or TiO₂ slag) has been increasing strongly, world over. Indian ilmenites with 50-53% TiO₂ can be used for production of TiO₂ pigment through chloride route, only after upgradation. However, upgradation of ilmenite has its own prospects and pitfalls. Apart from technical issues, factors like high power tariff, inadequate infrastructure facilities, complex and expensive logistics, disposal of process wastes, requirement of suitable solid reductants, market preferences, etc., make ilmenite upgradation formidable. In this context, the upgradation of Indian ilmenites are discussed in this paper.

**SOLVENT EXTRACTION SEPARATION AND RECOVERY OF Cd(II), Ni(II) AND Co(II) FROM CHLORIDE LEACH LIQUORS OF SPENT BATTERIES WITH COMMERCIAL EXTRACTANTS (CYANEX 923 AND CYANEX 272)**

B. Ramachandra Reddy, D. Neela Priya and P. Radhika  
Indian Institute of Chemical Technology (CSIR), Hyderabad – 500 007  
Email: brcreddy@iict.res.in

This paper reports the development of environmental friendly hydrometallurgical flowsheet for the separation and recovery of Cd, Ni and Co from chloride leach liquors of spent Ni – Cd batteries by solvent extraction technique using commercial extractants, Cyanex 923 and Cyanex 272. Leach liquor (LL) contains Cd - 6.272, Ni – 21.56, Co – 0.14 (g/l) with pH 1. Cd separation was carried out by contacting the LL with 0.6 M Cyanex 923 in two stages at A:O ratio of unity. A three-stage stripping of Cd from L.O (6.267 g/l Cd) at A:O phase ratio of 1.75 yielded > 99.9% Cd efficiency. Ni and Co co-extraction was nil.

**ELECTROCHEMICAL REDUCTION OF TiO₂ TO PRODUCE TITANIUM SPONGE**

Ch.R.V.S. Nagesh, C.S. Ramachandran and V.V. Bhanuprasad  
DMRL, Kanchanbagh, Hyderabad-500 058

In the present work electrochemical reduction of TiO₂ granites at a temperature of 950°C in molten calcium chloride bath under argon atmosphere carried out in the new experimental set up which has been very encouraging and sponge grains with complete metallization could be prepared for the first time by this novel route. Characterization of sponge samples by SEM and EDAX confirmed titanium metal with less than 5000 ppm oxygen.

**FFC CAMBRIDGE PROCESS: A NOVEL MOLTEN SALT ELECTROMETALLURGICAL PROCESS FOR REDUCTION OF METAL OXIDES**

K.S. Mohandas and D.J. Fray  
University of Cambridge, Cambridge CB2 3QZ, United Kingdom.  
Email: djf25@hermes.cam.ac.uk

The FFC (Fray-Farthing-Chen) Cambridge process is a new process for production of metals and alloys from their solid oxides directly by molten salt electrolysis. The process is especially suitable for reduction of oxides of the transition metals and actinides. Presently the process is being studied, in pilot plant scale, for the production of titanium metal and Ti-based alloys. The paper gives an overview of the process and its present status with respect to titanium production. Preliminary experimental results on the electroreduction of zirconia and silica are presented.

**PERFORMANCE ENHANCEMENT OF ANODE BAKING FURNACES AT HINDALCO’S ALUMINIUM SMELTER**

S.C. Tandon, Arun Kumar and R.N. Prasad  
Hindalco Industries Ltd., Renukoot – 231 217, Sonbhadra, U.P.  
Email: rmprasad@adityabirla.com

In view of increased primary aluminum smelting capacity at HINDALCO, enhancement of anode baking became necessary.
A performance enhancement programme for Bake Furnaces was undertaken to increase productivity, optimise fuel oil consumption and improve anode quality & refractory life. A strategic plan for regulating heat distribution in Bake Furnaces was worked out by introducing micro-processor based fuel firing and draft control system. There is substantial gain in anode baking capacity and quality of carbon anodes besides reduction in fuel oil consumption. Heat Regulation System so developed is a low cost retrofit solution for performance enhancement of anode Bake Furnaces.

INVESTIGATIONS IN THE SCALEUP STUDIES FOR HIGH PURITY ALUMINIUM
Central Electrochemical Research Institute, Karaikudi 630 006
E Mail: tselvind@rediffmail.com

Commercial aluminium has a purity of 99.5-99.7%. The important impurities in the primary aluminium are Fe and Si with traces of alkali and alkaline earth metals. The present investigation deals with a two-layer electro-refining process, in which, commercial molten aluminium acts as the anode and high pure molten aluminium acts as the cathode. Both the electrodes are separated by a thin refractory partition and allowed to float over a molten electrolyte. Electro-refining cells of different capacities upto 1000A are operated and studies have been carried out. The refined metal has a purity of more than 99.9% with traces of impurities like Fe and Si. Further investigations are under progress for improving the quality of the refined metal and the refining process in an economical manner.

COMMERCIALISATION OF TITANIUM SPONGE PRODUCTION IN INDIA
C.S. Ramachandran and Ch. R.V.S Nagesh
Defence Metallurgical Research Laboratory, Kanchanbagh PO, Hyderabad-500 058

This paper brings out the results of the technology demonstration and quality data of the Titanium sponge production in India. A road map has been evolved for early commercialization of the technology developed at DMRL for the country’s self reliance with respect to this strategic metal.

ELECTRO-WINNING OF COBALT FROM PURIFIED LEACH LIQUORS OF SECONDARY SOURCES
Pamela Alex, A.C. Bidaye, I.G. Sharma and A.K. Suri
Material Processing Division, Bhabha Atomic Research Centre, Mumbai—400085
Email: alexpamela57@yahoo.co.in

In the electro-winning campaign of cobalt, the optimum parameters such as a temperature of 60°C, a CCD of 400 A/M² and a minimum pH of 3, established using synthetic solutions were test examined on leach liquors generated during processing of secondary resources of cobalt. The findings were comparable and reproducible except, a decrease in current efficiency from 95% to 80%.

EXTRACTION OF URANIUM USING ION IMPRINTING TECHNOLOGY
J. Mary Gladis, P. Metilda and T. Prasada Rao
Regional Research Laboratory(CSIR), Trivandrum. Email: tprasadarao@rediffmail.com

Ion imprinting technique creates plastic receptors that can specifically recognize and bind ions. Ion imprinted polymer (IIP) particles were prepared for the extraction of uranium by forming polymerizable complex of uranium and allowed to copolymerize styrene and divinyl benzene in the presence of porogen. The studies on the synthesis of uranyl IIP materials using binary / ternary complexes and different porogens were carried out to get efficient IIP for the extraction of uranium. Hence, ion imprinting technique renders a unique method for the extraction from sea water and lean ores and minerals and recovery from nuclear spent fuels.

4-ACYLBIS(1-PHENYL-3-METHYL-5-PYRAZOLONES) AS EXTRACTANTS FOR LANTHANOIDS
Rani Pavithran and M. L. P. Reddy
Regional Research Laboratory, Thiruvananthapuram-695 019.
Email: mlpreddy@yahoo.co.uk

4-Acylbispyrazolones with varying polymethylene chain length (n = 4, 6, 8 and 10) have been synthesized and examined their solvent extraction behavior towards trivalent lanthanoids (Nd³⁺, Eu³⁺ and Tm³⁺). The extraction of Ln³⁺ ions increases monotonically with increasing atomic number of these metal ions. These reagents showed an initial increase in the extraction efficiency of Ln³⁺ ion with increasing polymethylene chain length, -(CH₂)n-, from n = 4 to n = 8 and thereafter a decreasing trend, for n = 10. The equilibrium constants of the extracted complexes, deduced by nonlinear regression analysis, were correlated with the polymethylene chain length.
ALUMINIUM ELECTROLYSIS – THE PAST AND FUTURE

M.K.B. Nair
Smelter Plant, National Aluminium Co. Ltd.,
Email: mkbnair@nalcoindia.co.in

Aluminium remained elusive till the end of 19th century, though it occupied 8% of the earth's crust. The youngest amongst non-ferrous metals, it has surpassed all others in production and myriad applications. This review highlights the short history, long and pain taking experience of Scientists and Technologists, successes and failures, and development of modern aluminium technology, with special reference to Indian aluminium industry.

BIOLEACHING OF INDIAN OCEAN NODULES WITH REFERENCE TO EXTRACTION OF VALUABLE METALS BY ASPERGILLUS NIGER

K. D. Mehta, Chitrangada Das, N. K. Singh and B. D. Pandey
MEF Division, NML, Jamshedpur – 831007
Email: kdmehtra@nmlindia.org

The biorecovery of the metals from the ores/ concentrates/ wastes is an alternate ecofriendly process to conventional pyro/ hydro-metallurgical processes. The advantageous use of the microbial phenomenon was explored in the present investigation for the bioleaching of valuable metals from the ferromanganese ocean nodules. Aspergillus niger procured from a culture bank was used to leach copper, nickel, cobalt, manganese and iron.

SELECTIVE REDUCTION OF POLYMETALLIC SEA NODULES

Sanjay Prasad
National Metallurgical Laboratory,
Jamshedpur - 831 007
Email: sprasad@nmlindia.org

Polymetallic sea nodules of Indian Ocean has been studied the effect of different reductants on reducibility of metals. Two reductants namely saw dust and fuel oil were chosen for the present investigation. It was found that near 700°C both are equally good reductants. Their reduction experiments were carried out in a tubular furnace. After the reduction the calcine was tested for their metallic content. Based on the results obtained it was found that 10% fuel oil reduces well all the metals. The reduction of 95%, 80% and 53% copper, nickel and cobalt respectively was found at 750°C in 90 minutes, whereas reduction with 20% saw dust was 95%, 93.5% and 68% copper, nickel and cobalt respectively at 700°C in 60 minutes.

A COMPARATIVE STUDY ON THE ESTIMATION OF TITANIUM IN COLUMBIUM ALLOY USING SPECTROPHOTOMETRY, XRF AND ICP-AES TECHNIQUES

R. Rajeev, Salu Jacob, Annamma Abraham, T.S. Ramasubramanian and K.G.Kannan
Vikram Sarabhai Space Centre, Trivandrum
Email: arerajeev@yahoo.com

Columbium alloy, C 103, containing hafnium and titanium as the major alloying elements, is a high temperature resistant alloy which is used for various aerospace applications. The precise and accurate determination of titanium in the alloy will be essential for the development and qualification of the material. Quantitative estimation of titanium in columbium alloy was carried out using Spectrophotometry, XRF and ICP-AES. Microwave digestion of the sample was carried out for rapid and effective dissolution. The matrix effect and spectral interference on the analytical lines of titanium in each technique are discussed. The analysis results were compared and verified by using standard addition method and by synthetic standards. The advantages and disadvantages of all the three techniques are highlighted.

DEVELOPMENT OF CU-CO-Fe PRE-ALLOYED POWDERS BY HYDROMETALLURGICAL PROCESS

Dr. Babasaheb Ambedkar Technological University,
Lonere, Raigad-402 103
* Indian Institute of Technology, Powai,
Mumbai-400 076
Email: thorat.rahul@rediffmail.com

The paper presents the synthesis of Cu-Co-Fe pre-alloyed powder by hydrometallurgical process for the consolidation of rock cutting diamond tools. Premixed salts of copper, cobalt, and iron were reduced in hydrogen atmosphere to develop the powder. The final microstructure of the powder was of two phase material (Copper and a-iron).
NON FERROUS ALLOYS

INFLUENCE OF HEAT TREATMENT PARAMETERS ON ABRASIVE WEAR BEHAVIOUR OF TWO CAST Al-Si ALLOYS

B. Shah Kinjal, Sandeep Kumar and D. K. Dwivedi*
National Institute of Technology, Hamirpur: 177005 (HP)
*Indian Institute of Technology, Roorkee: 247 667 (UP)
Email: dwivedi_rech@hotmail.com

In the present paper, influence of heat treatment parameters (aging time & temperature) on abrasive wear behavior of two cast Al-12%Si-0.6Mg-3%Cu and Al-18%Si-0.6Mg-3%Cu has been reported. The wear resistance initially increases with increase in ageing time and subsequently decreases. Similarly the wear resistance increases with increase in ageing temperature from 150 to 190°C and thereafter decreases. SEM and optical microstructural studies were also carried out to establish the relation between microstructure and mechanism of wear.

CHALLENGES IN DEVELOPMENT OF DISPERSION STRENGTHENED Cu-8Cr-4Nb ALLOY

Kedar Bhide and N.B.Dhokey
Govt. College of Engineering, Pune –411005
Email: k_bhide2000@yahoo.com

Copper alloys with high strength and high thermal conductivity containing fine, dispersed particles have received a lot of attention. In the present work liquid metallurgy route was attempted. Initial part of the research was focused on understanding thermodynamic aspects such as solubility, stability of the Cr,Nb phase, selection of crucible. Trials were performed in vacuum induction furnace. After conducting the material characterization, conclusions were drawn to highlight problems faced in the development of this alloy.

ROLE OF ELECTROPLATED INTERLAYERS IN CONTINUOUS DRIVE FRICTION WELDING OF AA 6061 TO AISI 304 DISSIMILAR METALS

G.Madhusudhan Reddy T.Mohandas, K. Mandar Govind Rao* and A. Sambasiva Rao
Defence Metallurgical Research Laboratory, Hyderabad - 50058
*National Institute of Technology, Warangal- 506004
Email: gmreddy_dmrl@yahoo.co.in

Metallurgical problems are inherent in the joining of aluminium alloy to stainless steel by conventional fusion welding processes. With this in mind the effect of Cu, Ni and Ag in the form of electroplating as interlayer materials has been investigated. EPMA of welds without interlayer revealed that the interface microstructure consists of Fe2Al5 with some FeAl3, which are highly brittle. Welds with copper and nickel as interlayers exhibited the presence of CuAl2 and Ni3Al intermetallics respectively which are less brittle compared to Fe2Al5 and FeAl3. On the other hand welds with silver interlayer exhibited good quality due to the formation of soft Ag3Al at the interface of the joint.

DEVELOPMENT OF DOUBLE-WALL CO-AXIAL FIN TUBE AS CLAD FOR RESEARCH REACTOR FUEL PIN

Rakesh Kumar, Arbind Kumar, Gargi Chaudhari and R P Singh
Bhabha Atomic Research Centre, Trombay, Mumbai – 400 085
Email: rakeshk@magnum.barc.ernet.in

Double-wall co-axial aluminum clad tube has been developed to increase the residence time of fuel in the research reactor. 25 double-wall co-axial fin tubes of dimensions 13.00 mm ID, 1.40 mm wall thickness (total) and 3500 mm long have been manufactured using the available facilities and raw material. The paper discusses in detail about the, process flow-sheet, quality evaluation techniques used and their results.

MICROSTRUCTURE AND MECHANICAL BEHAVIOUR OF MULTIPHASE Mo-Si-B ALLOYS

A. K. Srivastava, *S. Raje, **Sweety Kumari, ***N. Eswara Prasad and R. Mitra
Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Kharagpur – 721 302,
West Bengal
*Department of Metallurgical Engineering
VNIT, Nagpur
**Defence Metallurgical Research Laboratory
P.O. Kanchanbagh,
Hyderabad – 500 058 (A.P.)
Email: rahul@metal.iitkgp.ernet.in

The mechanical behaviour of Mo-Si-B or Mo-Si-B-Al alloys showing different volume fractions of α-Mo, Mo3Si, Mo5SiB2 as well as fine particles of SiO2 or Al2O3 in the microstructure has been studied. Considerable improvement in the room temperature fracture toughness and flexural strength is achieved, because of crack bridging and constrained plastic deformation in ductile α-Mo phase. Compressive yield strengths and work hardening behavior of the Mo-Si-B alloys in the temperature range of 1100-1350°C, show impressive strength retention due to the presence of Mo3Si and Mo5SiB2 phases.
EFFECT OF Mo ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF Nb-Si-Mo ALLOYS

Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Kharagpur – 721302, West Bengal
*Defence Metallurgical Research Laboratory,
Hyderabad – 500 058
Email: rahul@metal.iitkgp.ernet.in

The effect of molybdenum on microstructure modulation and mechanical properties of three Niobium-Silicon-Molybdenum alloys have been investigated. The influence of Mo on volume fraction, size and morphology of the phases, lattice parameter of NbSS particles, and on hardness and indentation fracture toughness of these refractory metal-intermetallic composites has been reported.

INTERMEDIATE TEMPERATURE OXIDATION BEHAVIOUR OF MO-Si-B AND Mo-Si-B-Al ALLOYS

Sharma Paswan, *V. V. Rama Rao, R. Mitra and S. K. Roy
Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Kharagpur – 721302
*Defence Metallurgical Research Laboratory,
Hyderabad – 500 058
Email: rahul@metal.iitkgp.ernet.in

The isothermal oxidation behaviour of selected Mo-Si-B ternary and Mo-Si-B-Al quaternary alloys in the temperature range 400-700°C and at 1150°C for periods between 20 h and 300 h in dry air was investigated. The effects of alloy composition, temperature and time of exposure on the oxidation kinetics and mechanisms were studied, with emphasis on the morphology and constituents of oxide scales. Prior short exposure of the alloys at high temperature, significantly improved their lower temperature oxidation resistance.

EFFECT OF COPPER ADDITIONS AND COLD WORKING ON AGING RESPONSE OF Al-0.5 Si-0.5 Mg - 1.0 Ni ALLOY

A.K. Bhargava, Y.V.S.S. Prasad and Mayur Marwal
Malaviya National Institute of Technology, Jaipur
Email: akmt@rediffmail.com

In the present work, effect of coper additions and cold working on ageing response of Al - 0.5 Si - 0.5Mg - 1.0Ni alloy have been studied and the results are compared with aluminum alloys 6061 and 4032. The present alloys Al-0.5Si-0.5Mg-1.0Ni-(0.95–1.42) Cu exhibit a peak hardness of 101 BHN in T6 condition as against 73 BHN exhibited by 6061 alloy in the same condition. The present alloys in the T8 condition (cold worked and artificially aged) shows the hardness 121 BHN which is comparable to 4032 alloy in T6 condition.

OXIDE-SCALE AND α-CASING CHARACTERISATION IN Ti6Al-4V ALLOY OXIDISED IN OXYGEN GAS

M.N. Mungole, M. Surendar and S. Bhargava
Dept. Met Engg., IIT, Kanpur.

In the present work oxidation study of Ti – 6Al – 4V alloy has been carried out in dynamic oxygen gas and the results related to characterization of oxide scale and α - casing in detail for the alloy oxidised at 1050, 1150, 1250, 1340 K for 2, 4, 8 and 12 hrs are presented. The oxide scale and α - casing morphology, their constituents, microhardness, thickness etc were determined through visual and microscopic observation, X-ray diffraction and microhardness measurement.

STUDIES OF PERMANENT MOULD CASTING AND RAPIDLY SOLIDIFIED Zn-27 Al ALLOY

Y.V.S.S. Prasad, A.K. Bhargava, S.K. Jain and Ramesh Chand
Malaviya National Institute of Technology, Jaipur
Email: akmt@rediffmail.com

In the present work Al-27 wt% Zn alloy produced by permanent mould casting and the same alloy is rapidly solidified (by melt spinning). The microstructure of permanent mould cast alloy consists of dendrites and eutectic mixture. Dendritic structure is absent in rapidly solidified (RS) alloy. The hardness of RS ribbons is more than the permanent mould cast alloy. On ageing melt spun alloy ribbons show an increase of hardness. XRD of melt spun product shows peaks from single phase as compared to two phases in permanent mould cast alloy.

HYDROGEN-INDUCED DELAYED FAILURE OF AA 7020 ALLOY

Santosh Kumar, T. Jagdish Babu and T. K.G. Namboodhiri
Department of Metallurgical Engineering
Banaras Hindu University,
Varanasi-221005
Email: tkgnam@satyam.net.in

AA 7020, an Al-Zn-Mg alloy, is widely used in aerospace applications. Weldments in this alloy were observed to crack upon storage. This study was conducted to determine whether
the cracking could be due to hydrogen embrittlement. The alloy, in T6, duplex aged and welded conditions, was found to be susceptible to hydrogen induced delayed failure. Air-quenching makes the alloy least susceptible to hydrogen. Susceptibility increases with water quenching or welding. The observed results are explained on the basis of the microstructure of the alloy.

METASTABLE PHASES IN Al-Fe ALLOYS: A STUDY BY MA AND RSP

S. S. Nayak, D. H. Kim *, S.K. Pabi and B. S. Murty **
Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Kharagpur 721 302, India
* Center for Noncrystalline Materials, Department of Metallurgical Engineering, Yonsei University, Seoul 120-749, South Korea
** Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Madras, Chennai 600 036, India
Email: sashank@metal.iitkgp.ernet.in

In present work, formation of metastable phases like micro/nano quasicrystals (RSP) and intermetallics like Al$_5$Fe$_2$, Al$_{13}$Fe$_4$ and Al$_3$Fe (with increasing thermodynamic stability) have been reported in Al-Fe alloys of nominal composition Al$_{100-x}$Fe$_x$ ($x$ = 2.5, 5, 10, 15 and 20). Highest hardness value of 12GPa was observed in the nanocomposites.

EFFECT OF Cu POWDER TYPE AND SINTERING TEMPERATURE ON MICROWAVE SINTERING OF Cu-10Sn ALLOYS

Uddanti Ravikiran and Anish Upadhyaya
Department of Materials & Metallurgical Engineering, Indian Institute of Technology, Kanpur-208016
Email: anishu@iitk.ac.in

The present work examines the effect of electrolytic, atomized and prealloyed bronze powder on the microwave sintering of Cu-10Sn alloys. The bronze alloys were sintered in transient liquid phase and supersolidus conditions at 700 and 840°C, respectively. The bronze compacts are sintered using microwave heating in 70% less time. Compared to conventional sintering, the microwave sintered bronze results in significant enhancement of mechanical properties. The difference in the mechanical properties has been correlated to the varying response of bronze powders to the sintering temperature and heating mode.

CHEMICAL CHARECTERISATION OF MAGNETOCALORIC Gd-Si-Ge ALLOY

Shanker, B. Shravan kumar and V. Lalitha kumari
Analytical Chemistry Group, D.M.R.L, Hyderabad-500058
Email: lalitha@dmrl.ernet.in

The paper deals with chemical characterisation of RE based magnetic Gd-Si-Ge alloys. Methods are developed and samples are analysed for Gd at 75-80% using complexometry and Optical Emission Spectrometry (OES), Si at 15-25% by gravimetry Ge at 15-30% and impurity elements of Cu, Fe and Al at ppm levels by Atomic Absorption Spectrometry (AAS). Results are validated by using synthetic standards.

INFLUENCE OF MICROSTRUCTURE AND TRACE RESIDUAL ELEMENTS ON THE CREEP PROPERTIES OF IMI834

H. Mishra, P. Ghosal, T.K. Nandy and P.K. Sagar
Defence Metallurgical Research Laboratory, Kanchanbagh, Hyderabad-58.
Email: himanshu201@rediffmail.com

The creep performance of near alpha Ti-alloys such as Ti-6242 and IMI 834 is significantly influenced by the microstructure and the presence of fast diffusing residual elements like Fe, Ni. In the present study, creep properties of three IMI834 melts, obtained from various sources containing different levels...
of Fe and Ni, have been evaluated. Based on the results, the mechanism for high temperature deformation has been proposed and the influence of Fe and Ni has been discussed in relation to the proposed mechanism and the information available in literature.

CONVERGENT NOZZLE IN SPRAY ATOMIZATION AND DEPOSITION OF 7075 ALUMINIUM ALLOY

M. Jeyakumar, G. S. Gupta and Subodh Kumar
Indian Institute of Science, Bangalore 560 012, India
Email: jkumar@met.iisc.ernet.in

7075 aluminum alloy is atomized and deposited on the substrate using two types of convergent nozzles, one is a convergent nozzle and another one is a convergent nozzle with 2 mm parallel portion. The variation of gas and melt flow rates and the properties of deposit such as yield, porosity and microstructure, are investigated.

INFLUENCE OF AGING CYCLES ON MECHANICAL PROPERTIES AND CORROSION RESISTANCE OF AFNOR 7020 ALUMINIUM ALLOY FORGINGS.

Basavaraj, Dr. B.K. Muralidhara* and V. Diwakara Rao**
G.B. Pant Polytechnic, Okhla, New Delhi.
*U.V.C.E., Bangalore University, Bangalore.
**Managing Director, Vishnu Forge Ltd., Bangalore
Email: csmurthy@indiatimes.com

Studies indicate that artificially aged AFNOR 7020 aluminum alloy exhibit superior mechanical properties. Artificial ageing treatment given twice appears to be more effective. However, corrosion resistance of artificially aged AFNOR 7020 aluminum alloy was found to be lower than that off naturally aged alloy.

MICROSTRUCTURE AND CYCLIC OXIDATION BEHAVIOUR OF Pt-ALUMINIDE COATING ON TI-BASE ALLOY IMI-834

D.K. Das
Defence Metallurgical Research Laboratory, Kanchanbagh, Hyderabad 500058.
Email: dipakdi1004@yahoo.co.in, dkd@dmlr.ernet.in

Near-á Ti-alloy such as IMI-834 and IMI-829 have poor high temperature oxidation resistance which severely restricts their use in gas turbine applications. Several protective coatings on the above alloys have been applied to improve their oxidation properties. In the present study, Pt-aluminide coating has been applied on IMI 834 alloy to enhance its oxidation performance. The microstructural features of this coating its oxidation performance at 650 and 750°C have also been studied.

STUDIES ON FRICTION WELDING OF ALUMINUM-COPPER (AA2014) ALLOY TO ALUMINUM-MAGNESIUM – SILICON ALLOY (AA6061)

M. Ashfaq, H. Khalid Rafi and K. Prasad Rao
Indian Institute of Technology, Madras
Email: ashfaq_m700@yahoo.co.in

Three important parameters Friction force, Forge force and Burn-off are varied during Friction welding of AA6061 to AA2014. Very fine recrystallized grain structure could be seen in the interface region. Hardness and tensile test results would be correlated with the findings from the microscopic images of the grain structure.

DEVELOPMENT OF LOCOMOTIVE PISTON FORGINGS USING AI-Si ALLOY

A.Venkata Ramana*, R.S.Tripathy, R.R.Bhat, G. Madhusudan and Jagannath Nayak*
Foundry & Forge Division, Hindustan Aeronautics Limited, Bangalore – 560 017
* Department of Metallurgical & Materials Engineering, NIT Karnataka, Surathkal
Email: rr_bhat@yahoo.co.uk

A locomotive piston forging generally undergoes closed-die forgings with feedstock of extruded Al-Si billets. The present work aims at use of indigenously produced direct chill (D.C.) cast billets followed by forging in hydraulic press. Tensile properties, hardness and microstructure of piston forgings made from of D.C. cast billet, 3-stages and 5-stages ‘C’ process are compared to piston forgings made from extruded billet. It is observed that 5-stages ‘C’ process billet gave superior mechanical properties when compared to billets with no C-process and with 3 stages C-process. Moreover, the piston forgings produced through direct forging of extruded billets showed comparable mechanical properties. Microstructural features revealed a fine distribution of Si particles with a grain size in the range of ASTM no. 8-8.5.

STUDY ON EFFECT OF SOLUTIONIZING/AGEING TEMPERATURE AND TIME ON GRAIN SIZE OF SU718 RINGS

Vaisakhi S Nandi, R. R. Bhat, D. Roy and D. Dutta
Foundry & Forge Division, Hindustan Aeronautics Limited, Bangalore
Email: rr_bhat@yahoo.co.uk

Rings made of Superalloy (SU) 718 are being widely used in Kaveri engine of Light Combat Aircraft (LCA) because of high strength upto 700°C with good corrosion resistance and excellent weldability. In the production of some of the larger size rings, rolling and heat treatment operations resulted in very coarse grains (ASTM grain size no. 1-2) with isolated fine grains.
EFFECT OF SECTION THICKNESS AND MODIFICATION MELT TREATMENT ON THERMAL ANALYSIS PARAMETERS OF A357 ALLOY

Sathyapal Hegde, Girish Kumar and K. Narayan Prabhu
National Institute of Technology Karnataka, Surathkal
P.O. Srinivasnagar 575 025, Karnataka State, India
Email: narayan_prabhu@hotmail.com

Thermal analysis is an effective NDT tool to assess the degree of modification. The thermal analysis parameters are known to vary significantly with casting conditions. The effect of melt treatment and casting section thickness on the thermal analysis parameters of Al-Si-Mg foundry alloy during solidification in metallic moulds was investigated.

HEAT TRANSFER AND SOLIDIFICATION BEHAVIOUR OF MODIFIED A357 ALLOY

Girish Kumar, Sathyapal Hegde and K. Narayan Prabhu
National Institute of Technology Karnataka, Surathkal
P.O. Srinivasnagar 575 025, Karnataka State, India
Email: narayan_prabhu@hotmail.com

The solidification behaviour of modified A357 alloy was investigated. The results revealed that the heat of solidification and casting/mould interfacial heat flux transients were affected significantly by modification melt treatment. A eutectic growth model was used to predict growth velocities and grain sizes. High growth velocities yielded fully modified structures.

INFLUENCE OF PROCESS PARAMETERS FOR THE PREPARATION OF AI-TI AND AI-B MASTER ALLOYS FOR THE GRAIN REFINEMENT OF AI-7SI ALLOY

S. A. Kori, V. Auradi and M. Chakraborty*
Basaveshwar Engineering College, Bagalkot – 587 102, Karnataka
*Indian Institute of technology, Kharagpur-721302.
Email: kori.shivu@lycos.com

In the present study various binary Al-Ti and Al-B master alloys prepared by salt route under different processing conditions were assessed for their grain refining efficiency on Al-7Si alloy. Results suggest that a reaction temperature of 800°C and a minimum reaction time of 60 min. were essential in order to achieve the completion of the reaction in Al-Ti and Al-B master alloys. Further, results of macroscopy and DAS analysis reveal that Al-7Si alloy shows better grain refining response to Al-3B and Al-3Ti master alloys prepared at 800°C-60min. when compared to the master alloys prepared under different reaction temperature and time.

EFFECT OF PHOSPHOROUS ADDITION ON DRY SLIDING WEAR BEHAVIOUR OF HYPREUTECTIC AI-SI ALLOYS

S.A. Kori, T.M. Chandrashekharaiah, B.M. Angadi and V. Auradi
Basaveshwar Engineering College, Bagalkot – 587 102,
Karnataka
Email: kori.shivu@lycos.com

In the present study, the effect of phosphorus addition on dry sliding wear behaviour of hypereutectic Al-Si alloys (Al-13, 14, 15, 17 and 20%Si) has been investigated using Pin-On-Disc wear testing machine. Various parameters such as composition of the alloy, normal pressures, sliding distances, and sliding speeds were studied. Wear test specimens were characterized by optical microscope and image analyzer. The results suggest that wear resistance decreases with increasing silicon content and increases with the addition of 0.02%P to the melt when compared to the as cast hypereutectic alloys.

DEVELOPMENT OF HIGH STRENGTH ALUMINUM ALLOYS FOR ELEVATED TEMPERATURE APPLICATIONS BY MECHANICAL ALLOYING

M. Sudhakara Rao, T. Raghu and G.G. Saha,
Defence Metallurgical Research Laboratory, Kanchanbagh, Hyderabad -500 058.
Email: hina_gokhale@rediffmail.com

A study has been taken up to synthesize two alloys systems: Al – Ti and Al – Ni – Zr by mechanical alloying. Milling of elemental powders has been carried out in a high energy ball mill for different milling conditions. As milled powders have been characterised for their size, microstructure and hardness. The progress of milling at different extents of milling time periods was followed by X – Ray diffraction of the powders. Lattice parameters and crystalline sizes of the alloys were evaluated from the X- ray data. Analysis has been carried out to understand the non – equilibrium solid solubility changes in the system.

CONTRIBUTIONS OF KERALA ARTISANS TO THE METALLURGICAL HERITAGE OF INDIA

S.G.K. Pillai, R.M. Pillai and A.D. Damodaran
Regional Research Laboratory, Thiruvananthapuram-695 019
Email: rmpillai@rediffmail.com

‘Aranmula Kannadi’ (Aranmula Metal Mirror) and ‘Kadavaloor Ottukinnam’ (Kadavaloor Eating Bowl) are the two remarkable contributions of unlettered Kerala artisans to the metallurgical heritage of India and Kerala in particular. These two processes had been evolved only from intuition and experience without any access to currently available knowledge or tools. This paper
highlights the processes involved in making the ‘Aranmula Kannadi’ and ‘Kadavaloor Ottukinnam’ and the metallurgical science behind these two processes.

**MICROSTRUCTURAL CHARACTERIZATION OF CALCIUM ADDED Al-7Si-0.3Mg-XFe ALLOY**

S.S. Sreeja Kumari, R.M. Pillai, S.G.K. Pillai, P. Prabhakar Rao and B.C. Pai
Regional Research Laboratory (CSIR), Thiruvananthapuram – 695 019.
Email: rmpillai@rediffmail.com

The microstructural characteristics of calcium added Al-7Si-0.3Mg-XFe (X= 0.2 and 0.8%) alloy have been investigated using, optical metallography, image analysis SEM/EDS and thermal analysis. It has been found that Ca addition modifies the eutectic Si structure and refines the size of platelike Fe–intermetallic phases. The mechanism for these microstructural changes has been discussed.

**EFFECT OF SQUEEZE PRESSURE ON THE MICROSTRUCTURE AND MECHANICAL PROPERTIES OF 2124-Al ALLOY**

K. Sukumaran, K.K. Ravikumar, S.G.K. Pillai, M. Ravi, V. John, R.M. Pillai and B.C. Pai
Regional Research Laboratory, Thiruvananthapuram-695 019

Squeeze casting is an alternative, well developed, cost effective metal shaping method adopted by many industries especially in the automobile sector for the manufacture of a host of components. In the present investigation, 2124-Al alloy was subjected to squeeze casting. The effect of squeeze pressure was correlated with the microstructural parameters such as DAS, features of porosity and other micro constituents and mechanical properties. The results indicate a considerable reduction of defects level with the increase of squeeze pressure of the order of 100MPa.

**QUALITY THIN WALL MAGNESIUM ALLOY CASTINGS THROUGH LOW PRESSURE CASTING PROCESS**

Regional Research Laboratory, Trivandrum
Email: vasansrini_72@yahoo.com

Producing defect free quality magnesium alloy casting for high temperature application is a challenging task. The present work aims to produce AZ91 magnesium alloy castings by LPC process using an indigenously designed and developed LPC machine. The microstructure and mechanical properties evaluated are compared with those of the gravity castings. Improved mechanical properties both room and high temperature are noticed with LP cast AZ91 alloy.

**BLISTER FREE HEAT TREATABLE ALUMINUM ALLOY CASTINGS BY SEMISOLID METAL PROCESSING**

B.R.K. Rao, V.M. Nimbalkar, A. Gaurav Rao, V.P. Balaji, Daya Lama, V.P. Deshmukh and A.K. Shah,
Naval Materials Research Laboratory, Ambernath – 421506, Thane.

Present work describes processing stages involved during Semi–solid processing (SSM) of Aluminium alloy LM25 feed stock raw materials and some of the trails initiated to demonstrate the SSM technology capability for producing both thin and thick wall castings with varied flow lengths. Surface blistering after heat treatment could be controlled by optimizing thixocasting filling profiles using the real time controlled die casting machine. The test components produced indicated good response during T6 heat treatment and achieved strength level greater than 300 MPa having better ductility in comparison to conventionally cast components.

**MICROSTRUCTURE EVOLUTION IN ISOTHERMALLY HELD SEMI-SOLID Al-7Si-0.3Mg ALLOY**

Shankargoud Nyamannavar*, M.Ravi and K. Narayan Prabhu*
Regional Research Laboratory, Trivandrum – 695 019
*National Institute of Technology Karnataka, Suratkal-575 025
Email: ravi@csrrlitrdb.ren.nic.in

In semi-solid metal (SSM) processing, to obtain spherical particles, the solid dendrites are broken up using mechanical, electromagnetic forces or by isothermally holding. After isothermal holding and cooling at higher rates, instabilities are formed on the primary α particles. The tolerable Fe content and the interaction of Sr modifier with Fe in the isothermally held 356 alloy has been studied (at 590 oC, holding for 8000 sec.) at various cooling rates (0.1 to 100 K/sec.) in terms of the instabilities, primary α particle size, entrapped liquid and the eutectic Si size and shape. Thermal analysis and quantitative microstructure analysis was used to correlate the evolved microstructural features.
STRUCTURE - PROPERTY CORRELATION STUDIES ON STRONTIUM MODIFIED Al-7Si-0.3 Mg ALLOY

K. Pratheesh*, M. Ravi, M.C. Shaji and V. John
*Vidhya College of Engineering, Trichur, Kerala
Regional Research Laboratory, Trivandrum-695 019
Email: ravi@csrrltrd.ren.nic.in

The morphology of eutectic Si in the slow cooled as cast microstructure of Al-7Si-0.3Mg (356) alloy is acicular, flake or plate shaped. Addition of modifiers such as Sr or Na changes acicular Si to lamellar or fibrous shape which leads to improved mechanical properties. The fading characteristics of the alloy melts subjected to modification using 0.02, 0.04, 0.06 and 0.08% Sr were assessed at different holding times of 10, 20, 30, 45, 60 and 90 minutes. The results indicate that when 0.02% Sr is used, fading starts at about 20 minutes itself. When 0.08% Sr is used, modified structure is observed even after 90 minutes of holding, but this results in an overmodified microstructure. The mechanical properties correlate reasonably well with the observed microstructures particularly the quantitative Si particle parameters measured by image analysis.

MICROPOROSITY FORMATION IN NORMALLY CAST AND SEMI-SOLID Al-7Si-0.3Mg ALLOY

M.Ravi, Roschen Sasikumar and Kalyanaraman*
Regional Research Laboratory, Trivandrum – 695 019
*National Institute of Technology Karnataka, Suratkal-575 025
Email: ravi@csrrltrd.ren.nic.in

In castings, porosity is detrimental to the mechanical properties, pressure tightness and corrosion resistance etc. Feeding difficulties were believed to be the reason for the formation of microporosity. However, calculations show that homogeneous as well as heterogeneous nucleation of pores in the liquid is very difficult. Based on the observations of bubble growth in succinonitrile-argon alloy by in-situ method a hypothesis is proposed here that the pre-existing bubbles are the source for porosity in the casting. This hypothesis was tested and verified by comparing porosity in samples of Al-7Si-0.3Mg alloy solidified under the same conditions with and without pre-existing bubbles in the normally cast as well as semi-solid alloy.

SECONDARY PROCESING

HOT WORKABILITY OF Ti-5.5Al-1Fe AND Ti-6Al-4V: A COMPARISON

V.V.Balasubrahmanyam, T.Seshacharyulu’ and Y.V.R.K.Prasad”
Andhra University, Visakhapatnam 530003
’Air Force Research Laboratory, Wright-Patterson AFB, OH 45433, USA
”Indian Institute of Science, Bangalore 560012

The hot workability of Ti-5.5Al-1Fe and Ti-6Al-4V is compared with the help of processing maps developed over wide temperature and strain rate ranges. At slow strain rates, both the alloys exhibit superplasticity in the α + β phase field and dynamic recrystallization in the α phase field, which are ideal for hot working these alloys. Regimes of damage mechanisms manifested as adiabatic shear bands in the α + β range and unstable flow in the β range occur at high strain rates and these deformation conditions should be avoided for obtaining controlled microstructures.
EQUAL CHANNEL ANGULAR PRESSING OF COMMERCIAL PURE ALUMINIUM

R P Sugyaneswar, T Thirumalai, J Krishnamoorthi, B Ravisankar and P C Angelo
PSG College of Technology, Coimbatore - 641 004
Email: r_shankar2002@yahoo.com

Equal Channel Angular Pressing (ECAP) is a method in which the grain size is refined to sub micro and nano meter level without any change in the dimension. The grain refinement in ECAP is achieved by forcing the sample through a specially designed die, which assists in deformation of material in its shearing plane. In the present work, the effect of strain by ECAP on commercial purity aluminum has been studied. The ECAP die has been designed and fabricated with the shearing plane angle 120°. Metallographic studies on Aluminum samples confirm appreciable grain refinement. The hardness is also increased significantly.

HOT WORKING CHARACTERISTICS OF IMI 834 ALLOY FOR COMPRESSOR ROTOR BLADE APPLICATIONS

R.Srinivasan, R.Mathivanan, M.S.Velpari and R.Krishnamoorthy
Hindustan Aeronautics Limited, Bangalore-560 017
Email: agm.aerospace@hal-india.co

The near alpha titanium alloy IMI 834 material was subjected to different types of hot working operations to realize thin aero foiled section precision blade forgings. Samples from various stages and different temperatures of forgings were analyzed for all properties after heat treatment and parameters optimized to achieve desired results.

EVALUATION OF EQUAL CHANNEL ANGULAR EXTRUSION AS AN INTERMEDIATE PROCESSING STEP PRIOR TO COLD EXTRUSION IN A 6XXX SERIES ALUMINIUM ALLOY

D. Nagarajan, Uday Chakkingal and P.Venugopal,
Materials Forming Laboratory, Indian Institute of Technology Madras.
Email: udaychak@iitm.ac.in

Equal Channel Angular Extrusion (ECAE) is a severe plastic deformation process for obtaining ultrafine-grained microstructures. In this study effect of subsequent processing of ECA extruded Aluminium alloy specimen by conventional cold extrusion has been investigated. Mechanical testing and microscopy were carried out to evaluate the benefits of ECA extrusion as a prior deformation step.

DEVELOPMENT OF MICROSTRUCTURES AND MECHANICAL PROPERTIES IN COMMERCIAL PURITY COPPER AFTER A COMBINATION OF EQUAL CHANNEL ANGULAR EXTRUSION AND COLD ROLLING

A. Krishnaiah, Uday Chakkingal and P. Venugopal
Materials Forming Laboratory, Indian Institute of Technology Madras.
Email: udaychak@iitm.ac.in

Equal channel angular extrusion (ECAE) as an intermediate process, was used to deform samples of pure copper using 120° die. ECAEed copper samples were rolled to ~50% reduction to study the microstructural and mechanical properties. The effect of ECAE as an intermediate processing step prior to rolling has been evaluated.

HOT EXTRUSION OF TITANIUM AND TITANIUM ALLOYS

S.K. Jha, Kumar Vaibhaw, P.K. Krishnan and N. Saibaba
Extrusion and Piercing Plant, Nuclear Fuel Complex, Hyderabad.
Email: skjha@nfc.ernet.in

This paper describes the different extrusion parameters used to extrude titanium and its alloys. This paper also elaborates the deformation mechanism operative during hot working of Titanium and its alloys. Large quantity of these alloys has been processed and meeting stringent quality requirement.

EXTRUSION OF URANIUM AND ITS HEAT TREATMENT

M.M. Hussain, A.K. Singh, S.P. Singh and R.P. Singh
Bhabha Atomic Research Centre, Trombay, Mumbai-400 085
Email: hussain@apsara.barc.ernet.in

The purpose of this paper is to highlight the optimization of important parameters for uranium extrusion and its heat treatment for fabrication of fuel rods for nuclear research reactors so as to achieve satisfactory fuel performance under reactor conditions. The paper also emphasizes the importance of die designs for uranium rod extrusion.
IMPORTANCE OF RAW MATERIALS CHARACTERIZATION ON THE QUALITY OF ALUMINUM ALLOY FORGINGS

Foundry & Forge Division, Hindustan Aeronautics Limited, Bangalore – 560 017
Email: rr_bhat@yahoo.co.uk

The characterization of raw material bar stock used for different metal working processes is an essential step in achieving good quality final products. In the present study, two cases of aluminum alloy forgings, where use of raw material with improper metallurgical characteristics had resulted in defects in the final forging, are discussed. In the first case, AA 7075 ring forging exhibited linear defects at its centre section during ultrasonic examination. The segregation of brittle, coarse intermetallic phases at the centre section of the raw material bar stock forging was identified as the cause for the observed defects in the final forging. In the second case, AA 2014 ring forging exhibited linear defects throughout its cross-section at various locations of the ring. Detailed investigation revealed that the raw material used for the forging process had significant amount of porosity and this porosity appeared to have survived during the subsequent hot deformation and had appeared as a linear indication during ultrasonic testing of the ring forging.

GRAIN REFINEMENT OF Cu-Zn-Al SMAS BY EQUAL CHANNEL ANGULAR PRESSING

R. Manna, Basava Kumar Mudda, N.K. Mukhopadhyay and G.V.S. Sastry
Centre of Advanced Study, Institute of Technology, Banaras Hindu University
Varanasi – 221005
Emails: rpmanna@rediffmail.com, gvssasstry2000@yahoo.com

Shape memory alloys(SMA) are those special class of alloys undergoing martensitic transformation which memorise or restore upon heating to a characteristic temperature their original shape, after deformation in martensitic state. Cu-Zn-Al SMAs are excellent with respect to their ductility and grain boundary fracture. However coarse grained structure in these alloys result in poor mechanical performance. The present work is aimed at refining the microstructure of Cu-Zn-Al SMAs by using Equal Channel Angular Pressing (ECAP) technique. The degree of microstructural refinement achieved and the transformation products will be analysed and discussed.

DELVELOPMENT OF HOT DEFORMATION TEXTURE AND MICROTEXTURE ON THE HOT ROLLED Zr-1Nb AND Zr-2.5Nb ALLOYS

C. Vanitha, M. Kiran Kumar, I. Samajdar, G.K. Dey and D. Srivastava
*Mater. Sci. Division, BARC, Trombay, Mumbai – 400085
Email: vanithac@iitm.ac.in

The nuclear components made up of zirconium alloys undergo dimensional changes during service are strongly affected by the neutron fluence and irradiation temperature. These dimensional changes are dependant on the crystallographic orientations. The present study brings out the results and analysis of warm/hot deformation texture and microtexture developments on Zr-2.5 and Zr-1Nb. It was found that Zr-1Nb material showed considerable change in the texture whereas Zr-2.5Nb material showed only a slight modification in texture.

DYNAMIC RECRYSTALLISATION AND FLOW INSTABILITIES IN HOT DEFORMED Mg-3Al-1Zn ALLOY

Annamalai University, Annamalainagar - 608 002.
* Regional Research Laboratory, Thiruvananthapuram - 695015
Email: raghukanthi@satyam.net.in

Processing maps were generated for Mg-3Al-1Zn (AZ31) alloy through which the hot deformation characteristics of the alloy were investigated. The domain of dynamic recrystallization (DRX) of this alloy was identified and the optimum condition for the hot working of the alloy was evolved. Hot extrusion was also conducted to validate the findings based on the processing maps.

EFFECT OF HEIGHT / DIAMETER RATIO ON THE HIGH TEMPERATURE DEFORMATION BEHAVIOUR OF TITANIUM ALLOY IMI 834

I.Balasundar, M Sudhakara Rao, T.Raghu and G.G.Saha
Defence Metallurgical Research Laboratory, Hyderabad – 500 058
Email: balasundar@dmrl.ernet.in

The deformation behavior of a material depends on its chemistry, initial microstructure, processing history, applied
temperature, strain rate, specimen geometry, applied state-of-stress (SoS) and SoS existing in the deformation zone. In this paper the effect of specimen geometry (height / diameter ratio – 1.0, 1.5, 2.0) on the high temperature deformation behavior of a titanium alloy (IMI 834) has been studied and reported. Finite element analysis was also carried out with varying specimen geometry in order to ascertain the reasons for the variation in deformation behavior under identical processing conditions.

EFFECT OF INGOT PROCESSING ON THE MICROSTRUCTURE AND THE MECHANICAL PROPERTIES OF THE Zr-2.5WT%Nb TUBES FOR PRESSURISED HEAVY WATER NUCLEAR REACTORS

T Sanyal and K Kapoor
Nuclear Fuel Complex, Hyderabad, India 500 062
Email: kapoork@nfc.ernet.in

In case of Zr-2.5 wt% Nb material for PHWR, the processing of melted and cast ingot to final tubes can be divided into two stages. In the first stage these ingots are processed to hollow billets though a series of thermo mechanical treatments. In the second stage these billets are hot extruded to hollow tube blanks, which are cold pilgered or cold drawn to tubes. In the current study, three processing methods were considered. Samples were collected at different stages for analysis like, optical microscopy, x-ray diffraction and transmission electron microscopy (TEM). Tensile properties were evaluated with samples taken from the axial direction of the tubes at the final stage. For analysis of fracture surface and chemical analysis on the fracture surface, SEM with EDS was used.

AEROSPACE MATERIALS

A NEW GENERATION MATERIAL FOR AEROSPACE APPLICATIONS

Pravin Dharammali and Sanjay Sawant
Govt. College of Engineering Pune- 411005,
Email: Pravin_dharammali@rediffmail.com

Al – Li alloy have been developed primarily to reduce the weight of Aircraft & Aerospace structures. Powder Metallurgical Technique is more effective in achieving greater compositional flexibility with regards to alloy design strategies. Vacuum casting is generally preferred for high purity Al casting. Recovery of Al-Li alloy has been investigated using techniques like ICP & weight analysis method. X-ray diffraction show the phases like T1 (Al,Cu,Li), T2 (Al,Cu,Li), q (CuAl), & d’ (Al,Li) which contribute to strengthening are precipitated after aging. Explosion potential of melt with water, with salt bath, Hydrogen contamination problem, toxicity of Li fumes formed during melting were the drawbacks during casting of Al-Li alloys.

Ni-Ti SHAPE MEMORY ALLOYS FOR AEROSPACE APPLICATIONS

Niraj Nayan, Govind, Sachin Gupta and K. Suseelan Nair
Vikram Sarabhai Space Centre, ISRO, Trivandrum – 695022.
Email: sachin_gupta@vssc.org

Shape memory alloys exhibit pseudoelastic as well as pseudoplastic behavior depending upon the temperature. During these transformations, it can accommodate strain upto 8% or exert stress upto 750 MPa by twinning and detwinnings processes. Thus, it provides tremendous opportunities to design actuators/sensors for many SMART systems. This paper focuses on the usage of NiTinol SMAs in space industry.

PROCESS REQUIREMENT AND PAYLOAD DEVELOPMENT FOR Mg EXPERIMENT ON GROWTH OF QUASICRYSTALS IN SPACE

N.K. Ramakrishna Naidu, Y.C. Ranaware, S.C. Sharma, K. Suseelan Nair and M.C. Mittal
Vikram Sarabhai Space Centre, Trivandrum – 695022
Email: yogesh_ranaware@yahoo.co.in

ISRO is poised to conduct its first mg experiment on the synthesis of Ga-Mg-Zn based quasicrystals aboard a recoverable space capsule (SRE Mission). The payload for this experiment consists of an Isothermal Heating Furnace (IHF), which has been designed and developed to withstand the harsh environment it will experience during ascent, orbital and reentry phases of the Mission. This paper brings out salient details of the process requirements for the experiment and highlights the development work carried out to design and realize the mg payload.

PROCESS PARAMETERS AND PROPERTY DEVELOPMENT IN C-FOAMS FOR SPACE APPLICATIONS

N.K. Ramakrishna Naidu, S.C. Sharma, K. Suseelan Nair and M.C. Mittal
Vikram Sarabhai Space Centre, Trivandrum-695 022
Email: yogesh_ranaware@yahoo.co.in

Reticulated vitreous carbon (RVC) foams are a new class of open cell, low-density materials that have attractive mechanical and thermal properties. This paper mainly highlights the experimental approach formulated to develop C-foam and the process details adopted to tailor its properties. The established process technique is based on impregnation of sacrificial substrate by a carbon-rich resin. The resin-enriched substrate is then subjected to progressive stages of pyrolysis, carbonization and graphitization under controlled conditions of temperature, heating and cooling rates and environment.
CHARACTERISATION OF CAST COLUMNAR GRAINED TURBINE AIRFOIL COMPONENTS FOR THE KAVERI ENGINE.
D. Chatterjee, N. Hazari and N. Das
Defence Metallurgical Research Laboratory, Hyderabad-500058
Email: dibyendu@dmrl.ernet.in
Ni-base super alloy have been the only class of materials used for the airfoil components in the turbine. Stringent evaluation procedures have been adopted to characterize the cast columnar grained airfoil components of nickel base super alloy CM247LC. This paper presents the evaluation procedures and results obtained by characterisation of castings with respect to the alloy chemistry, microstructure of the cast component, mechanical properties, various physical and solidification defects through stringent non destructive tests.

METALLURGICAL ANALYSIS ON CRACKED Ti-6Al-4V LINER OF GAS STORAGE BOTTLE USED IN LIQUID PROPULSION SYSTEM OF SATELLITE LAUNCH VEHICLE
Abhay K. Jha, V. Diwakar, K. Sreekumar and M.C. Mittal
Materials and Metallurgy Group, Vikram Sarabhai Space Centre, Indian Space Research Organisation (ISRO), Trivandrum 695 022
Email: k_sreekumar@vssc.org
A gaseous helium storing gas bottle with Ti-6Al-4V liner, fabricated by electron beam welding of two forged and machined hemispheres (designated as male and female domes) and wound with Kevlar fibre around it, failed prematurely during the auto frettage cycle of pressure testing. The failure was identified to be due to the differences and non-uniformity in the microstructures of the domes.

METALLURGICAL ANALYSIS OF THE FAILED ISOGRID PROPELLENT STORAGE TANK
Abhay K. Jha, P. Ramesh Narayanan, V. Diwakar, K. Sreekumar and M. C. Mittal
Materials and Metallurgy Group, Vikram Sarabhai Space Centre, Indian Space Research Organisation (ISRO), Trivandrum 695 022
Email: k_sreekumar@vssc.org
A cryo engine liquid Oxygen tank, made of AA2219, with isogrid configuration and welded with imported recess cone sub-assembly failed prematurely during proof pressure testing. A microstructural traverse revealed that the recess cone ring contained clusters of non-uniformly distributed particles, persisting from the melting stage of the material. Cracks, originating at the weld repair zones propagated fast during the pressure testing along the favorably oriented grain boundaries thickened by liquation phenomenon.

METALLURGICAL ANALYSIS OF THE FAILURE OF LIQUID OXYGEN (LOX) TANK DURING POST – PROPELLENT EXPULSION TRIAL (PET)
Abhay K. Jha, V. Diwakar, K. Sreekumar and M. C. Mittal
Materials and Metallurgy Group, Vikram Sarabhai Space Centre, Indian Space Research Organisation (ISRO), Trivandrum 695 022
Email: k_sreekumar@vssc.org
High strength Al-Mg-Zn alloy 7010 has been developed indigenously for aeronautical applications. This alloy has excellent Stress Corrosion Cracking (SCC) and exfoliation resistance compared to the earlier 7075 alloy. The over-aged, T73651 temper has been developed for this purpose. SCC and exfoliation resistance have been verified by testing as per ASTM G47 and ASTM G34 respectively. Indigenously developed 7010 alloy has been certified by airworthiness agencies for aeronautical use.

CHARACTERIZATION OF INDIGENOUSLY DEVELOPED AERONAUTICAL GRADE 7010 ALUMINIUM ALLOY EXTRUSIONS FOR CORROSION PROPERTIES
M. K. Sridhar, B. K. Murulidhara * and P. Raghothama Rao **
*Aeronautical Development Agency, Bangalore
**University Viswesvarya College of Engg., Bangalore
Email: mks@etmail.ada.gov.in
High strength Al-Mg-Zn alloy 7010 has been developed indigenously for aeronautical applications. This alloy has excellent Stress Corrosion Cracking (SCC) and exfoliation resistance compared to the earlier 7075 alloy. The over-aged, T73651 temper has been developed for this purpose. SCC and exfoliation resistance have been verified by testing as per ASTM G47 and ASTM G34 respectively. Indigenously developed 7010 alloy has been certified by airworthiness agencies for aeronautical use.
DEVELOPMENT OF AA7449 ALLOY FORGING FOR AERO APPLICATIONS

R.Mathivanan, Debashis Roy, Karthikeyan, R.Krishnamoorthy and R.R.Bhat
Foundry & Forge Division, Hindustan Aeronautics Limited, Bangalore – 560 017
Email: rr_bhat@yahoo.co.uk

The continued efforts to reduce weight and thereby cost in aeronautical industries led to the development of several newer aluminium alloys. One such alloy–AA 7449 has a tensile strength as high as 580 MPa with 8% elongation. The alloy is thought of as a likely material to replace 7075 and 7150 alloys in aeronautical applications. Literature available on forgeability and heat treatment aspects of AA7449 is scanty. In view of this, an attempt was made to study the forgeability and heat treatment response of this alloy for aeronautical applications.

FRICITION STIR WELDING OF AA2219 AL ALLOY

S. Biju, R.K. Gupta, K. Chenniappan, B.R Ghosh and P. P. Sinha
Vikram Sarabhai space Centre, Trivandrum-22
Email: rohitkumar_gupta@vssc.org

Aluminium alloy AA2219 is reported to have dramatically low yield strength in the fusion welded weldments. Friction stir welding (FSW) is a newly developed solid state welding process, which was tried on AA2219 Al. alloy to eliminate all the deleterious metallurgical factors otherwise present in all the fusion welding processes. In this paper, first cut observations with respect to a limited number of tool configurations used in the initial experiments are presented. It has been found that the weld strength is a function of tool configuration, applied pressure, tool rotation (rpm), and travel speed.

PROCESSING OF ADVANCED MATERIALS FOR AEROSPACE APPLICATIONS THROUGH VACUUM HOT PRESSING

A.K. Shukla, R. Suresh Kumar, M.G. Samuel, S. Babu, Gopinath Pai and M.C. Mittal
Materials and Metallurgy Group, Vikram Sarabhai Space Center, ISRO
Thiruvananthapuram 695022
Email: mv_gopinathpai@vssc.org

New developments in aerospace technologies call for processing of advanced materials like intermetallics, ceramics and ceramic-matrix composites that have to perform under extreme environments. Vacuum Hot Pressing is one of the preferred methods for high temperature processing under controlled environment. The present paper discusses some of our experiences in the processing of silicon carbide based advanced ceramics. The role and effect of different sintering additives was studied using different material characterization techniques. The effect of processing parameters like pressure, temperature and time on the densification behavior of these materials is also presented.

MAIN GEAR BOX HOUSING CASTING FOR A HELICOPTER AND ITS EVALUATION FOR AIRWORTHINESS CERTIFICATION

Kishora Shetty, 'R. Raghavendra Bhat, P. Raghothama Rao and D. Pradeesh Kumar
Regional Centre for Military Airworthiness (Foundry & Forge), Vimanapura P.O, Bangalore – 560 017.
'Hindustan Aeronautics Limited, Foundry & Forge Division, Vimanapura P.O, Bangalore – 560 017.
E-mail: kishora_shetty@yahoo.com

The Main Gear Box (MGB) housing casting of the Advanced Light Helicopter (ALH) is a complicated, large sized sand casting made of magnesium alloy. The castings were indigenously produced and evaluated for Airworthiness certification. During major overhaul of helicopters at scheduled inspection of 250 flying hours, cracks were noticed on the longitudinal booster cut-out area of swash plate attachment region, at the vertical rib connected to the MGB wall and attached body. Three failed indigenous MGB housings were subjected to detailed failure analysis. This paper deals with the metallurgical failure investigation, modifications incorporated to casting after failure investigation and evaluation of the casting for airworthiness certification.

ULTRA HIGH STRENGTH Al ALLOY EXTRUSIONS BY I/M ROUTE

Defence Metallurgical Research Laboratory, Hyderabad
Email: ashim_mukhopadhyay@yahoo.com

The present work reports the results on 7055 Al alloy extrusions demonstrating that optimization of alloy composition, homogenization schedule, extrusion processing variables and post-solutionizing aging heat treatments leads to the attainment of significantly high tensile yield strength of 725 MPa. Such tensile properties (as shown in the following table) are most reproducible.
COMPARISON OF CONVENTIONAL AND NON-CONVENTIONAL METHOD OF ANODIZING FOR AEROSPACE MATERIAL

I. B. Dave*, S. C. Khurana and K. B. Pai
Metallurgical Engg., Deptt., M.S. University of Baroda, Baroda.
S&. S.S. Ghandhy College of Engg. & Tech. Surat
Email: trpprof-trp@msubaroda.ac.in

Little information is available about the nature & quality of film formed on Al-Li alloys during anodizing. In this paper, an attempt has been made to evaluate and study the quality of passive anodized oxide film. Studies have been carried out on the oxide film developed on Al-Cu (2014) and Al-Cu-Li (1441, 8090) alloys before and after anodizing using Potentio-dynamic and Electrochemical Impedance (EIS) techniques in various concentrations of NaCl viz. (0.5%, 2%, 3.5%) solutions. The results obtained were systematically evaluated and discussed.

CHARACTERIZATION OF AGEING BEHAVIOUR IN 18 wt% NICKEL MARAGING STEEL USING ULTRASONIC PARAMETRES

K.V. Rajkumar, Anish Kumar, T. Jayakumar, Baldev Raj and K.K.Ray*
Indira Gandhi Centre for Atomic Research, Kalpakkam – 603 102
*Indian Institute of Technology, Kharagpur - 721 032

In the present work characterization of ageing behavior in 18 Wt Pct Nickel maraging steel have been studied with the use of ultrasonic parameters. Results revealed that hardness and ultrasonic parameter (longitudinal wave velocity) exhibited a similar behaviour with aging time. The influence of intermetallic phases such as Ni₃Ti and Fe₂Mo and the reversion of martensite to austenite formed by thermal ageing treatments on the ultrasonic parameters have been evaluated.

SHAPE MEMORY ALLOYS AND THEIR APPLICATIONS IN A FIGHTER AIRCRAFT

B. Ashok
ADA, Bangalore
Email: ashoktwinn@yahoo.com

Shape memory alloys are unique from other materials as under certain circumstances they can remember and revert back to their original shape. This paper recounts the experiences in devising unique method in assembling these ferrule rings in the pipe assemblies and training the manpower in the assembly techniques. Compared to conventional shrink fit or swaged joints, the joints made of shape memory alloys are a “true joint”, reliable and unlike other joints offers constant clamping stress over the entire aircraft service.
MICROSTRUCTURAL ENGINEERING

STUDY ON THE ENHANCED FRACTURE TOUGHNESS OBSERVED IN ALUMINA-13 WT % TITANIA AS PLASMA SPRAYED COATINGS

R.Venkataraman, R.Krishnamurthy1, D.K.Das2 and B.Venkataraman2
National Metallurgical Lab, Jamshedpur, 1 Indian Institute of Technology Madras, Chennai, 2 Defence Metallurgical Lab, Kanchanbagh, Hyderabad.
Email: rkrivenkat@yahoo.co.in

A systematic investigation on the fracture toughness measurements of plasma sprayed alumina-13 wt% titania coatings by microindentation technique was carried out. The enhancement in the adhesive strength of the as plasma sprayed coatings was observed when tested with a newer technique of adhesive/cohesive strength measurement developed exclusively for thinner coatings of thickness less than 380 ms. The testing method apparently conform the modified version of the ASTM D-3359-B crosshatch testing methodology.

MICROSTRUCTURAL CHARACTERIZATION OF PSEUDO-BINARY Gd5Si4 – Gd5Ge4 ALLOYS

M. Manivel Raja, R. Balamuralikrishnan, R. Gopalan, V. Lalitha Kumari and V. Chandrasekharan
Defence Metallurgical Research Laboratory, Hyderabad – 500 058.

The pseudo-binary Gd5Si4 – Gd5Ge4 alloys are potential candidates for magnetic refrigeration applications, as they show giant magneto-caloric effect (MCE) near room temperature due to the magneto-structural transition. The results of structural and magnetic studies on arc-melted Gd5(SixGe1-x)4, with x = 0.375, 0.425 and 0.5 alloys were reported in this paper.

EFFECT OF PRE-STRAINING ON LOW CYCLE FATIGUE BEHAVIOUR OF NEAR α TITANIUM ALLOY IMI834 AT ROOM TEMPERATURE

K.V. Sai Srinadh and Valk Singh
Banaras Hindu University, Varanasi-221005
E-mail: vakil@bhu.ac.in ; kvssaisrinadh@yahoo.com

Effect of 15% pre straining by cold rolling, on low Cycle Fatigue (LCF) behavior of the near-α titanium alloy IMI 834, markedly increases fatigue life at low strain amplitudes, reduces fatigue life at high strain amplitudes and is attributed to exhaustion of ductility of the material.

STRUCTURE PROPERTY CO-RELATIONS IN A CONTROLLED TRANSFORMATION SEMI AUSTENITIC STAINLESS STEEL

S. Narahari Prasad and Pallab Sarkar
Mishra Dhatu Nigam Ltd, Hyderabad.

In this paper, an attempt has been made at MIDHANI to relate the properties of MDN-60 with the composition by means of an empirical relation. This paper also describes the effect of each element on its structure and properties.

EFFECT OF DELTA FERRITE ON PROPERTIES OF A PRECIPITATION HARDENABLE MARTENSITIC STAINLESS STEEL

S. Narahari Prasad and U.V.Gururaja Mishra
Dhatu Nigam Ltd. Hyderabad-500 058.

This paper describes the effect of delta ferrite and homogenization treatment and properties of a precipitation hardenable martensitic stainless steel MDN-59.

EFFECT OF MICROSTRUCTURE ON THE UNLUBRICATED WEAR BEHAVIOR OF A ZINC-ALUMINIUM ALLOY

Pritha Choudhury
Indian Institute of Technology, Kanpur – 208016
E-mail: prithac@iitk.ac.in

This paper investigates the effect of the addition of commercial master alloys Al-5Ti-1B and Al-5Sr to the melt with respect to the microstructures and unlubricated wear properties of a zinc-aluminium alloy. Addition of the master alloys modifies the microstructure, improves the bulk hardness and the wear resistance of the zinc-aluminium alloy.

METALLOGRAPHIC CHARACTERIZATION OF ACTIVE METAL BRAZED CERAMIC-METAL JOINTS

P.Prakash, T.Mohandas and P. Dharma Raju1
Defence Metallurgical Research Laboratory, Hyderabad-500 058, 1National Institute of Technology, Warangal-500 004.

In this work, SiC & Al10, Ceramic is joined to itself and to other structural materials such as AISI 304 SS, Inconel 718 etc, through Active Metal Brazing route. Detailed
A microstructural analysis of these joints was carried out using Optical, SEM, EPMA and XRD, to understand the chemistry of these interfaces, which influences the performance of these joints.

**CHARACTERISATION OF HIGH-ENERGY MILLED HEAVY ALLOY SYSTEMS**

P. Ghosal, A.K. Singh and T. P. Bagchi  
Defence Metallurgical Research Laboratory, Kanchanbagh (PO) Hyderabad - 500 058.

Elemental mix, swarfs and filed chips of heavy alloy were subjected to high-energy milling and stress-relieving annealing. XRD and TEM showed reduced stress level after annealing sans grain growth. Lattice parameter of tungsten decreased, lattice parameters of nickel-base matrix increased due to solid solution effect. Possible size reduction mechanism discussed.

**MICROSTRUCTURAL INVESTIGATIONS ON GIANT MAGNETOSTRICTIVE Tb-Dy-Fe SYSTEM**

Mithun Palit, S. Pandian, R. Balamuralikrishnan, A.K. Singh and V. Chandrasekaran  
Defence Metallurgical Research Laboratory, Hyderabad – 500 058.

In this present study alloy of \((\text{Tb}_{0.27}\text{Dy}_{0.73})\text{Fe}_{1.95}\) was cast in rod form and studied for the microstructural features in as-cast condition, followed by a post - heat treatment (1123 K) condition. The texture development was studied by zoning the as-cast rod. Details of these studies are presented in this paper.

**GRAIN BOUNDARY EFFECTS ON SPINODAL DECOMPOSITION**

H. Ramanarayan and T.A. Abinandanan  
Indian Institute of Science, Bangalore 560 012  
E-mail: abinand@met.iisc.ernet.in

The results on the effect of a grain boundary on spinodal decomposition, studied using a phase field model of a polycrystalline alloy are presented. In particular, the study is focussed on the role of an enhanced diffusivity at the grain boundary that leads to an interesting new phenomenon: discontinuous spinodal decomposition.

**ELASTIC STRESS EFFECTS ON GROWTH AND MORPHOLOGICAL EVOLUTION**

M.P. Gururajan and T.A. Abinandanan  
Indian Institute of Science, Bangalore-560 012.  
E-mail: abinand@met.iisc.ernet.in

In this presentation, we describe a diffuse interface formulation for studying elastic stress effects on growth and morphological evolution in an elastically inhomogeneous system and a few preliminary results in a model binary alloy system.

**A COMPARATIVE STUDY OF RECRYSTALLIZATION BEHAVIOUR OF TWO PACKAGING ALLOYS BY DIFFERENTIAL SCANNING CALORIMETRY (DSC)**

Rajat K. Roy, Sujoy Kar¹, Karabi Das, Siddhartha Das  
Indian Institute of Technology, Kharagpur-721302, India,  
¹The Ohio State University, OH-43210, USA  
E-mail: sdas@metal.iitkgp.ernet.in

Recrystallization behaviour of two packaging alloys AA1235 and AA8011 was studied by differential scanning calorimetry (DSC), electrical resistivity, hardness measurement and electron microscopy. The alloy AA1235 shows high activation energy for precipitation but low activation energy for recrystallization than the other alloy. For AA8011 alloy higher amount of Fe particles inhibits the start of recrystallization.

**MICROSTRUCTURAL EVALUATION OF ThO₂-3.75%UO₂ PELLETS PREPARED BY CAP PROCESS**

Bhabha Atomic Research Centre, Mumbai-400 085.  
E-mail: tkutty@magnum.barc.ernet.in

ThO₂-3.75%UO₂ fuel is prepared at AFFF, Tarapur by a relatively new process called Coated Agglomerate Pelletization (CAP) technique which is based on minimizing the number of process steps required for shielded operation. This paper deals with microstructural studies on the above pellet using optical microscopy, scanning electron microscopy (SEM) and electron probe microanalysis (EPMA).
CBED-HOLZ: A TEM-BASED TECHNIQUE FOR ACCURATE LATTICE PARAMETER MEASUREMENT

R. Balamuralikrishnan, D.V. Sridhara Rao and K. Muraleedharan
Defence Metallurgical Research Laboratory, Kanchanbagh PO, Hyderabad
E-mail: ksp@dmrl.ernet.in

The transmission electron microscopy based convergent beam electron diffraction - higher order Laue zone (CBED-HOLZ) lines technique is the only technique wherein accurate lattice parameter (to fourth decimal in nm) information can be obtained with very high spatial resolution. The CBED-HOLZ technique, and its application to nickel-base superalloys and semiconductor heterostructures, will be presented.

PHASE STABILITY AND MICROSTRUCTURAL STUDY OF A NEW Ti2AlNb TITANIUM ALUMINIDE

G. Sreenivasulu, P. Ghosal1, T.K. Nandy1, Vikas Kumar1, V.V. Kutumba Rao and D. Banerjee2
College of Engineering, GITAM, Visakhapatnam 530045,
1 Defence Metallurgical Research Laboratory, Kanchanbagh, Hyderabad – 500 058,
2 DRDO Sena Bhavan - B wing, New Delhi 110011.

Phase transformation and microstructure of a Nb-rich O+B2 alloy (Ti-20Al-25Nb-1Mo) is investigated following a variety of heat treatments. A detailed phase identification and microstructural characterization involving optical, scanning / transmission electron microscopy and X-ray diffraction are carried out and the results are discussed in relation to the available phase diagrams and existing literature.

COLD DEFORMATION TEXTURE AND MICROSTRUCTURE DEVELOPMENTS IN SINGLE AND TWO PHASE Zr-BASED ALLOYS

M. Kiran Kumar, C. Vanitha, I. Samajdar, G.K. Dev1, R. Tewari1, D. Srivastava1 and S. Banerjee1
IIT Bombay, Powai, Mumbai,
1 BARC, Trombay, Mumbai
E-mail: mkiran@iith.ac.in

The deformation texture development in single and two-phase zirconium based alloys has been studied. The texture modifications in single-phase system could be captured by ‘only prismatic slip’. In two-phase, the texture developments in a did depend on the apparent continuity/discontinuity of second phase β. A generalization of ‘in-plane rigid body rotation’ was able to explain the observed lack of textural changes around a continuous β.

MICROSTRUCTURAL CHANGES IN AA 2219 ALUMINIUM ALLOY UNDER HIGH STRAIN RATE

Abhay Kumar Jha, G.Naga Shiresha and K. Sreekumar
Vikram Sarabhai Space Centre (ISRO), Trivandrum 695 022.

This experimental study was to evaluate the microstructural changes in AA 2219 Aluminium alloy under high strain rate. The Aluminium alloy welded plates were subjected to Ballistic Impact using different projectiles traveling at 400-900 m/sec. The differences in the microstructures in the plates pierced and not pierced by the projectiles are interpreted with respect to the high strain rate deformation behavior of the material.

EFFECT OF MICRO ALLOYING ELEMENTS ON THE AGEING BEHAVIOUR OF COPPER ADDED HSLA STEELS

S. K. Ghosh, A. Halder1 and P.P. Chattopadhyay
BE College, Howrah, 1 Tata Steel, Jamshedpur

In the present study, an attempt has been made to study the Ti, B micro alloying addition on Cu added low carbon HSLA steels to understand the transformation behavior of Austenite and precipitation behavior of Cu in the transformed microstructure.

SLUGGISH TRANSITION OF COPPER TO BRASS TYPE TEXTURE IN METASTABLE AUSTENITIC STAINLESS STEEL

B. Ravi Kumar, B. Mahato, P.K. De, N.R. Bandyopadhyay1 and D. K. Bhattacharya2
National Metallurgical Laboratory, Jamshedpur- 831007
1 Bengal Engineering College, Howrah. 2 Central Glass and Ceramic Research Institute, Kolkata.
E-mail: ravik@nmlindia.org

The present work describes the transition of copper type texture to brass type in the austenite phase of the metastable austenitic stainless steel (SS), which is associated with mechanical twins during deformations process. However, the present study based on texture measurements by x-ray diffraction method, has shown the sluggishness in the texture transition. This is explained in terms of strain induced martensite formation.
EFFECT OF AGEING TREATMENT ON THE CORROSION PROPERTIES OF ALLOY 800
Bhabha Atomic Research Centre, Trombay, Mumbai- 400 085.
E-mail: pkde@apsara.barc.ernet.in

Electron probe microanalysis revealed different extent of Cr-depletion adjacent to Cr-carbides for the samples of Alloy 800 aged at 700°C for 5 and 10 minutes. Inferior corrosion resistance displayed by the sample aged for longer period as compared to annealed one could be attributable to the Cr-depletion adjacent to Cr-carbides.

MICROSTRUCTURAL INVESTIGATIONS OF LONG TERM SERVICE EXPOSED ALLOY 800 TUBES
S. Chowdhury, B. Misra, P. J. Potdar1 and M. Sundararaman1
Heavy Water Board, Mumbai-400094,
1 Bhabha Atomic Research Centre, Mumbai-400085
E-mail: pkde@apsara.barc.ernet.in

In this paper, the results of a detailed investigation carried out on Alloy 800 tubes which have seen prolonged service life as pig tail in many heavy water tubes is presented. Detailed TEM examination revealed that M23C6 type of carbide has extensively precipitated in all the tubes but the volume fraction of carbide precipitate is different for tubes supposed to have undergone identical service conditions.

DEFORMATION BEHAVIOUR OF LAMELLAR TITANIUM ALUMINIDES
J.B. Singh, M. Sundararaman, A. Couret 1, G. Molenat 1 and R. Kapoor
Bhabha Atomic Research Centre, Mumbai-400 085,
1 CEMES – CNRS, BP 4347, 31 055, Toulouse Cedex 4, FRANCE
E-mail: pkde@apsara.barc.ernet.in

Deformation behaviour of two-phase TiAl based lamellar alloys has been studied as a function of lamellar spacing at different test temperatures between 25°C and 600°C in compression mode. Yield strength was found to decrease with increasing temperature. The microstructure of the deformed alloy was investigated using a transmission electron microscope.

EVOLUTION OF MICROSTRUCTURE OF LAMELLAR TITANIUM ALUMINIDE ALLOY
M. Sundararaman, J. B. Singh, Garima Sharma and S. Banerjee
Bhabha Atomic Research Center, Mumbai-400 085.
E-mail: pkde@apsara.barc.ernet.in

The evolution of the lamellar structure has been studied in detail in a Ti-47.8%Al-2%Cr-0.2%Si alloy in which different lamellar spacing have been created by suitably altering the cooling rate from the solutionizing temperature. The possible methods of formation of interfaces and small angle boundaries have been identified and the mechanisms responsible for the formation of two phase lamellar structure and also the evolution of lamellar boundaries have been discussed in this presentation.

MARTENSITES IN Zr-1Nb ALLOY
S. Neogy, D. Srivastava and G. K. Dey
Bhabha Atomic Research Centre, Mumbai-400 085.

Zr-1Nb alloy is being used as cladding material in pressurized water reactors. The performance of this material is very sensitive to microstructure and thermomechanical treatment. In the present work, martensitic transformation in this alloy has been studied with respect to the morphology, crystallographic aspects and variant arrangements of the martensites.

TERMINAL SOLID SOLUBILITY OF HYDROGEN IN Zr-ALLOY PRESSURE TUBE MATERIALS
S. Mukherjee and R. N. Singh
Bhabha Atomic Research Centre, Mumbai-400 085.
E-mail: mms@apsara.barc.ernet.in

The terminal solid solubility of hydrogen in the Zr-alloy samples was determined using dilatometry. The enthalpies of hydride dissolution and precipitation for Zircaloy-2 pressure tube material were 30-34.5 and 25.9-26.3 kJ/mol, respectively, whereas the corresponding enthalpies for Zr-2.5Nb pressure tube material were 35.44 and 17.5 - 22.8 kJ/mol, respectively.

ATOMIC FORCE MICROSCOPIC STUDIES OF P/M ALLOYS
S.K.Tiwari, R.K. Gupta and A. Upadhyaya
Indian Institute of Technology, Kanpur-208016.
E-mail: anishu@iitk.ac.in

Atomic force microscopy (AFM) is a useful characterization tool for surface topographical investigation of materials with atomic resolution. This study demonstrates the application of
AFM to image morphology and interface of a range of systems, such as liquid phase sintered tungsten heavy alloys, supersolidus sintered Cu-Sn and ODS-stainless steels; nano-SiO₂ powders.

**ELECTROCHEMICAL IMPEDANCE SPECTROSCOPIC STUDIES ON A TYPE 316 STAINLESS STEEL WITH BIOFILM**

P. Muraleedharan, R. P. George and H.S. Khatak
Indira Gandhi Centre for Atomic Research, Kalpakkam, Tamil Nadu
E-mail: pmurali@igcar.ernet.in

In the present study, electrochemical impedance spectrography has been used to understand the time-dependent changes in a fresh water bio film formed on Type 316 SS and its influence on the passivity of the underlying material.

**FATIGUE THRESHOLD OF FERRITE BAINITE DUAL-PHASE STEELS**

A. Kumar, S. B. Singh and K. K. Ray
Indian Institute of Technology, Kharagpur - 721 302.
E-mail: kkrtmt@metal.iitkgp.ernet.in

The influence of bainite content on the tensile properties and fatigue threshold of a few ferrite-bainite dual-phase steels of identical chemistry has been examined. The hardness and yield strength of these steels increase, while their fatigue threshold values initially increase and then decrease with increasing bainite content.

**CHARACTERISATION OF FLOW BEHAVIOR OF Cu-STRENGTHENED HIGH STRENGTH LOW ALLOY STEEL**

S.K. Das¹, S. Shivaprasad, S. Chatterjee¹ and S. Tarafder
National Metallurgical Laboratory, Jamshedpur-831007, ¹B.E. College (D.U.), Howrah
Email: sapan@nmlindia.org ravik@nmlindia.org,

This paper highlights the flow behavior of the Cu bearing HSLA steel subjected to different thermal treatment procedures. The flow behavior of steel is found to be greatly influenced by the micro constituents mainly the Cu rich precipitates, reverted austenite and new dislocated martensite formed after ageing at high temperature.

**FAILURE ANALYSIS OF CAST IRON RINGS IN TV GLASS PLANTS: AN IN-DEPTH STUDY**

P.K. Shukla, S. Rajeswari and S. Sangal
Indian Institute of Technology, Kanpur-208016.
E-mail: sangals@iitk.ac.in
shuklapk@iitk.ac.in

Ductile cast iron rings are used as mold parts in the manufacturing process of TV Glass parts. They come in continuous contact with molten glass in the forming process and are subjected to high temperature and pressure conditions, resulting in the change in the morphology of the cast iron at the interface. This is discussed in detail in the paper.

**USE OF X-RAY DIFFRACTION IN THE DETERMINATION OF RESIDUAL STRESS OF INDUSTRIAL COMPONENTS**

B. Ravi Kumar
National Metallurgical Laboratory, Jamshedpur - 831007
E-mail: ravik@nmlindia.org

In this paper, the use of X-ray diffraction techniques is discussed with suitable examples related to problems associated with residual stresses in industries.

**STRUCTURE-PROPERTY CORRELATIONS IN MICROALLOYED HSLA STEEL PLATES MANUFACTURED THROUGH CONTINUOUS CASTING ROUTE**

Defence Metallurgical Research Laboratory, Kanchanbagh PO, Hyderabad
E-mail: bmk_pgh@yahoo.com bmk@dmrl.ernet.in

Plates of microalloyed HSLA steel with thickness varying from 8mm to 18mm were manufactured through SAIL by controlled rolling of continuously cast slabs. Samples from these plates were subjected to macro etching, microstructural investigation and mechanical testing. Differences in the microstructural features (between the different plates) that are likely responsible for differences in the observed sub-zero impact toughness properties between the thinner (8, 10 and 12mm thickness) and thicker (14, 16 and 18mm) plates will be presented.
MICROSTRUCTURAL AND MICROCHEMICAL INVESTIGATIONS OF Ti-5Ta-1.8Nb WELDMENTS USING ANALYTICAL TRANSMISSION ELECTRON MICROSCOPY

Arup Dasgupta, T.Karthikeyan, S.Saroja, M. Vijayalakshmi and V.S.Raghunathan
IGCAR, Kalpakkam 603 102
E-mail: saroja@igcar.ernet.in

Detailed microstructural and microchemical investigations using analytical TEM technique on weldments of a developmental Ti-5Ta-1.8Nb alloy will be presented here. In addition, the Temperature-Time profile at various locations of the weldment is being simulated to predict the microstructure at any location and compare these with experimental evidence.

MICROSTRUCTURE CONTROL THROUGH DESIGN OF TREATMENTS AND CONSEQUENT EFFECT ON PROPERTIES OF Ti-5%Ta-1.8%Nb ALLOY

R. Mythili, S.Saroja, M.Vijayalakshmi and V.S.Raghunathan
IGCAR, Kalpakkam 603 102
E-mail: saroja@igcar.ernet.in

This paper describes methods for enhancement of corrosion and mechanical properties in a high corrosion resistant Ti-5%Ta-1.8%Nb alloy by microstructure control through design of treatments, based on commercial experience of a+b Ti alloys. The alloy when solution treated (1113K) and aged (823-873K) in the a+b phase field imparts high strength and ductility to the alloy.

MICROSTRUCTURAL CHARACTERIZATION OF INTERCRITICAL ZONE IN WELDMENT OF MODIFIED 9Cr-1Mo STEEL

V. Thomas Paul, S.Saroja, M.Vijayalakshmi and V.S.Raghunathan
IGCAR, Kalpakkam 603 102
E-mail: saroja@igcar.ernet.in

This paper discusses the reasons for failure in Inter Critical Region in a modified 9Cr-1Mo steel weldment. The failures have been attributed to the weak boundary between martensite and soft ferrite Low defect density, fresh nucleation and coarsening of pre-existing precipitates suggest over tempering of ferrite, typical of the temperature (Ac₃-Ac₁) experienced by this region.

SERRATED YIELDING IN PRIOR DEFORMED AND THERMALLY AGED ALLOY D9

K.G. Samuel, S.K. Ray and Baldev Raj
Indira Gandhi Centre for Atomic Research, Kalpakkam 603 102.
E-mail: samuel@igcar.ernet.in

Serrated yielding behavior of a fully austenitic 15Cr-15Ni titanium modified stainless steel (D-9) is studied in a prior deformed condition after thermal ageing. The results are compared with the behavior of a well annealed material.

FRACTURE BEHAVIOR OF AZ91 MAGNESIUM ALLOY

Regional Research Laboratory, Trivandrum- 695 019.
E-mail: utspillai@rediffmail.com

Even though the use of Mg alloys are in increasing trend, not much research work has been carried out on these alloys compared to aluminum alloys to understand the microstructural features which influence the mechanical properties. Scanning Electron Microscopy (SEM) observations were carried out to examine the fracture behavior and micro-fracture mechanisms of Si and Sb added AZ91 Mg alloy samples ruptured by tensile and impact tests. The effect of Si and Sb on the fracture mode was also studied in detail.

INVESTIGATION ON MICROSTRUCTURE AND HIGH TEMPERATURE PROPERTIES OF Si AND Sb ADDED AZ91 MAGNESIUM ALLOY

A. Srinivasan, J. Swaminathan¹, T. Soman, S.G.K. Pillai, U.T.S. Pillai and B.C. Pai
Regional Research Laboratory, Trivandrum-695019, ¹National Metallurgical Laboratory, Jamshedpur.
E-mail: utspillai@rediffmail.com

AZ91(Mg-9Al-1Zn-0.2Mn) magnesium alloy finds industrial applications because of its improved room temperature mechanical properties but its high temperature applications are restricted because of its poor creep resistance. In the present investigation, Si and Sb are added to AZ91 alloy to study its effect on the microstructure and mechanical properties. Room as well as the high temperature (150°C) mechanical properties and creep behavior are evaluated and they are correlated with the detailed microstructure.
EFFECT OF WELD BEAD MORPHOLOGY ON THE MICROSTRUCTURE OF COPPER BORON STEEL WELD

Naval Materials Research Laboratory, Mumbai,
1 Govt. Engg. College, Raipur

Submerged arc welding of a high strength structural steel was carried out to correlate the weld metal microstructure with the weld bead morphologies. The morphologies like nugget area, penetration, reinforcement and the parameters (NA/C1) were observed to have a very good correlation with the welding parameters.

ASPECTS RELATING TO THE ORIENTATION RELATIONSHIP OF NANOSCALE PRECIPITATES WITH THE AUSTENITE MATRIX IN ALLOY D9

R. Divakar, A. Banerjee, S. Raju and E. Mohandas
Indira Gandhi Centre for Atomic Research, Kalpakkam, TN-603102.
E-mail: divakar@igcar.ernet.in

Alloy D9 is titanium modified 316 austenitic stainless steel. The present work is an analysis of Moire fringes formed due to the overlap of the austenite matrix and the TiC precipitates and of the lattice images of the precipitates, matrix interface.

DEVELOPMENT OF MAGNETIC ANISOTROPY IN Nd-Fe-B RING MAGNET

S. Prakash Narayan and H.S. Jain
Regional Research Laboratory, Bhopal
1BHEL corporate R&D, Hyderabad

In this paper, a study has been carried out for the preparation of radially oriented Nd-Fe-B ring magnets and a process optimization has been done by varying die-punch, temperature and applied force to develop magnetic anisotropy in the radial direction.

CONTROL OF LAVES PHASE IN INCONEL 718 ELECTRON BEAM WELDS THROUGH THE USE OF DIFFERENT BEAM OSCILLATION TECHNIQUES

Defence Metallurgical Research Laboratory, Kanchanbagh, Hyderabad-500 058.
1 Defence Research and Development Laboratory, Kanchanbagh, Hyderabad-500 058.
2 Indian Institute of Technology, Madras, Chennai- 600 036.
E mail: aginaparru@yahoo.com

Inconel 718, has excellent weldability, however it has a limitation in the form of niobium segregation (laves phase) which leads to degradation of mechanical properties. A detailed study was taken up to reduce the niobium segregation in 718.
electron beam welds during welding stage itself. The SEM and EPMA analysis showed that there was significant reduction of niobium segregation in the interdentritic regions and the mechanical properties were found to be superior to oscillated beam weldments.

HIGH STRESS ABRASIVE WEAR BEHAVIOR OF ALUMINIUM ZINC ALLOY: EFFECT OF ALLOY COMPOSITION

V. Rajput, D.P. Mondal and S.Das
Regional Research Laboratory (CSIR), Bhopal-462 026.
E-mail: sdas@rrlbpl.org

This paper presents the abrasive wear behavior of Al-Zn alloy with Zinc concentration varying from 30-70%. Experimental parameters such as load, abrasive size, distance etc. were correlated with materials parameters. It shows that smearing of phases leads to lowering of wear rate during two-body abrasive wear.

EFFECT OF HOLD PERIOD ON LOW CYCLE FATIGUE BEHAVIOUR OF NEAR α-TITANIUM ALLOY IMI834 AT ROOM TEMPERATURE

K.V. Sai Srinadh and Vakil Singh
Banaras Hindu University, Varanasi-221005
E-mail: vakil@bhu.ac.in
kvsaisrinadh@yahoo.com

Effect of hold period on Low Cycle Fatigue (LCF) behaviour of the near α-titanium alloy IMI834 has been studied, at room temperature. LCF tests were conducted at a constant strain rate of 0.008s⁻¹. The deleterious effect of hold on fatigue life was relatively more for compressive hold than that for tensile hold.

EFFECT OF MINOR ADDITIONS ON STRUCTURE AND PROPERTIES OF FERRITIC STAINLESS STEEL

O.P. Sinha and M. Chatterjee
Mishra Dhatu Nigam Limited, Hyderabad

This paper deals with the effect of minor addition of Nitrogen and Ni on the microstructure and properties of conventional AISI 430 ferritic steel under different heat treatment conditions.
FRACTURE MODE TRANSITIONS DURINGIndentATION OF Tin COATINGS ON STEELS: THE ROLE OF FILm THICKNESS AND SUBSTRATE PLASTICITY

S. Bhowmick, K. Ravindranath1, V. Jayaram and S.K. Biswas
Indian Institute of Science, Bangalore,
1 Multi-Arc (India) Ltd., Mumbai
suresha@platinum.met.iisc.ernet.in

In this paper, TiN film coating on Al, mild steel, stainless steel and high speed steel are carried out and qualitative model is developed to explain the fracture mode transition on the basis of competition between the ability of the film to slide and the development of significant plastic deformation.

EVALUATION OF FATIGUE CRACK GROWTH RATES OF DIFFERENT FERRITIC STEELS USING STANDARD AND NON-STANDARD SPECIMENS

Priti Kotak Shah and S. Chatterjee
Bhabha Atomic Research Centre, Mumbai–400 085

This paper deals with the fatigue crack growth measurement using K-Decreasing method during precracking of standard (CT specimen) and non-standard (Charpy, V-notch and 3-P bend specimens) specimens of four ferritic steels namely A533B, SA 333, Grade 6 and 20Mn-Mo-Ni55.

EVALUATION OF IRRADIATION EMBRITTLEMENT OF AISI 403 MODIFIED STEEL

U. K. Viswanathan, S. Anantharaman,
K.S. Balakrishnan, S. Chatterjee and
K.C. Sahoo
Bhabha Atomic Research Centre, Mumbai–400 085

To monitor the extent of neutron irradiation induced embrittlement, impact test specimens were irradiated in CIRUS reactor to a fluence of 1 x1019 n/cm² (E>1 MeV) at 290° ±10° C. Based on the observed increase in the Cν -41J transition temperature, the end fitting material is found to be safe for continued operation up to the end of life fluence of 6 x1019 N/cm² (E>1 MeV).

EVALUATION OF ULTIMATE TENSILE STRENGTH AND FRACTURE TOUGHNESS OF ZIRCALLOYS BY SMALL PUNCH TEST (SPT)

B.N. Rath, R.S. Shriwastaw, V.P. Jathar,
E. Ramadasan and K.C. Sahoo
Bhabha Atomic Research Centre, Trombay,
Mumbai–400 085
E-mail: rathpanda@rediffmail.com

Neutron irradiation degrades mechanical property of Zirconium alloys used in nuclear reactors. Small Punch Test (SPT) technique which uses TEM size specimens (3 mm ø × 250 µm thick) is being developed to reduce man-rem exposure for evaluating mechanical property changes in irradiated Zircalloy tube material at various temperatures.

EVALUATION OF FRICTION WELDED AISI 430 FERRITIC STAINLESS STEEL JOINTS

P. Sathiya, S. Aravindan¹ and A. Noorul Haq¹
J.J. College of Engineering and Technology,
Tiruchirappalli –620 009, Tamil Nadu,
¹ National Institute of Technology,
Tiruchirappalli –620 015, Tamil Nadu
E-mail: paulsathiya@yahoo.co.in

Present study utilized a continuous drive friction-welding machine and ferritic stainless steel cylindrical specimens of similar composition and shape (equal diameter and length) were subjected to friction welding. The processing parameters such as Friction Pressure, Friction Time, Upsetting Pressure and upsetting time were changed in order to understand the role of parameters on the strength related aspects of friction-processed joints.

EFFECT OF METAL SURFACE TEXTURE ON METAL/ QUENCHANT INTERFACIAL HEAT TRANSFER

K. Narayan Prabhu and Peter Fernandes
National Institute of Technology Karnataka, Surathkal
E-mail: prabhukn_2002@yahoo.co.in

The effect of metal surface texture on heat transfer rates during quenching in various media was investigated. Heat transfer analysis, microstructure studies and hardness profiles showed that the effect of metal surface roughness on quenching was significant for water and brine while its effect in high viscosity oils was marginal.
THE EFFECT OF PRE-STRAIN ON DUCTILE FRACTURE BEHAVIOUR OF INTERSTITIAL FREE STEEL

S. Majumdar* and K.K. Ray
Indian Institute of Technology, Kharagpur, *On study leave from TISCO Pvt. Ltd. Jamshedpur

The critical void nucleation strain ($\varepsilon_c$) and dimple characteristics have been estimated for a series of broken pre-strained tensile specimens of interstitial free steel. The magnitude of $\varepsilon_c$ initially increases and then decreases with increased pre-strain. But the dimple size is found to bear a proportional relationship with $\varepsilon_c$ and can be used to predict the later.

EVALUATION OF TENSILE PROPERTY DATA ON TUBULAR COMPONENTS - A CHALLENGE

K.S. Balkrishnan, A.B. Tamhne, S. Anantharaman, S. Chatterjee, and K.N. Mahule
Bhabha Atomic Research Centre, Mumbai-400 085, India
E-mail: krish1022@yahoo.co.in

This paper brings out the results of irradiated ring tension tests conducted on irradiated nuclear reactor fuel element cladding (14 mm outer diameter and 0.89 mm wall thickness) at room temperature as well as on irradiated pressure tubes (90 mm outer diameter and 4.2 mm wall thickness) performed at various test temperatures.

EVALUATION OF EMBRITTLEMENT ON IRRADIATED COOLANT TUBES

K.S. Balakrishnan, Priti Kotak Shah, and S. Chatterjee
Bhabha Atomic Research Centre, Mumbai-400 085

Assurance against leak before break (LBB) based on fracture toughness data is a vital pre-requisite for the safe operation of pressure tube (PT). Fracture toughness properties of four irradiated PTs with Effective Full Power Years of operation ranging from 3.5 to 9.5 and having hydrogen contents up to 200 ppm were evaluated and analyzed vis-a-vis assurance against LBB of PTs during reactor operation.

ROLE OF BORON ADDITION ON THE TOUGHNESS PROPERTIES OF COPPER-PHOSPHORUS CONTAINING WEATHER RESISTANT STEEL

M.L. Narula and S.K. Sen
RDCIS, SAIL, Ranchi-834002
E-mail: mln@sail-rdcis.com

In the weather resistant steels, presence of phosphorous induces brittle fracture at the grain boundaries associated with its segregation. This results in decrease in toughness properties of the steel and restricts its use to low temperature applications. The problem has been overcome by extensive laboratory investigations by addition of boron. Results of the tensile, impact and metallography studies have been described in this paper to propose a mechanism by which boron improves toughness properties of high phosphorous steel.

INTEGRITY ASSESSMENT OF RPV STEELS THROUGH MASTER CURVE – A NEW APPROACH

S. Chatterjee and K.S. Balakrishnan
Bhabha Atomic Research Centre, Mumbai-400 085
E-mail: krish1022@yahoo.co.in

The utilization of fatigue precracked Charpy impact type of specimens for the integrity assessment of pressure vessel (PV) steels through the Master curve approach, has been standardized by participating in a round robin programme involving many advanced laboratories. The paper discusses the procedure followed in the standardization and the results obtained by using two PV steels.

HIGH TEMPERATURE TENSILE AND LOW CYCLE FATIGUE (LCF) BEHAVIOUR OF 9Cr-1Mo-1W STEEL

B.R. Panda and Vakil Singh
Banaras Hindu University, Varanasi – 221 005
E-mail: bhuban_met@yahoo.co.in

The tensile behaviour of the 9Cr-1Mo-1W steel was studied from RT-650°C. Dynamic strain aging is observed at 300°C. Uniform strain decreases with increase in temperature above 300°C. The LCF behaviour of the 9Cr-1Mo-1W steel is investigated. The cyclic stress response behavior showed a continuous cyclic softening up to failure. The fatigue life decreased as the temperature increased.
FLAW ACCEPTANCE STANDARD IN CODES: WORKMANSHIP VS FITNESS-FOR-PURPOSE

B.K. Shah
Bhabha Atomic Research Centre, Mumbai-400 085

The flaw acceptance clauses in various codes give the Non-Destructive Testing (NDT) methods to be used and the maximum size of flaws which can be tolerated. Specified acceptance levels for flaws are essentially based on ‘Good Workmanship’. There is a need to assess the significance of flaws with respect to Fitness-For-Purpose (FFP) which is based on fracture mechanics. British Standard Institution has issued BS 7910 (1999) ‘Guide on methods for assessing the acceptability of flaws in metallic structures’ which is being used worldwide for assessing acceptability of flaws with respect to fitness-for-service. This presentation will discuss the methodologies for assessing flaw severity and illustrate the concept with some case studies.

STUDY OF THE STRAIN AGING BEHAVIOUR IN ULTRA LOW CARBON BAKE HARDENING STEEL

N. Bhagat1, 2, S. J. Baek2 and Hu-Chul Lee2
1 School of Materials Science and Engineering, Seoul National University, South Korea,
2 Tata Steel, Jamshedpur, Jharkhand-831001

In the present work, the effect of tensile strain (0.5 - 4%) and solute content (1.2 – 5.1 ppm) on the strain aging behaviour of ultra low carbon bake hardening steel has been studied. The yield point elongation increased with the increase in deformation till 4 %, whereas the “Y increased abruptly at 0.5 % with no major change at higher strain. Kinetics of the strain aging process was assessed using Cottrell-Bilby approach.

HOMOGENISATION AND AGEING BEHAVIOUR OF COPPER BEARING IF STEELS

R. K. Rana, S. B. Singh and O. N. Mohanty
Indian Institute of Technology Kharagpur
E-mail: sbs22@metal.iitkgp.ernet.in

Ageing behaviour of IF steel containing 0.8 wt% Cu was studied using a variety of techniques including Thermo Electric Power (TEP). Excellent ageing response was obtained after proper homogenisation. Thermo Electric Power (TEP) measurements showed that Cu has a negative co-efficient of TEP in iron.

STUDY OF LOW TEMPERATURE ANNEALING ON DEEP DRAWN STEEL CARTRIDGE CASE FOR DEFENCE APPLICATION

L.B.Singh and D.K.Sarkar
Ordnance Factory, Ambarnath-421 502
E-mail: lbsmsu@yahoo.co.in

A study has been carried out to see the effect of low temperature annealing at 350°C with 1¼ hours soaking time on finished Cartridge Case. Ten numbers of Cartridge Cases of the same lot having same chemical composition were subjected to hardness, tensile strength, elongation testing and microstructure analysis before and after low temperature annealing. These properties were tested at the points of 10mm, 50mm and 140 mm from the mouth end of the Cartridge Cases.

MICRO-MECHANISMS OF HIGH TEMPERATURE FATIGUE CRACK GROWTH IN IMI-834 NEAR α TITANIUM ALLOY

G.Nagalaxmi and Vikas Kumar
Defence Metallurgical Research Laboratory, Kanchanbagh, Hyderabad –500 058
E-mail: nagalaxmi@dmrl.ernet.in

Effect of various parameters on high temperature fatigue behavior of a near α titanium alloy has been investigated using Single Edge Notch Tension (SENT) specimen configuration on a computer controlled servo hydraulic MTS-880 test system. It is observed that higher temperatures, longer hold times and lower frequencies lead to high fatigue crack growth rates. Extensive SEM fractographic investigations revealed mainly cleavage features at lower ΔK levels and striation types at higher ΔK levels. Specimens corresponding to high temperatures, low frequencies and large hold times show presence of oxide features and cavitations.
HIGH TEMPERATURE MECHANICAL BEHAVIOUR OF SUPERALLOY IN 718

K. Sisupalan, G. Venkata Narayana, V.M.J. Sharma, K. Thomas Tharian, V. Diwakar and K. Sree Kumar
Vikram Sarabhai Space Centre (ISRO), Trivandrum 695 022,

This paper presents the high temperature deformation behavior of IN 718 super alloy. Isothermal constant strain rate tensile tests were conducted at 873, 973, 1073 and 1173 K with initial strain rates of 0.01, 0.1 and 1.0 s\(^{-1}\). The effect of hot deformation parameters such as strain, strain rate and deformation temperature on strain hardening and flow stress properties were analyzed. The results are discussed in the light of the microstructural and fractographic features.

STUDIES ON HEAT TREATMENT FIXTURES FOR FORMED COMPONENTS

R.S. Amruth Kumar, N.S. Mahesh, R.R. Bhat\(^1\) and Subrahmanya Shastry\(^1\)
M.S. Ramaiah Institute of Technology, Bangalore
1 Hindustan Aeronautics Limited, Bangalore-560 017.
E-mail: rr_bhat@yahoo.co.uk

Commonly used fixture material is plain carbon steel owing to its cost. Warpage, deformation and scaling of plain carbon steel fixtures were noticed due to repeated heating and quenching resulting in considerable decrease in the life of the fixtures. With this in view, an attempt has been made to investigate and recommend suggestions for increasing the working life of heat treatment fixtures. The primary goal of the present work is to identify an alternative fixture material to suit the conditions prevailing in heat treatment cycles.

WEAR STUDIES ON IRON ALUMINIDE INTERMETALLIC ALLOY

Garima Sharma and M. Sundararaman
Bhabha Atomic Research Centre, Mumbai-400 085

Room temperature dry sliding wear behavior of DO\(_3\) based iron aluminides has been investigated using a pin on disk and ball on plate wear tester. Tests were carried out for different composition of iron aluminides and also with chromium addition at a range of load and sliding speed. The micro mechanism responsible for wear was studied by SEM.

STUDY OF WEAR BEHAVIOUR OF AUSTEMPERED DUCTILE IRON

Ritha Kumari and P. Prasad Rao
National Institute of Technology, Surathkal, Karnataka.
E-mail: ppr@nitk.ac.in

The present investigation is taken up to study the influence of microstructure on the wear behavior of ADI. Wear test results showed that a microstructure consisting of lower bainite and less retained austenite with high carbon content is always beneficial to wear resistance. At high austempering temperatures the retained austenite is instrumental in improving the wear resistance.

VARIATION IN STRUCTURE-PROPERTY OF PH 13-8 Mo STAINLESS STEEL UNDER IDENTICAL HEAT-TREATMENT CONDITIONS

J. Mitra and P.K. De
Bhabha Atomic Research Centre, Mumbai 400 085.
E-mail: pkde@apsara.barc.ernet.in

PH 13-8 Mo stainless steel samples from three different batches of melt were subjected to identical heat-treatment. However, significant variation in the tensile and impact properties was noticed although, crucial elements were found in the specified range. Change in the prior austenite grain size appeared responsible for this variation.

OPTIMIZATION OF HEAT TREATMENT PARAMETER OF Co-Cr-W-Ni SUPERALLOY PLATES / SHEETS

R.K. Gupta, B.R. Ghosh, P.P. Sinha
Vikram Sarabhai Space Centre, Trivandrum-695 022.
E-mail: rohitkumar_gupta@vssc.org

In the course of the development of the alloy extensive studies on the optimization of the heat treatment parameter of this alloy was carried out. Experimental results and their analysis could lead to the establishment of optimized heat treatment parameters with respect to desired mechanical properties. This paper presents the experiments conducted and analysis of the data evolved to achieve the desired properties.
FATIGUE BEHAVIOUR OF IN718 WELDMENTS
Sivaprasad Katakam, S. Ganesh Sundara Raman, C. V. Srinivasa Murthy1 and G. Madhusudhana Reddy2
Indian Institute of Technology Madras,
1 Defence Research and Development Laboratory, Hyderabad,
2 Defence Metallurgical Research Laboratory, Hyderabad
E-mail: ganesh@iitm.ac.in

Techniques like pulsed current and arc oscillation in gas tungsten arc welding reduce segregation of Nb in the interdendritic region of IN718 welds and improve tensile properties and stress rupture life of welds. The present investigation deals with the fatigue behaviour of IN718 weldments prepared using these techniques.

TRIBOLOGICAL CHARACTERISTICS OF ELECTRODEPOSITED NANOCRYSTALLINE Ni-Fe-W ALLOYS
K. R. Sriraman, S. Ganesh Sundara Raman and S. K. Seshadri
Indian Institute of Technology Madras, Chennai-600036.
E-mail: sk_seshadri@yahoo.com

In this paper the deposition characteristics and tribological studies of Ni-Fe-W poly alloy are discussed. The wear depths of the coatings initially increased with lower hardness values, then showed a decreasing trend and then tend to increase. Maximum resistance to wear was observed at peak hardness values. Beyond a critical amount of W in the coating the crystallite size reduction reduced the hardness thereby showing reverse Hall-Petch behavior and thus this contributed to reduction in the wear resistance. The scanning electron micrographs confirmed the effective material transfer from the pin to the counter disc thereby confirming to mild adhesive wear mechanism.

EFFECT OF SUBSTRUCTURE ON THE WEAR BEHAVIOUR OF STEEL
V. Toppo, S. B. Singh and K. K. Ray
Indian Institute of Technology, Kharagpur-721302.
E-mail: kkmnt@metal.iitkgp.ernet.in

The effect of pre-strain on wear behavior of plain carbon steel has been examined. The wear rate of the steel was found to increase with increasing pre-strain up to a critical level. The observed variation in wear rate with pre-strain has been discussed using the dominance of delamination and oxidative wear.

A RE-EXAMINATION OF LUDWIGSON STRESS-STRAIN RELATIONSHIP
K.G. Samuel and P. Rodriguez1
Indira Gandhi Centre for Atomic Research, Kalpakkam 603102.
1 Indian Institute of Technology, Chennai-600036.
E-mail: samuel@igcar.ernet.in

This paper presents a re-examination of the Ludwigson relation and the often cited explanation for the Ludwigson type strain hardening found in stainless steels to a changeover from planar slip to cross slip. It is observed that the transition strain which is about 25% in as received material still persists and is as large as 10-11% even after the material was given a prior cold work of 24.7%. The results also reinforce the point that work hardening is a more appropriate parameter than stress or strain to describe the “hardness/strength/microstructural” state of a specimen.

THE SCALING OF STRAIN-HARDENING INDEX AND STRAIN-HARDENING COEFFICIENT WITH YIELD STRENGTH IN TYPE 316 STAINLESS STEELS
K.G. Samuel, S.K. Ray and P. Rodriguez1
Indira Gandhi Centre for Atomic Research, Kalpakkam 603102, India.
1 Indian Institute of Technology, Chennai 600036.
E-mail: samuel@igcar.ernet.in

Strain hardening parameters ($K$ and $n$) derived from the true stress-true plastic strain relationship following Hollomon relation in tensile deformation of three types of austenitic stainless steels, subjected to different thermo-mechanical treatments to vary its initial microstructure and yield strength, was investigated and the results are discussed.

DEPENDENCE OF STRAIN HARDENING PARAMETERS WITH STRENGTH AND ITS USEFULNESS TO ASSESS THE TOUGHNESS OF THE MATERIAL
K.G. Samuel, S.K. Ray and P. Rodriguez1
Indira Gandhi Centre for Atomic Research, Kalpakkam 603102.
1 Indian Institute of Technology, Chennai 600036.
E-mail: samuel@igcar.ernet.in

This paper presents the various possible dependence of Hollomon work hardening parameters $K$ and $n$, derived from the true stress-true plastic strain data for tensile deformation, with the initial yield strength of the material. It is also shown that these parameters can be used to assess the toughness of the material in terms of the plastic strain energy at the test
temperature up to the onset of tensile instability. It is shown that the suitability of a material in terms of its strength and toughness at the temperature of its intended use can also be assessed with the knowledge of $K$ and $n$ from a simple tensile test.

### SHORT CRACK VIS-À-VIS LONG CRACK THRESHOLD IN STEEL

**K. K. Ray and N. Narasaiah**
Indian Institute of Technology, Kharagpur - 721302.
*Currently with National Metallurgical Laboratory, Jamshedpur - 831007.
E-mail: kkmrt@metal.iitkgp.ernet.in

The short and long crack fatigue thresholds and the influence of microstructure on the nature of short crack path have been examined for 0.003, 0.25 and 0.47% carbon steels using a recently developed technique. The ‘near long crack fatigue threshold’ values obtained from short crack growth studies are in good agreement with the corresponding fatigue threshold for the long cracks.

### INVESTIGATION AND CONTROL OF TRANSVERSE CRACKS AND OTHER CONCAST DEFECTS FOR CRNO-GRADES STEEL AT RSP

Rourkela Steel Plant, Rourkela

Cold rolled non-oriented (CRNO) grades of electrical Steel is basically a low carbon- Fe-Si alloy with large amount of aluminium. Presence of silicon and aluminium contributes to the elimination of allotropic transformation in Iron and consequently these alloys can be annealed at high temperature to obtain large grains, better watt-loss property. However, because high silicon and aluminium content, these grades are crack sensitive and exhibit low ductility and strength at elevated temperatures along with columnar structures and low thermal conductivity, which make these grades of steel difficult for continuous casting. This paper describes in detail the mechanism of defects generation, corrective action taken, with special emphasis on the prevention of “transverse cracks” in CRNO grades.

### MODELLING AND SIMULATION

**MIXING TIMES AND CORRELATION FOR DUAL PLUG STIRRED LADLE: QUANTIFYING THE ROLE OF AN UPPER BUOYANT PHASE**

**D. Mazumdar**
Indian Institute of Technology, Kanpur-208016.
E-mail: dipak@iitk.ac.in

Mixing times in water model ladles fitted with twin porous plugs were measured for various operating conditions. It was shown that for a slag free situation, mixing times and operating variables (liquid depth, vessel radius and gas flow rate, $Q$) are related as: $\tau_{mix, 95\%} = 15Q^{-0.38}L^{0.50}R^{2.8}$. Then the corresponding relationship in the presence of slag is expressed through the equation:

$$\tau_{mix, 95\%} = 60 \eta^{0.3}Q^{-0.33}L^{-0.7}R^{2.0},$$

in which, $\eta$ is the fractional slag depth ($=\Delta L/L$).

### TRANSPORT PHENOMENA IN SPRAY DEPOSITION: A MATHEMATICAL MODEL

**S. Harikishore and S.C.Koria**
Indian Institute of Technology, Kanpur
Email : satishch@iitk.ac.in

Transport phenomena play an important role in spray deposition. The microstructure and the mechanical properties of as-deposited material depend on thermal and solidification histories of the droplets. Employing Langragian and Lumped-Heat-Capacity approaches and rapid solidification phenomenon to study the thermal and solidification behaviour of droplets develops a mathematical model. The results of the calculations are presented as a function of several process technological parameters.

### PHASE DISTRIBUTIONS IN MCrAlY COATINGS AND THEIR INTERACTIONS WITH NICKEL BASED ALLOYS-THROUGH COMPUTATIONAL MODELLING

**D. R. G. Achar**
Indian Institute of Technology Madras.
E-mail: achar@itm.ac.in

Computational simulation modeling has been applied to follow phase changes and inter diffusion processes in the temperature range between 950 and 1050°C in the MCrAlY coating materials containing Co and Rhenium. Further, interdiffusion between NiCoCrAlY coating and a Ni-based superalloy...
substrate material at 1000°C has been simulated and results compared with the experimental findings.

MONTE CARLO SIMULATIONS OF MICROSTRUCTURAL EVOLUTION IN MODEL Ni-Al-X (X = Cr, Co, Re) SYSTEMS

R. Sankarasubramanian and R. Balamuralikrishnan
Defence Metallurgical Research Laboratory, Hyderabad

Monte Carlo simulations of model ternary Ni-Al-X (X = Cr, Co, Re) systems, using pairwise interatomic potentials, have been performed as a prelude to understanding the microstructure evolution in actual nickel base superalloys. The microstructural evolution in terms of different order parameters, the partitioning of the ternary element into the ordered and disordered regions, and the sublattice occupancy within the ordered structure will be presented.

STUDY OF PARTICLE SEPARATION BY FLUIDIZATION

A.K. Mukherjee and B.K. Mishra
Tata Steel, Jamshedpur.
E-mail: akmukherjee@tatasteel.com
1 Indian Institute of Technology Kanpur. E-mail: bk@iitk.ac.in

Research work on fluidization indicates that particles of size ratio below 0.2 and above 0.6 tend to either mix or segregate. Particles of intermediate size ratios behave either way depending on the fluid velocity. Present study uses experimental data and a DEM based model to study the influence of fluid velocity on fluidization characteristics for all three types of particles.

VIRTUAL SENSORS IN RE-HEATING FURNACE

K. Suresh Kumar, Anubha Prasad, Anurag Agnihotri and Navin Kumar
Tata steel, Pune
E-mail: ksuuresh@aut.tatasteel.com

The side wall thermocouples in the furnace are used to control the zonal temperatures whereas, the thermocouples in the roof and hearth (Top/bottom) are used to deduce the slab temperature which are prone to fail and difficult to maintain. The Top/bottom thermocouples have been replaced by virtual sensors.

EFFICIENCY ENHANCING SOLUTION FOR HEAT TREATMENT OPERATIONS: MODEL BASED DESIGN OF OPTIMAL PROCESS CYCLES

Satyam S. Sahay, Jeevan Jaidi and Karthik Krishnan
Tata Research Development and Design Centre, Pune 411 013.
E-mail: satyam.sahay@tcs.com

Heat treatment operations have significant bearings on plant productivity, energy, quality and emissions. Nevertheless, they are empirically designed in the plant, which results in sub-optimal operations. In this presentation, a formal approach of designing optimal heat treatment cycles through process modeling will be elaborated through successful industrial case studies.

MONTE CARLO STUDY OF INTERFACIAL PROPERTIES OF PHASE SEPARATING ALLOYS

Saswata Bhattacharyya, Ferdinand Haider 1 and T.A. Abinandanan
Indian Institute of Science, Bangalore 560012,
1 Institut fur Physik, Universitaet Augsburg, Augsburg, Germany

We have studied the interfacial properties of phase separating binary alloys using Monte Carlo (MC) simulation technique. The interfacial free energy is computed using direct thermodynamic integration procedure. We have determined the equilibrium shapes of precipitates from the simulations and compared them with the corresponding Wulf shapes.

VALIDATION OF PHASE FIELD MODEL FOR STUDYING PRECIPITATION GROWTH KINETICS

R.Mukherjee and T.A.Abinandanan
Indian Institute of Science, Bangalore, 560012
E-mail: abinand@met.iisc.ernet.in

In this paper an attempt has been made to demonstrate the correctness of a phase field model in a kinetic setting, by validating it against known results for precipitate growth kinetics.
FINITE ELEMENT METHOD BASED SIMULATION OF WATER COOLING OF RODS

Rajeev Baskiyar
RDCIS, SAIL, Ranchi- 834002
E-mail: broy@sail-rdcis.com

Accelerated cooling of hot-rolled steels is being increasingly used as a value addition tool. A predictive capability of the transient temperature profile of the stock being cooled is necessary for tailoring the required product properties. The paper deals with the approach for the development of a mathematical model for water-cooling of rods using the Finite Element Method (FEM) and discusses alternative cooling strategies using the simulation results.

EFFECT OF STRESS TRIAXIALITY ON DUCTILE FRACTURE BEHAVIOR OF NEAR α-TITANIUM ALLOY IMI-834 – A MICRO-MECHANICS APPROACH

Jalaj Kumar, B. Venkateswara Rao¹, S. Padma², B.Srivathsra and Vikas Kumar
Defence Metallurgical Research Laboratory, Hyderabad, ¹ Gandhi Institute of Technology and Management, Vizag,
² College of Engineering, JNTU, Kakinada
E-mail: jalaj@dmrl.ernet.in

The limitations of global fracture mechanics for assessment of integrity of critical structures / components in complex engineering situations has motivated the development of micro-mechanics based local fracture approaches. In the present investigation, several micro-mechanics models have been explored to study the effect of stress triaxiality on ductile fracture behavior of near- α Titanium alloy IMI-834 with the help of axi-symmetrically notched tensile round bars, experimentally and by finite element simulation.

SIMULATION OF MIXING AND SEGREGATION IN TUMBLING MIXERS THROUGH DEM

V. Hema, S. Subasini, K. Usha, S.Savithri and G.D. Surender
Regional Research Laboratory, Trivandrum-695019.
E-mail: hemaasok@yahoo.com

This work is directed towards the fundamental understanding of the mixing and segregation behavior in the simplest prototype of the tumbling mixer-rotating cylinder. The theoretical simulation is based on discrete element method where each individual particle is tracked using Newton’s equation of motion. The mixing and segregation patterns are quantified in terms of the rotational speed, fill fraction, size ration, density ratio of the particles.

METAL FLOW INVESTIGATION AND PREFORM OPTIMIZATION IN CLOSE DIE FORGING

N.K. Singh and Gojamgunde Deepak Satish
National Institute of Foundry and Forge Technology, Ranchi-834003
E-mail: niranjanksingh@rediffmail.com

In this work FEM software named DEFORM-3D is used for the front axle beam (an automobile component) forging simulation. 3D models of dies and preform shapes have been prepared and exported to DEFORM. Metal flow simulations have been carried out for these dies and results for these simulations are analyzed. With the help of these results modifications have been made in die design and perform shape. By detailed analysis of these results efforts have been made to find out optimum die design which gives better metal flow; better yield, less load requirement and minimum stress on dies.

POROSITY DISCRIMINATION IN CAST MICROSTRUCTURES

Asim Tewari
GMTCI, Bangalore
E-mail: asim_tewari@yahoo.com

An algorithm is developed to distinguish two kinds of porosities (shrinkage and gas) from each other based on their structure (shape and size) and spatial scatter. The algorithm uses morphological transformations on gray scale images of the microstructure. This technique will lead to a better understanding and control of the solidification process to minimize the porosity formed in the solid.

SIMULATION STUDIES ON THE PARAMETERS THAT AFFECT THE MATERIAL FLOW IN EQUAL CHANNEL ANGULAR EXTRUSION (ECAE) PROCESS

Defence Metallurgical Research Laboratory, Hyderabad
E-mail: divakar@igcar.ernet.in

Simulation studies were carried out to understand the mechanics of ECAE process and to evaluate the effect of various parameters (die corner angle, friction, and material property) that affect material flow.
ENGINEERING A DESIRED GRADIENT IN FGM BY MEANS OF COMPUTER SIMULATION

Regional Research Laboratory, Trivandrum-695019.
E-mail: utspillai@rediffmail.com

A computer simulation is performed using a numerical technique for tailoring the composition gradient in a centrifugally cast metal-ceramic FGM. For the purpose, the motion of ceramic particles in a viscous molten metal under a centrifugal force is modeled and the gradient composition formation is then simulated by considering the movement of each particle that is suspended in the viscous metal. The results of the simulations are compared with the experiment results to validate the efficiency of the model in tailoring the composition gradient.

MEASUREMENT AND MODELLING OF THERMOPHYSICAL PROPERTIES OF TITANIUM STABILISED NUCLEAR GRADE AUSTENITIC STAINLESS STEEL (ALLOY D9)

Aritra Banerjee, S. Raju, R. Divakar, and E. Mohandas
Indira Gandhi Centre for Atomic Research, Kalpakkam – 603 102.
E-mail: sraju@igcar.ernet.in

In the present study, thermal expansion and enthalpy of Alloy D9 austenitic steel were measured and the experimental results were comprehensively modelled to obtain a complete set of thermophysical properties, including high temperature bulk modulus and Grüneisen parameter as a function of temperature.

ADVANCED MATERIALS AND PROCESSES

THERMO-MECHANICAL TREATMENT OF SPRAY FORMED Cu-Ni-Si ALLOY

V. C. Srivastava and P. K. De
Metal Extraction & Forming Division
National Metallurgical Laboratory, Jamshedpur-831 007

The effect of various thermo-mechanical treatments on spray formed Cu-2.4Ni-0.6Si alloy has been studied. The as-spray formed alloy shows refined microstructure with increased solid solubility giving better ageing response. The maximum hardness is observed for solutionised and cold rolled alloy. The maximum electrical conductivity is observed for only high degree of cold deformation but with rapid decrease in hardness during ageing. A combination of good conductivity and hardness is achieved after cold rolling to 40% reduction followed by isothermal ageing. The alloy shows interesting evidence of discontinuous precipitation, which occurs primarily at the grain boundaries and deformation bands.

PREPARATION AND CHARACTERISATION OF SmB₆ BY MOLTEN SALT ELECTROLYSIS

S.Devaki, A.Visuvasam, S.Angappan, L.John Berchmans and C.O.Augustin
Central Electrochemical Research Institute.
Karaikudi-630006.
Email:caugustin@rediffmail.com

Rare Earth metals with Boron have recently been recognized as promising materials, owing to their high melting point, high strength and chemical stability in aggressive environments, which find application in many specialized areas. The present investigation aims to synthesize Samarium Hexaboride by molten salt metallurgy. SmB₆ crystals were synthesized using Oxy-Fluoride melt at 850°C with Molybdenum cathode and Graphite anode at various current densities and characterized. The XRD patterns confirm the cubic crystal structure.

DUPLEX CASTING OF LEADED ALUMINIUM ALLOYS

J.P. Pathak, Sunil Mohan and S.N. Ojha
Center of Advanced study, Department of Metallurgical Engineering
Institute of Technology, Banaras Hindu University,
Varanasi-221005

Duplex casting s of Al-Cu-Pb alloys produced by melt stirring followed by its centrifugal casting are described. Variation in Pb content is shown to be within 2% in the longitudinal direction compared to 7% in the transverse direction of the castings. The effect of process variables on microstructure and chemical homogeneity of the castings is discussed.

COMPRESSIVE DEFORMATION CHARACTERISTICS OF CLOSED CELL ALUMINIUM FOAM: EFFECT OF MATRIX MATERIAL

D. P. Mondal, and S. Das
Regional Research Laboratory (CSIR),
Bhopal-462026, India.
Email:sdas@rrlblr.org

This paper deals with the compressive deformation behavior of Aluminium, Aluminium alloy and Al-SiC composite closed cell foam. The stress-strain diagrams of these foam materials would be discussed paying particular emphasis to the densification strain and plateau stress. Effect of SiC particle on the Compressive deformation behavior is studied.
SYNTHESIS OF NiO NANOPARTICLES THROUGH WATER-IN-OIL MICROEMULSION TECHNIQUE

Prakash. P and Ashok. M. Raichur *
Department of Metallurgy, Indian Institute of Science, Bangalore - 560 012
Email:amr @met.iisc.ernet.in

Nickel Oxide (NiO) nanoparticles were synthesized through Water-in-oil microemulsion technique at high R-ratio (R ratio is the molar ratio of water to molar ratio of the surfactant) using n-heptane as the hydrocarbon phase, Aerosol-OT as a surfactant and nickel chloride solution as aqueous phase. It is found that the nanoparticles synthesized within the microemulsion region have narrow distribution compared to the nanoparticles synthesized outside the microemulsion region. The synthesized nanoparticles were characterised using X-ray diffraction (XRD) and Transmission Electron Microscopy (TEM).

REFINED MOLYBDENITE AS A LUBRICANT ADDITIVE

Manoj Kumar*, T. R. Mankhand and P. M. Prasad**
* National Metallurgical Laboratory, Jamshedpur 831007
** Department of Metallurgical Engineering, Institute of Technology, Banaras Hindu University, Varanasi 221005
Email:manoj_nfp@rediffmail.com

Refined molybdenite prepared from an indigenous low-grade moly concentrate has been tested for its suitability as a solid additive to lubricant employing extreme pressure testing procedure. Results indicate a vast improvement in all the required tribological properties. Moreover, performance of our refined molybdenite has been found comparable with that of an imported high-grade molybdenite.

SOME STUDIES ON STRUCTURAL CHARACTERIZATION OF Ni-Mn-Ga BASED FERRO MAGNETIC SHAPE MEMORY ALLOYS

R.P. Mathur*, P Ghosal*, V. Chandrasekaran* and S.Ray**
*Defence Metallurgical Research Laboratory, P.O. Kanchanbagh, Hyderabad 500 058
** Department of Metallurgical & Materials Engineering Indian Institute of Technology, Roorkee 247 667
Email: raghumathur@rediffmail, mathur@dmrl.ernet.in

Ferro-Magnetic Shape Memory alloys based on Ni$_3$MnGa composition have been prepared through Vacuum Arc Melting (VAM) using elemental constituents and the binary master alloys as starting materials. The results of the micro-structural and chemical characterizations of these alloys are presented in this paper.

RECENT ADVANCES IN P/M OF NON-FERROUS ALLOYS BY MICROWAVE SINTERING

Anish Upadhyaya
Department of Materials and Metallurgical Engineering Indian Institute of Technology, Kanpur 208016, India
Email: anishu@iitk.ac.in

The present paper describes the sintering behaviour of bronze and tungsten heavy alloys. Premixed 92.5W-6.4Ni-1.1Fe (wt.%) and 90Cu-10Sn alloys were sintered using both conventional as well as microwave heating and their densification responses have been compared. The study also includes the phase analysis and mechanical properties comparison of microwave sintered compacts vis a vis their conventional counterparts.

PROCESSING AND CHARACTERISATION OF W AND W + Os ALLOYS FOR USE AS DISPENSER CATHODES IN MICROWAVE TUBES (118)

N.C. Upadhyay
Dept. of Met. Engg., MNIT, Jaipur

The electromagnetic spectrum is rapidly getting congested at the traditional Microwave frequencies with the increased use of terrestrial and space communication leading to an ever-increasing demand for still higher frequencies and power. This has led to a critical assessment of existing device technology, systems and innovations as well as improved materials. In the modern microwave tubes, one of the important constraints is the electron Emitter, which has to provide higher emission density at lower operating temperature, yielding long life. In addition the electron emitter has to provide uniform emission across its entire cross-section. Surface porosity, operating temperature and the quantity of Emission compound play a significant role in uniform emission and longer life of the Dispenser cathodes.

A METHOD FOR SYNTHESIS OF NANOSTRUCTURED ALUMINA & ALUMINA BASED CERAMICS

S.Senthil Kumar, K.V. Ramana Rao and J.Mukhopadhyay
Jawaharlal Nehru Aluminum Reasearch Development & Design centre
Amravati Road, Wadi, Nagpur
Email:directjn_npg@sancharnet.in

In the present communication the details of a low temperature combustion synthesis (LCS) used for the production of
alumina nano-particles is presented. The process utilizes the in-built exothermicity of combustion of reaction system. This process also produces a compositionally homogeneous mixture and enables the synthesis at lower ignition and combustion temperature.

**THERMAL CONDUCTIVITY OF NANOCRYSTALLINE Ti/Zr-BASED METAL-HYDRIDES FOR COMPRESSOR DRIVEN REVERSIBLE HEATING-COOLING SYSTEM**

S. Bera*, E. Prasad*, M. Ramgopal**, S. Bhattacharya** and I. Manna*

*Metallurgical and Materials Engineering Department, I. I. T., Kharagpur 721 302
**Mechanical Engineering Department, I. I. T., Kharagpur 721 302
Email: imanna@metal.iitkgp.ernet.in

The present study concerns synthesizing nanocrystalline AB$_2$ type (Ti,Zr)(Fe,Cr)$_2$ quaternary alloys, characterizing their microstructure, assessing thermal conductivity of the powder compacts with or without graphite addition, and thermodynamic calculations for determining enthalpy of hydride formation for use of these nano-hydrides in pressure-driven reversible heating-cooling applications.

**NANOFUID FOR ADVANCED HEAT TRANSFER APPLICATIONS**

M. Chopkar*, S. Kumar*, P. K. Das** and I. Manna*

*Metallurgical and Materials Engineering Department, Indian Institute of Technology
**Mechanical Engineering Department, Kharagpur, W.B. 721 302
Email: imanna@metal.iitkgp.ernet.in

Nano-fluid is a stable colloidal dispersion of solids in a fluid for enhanced heat transfer. We have synthesised water-based nano-fluid by dispersing nanocrystalline Al-Cu/Al-Ag powders and carried out appropriate conductivity measurements. The initial results reveal encouraging trend. Analytical modelling shows high aspect ratio of particle enhances thermal properties of the nanofluid.

**DEVELOPMENT OF A DIAGNOSTIC TOOL FOR INDUSTRIAL SCALE GRINDING SYSTEMS**

B. Behera, B.K. Mishra, and C.V.R. Murty

Department of Materials & Metallurgical Engineering
Indian Institute of Technology Kanpur
Email: bk@iitk.ac.in

The grinding efficiency of semi autogenous milling or ball milling depends on the tumbling motion of the total charge within the mill. By proper monitoring of the charge motion the energy efficiency of grinding mills can be increased. The research work pursued here is to capture and interpret the vibration signals to predict the tumbling action of the charge. It is shown that this approach is very effective in monitoring the charge profile in tumbling mills.

**INVESTIGATION OF CONNECTING ROD FORGING DEFECTS AND THEIR REMEDIAL MEASURES**

M.K. Agrawal* and P. Aiket**

* Deptt. of Met. Engg. & Mat. Sc, National Institute of Technology, Jamshedpur
** Tata Motors, Jamshedpur

Connecting rod, produced by close die forging, gives good ductility, toughness and lightness and is free from casting defects. However, in forging process, number of rejections are very large due to faulty design of die, wrong processing technologies, chemistry of steel etc. The present work deals with the reasons for the rejection and its remedies to reduce the forging defects of connecting rods.

**CONSOLIDATION AND CHARACTERIZATION OF FIELD-ASSISTED SINTERED AND HOT PRESSED RAPIDLY SOLIDIFIED HYPEREUTECTIC Al-Si-Fe-X ALLOY**


* Department of Metallurgy and Materials Engineering (MTM)
Katholieke Universiteit Leuven (K.U. Leuven)
Kasteelpark Arenberg 44, B-3001 Leuven, Belgium
**Sastry.KandukuriYagnanna@mtm.kuleuven.ac.be
Powder Light Metals GmbH, Am Wiesenbusch 2
D-45966 Gladbeck, Germany
rschattevoy@powder-light-metals.com

Rapidly solidified pre-alloyed Al-17Si-5Fe-3.5Cu-1.1Mg-0.6Zr (wt%) powder was densified using hot pressing and field-assisted sintering (FAST) at 350, 400 and 450°C. It was
observed that full density was reached at lower temperatures and mechanical loads and also in very shorter time during FAST when compared to hot pressing. FAST compacts exhibited higher hardness but similar microstructural features when compared to hot pressed compacts.

**CONTROLLED VACUUM LOW TEMPERATURE SINTERING OF UO₂ PELLETS**


‘Radiometallurgy Division, Nuclear Fuels Group, Bhabha Atomic Research Centre, Trombay, Mumbai 400 085

Email:tkutty@magnum.barc.ernet.in

A new process has been developed in Radiometallurgy division, called Controlled Vacuum Low Temperature Sintering (CVLTS) for the fabrication of nuclear fuel pellets. In this process by controlling the vacuum level in the furnace, it is possible to achieve good quality pellets with high density. This paper deals with the vacuum sintering of UO₂ and discusses the merits and demerits of vacuum in the sintering.

**STRUCTURAL ASPECTS OF ELECTROLESS Ni-B AND Ni-W-B ALLOY DEPOSITS**

M. Palaniappa and S.K. Seshadri

Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras

Chennai – 600 036

This paper deals with synthesis and characterization of binary Ni-B and ternary Ni-W-B alloy deposits. Incorporation of tungsten results in reduction of boron content in the deposit leading to a crystalline structure. Precipitation of borides is delayed in the ternary Ni-W-B alloys when compared to the binary Ni-B alloys. Incorporation of tungsten leads to a thermally stable electroless deposits.

**DISPERSION OF TaC IN Ni₃Al MATRIX BY MECHANICAL ALLOYING**

K. Satya Prasad, Vydehi A. Joshi, A.M. Sriramamurthy and B.S. Murty*

Defence Metallurgical Research Laboratory, Kanchanbagh, Hyderabad

*Indian Institute of Technology, Madras

Email:ksp@dmlr.ernet.in

Tantalum in superalloys, enhances creep through partitioning to the intermetallic phase gamma prime (Ni₃Al). It also forms carbide which is quite hard and compatible and strengthens the alloy. An attempt is made to get a submicroscopic and uniform distribution of TaC in Ni₃Al by mechanical alloying. Elemental powders of Ni, Al, C and Ta-Al master-alloy were milled in planetary mill from 10 to 40h. This paper presents the details of milling and the microstructural characterization using SEM and TEM.

**PREPARATION OF NOVEL MIXED METAL OXIDE TUNGSTATES**

S. Asha, K.V.O Nair and J James

Regional Research Laboratory (CSIR), Thiruvananthapuram-695 -19

Email : j21058@yahoo.com

The present paper reports the synthesis and characterization of three novel mixed metal oxide tungstates viz., Ba₂SmWO₆, Ba₂EuWO₆ and Ba₂GdWO₆ by conventional solid-state reaction route. Experimentally obtaining their X-ray powder diffraction patterns, theoretically calculating their XRD profile and comparing and refining the data established the structure of these compounds as a perovskite structure. The variation of dielectric properties with applied frequency indicate their potential for use as ionic conductors in sensors and SOFC etc.

**STUDIES ON MELTING AND PROCESSING NIOBIUM BASE ALLOYS**

V.V. Satya Prasad and R.G. Baligidad

Defence Metallurgical Research Laboratory, Kanchanbagh PO, Hyderabad

Niobium base alloys command a great deal of attention because niobium has the lowest density of all refractory materials, a property which is of great significance for the design of rotating components of aero engines. Preliminary experimental work has been carried out by melting, processing and characterization of three niobium based alloys, namely Nb – 1Zr, Nb – 1Zr – 0.1C, Nb – 10Hf – 1Ti. This paper discusses the salient features of the aforementioned experimental study.

**THE EFFECT OF NbC PRECIPITATES ON THE SHAPE MEMORY BEHAVIOUR OF Fe-Mn-Si-Cr-Ni SHAPE MEMORY ALLOYS**

Bikas C. Maji, Madangopal Krishnan and A. Biswas

Materials Science Division, Bhabha Atomic Research Centre, Mumbai – 400 085.

Email:pkde@apsara.barc.ernet.in

Shape memory effect (SME) in Fe-Mn-Si-Cr-Ni alloys is associated with γ to ε martensite transformation. These alloys suffer from incomplete SME due to permanent deformation of low strength γ matrix. Nb and C have been added to strengthen γ by precipitation of coherent NbC phase. The improvement of SME due to NbC precipitation strengthening will be discussed.
EXPERIMENTAL STUDY OF BRAZING OF Al2O3 WITH GRAPHITE


*Materials Science Division, Bhabha Atomic Research Centre, Mumbai-400 085
**Central Electronics Engineering Research Institute, Pilani-333031
***Centre for Design and Manufacture, Bhabha Atomic Research Centre, Mumbai-400085

Email:pkde@apsara.barc.ernet.in

Graphite and C/C composites are basically brittle and need to be combined with structural ceramics like Al2O3 for specific space applications. The preset work focuses on joining of commercial grade alumina (Al2O3) to graphite by conventional brazing and also by active metal brazing in the temperature range 900-1000°C. The SEM/EPMA studies indicated that good bonding could be achieved by both brazing process mentioned above and the specimens brazed at optimised conditions passed He-leak test.

3-D RECONSTRUCTION OF THE PORE-STRUCTURE OF NiTi PREPARED BY SHS

Aniruddha Biswas and Madangopal Krishnan
Materials Science Division
Bhabha Atomic Research Centre
Mumbai-400085

Supelastic porous NiTi is a promising bone prosthesis material. In the current work, porous and single phase NiTi was prepared by thermal explosion by combining with a post-reaction heat-treatment. A reconstruction technique based on serial sectioning was adopted to build the 3-D pore structure and estimate the actual surface area of the specimen.

PREPARATION OF POROUS NiTi BY TWO DIFFERENT MODES OF SHS

Aniruddha Biswas
Materials Science Division
Bhabha Atomic Research Centre
Mumbai-400085
Email:pkde@apsara.barc.ernet.in

SHS is a unique technique that can create prosthesis-quality open and interconnected pores covering the required range of sizes and volumes. The current work describes the preparation of porous NiTi from the elemental powder mixture of Ni and Ti using two different modes of SHS namely, Plane Wave Propagation and Thermal Explosion.

DEVELOPMENT OF AI-Al,Ti ALLOY THROUGH MECHANICAL ALLOYING (MA)

G.P. Khanra, S. Girikumar, Gangadhar De and K. Suseelan Nair
Special Materials Division
Materials and Metallurgy Group
Vikram Sarabhai Space Centre, Trivandrum
Email:ganga47@rediffmail.com

In the present study, the alloy was prepared through mechanical alloying in an attritor mill using elemental Al and Al-Ti master alloy powders. The mixed powder was subsequently sintered and hot extruded. XRD analysis revealed that Al,Ti is formed in the alloyed powder only after heat treatment at 500°C. Hot extruded Al-10wt%Ti alloy exhibited good retention of hardness up to 400°C. The presence of stable uniformly dispersed fine coherent Al,Ti phase in Al matrix is found to be responsible for contributing attractive mechanical properties.

SYNTHESIS OF METAL FOAM: PRESENT STATUS AND FUTURE PROSPECTS

Sunil Banerjee, Himanshu Kelkar, S.Das and DP Mondal
Metal Composite Group
Regional Research Laboratory (CSIR) Bhopal
Email:sdas@rrlbpl.org ; sdas88@hotmail.com

In this present paper, a detailed comparison of the processes already developed for making foams by various researchers, technologists and industries will be presented. Additionally the parameters which control the processing and stability of foam formation will be correlated and will be discussed during the presentation. This presentation will also bring out the processes being used by RRL, Bhopal for making metal foam.

DEFORMATION AND FRACTURE BEHAVIOR OF ALUMINIUM AND ALUMINIUM COMPOSITE FOAM

Himanshu Kelkar, Sunil Banerjee, S. Das and DP Mondal
Metal Composite Group, Regional Research Laboratory (CSIR), Bhopal
Email: sdas@rrlbpl.org ; sdas88@hotmail.com

This paper basically deals with the study of fracture behavior of Aluminium and Aluminium Composite closed cell foam in compressive and tensile deformation conditions. Efforts have been made to correlate the factors such as cell geometry, material composition with stress-strain diagram.
**PALLADIUM BASED HYBRID HETEROGENEOUS MATERIALS: SYNTHESIS AND CHARACTERIZATION**

Sobhi Daniel, P. Prabhakara Rao, M. Nandakumar and T. Prasada Rao*
Regional Research Laboratory (CSIR), Trivandrum.
E-mail: tprasadarao@rediffmail.com

The synthesis of hybrid heterogeneous palladium based catalyst materials was accomplished in a straightforward, two step reaction using solid phase extraction (SPE). This involves functionalization of solid inorganic sorbents such as Al₂O₃, silica gel and TiO₂ with organic chelate, i.e. dimethyl glyoxime (DMG). The above functionalized materials were transformed into palladium ion sorbed DMG functionalized materials by SPE. All the synthesized materials were characterized by FT-IR, TGA, DTA, XRD, UV-visible, SEM, EDS and N₂ adsorption surface area and pore size measurements. One of the best synthesized materials was used for the catalytic evaluation using Heck reaction.

**STRUCTURAL DEFECTS IN ALUMINIUM FOAMS AND THEIR LIKELY CAUSES**

S.N. Sahu, B. Sudhakar, V.K.W.R. Kulkarni, N. Ramachandra Rao, Venkataswamy and Amol A. Gokhale
Defence Metallurgical Research Laboratory, Kanchanbagh P.O. Hyderabad 500 058
Email: amol@dmrl.ernet.in

Aluminium foam experimental ingots 95 mm diameter and 0.2-0.4 relative densities were produced using a recently established apparatus. The cells were polyhedral, closed in general and of 3-5 mm size. Integrity, scale and uniformity of the cell structure were sensitive to the raw materials used, and foaming and solidification.

**SYNTHESIS AND CHARACTERIZATION OF NANO γ—BRASS ALLOYS AFTER MECHANICAL MILLING**

D. Mukherjee, R. Manna, I. Manna*, and N.K. Mukhopadhyay
Department of Metallurgical Engineering, Institute of Technology, Banars Hindu University, Varanasi – 221005
*Department of Metallurgical and Materials Engineering, I.I.T Kharagpur, E-mail: mukho_nk@rediffmail.com

The Cu-Zn alloy (g-brass phase) obtained after conventional melting and casting was employed for mechanical milling, a novel technique for producing nanocrystalline phases, at various milling intensity and milling time ranging from 5h to 40h. The milled and un-milled samples were then characterized for understanding the evolution of the phases. The aim of the present investigation is to optimize the process parameters in order to obtain the nanocrystals of γ-phase and to understand the stability of this phase.

**DEVELOPMENT OF HIGH STRENGTH AND STRONGLY CUBE TEXTURED Ni ALLOY SUBSTRATES FOR COATED CONDUCTOR APPLICATION**

V. Subramanya Sarma*, J. Eickmeyer**, L. Schultz **“and B. Holzapfel”**
*Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Madras, Chennai-600 036, India
**Leibniz Institute for Solid State and Materials Research (IFW), Helmholtz street 20, Dresden, 01069, Germany
E-mail: vsarma@iitm.ac.in

We report on the development of thin (80 thickness) Ni-4.5%W/Ni-10%W composite substrates with strong cube texture, high strength (yield strength > 200 MPa) and reduced magnetisation losses for coated conductor application. The strong cube texture was obtained through an optimised two-step annealing following heavy cold working.
DEVELOPMENT AND CHARACTERISATION OF A Ni₅₀Fe₃₇Co₁₃ SOFT-MAGNETIC ALLOY FOR APPLICATION IN THE MAGNETIC SWITCH OF DIVERSE SAFETY ROD DRIVE MECHANISM (DSRDM) OF PROTOTYPE FAST BREEDER REACTOR (PFBR)

P.V. Sivaprasad*, R. Nagarajan*, R. Veeraswamy**, G. Markandeyulu***, S. Raju*, M. Krishnaiah***, M. Venkatakshman*** and Baldev Raj*
*Metallurgy and Materials Group, ***Engineering Development Group
**Chemistry Group, Indira Gandhi Centre for Atomic Research, Kalpakkam
****Department of Physics, Indian Institute of Technology, Chennai
Email:prasad@igcar.ernet.in

The paper discusses the development of a sensor material with a Curie temperature in the range 625–630°C for application in fast breeder reactors. Ni₅₀Fe₃₇Co₁₃ was identified to possess this Tc based on trial melts and characterisation of the thermal properties of this alloy. The problems faced during thermo-mechanical processing are discussed.

ALLOYED NICKEL BASE SUBSTRATE TAPES FOR COATED SUPERCONDUCTOR APPLICATIONS

P.P. Bhattacharjee, R.K. Ray and A. Upadhyaya
Department of Materials and Metallurgical Engineering
Indian Institute of technology Kanpur
India – 208016
Email:rkray@iitk.ac.in

The current work investigates the possibility of preparing single layer and multi layer substrate materials of Ni, Ni/Ni-W and Ni/Ni-Mo through P/M route for coated superconductor applications. The tapes developed very sharp cube texture after 95% cold rolling and annealing and also had good mechanical strength, suggesting that P/M route can be very well suited as a potential method for preparing such tapes.

SYNTHESIS OF COPPER TANTALUM ALLOYS BY MECHANICAL ALLOYING

M.Sudhakara Rao, T. Raghu and G.G.Saha
Defence Metallurgical Research Laboratory, Kanchanbagh, Hyderabad-500 058
Email:hina@dmrl.ernet.in

A study has been taken up to synthesize Cu-5Ta system by mechanical alloying. Milling of elemental powders has been carried out in a high-energy planetary ball mill for different milling conditions. As milled powders have been characterized for their particle size, particle shape, morphology, microstructure, X-Ray diffraction (XRD) patterns and hardness. XRD data has been further analyzed to estimate lattice parameter and crystallite size of both copper and tantalum. Results have been examined to evaluate the extent of non-equilibrium solid solubility in the system during mechanical alloying. The results obtained from these experiments were be presented and discussed in this paper.

NANOCRYSTALLINE PHOTOCATALYTIC TITANIUM OXIDE FOR CATALYSTS, SELF-CLEANING AND ANTI ALGAL COATINGS

Pradeepan Periyat, K.V. Baiju, C.P.Sibu, P.Perumal, P. Krishna Pillai, P. Mukundan and K.G.K. Warrier*
Ceramic Technology Division, Regional Research Laboratory (CSIR), Industrial Estate, Trivandrum – 695 019
Email:warrierkgk@yahoo.com

Photocatalytic titanium dioxide finds promising applications as self-cleaning and anti soiling coatings on various substrates such as glass, metal, plastics and ceramics. The synthesis of high surface area photoactive titania from titanyl sulphate precursor through a colloidal process is presented. The titania

CRYSSTALLITE SIZE EFFECT ON NANO-FERROELECTRICS BY MECHANICAL ALLOYING

S. K. S. Parashar, R. N. P. Choudhary and B. S. Murty*
Department of Physics and Meteorology, Indian Institute of Technology, Kharagpur, 721302
*Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Madras, Chennai-600036
E-mail:parashar@phy.iitkgp.ernet.in

Nanoferroelectrics prepared by mechanical alloying exhibit exceptionally high dielectric constant. X-ray diffraction (XRD) studies shows PZT compound has new cubic phase in milled condition and tetragonal on annealing. Detail studies of dielectric properties of nanoferroelectric as a function of temperature shows that Tc decreases with the decrease in crystallite size and diffusivity increases with increase in milling time.

ALLOYED NICKEL BASE SUBSTRATE TAPES FOR COATED SUPERCONDUCTOR APPLICATIONS

P.P. Bhattacharjee, R.K. Ray and A. Upadhyaya
Department of Materials and Metallurgical Engineering
Indian Institute of technology Kanpur
India – 208016
Email:rkray@iitk.ac.in

The current work investigates the possibility of preparing single layer and multi layer substrate materials of Ni, Ni/Ni-W and Ni/Ni-Mo through P/M route for coated superconductor applications. The tapes developed very sharp cube texture after 95% cold rolling and annealing and also had good mechanical strength, suggesting that P/M route can be very well suited as a potential method for preparing such tapes.

SYNTHESIS OF COPPER TANTALUM ALLOYS BY MECHANICAL ALLOYING

M.Sudhakara Rao, T. Raghu and G.G.Saha
Defence Metallurgical Research Laboratory, Kanchanbagh, Hyderabad-500 058
Email:hina@dmrl.ernet.in

A study has been taken up to synthesize Cu-5Ta system by mechanical alloying. Milling of elemental powders has been carried out in a high-energy planetary ball mill for different milling conditions. As milled powders have been characterized for their particle size, particle shape, morphology, microstructure, X-Ray diffraction (XRD) patterns and hardness. XRD data has been further analyzed to estimate lattice parameter and crystallite size of both copper and tantalum. Results have been examined to evaluate the extent of non-equilibrium solid solubility in the system during mechanical alloying. The results obtained from these experiments were be presented and discussed in this paper.

NANOCRYSTALLINE PHOTOCATALYTIC TITANIUM OXIDE FOR CATALYSTS, SELF-CLEANING AND ANTI ALGAL COATINGS

Pradeepan Periyat, K.V. Baiju, C.P.Sibu, P.Perumal, P. Krishna Pillai, P. Mukundan and K.G.K. Warrier*
Ceramic Technology Division, Regional Research Laboratory (CSIR), Industrial Estate, Trivandrum – 695 019
Email:warrierkgk@yahoo.com

Photocatalytic titanium dioxide finds promising applications as self-cleaning and anti soiling coatings on various substrates such as glass, metal, plastics and ceramics. The synthesis of high surface area photoactive titania from titanyl sulphate precursor through a colloidal process is presented. The titania

CRYSSTALLITE SIZE EFFECT ON NANO-FERROELECTRICS BY MECHANICAL ALLOYING

S. K. S. Parashar, R. N. P. Choudhary and B. S. Murty*
Department of Physics and Meteorology, Indian Institute of Technology, Kharagpur, 721302
*Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Madras, Chennai-600036
E-mail:parashar@phy.iitkgp.ernet.in

Nanoferroelectrics prepared by mechanical alloying exhibit exceptionally high dielectric constant. X-ray diffraction (XRD) studies shows PZT compound has new cubic phase in milled condition and tetragonal on annealing. Detail studies of dielectric properties of nanoferroelectric as a function of temperature shows that Tc decreases with the decrease in crystallite size and diffusivity increases with increase in milling time.
is modified by incorporation of certain dopants that increase above properties and is better in activity compared to certain commercial counterparts. Nanocoatings were developed on various substrates and further characterized by microscopy, contact angle measurements and photocatalytic activity. Transparent coatings were obtained and they also exhibit excellent capacity to prevent growth of algae on exposure to environment.

**NANOCRYSTALLINE RARE EARTH PHOSPHATE FOR ELECTRICAL AND HIGH TEMPERATURE APPLICATIONS**

R. Rohith, K. Rajesh, P. Mukundan and K. G. K. Warrier*

Ceramic Technology Division, Regional Research Laboratory (CSIR), Trivandrum – 695 019

Email: warrierkgk@yahoo.com

Photocatalytic titanium dioxide finds promising applications as self-cleaning and anti-soiling coatings on various substrates such as glass, metal, plastics and ceramics. The synthesis of high surface area photoactive titania from titanyl sulphate precursor through a colloidal process is presented. The titania is modified by incorporation of certain dopants that increase above properties and is better in activity compared to certain commercial counterparts. Nanocoatings were developed on various substrates and further characterized by microscopy, contact angle measurements and photocatalytic activity. Transparent coatings were obtained and they also exhibit excellent capacity to prevent growth of algae on exposure to environment.

**SYNTHESIS AND CHARACTERIZATION OF NOVEL CERAMIC VANADATES**

L. Shamla, S. Senthil Kumar, K.V.O Nair and J. James

Regional Research Laboratory (CSIR), Thiruvananthapuram – 695 019

Email: jamesj21058@yahoo.com

The preparation of four mixed metal oxide vanadate compounds viz., Mg₂NdVO₆, Mg₂PrVO₆, Mg₂YVO₆ and Mg₂CeVO₆ as coarse-grained particle by solid-state reaction and as nanoparticles by combustion method is reported. Experimental X-ray diffraction, theoretical profile calculation and profile fitting establish the structures of these compounds. The compounds Mg₂NdVO₆, Mg₂PrVO₆ and Mg₂YVO₆ have a tetragonal zircon structure and Mg₂CeVO₆ have a cubic pyrochlore structure. The dielectric properties (dielectric constant, dielectric loss and conductivity) of the coarse grained powder based sintered pellets and the nanoparticle sintered pellets are compared.

**ULTRA LOW DENSITY SILICA AEROGELS FOR VARIOUS APPLICATIONS IN FUEL GAS STORAGE, NANO POROUS MICRO SPHERES AND AS ELECTRONIC SUBSTRATES**

S. Smitha, S. Abhijit, P.R. Aravind, P. Shajesh, P. Krishna Pillai, P. Mukundan and K.G.K.Warrier

Ceramic Technology Division, Regional Research Laboratory (CSIR), Trivandrum – 695 019

Email: warrierkgk@yahoo.com

Synthesis and properties of ultra low density mesoporous silica aerogels as candidates for various applications are reported. High surface area (750m²g⁻¹) silica-alumina mixed oxide aerogels have been synthesized from Tetraethoxysilane(TEOS) and boehmite for possible gas storage application. Silica microsphere was prepared from TEOS by emulsifying the sol with cationic surfactants. Surface modification with trimethylchlorosilane resulted in hydrophobic silica microsphere. Contact angle of microspheres was found to be 85° Organic-silica aerogel hybrid was prepared through sol-gel reaction between TEOS and 3-glycidoxypropyltrimethoxysilane (GPTS) which is proved to be a good network forming agent. The dielectric constant of the samples varied between 2.2 and 2.86 (at 13MHz).

**METALS AND ALLOYS FOR BIOMEDICAL IMPLANTS**

Swati Sinha and P.K. Shrivastava

Dept. of Metallurgical Engineering, Govt. Engineering college, Raipur (C.G)

Email: Shrivastavap54@rediffmail.com

Superior combination of biocompatibility, corrosion resistance and mechanical properties makes titanium and its alloys one of the best materials for biomedical applications. However, inadequate bonding between the implant surface and the surroundings bone structure, coupled with gross mismatch in mechanical properties between titanium and natural bone severely limits the long term performance of conventional titanium bone replacements. The use of different materials as biomedical implants not only requires a detailed knowledge of their individual behaviour in a biological environment, but also an understanding of the processes occurring in the contact regions between the selected material couples. In this paper problems such as contact and crevice corrosion are taken into consideration.
NEW RUTILE-SPINEL MIXTURE DIELECTRICS FOR MICROWAVE SUBSTRATE APPLICATIONS

K. P. Surendran and M. T. Sebastian
Ceramic Technology Division, Regional Research Laboratory, Trivandrum 695 019
Email : mailadils@yahoo.com

The dielectric loss phenomena of ZnAl₂O₄ spinels is explored in an effort to develop a suitable material for microwave substrate applications. The dielectric properties of this spinel was tailored by preparing mixtures with TiO₂ to tune their temperature coefficient of resonant frequency close to zero. It was found that a low dielectric constant material 0.83ZnAl₂O₄-0.17TiO₂ has excellent dielectric properties for possible applications in microelectronic packaging. The substrate characteristics of the new temperature stable low loss material 0.83ZnAl₂O₄-0.17TiO₂ which is even advantageous over alumina, have been investigated.

PROCESSES, PRODUCTS AND TECHNOLOGIES IN THE TITANIUM INDUSTRIAL SECTOR

K. Gopinathan Nair
Travancore Titanium Products Limited
Thiruvananthapuram 695 021
E-mail  : travancoretitanium@vsnl.com /
            tpmktng@sancharnet.in

In the ‘Gods own country’ – Kerala, the richest mineral resource is undoubtedly the black sand- Ilmenite. Titanium, its alloys and the versatile pigment TiO₂ form part of the value added materials from this rich mineral. This paper covers the development of compounds of titanium with special reference to titanium dioxide rutile grade in TTP. The emerging trends in synthesis and application of titanium compounds are also discussed.

INFLUENCE OF MILLING MEDIA ON KINETICS OF CuO/Cu₂O REDUCTION BY Al DURING HIGH-ENERGY BALL MILLING

T. Venugopal, K. Prasad Rao and B. S. Murty
Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras, Chennai 600 036

CuO/Cu₂O and Al have been reactively milled in a high-energy planetary ball mill to produce Cu-Al₂O₃ nanocomposites with the crystallite size of about 15 nm. The effect of milling media on reaction kinetics has been studied. The reaction kinetics have been correlated to the energy imparted during milling.

COMPOSITE

EROSION BEHAVIOUR OF CAST AND ROLLED ALUMINIUM BASED METAL MATRIX COMPOSITE

S. Chatterjee*, T. K. Pal*, R. M. Pillai** and B. C. Pai**
* Metallurgical Engineering Department, Jadavpur University, Kolkata – 700 032
** Regional Research Laboratory, Thiruvananthapuram – 695 019
Email : t_k_pal@yahoo.com

The purpose of this paper is to compare the erosion behaviour between cast and rolled AlMMCs reinforced with 15% silicon carbide particulates. Solid particle erosion tests of cast and rolled Aluminium Metal Matrix Composite (AlMMCs) with 15% Silicon Carbide particulate were carried out at different impingement angles e.g. 300, 600 and 900. The erosion tests were performed using 210-300 µm quartz sand particles with a particle feed rate of 5 g/min and particle velocity of 30 ms⁻¹. A stand-off distance of 10 mm was maintained for all the test. Eroded surfaces of rolled and cast AlMMCs samples were observed under SEM to study the micro-mechanisms of material removal.

EFFECT OF INTERFACE CHARACTERISTICS ON RESPONSE OF 2124 Al-SiC AND XD Al-TiC COMPOSITES TO HEAT TREATMENTS AND THERMAL CYCLING

Sharmilee Pal*, R. Maiti*, R. Mitra* and V.V. Bhanuprasad**
*Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Kharagpur – 721302,
West Bengal
**Ceramics and Composites Group, Defence Metallurgical Research Laboratory, P.O. Kanchanbagh, Hyderabad – 500 058, A.P.
Email: rahul@metal.iitkgp.ernet.in,
r Rahul_mitra2001@yahoo.com

The particle-matrix interfaces of a powder metallurgy (P/M) processed 2124 Al- 5, 15 or 25 vol.% SiC composites, as-extruded, solution treated or artificially aged conditions have been studied with emphasis on alloy segregation and its effect on aging kinetics. While interfaces in ex-situ 2124 Al-SiC composites show reduced microhardness due to cracking on repeated thermal cycles between 500°C and 0°C, those of in-situ pure Al-TiC composites show work hardening with increased density of dislocations. However, interfaces with brittle reaction products in heat-treated Al-TiC composites show decohesion.
DRY SLIDING WEAR BEHAVIOR OF THE Al2219/SiCp–GRAPHITE METAL MATRIX COMPOSITES

S. Basavarajappa and G. Chandramohan
Dept. of Mech. Engineering, PSG College of Technology, Coimbatore-641 004
Email: basavarajappas@yahoo.com

Al2219 alloy was used as a matrix material and SiCp, Graphite are used as reinforcement. The composite was fabricated using gravity casting technique. Results reveal that the wear rates of the composites were lower than that of the matrix alloy and further decreased with the increase in the reinforcement content. Increase in the applied load increased the wear severity by changing the wear mechanism from abrasion to particle cracking induced delamination wear.

HIGH TEMPERATURE OXIDATION BEHAVIOR OF STAINLESS STEEL COMPOSITES

S.S. Panda, S.C. Soni and A. Upadhyaya
Department of Materials and Metallurgical Engineering, Indian Institute of Technology, Kanpur 208016
Email: anishu@iitk.ac.in

This work investigates the oxidation behavior of stainless steel-YAG composites. Oxidation studies of these steel composites were conducted between 700 to 1100°C for varying time (1-10 hrs) under a controlled dry air. The high-temperature oxidation behavior of P/M stainless steel reveals remarkable difference from their wrought counterparts. Varying amounts of YAG (up to 10 wt.%) were added to both ferritic and austenitic stainless steel and the compact was solid-state sintered at 1200°C for 1h. Addition of YAG led to significant enhancement in oxidation resistance. The oxidation mechanisms in these stainless steels have been correlated to the microstructure.

INTERMETALLIC BONDED TUNGSTEN COMPOSITES FOR ORDNANCE APPLICATIONS

Mayadhar Debata and Anish Upadhyay
Department of Materials & Metallurgical Engineering, Indian Institute of Technology, Kanpur
Email: anishu@iitk.ac.in

This study investigates the sintering behaviour of Ni3Al and Fe3Al intermetallic bonded tungsten composites (IWC). The prime goals of this study are to understand the densification and microstructural characterization. Sintering of the IWCs was carried at 1500°C. Microstructures of the sintered alloys were characterized by optical and scanning electron microscopy. Both Vickers bulk and microhardness of IWCs were measured. Compared to conventional W-Ni-Fe alloys, IWCs exhibit refined microstructure and enhanced mechanical properties in both static as well as dynamic conditions.

SYNTHESIS AND CHARACTERISATION OF (Ti,V)C/ (Ti,W)C– REINFORCED IRON MATRIX COMPOSITES PRODUCED BY COMBUSTION (SHS) PROCESS

O.P. Modi and A. Chrysanthou*
Regional Research Laboratory (CSIR), Bhopal – 462 026
* Dept. of Aerospace, Automotive and Design Engineering, University of Hertfordshire, Hatfield, Herts AL 10 9 AB, UK
Email : om_prakashmodi@hotmail.com

This investigation reports on the combustion synthesis of in-situ iron matrix composites containing solid solution mono carbides of (Ti,V)C and (Ti,W)C.

FABRICATION AND CHARACTERIZATION OF Zr BASED BULK METALLIC GLASS/ W FIBRE COMPOSITE

Bhabha Atomic Research Centre, Mumbai 400 085
**Defence Metallurgical Research Laboratory, Kanchanbagh, Hyderabad 500 058, India
Email: pkde@apsara.barc.ernet.in

The present work describes the fabrication and characterization of bulk metallic glass composite reinforced with W fibres. Zr52Ti4Al6Cu19Ni14 (at%) alloy was used to make the bulk metallic glass matrix. Various combinations were used to create composites. These composites were characterized by different microscopy techniques and their mechanical properties were estimated.
EFFECT OF GRAPHITE ADDITION TO AN OIL LUBRICANT ON THE WEAR RESPONSE OF A ZINC-BASED ALLOY AND ITS COMPOSITE

B.K. Prasad and O.P. Modi
Regional Research Laboratory (CSIR), Bhopal-462026
Email: om_prakashmodi@hotmail.com

In this investigation, the role played by graphite particles, when suspended in an oil lubricant, towards controlling the sliding wear response of a zinc-based alloy has been examined. The influence of reinforcing silicon carbide particles in the alloy matrix was also studied on similar lines. The study shows that mere presence of a solid lubricant like graphite in oil may not be beneficial always and that maximum benefit in terms of better wear performance could be realized only through a critical quantity of the solid lubricant. Also, factors like the formation, stability and rupture of the lubricating film/layer play a dominant role in governing the overall wear behaviour of the samples.

RANDOMISATION OF TEXTURE DURING HOT WORKING OF Al-SiC COMPOSITES

Sandip Ghosh Chowdhury, P.K.De, B.Ravikumar, Swapan K.Das and B.Munda
Materials Science & Technology Division, National Metallurgical Laboratory, Jamshedpur, 831007
E-mail: sgc@nmlindia.org

In the present paper, the evolution of texture during cold rolling of Al-based metal matrix composites has been investigated. The matrix is 2124 Al-alloy with a substantial amount of intermetallic precipitates of size 5-10mm. The material has 10% by weight SiC particulate; the size of the particulates is ~10mm. The composite was cast into 38mm thick slab by adopting vortex method and then solution-treated at 550°C by giving T6 treatment. The slab was deformed upto ~50% by hot forging; finally the slab was hot rolled at 450°C to unidirectionally from a plate thickness of 20mm to 6mm, resulting in total ~85% deformation. It has been observed that the changes in bulk texture on rolling were found to be insignificant, although there is minute change in the textural components after large deformation.

EFFECT OF PARTICULATE TYPE (Al2O3 AND ZrSiO4) ON MICROSTRUCTURE AND AGING BEHAVIOUR OF Al-4.5Cu MATRIX COMPOSITE SYNTHESIZED BY STIR CASTING ROUTE

Sanjeev Das, Karabi Das and Siddhartha Das
Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Kharagpur – 721302
Email: karabi@metal.iitkgp.ernet.in

Microstructure and ageing behaviour of Al2O3/ZrSiO4 particulate reinforced Al-4.5wt%Cu matrix composite, produced by stir casting route, was studied in the present investigation. It was found that both the composites showed acceleration in aging compared to the monolithic alloy. However, the Al2O3 reinforced composite showed more acceleration compared to the ZrSiO4 reinforced composite.

EFFECT OF BERYLLIUM ADDITION IN Al-7Si-0.3Mg / SiCp COMPOSITES

K.R.Ravi, V.M.Sreekumar, R.M.Pillai and B.C.Pai
Metal Processing Division, Regional Research laboratory, Thiruvananthapuram - 695 019.
Email: rmpillai@rediffmail.com

The present work investigates the effect of beryllium addition on the microstructural characteristics of Al-7Si-0.3Mg / 15 % SiCp composites. Varying amounts of beryllium (0.005, 0.05, 0.1 and 0.2 wt%) were added using Al-5%Be master alloy. Microstructures have been characterized using optical metallurgy, image analysis and SEM/EDS.

EFFECT OF HEAT TREATMENT ON EXPLOSIVELY CONSOLIDATED 2124 Al-20 Vol.% SiCp COMPOSITES

K. Siva Kumar, V. Balasubrahmanyam and T. Balakrishna Bhat
Defence Metallurgical Research Laboratory, Hyderabad-500 058
Email: kumarsiva9@rediffmail.com

2124 Al alloy reinforced with 20 vol.% silicon carbide particulate has been consolidated using explosive compaction technique. The composites have been fabricated by using explosive pad thickness of 8, 14 and 20 mm. The effect of processing conditions on density, hardness and microstructure of the composites has been studied. After explosive compaction the composites have been solutionized at 495°C for 75 minutes followed by water quenching. The solutionized compacts have been aged at 180°C for 6 hours. The resulting microstructure and hardness have been compared with those of compacts in as-compacted condition.
PRODUCTION OF FUNCTIONALLY GRADED MATERIALS BY CENTRIFUGAL CASTING TECHNIQUE

Metals Processing Division, Regional Research Laboratory, CSIR Trivandrum – 695019
Email: rmpillai@rediffmail.com

Functionally graded materials exhibit gradual transitions in the microstructure and/or the composition in a specific direction, the presence of which leads to variation in the functional performance within a part. The present study describes the production and characterisation of functionally graded aluminium matrix composites of aluminium-silicon alloys (LM25 and LM13) reinforced with SiC and graphite particles and hyper eutectic aluminium-silicon alloys using both horizontal and vertical centrifugal casting method.

FINE GRAINED ALUMINUM TITANATE AND ALUMINA MATRIX COMPOSITE FOR LOW THERMAL EXPANSION AND THERMAL SHOCK APPLICATIONS

M. Jayashankar, S. Ananthakumar, P. Mukundan and K.G.K. Warrier
Ceramic Technology Division, Regional Research Laboratory (CSIR), Trivandrum-695 019
Email: warrierkgk@yahoo.com

We have synthesised fine grained Aluminium Titanate (AT) and AT-Al2O3 composite by colloidal method from AlOOH and TiCl4. AT phase was formed at 1379°C. 98% density was obtained on sintering at 1550 °C. The average grain size of aluminium titanate was 1-2 mm. Composites had low thermal expansion, and excellent thermal shock properties. The mechanical strength of composite containing 5wt% aluminium titanate is ~135 N/m² and that of pure alumina is ~76.92 N/m² at 600 °C.

DYE INTERCALATED NATURAL LAYERED ALUMINO SILICATES- EMERGING ECOFRIENDLY COMPOSITE NANO PIGMENTS

A. Asif, P. Krishna Pillai, P.Perumal and K.G.K. Warrier*
Ceramic Technology Division, Regional research laboratory (CSIR), Industrial Estate, Trivandrum-695019
Email:warrierkgk@yahoo.com

We report here the synthesis and UV stability of methylene blue intercalated montmorillonite clays (2:1). Effects of mono ion exchange, substitution under stirring, ultrasonication, refluxing and aging at different temperatures on the extent of intercalation were studied. A range of colours have been prepared and their stability towards UV light as against pure dye has been compared. Extent of intercalation was found to be influenced by time for mechanical methods. Intermediate exchange did influence the intercalation of methylene blue positively.

CORROSION & SURFACE ENGINEERING

ELECTROCHEMICAL STUDIES ON P/M AUSTENITIC STAINLESS STEEL DISPERSION STRENGTHENED WITH GARNETS

Shashank M Tiwari and Anish Upadhyaya
Department of Materials and Metallurgical Engineering
Indian Institute of Technology, Kanpur 208016
E-Mail: anishu@iitk.ac.in

This study correlates the electrochemical response of sintered stainless steel (SS) and SS-garnet (YAG) composites with porosity, microstructure and interfacial chemistry chemistry. The corrosion rate was measured in a 0.1N H2SO4, and 0.1N HCl solution using DC potentiodynamic polarization tests. The effect of sintering temperature (solid-state and supersolidus) and YAG addition on the corrosion rate, passivation and pitting behavior is critically examined.

THE INFLUENCE OF REPAIR WELDING ON THE STRESS CORROSION CRACKING (SCC) BEHAVIOR OF AA2219 ALUMINUM ALLOY WELDMENTS IN 3.5% NaCl SOLUTION

A. Venugopal, V. Diwakar and K. Sreekumar
Material Characterisation division, Materials and Metallurgy Group,
Vikram Sarabhai Space Centre, Indian Space Research Organisation (ISRO), Trivandrum 695 022
Email:k_sreekumar@vssc.org

Comparison of the SCC resistance of repair welded Aluminium alloy AA2219 with that of virgin weld made of auto AC-TIG welding process is made. Pitting susceptibility using 3.5%NaCl solution was examined on various sections of the weldment such as weld nugget, weld + fusion zone and HAZ to identify the weakest zone of the weldment. SSRT at a strain rate of 5 x 10^-7s-1 to evaluate UTS, YS, %E and time to failure were obtained on base metal and repair welded samples both in air and 3.5% NaCl. Fracture morphology of the failed samples was examined in SEM for all the samples.
CORROSION AND WEAR BEHAVIOUR OF AN UNMODIFIED AND MODIFIED Al-Ni EUTECTIC ALLOY

Department of Metallurgical and Materials Engineering
IIT Kharagpur 721302
Email: uk@metal.iitkgp.ernet.in, uday_chatterjee@yahoo.com

Magnesium modified Al-6%Ni eutectic alloy has shown a higher resistance to general corrosion in NaCl, H2SO4 and NaOH solutions and also a higher resistance to stress corrosion cracking in NaCl+ LiCl+ H2O2 solution than the unmodified alloy. The modified alloy has also shown a higher wear resistance. A structural correlation has been presented.

AQUEOUS CORROSION BEHAVIOUR OF DUCTILE IRON AND DUCTILE IRON CONTAINING COPPER

A.O.Surendranathan, K.R.Hebbar and H.V.Sudhaker Nayak
Metallurgical and Materials Engineering Dept.,
NITK, Surathkal
Srinivasnagar (D.K.) – 575 025
Email: nathan@nitk.ac.in

This paper describes the corrosion behaviour of alloyed spheroidal graphite irons containing 0.5% and 1.0% copper in natural sea water, dilute sulphuric acid and dilute sodium hydroxide solutions and compares it with that of unalloyed ductile iron. The study has been made in the ascast, annealed and cold worked (upto 28% reduction in thickness) conditions at three different temperatures. Since the alloying addition brings changes in the proportion of phases, in spite of alloying addition being small, the corrosion behaviour of the material in the three conditions was different, indicating corrosion behaviour to be structure sensitive.

CORROSION BEHAVIOUR OF A HEAT TREATED 6Mn-5Cr-2Ni-1.5Cu WHITE CAST IRON

C.P. Sharma
Department of Metallurgical Engineering, Malaviya
National Institute of Technology, Jaipur –302017
Email:cpus@rediffmail.com

Fe- 6 Mn- 5 Cr- 2 Ni- 1.5 Cu white cast iron was studied to investigate the effect of microstructure on the corrosion behaviour in a 5% NaCl solution. Microstructures comprised of mostly austenite were found to be better than those comprised of martensite from the point of view of corrosion resistance.

LOCALIZED CORROSION OF A MAGNESIUM ALLOY, AZ91

R.K. Singh Raman
School of Physics and Materials Engineering
Bldg 69, Monash University (Melbourne), Victoria, 3800, Australia
Email: Raman.Singh@spme.monash.edu.au

Micro-galvanic corrosion of magnesium alloys due to formation of cathodic intermetallic phases is reported in the case of one of the most common Mg-alloys, AZ91. Ageing produces secondary β-phase (Mg17Al12) in addition to the primary microstructure, Mg-Al-Zn solid solution (α phase). The β-phase, which shows considerably more corrosion resistance is cathodic to the α phase, and hence the two phases in contact cause galvanic corrosion. The β phase is some 300 mV positive to the α phase. However, contrary to the common view on the role of β-phase in facilitating galvanic corrosion, there are also reports suggesting improved corrosion resistance due development of a passive layer over the β-phase. This paper presents examination of localized corrosion in the region of β phase and surrounding eutectic α in a magnesium alloy AZ91, and the possibility of improving corrosion resistance by surface modification.

EFFECT OF HYDROGEN ON CORROSION BEHAVIOR OF PIPELINE STEEL IN CO2/H2S ENVIRONMENT

G. S. Das and A. S. Khanna
Corrosion Science & Engineering
Indian Institute of Technology Bombay
Powai, Mumbai-400076
Email:gsdas@met.iitb.ac.in

gsdniff@yahoo.com

Few experiments have been carried out in high temperature and high pressure in a closed autoclave system. The temperatures and partial pressure of CO2 were varied from 30-120°C and 50-300 psi respectively. The corrosion rates of steel increases up to 90°C due to formation of porous iron carbonate film on the metal surface. The small addition of H2S (0.4 ppm) severely increases the corrosion rate because it poisons the recombination reaction of hydrogen evolution, resulting in atomic hydrogen entering the metal surface and developing pressure. This results in initiation and formation of cracks. The corrosion products formed on the metal surface were observed by using scanning electron microscope and X-ray diffraction technique.
OPTIMIZATION OF PROCESSING ROUTE FOR IMPROVED CORROSION RESISTANCE IN Ti-5%Ta-1.8%Nb ALLOY

R. Mythili, S.Saroja*, M.Vijayalakshmi and V.S.Raghunathan
Materials Characterization Group, IGCAR, Kalpakkam 603 102
Email: saroja@igcar.ernet.in ; msai@vsnl.com

A series of Thermo Mechanical Processing stages produced an equiaxed microstructure with inter and intra-granular nodular b, essential for possessing good corrosion resistance in a Ti-5%Ta-1.8%Nb alloy. This paper discusses the mechanism of formation of such a microstructure based on which, the processing route for this alloy has been finalized.

CORROSION BEHAVIOR OF THERMOMECHANICAL TREATED AND CORROSION RESISTANT STEELS

S.R.Raval and K.B.Pai
Faculty of Technology and Engineering
M.S.University of Baroda
Vadodara – 390001
Email: trpprof-trp@msubaroda.ac.in

In the present work an attempt has been made to study the corrosion behavior of a thermo-mechanically treated steel and thermo-mechanically treated corrosion resistant steel, by carrying out electrochemical studies. These studies throw light on both, the corrosion behavior of the steels as well as the characteristics of passive films formed on the surfaces of steel. It has been found out that in case of thermo-mechanically treated corrosion resistant steel the corrosion resistance is more than two and a half times in comparison to thermo-mechanically treated steel. Likewise the electrochemical impedance values of thermo-mechanically treated steel is three to twenty two times less than that of thermo-mechanically treated corrosion resistant steel. Thus, much superior type of film is generated on the thermo-mechanically treated corrosion resistant steel, which imparts high corrosion resistance to this type of steel.

STUDIES ON EFFECT OF Al AND Pb ADDITIONS IN GALVANIZING BATH OF SHEET STEEL

U. V. Vala*, R. K. Singh**and K. B. Pai
Metallurgical Engg., Deptt., M. S. University of Baroda
*Mechanical Engg., Deptt., SVIT, Vasad
** Steelco Gujarat Ltd., Palej
Email:trpprof-trp@msubaroda.ac.in

The applications of Al – Zn coatings on steel has grown substantially in recent times on account of its apparent advantages over galvanized sheets. The alloy coatings are obtained by a continuous process of immersion of the steel sheet in a bath containing the molten coating. This paper presents the result of a study aimed at understanding the corrosion mechanism of Al – Zn coating on steel and a comparison with the behaviour of galvanized sheets. Research has been carried out in different types of Industrial environments. Unlike the Galvanized coating, which suffers a generalized attack of its surface. The Al – Zn coating undergoes a localized type of attack, which commences in the inter-dendrite regions of the material. Analysis performed by SEM on samples in the different industrial environment, makes it possible to propose a mechanism to explain the successive stages in the corrosion process of Al – Zn coating up to attack of the base steel.

INFLUENCE OF RAPID SOLIDIFICATION ON CORROSION BEHAVIOUR OF Li CONTAINING Al-Zn-Mg ALLOYS

A.K.Bhattamishra
National Metallurgical Laboratory, Jamshedpur-831007
Email: vrao@nmlindia.org
akbm@nmlindia.org

Literature on corrosion behaviour of ribbons of lithium containing Al-Zn-Mg alloys in aggressive chloride media is scanty. The objective of the present paper is to study on the corrosion behaviour of lithium containing Al-Zn-Mg , Al-Zn-Mg-Mn alloys and Al-Zn-Mg-Cu and Al-Zn-Mg-Cu-Cr alloys in 3.5% NaCl solution and natural sea water collected from bay of Bengal. The aluminium alloys were produced in the form of thin ribbon in a rapid solidification unit Model 2M of Marko Materials (USA). It is found that corrosion rate of the alloys increases as concentration of NaCl increases and lithium addition improves corrosion resistance of Al-4.2Zn-1.8Mg-0.28Mn (T6) alloy ribbons. Further, corrosion resistance of Al-5.6Zn-2.5Mg-1.3Cu-0.4Li (T6) alloy ribbons is superior to Al-5.6Zn-2.5Mg-1.3Cu-0.2Cr-0.4Li (T6) alloy ribbons in otherwise identical conditions of experimentation.

INFLUENCE OF Mo ALLOYING ON THE CREVICE CORROSION BEHAVIOUR OF TITANIUM

Kulandaivelu Ravichandran and Toshiyasu Nishimura
Corrosion Resistant Design Group, Steel Research center,
National Institute for Materials Science (NIMS),1-2-1, Sengen, Tsukuba, baraki, 305-0047, Japan
Email: Kulandaivel.ravichandran@nims.go.jp

Crevice corrosion of titanium in different concentrations of NaCl were investigated at 100 °C with the aid of microelectrodes. Based on the crevice corrosion data a model crevice environment was simulated. The influence of Mo alloying over Ti and molybdate addition in the simulated crevice environment on pure titanium, towards crevice corrosion were studied with help of electrochemical studies.
WEAR BEHAVIOR OF PLASMA NITRIDED H11 TOOL STEEL

Ms.Y.N.Pawar* and P.R.Abhyankar*
*Department of Metallurgical Engineering, Pune Institute of Engineering & Technology, Pune 411005.
E-mail: ynp@meta.coep.org.in
pra@meta.coep.org.in

A comparative study of microstructural, mechanical & tribological properties of hardened, gas & plasma nitrided Tool Steel H11 is presented here. Specimens were characterized by SEM to understand wear mechanism. Adhesion in hardened while delamination in nitrided specimen was the modes of wear. Plasma nitriding decreased the adhesive wear substantially.

LASER SURFACE MODIFICATION OF MARTENSITIC STAINLESS STEEL

Vamsi Chaitanya Bommi* M. Krishna Mohan**
**Dept. of Metallurgical Engineering, NIT–Warangal-506004. Email:mkmohan@nitw.ernet.in vamsidmt@yahoo.com

Surface modification using laser beam is a prominent process to improve hardness characteristics at specific locations to make the component functionally more efficient. In the present work, surface treatment of a Martensitic stainless steel using a CW CO₂ laser has been carried out to study the effect of process variables on hardening characteristics.

PROPERTIES OF ALUMINA FILMS DEPOSITED BY FLAME PYROLYSIS

R. Kavitha and V. Jayaram
Department of Metallurgy, Indian Institute of Science, Bangalore
Email:kavi@met.iisc.ernet.in

Alumina films have been successfully deposited on amorphous silica and stainless steel substrates by flame pyrolysis. The film properties, including roughness, hardness and the microstructure, were investigated. The as-deposited films are amorphous and post-deposition annealing converts them to alpha alumina. A comparison of the hardness values shows that alpha alumina is twice as hard as the amorphous alumina film.

CATHODIC CALCIUM PHOSPHATE COATING ON Ti-6Al-4V

R.Narayanan and S.K.Seshadri*
*Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras
Chennai – 600 036
Email: sk_seshadri@yahoo.com

Natural bone contains calcium phosphate mineral called hydroxyapatite. Titanium surface containing hydroxyapatite coatings have good adhesion with natural bone. In this study, hydroxyapatite was cathodically deposited on Ti-6Al-4V surface. The coatings were analyzed for corrosion in physiological solution by immersion and electrochemical polarization.

STUDIES ON WEAR AND EROSION PROPERTIES IN LASER COMPOSITE SURFACED ALUMINIUM WITH SILICON CARBIDE AND ALUMINA

J. Dutta Majumdar*, B. Ramesh Chandra*, A. K. Nath**, R. Kaul” and I. Manna*
*Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Kharagpur, WB-721302
**Laser R &D-Block B, Centre for Advanced Technology, Indore – 452 013
Email:jyotsna@metal.iitkgp.ernet.in

In the present study, laser composite surfacing of commercial Al with SiC and TiB₂ has been carried out by pre-placing the said powders and subsequently, melting it using a 2 kW continuous wave CO₂ laser. The effect of process parameters on the microstructure and microhardness was studied in detail. Finally, the kinetics and mechanism of wear were investigated.

ANODIC OXIDE COATING ON Ti-6Al-4V IN PHYSIOLOGICAL SOLUTION

Sraboni Datta, R.Narayanan and S.K.Seshadri*
*Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras
Chennai – 600 036
Email: sk_seshadri@yahoo.com

Anodic oxidation of Ti-6Al-4V was carried out in 1N H₃PO₄ for different current densities and times. Porosity of the coatings was studied in great detail. Corrosion of the coatings was studied in physiological solution simulating body condition by immersion and by electrochemical polarization. The results are correlated with porosity levels.
STUDIES ON LASER MODIFIED SURFACE OF ELECTROLESS Ni-W-P ALLOY DEPOSITS

*Department of Metallurgical and Materials Engineering
Indian Institute of Technology Madras
Chennai – 600036, Tamilnadu
**Materials Characterisation Group
Indira Gandhi Center for Atomic Research
Kalpakkam – 603102, Tamilnadu
Email: sk_seshadri@yahoo.com

This paper discusses the effect of laser surface modification on electroless Ni-W-P deposit. Mild steel coupons were used as substrate for deposition. Parameters like power density and dwell time were varied. It was noted that increased laser power density or preheating time led to surface melting. Optical and electron microscopic observations were used to interpret the changes in structural properties of the modified surface layers.

MICROSTRUCTURAL CHARACTERIZATION OF THIN FILMS OF DOPED CERIUM OXIDE GROWN BY PULSED LASER ABLATION

P. Kuppusami, K. Muthukumaran*, R. Divakar, E. Mohandas and V. S. Raghunathan
Physical Metallurgy Section, Indira Gandhi Centre for Atomic Research,
Kalpakkam-603 102,Tamilnadu.
*Department of Physics, Anna University, Chennai-600 025
Email: mvl@igcar.ernet.in

In this paper, we report the formation of 5 mol% Gd$_2$O$_3$ doped cerium oxide (GDC) films deposited by pulsed laser ablation on oriented silicon (Si) and sodium chloride substrates over a broad range of temperature, pressure and energy. We have investigated these films because of their application in solid oxide fuel cells and in gas sensors. This material is an oxygen ion conductor with oxygen deficient fluorite structure and has a higher oxygen ion conductivity than the conventional zirconia based electrolytes. High thermal shock resistance, chemical resistance to reactants and reasonable phase stability are other key properties of this material.

ENVIRONMENT AND RECYCLING

REMOVAL OF HEAVY METAL IONS FROM CONTAMINATED WATER BY MANGANESE NODULES LEACHED RESIDUE

N. N. Das and R. K. Jana
National Metallurgical Laboratory, Jamshedpur – 831 007
Email: dasnn@nmlindia.org

The potential of manganese nodule leached residue as adsorbent for removal of heavy metals from contaminated water bodies has been examined. Leached residues, collected from the sea nodules Pilot plant operated at Hindustan Zinc Limited, is mostly amorphous and contains fine particles (d$_{50}$=18.5µm) of oxide/oxyhydroxides of Mn, Fe, Si and Al along with other minor metal constituents. Adsorption of different heavy metal ions (Pb$^{2+}$, Cu$^{2+}$ and Cd$^{2+}$) from their aqueous solution and simulated water matrix with varying experimental parameters by batch adsorption method revealed the adsorption is fairly rapid and more than 80 % adsorbed in first 15 minutes.

CEMENTATION OF SILVER FROM WASTE DOMESTIC BUTTON CELLS

N.Sathaiyan
Central Electrochemical Research Institute, Karaikudi-630 006

Waste domestic silver oxide button cells used in watches were processed to recover around 95% of silver. These button cells were cut open to liberate the active materials having mainly silver and zinc. This active material was leached with nitric acid and zinc powder was employed to cement out silver in the leach solution and the purity level of silver was 96.2%. The effect of silver ion concentration, pH, agitation and temperature were investigated on cementation and discussed.

VALUE ADDED OXIDES FROM METALLURGICAL WASTES

R.John Felix Kumar, S.Raman Shankara Narayanan
Department of Metallurgical Engineering
National Institute of Technology
Thiruchirappalli-620 015
Email: raman@nitt.edu, ramntech1981985@yahoo.com

Value added products such as pure oxides could be produced from the large quantities of metallurgical wastes generated during smelting/ refining. The effort made towards the separation of iron oxide and silica is briefly described in this paper. The relative yields and purity of products are also discussed.
CURRENT TRENDS IN THE ENGINEERING AND MANAGEMENT INTERVENTIONS TO COMBAT ENVIRONMENTAL STRESSES IN ALLOY & SPECIAL STEEL ROLLING MILLS

S Ramachandran* and R Baskar
*Dept. of Chemical Engineering, Kongu Engineering College, Erode, Tamil Nadu
Email:jeyramrad@yahoo.com

Modern rolling mills complexes pose a radical challenge to the environmental engineer due to the diverse nature of the pollutants emitted by them. An integrated approach to overcome these environmental stresses is necessary to make them environmentally sustainable. This paper critically reviews the different methods and techniques available to the environmental engineer for successful abatement of environmental problems associated with a rolling mill complex.

RESPONSE OF Fe-TiC AND COBALT-BASED HARDFACED MATERIALS IN EROSIVE-CORROSIVE ENVIRONMENT

O.P. Modi, B.K. Prasad, A. K. Jha, V.P. Deshmukh* and A.K. Shah*
Regional Research Laboratory (CSIR), Bhopal – 462 026
* Naval Materials Research Laboratory, Amburnath, Shil-Badlapur Road, Addl. Amburnath, Distt. Thane – 421 506
Email : om_prakashmodi@hotmail.com

The present investigation reports the observations relating to the erosion-corrosion behaviour of the Fe-TiC and cobalt-based hardfaced layers separately deposited on an En 31 steel in 3.5% NaCl aq. environment. Sample rotation method was adopted for conducting the erosive-corrosive tests at a linear traversal speed of 4.47 m/s over varying test durations of 8-32 hrs. The study shows that the wear loss was strongly dependent on test duration and the nature of the test samples. The hardfaced layers exhibited substantially reduced wear rate as compared to that of the substrate. Further, the cobalt based material performed the best.

A NOVEL METHOD FOR DISPOSAL OF TAR DECANTER SLUDGE

RDCIS, SAIL, Ranchi-834002
E-mail: bko_rdcishsl@sancharnet.in

At Bokaro Steel Limited, about 10 t / day tar decanter sludge (TDS) is generated during settling of coal tar in the decanters. This material is considered as a toxic and hazardous waste product, creating problem for its disposal. RDCIS, SAIL has developed a novel system for effective disposal of TDS by mixing it with coal blend prior to carbonization in the coke oven batteries. Addition of TDS in coal blend has proved to be an effective waste disposal measure, when equivalent quantity of coal is saved, resulting in financial benefit of Rs. 1.50 Crore per annum.

SOLID WASTE MANAGEMENT IN METALLURGICAL INDUSTRY

B.G. Reddy
(Dy. Chief Manager Systems)
Visakhapatnam Steel Plant, Visakhapatnam
Email: bollareddy99@rediffmail.com

A Metallurgical industry generates a number of solid wastes and many of them contaminate environment. A case study has
been made in Visakhapatnam Steel Plant on Management of solid by-products. Of the solid wastes generated, more than 35% are re-used reducing the input cost. They are also sold which earn good revenue or stacked in addition to re-cycling. A number of initiatives are taken for design modification. Ways for further improvement are suggested.

**DEINKING OF INDIAN NEWS PAPER BY AGGLOMERATE FLOTATION**

D.K. Sengupta and R. Bhima Rao  
Regional Research Laboratory, Bhubaneswar 751 013  
E-mail: bhimarao@rrlbhu.res.in

In this study, the newspapers are pulped prior to flotation and further processing is generally done by (a) heating at a temperature between 45 °C and 65 °C, (b) adjustment of pulp density to 5% (c) addition of sodium silicate of 2-3%, sodium hydroxide of 1%, hydrogen peroxide of 0.7-1.0% and surfactant of 0.4-3%. Calcium ion is also used as activator for adsorption of anionic collectors such as oleic acid (Hornfeck, 1987). The chemicals used for deinking pose a number of problems in both deinking plant as well as in subsequent operations due to foam formation. While calcium chloride is added as an activator, calcium may deposit as carbonate whereas chloride ion may lead to corrosion problems.

**UTILISATION OF STEEL PLANT SOLID WASTE IN SINTRING**

B.N. Roy*, S.N. Sinha** and U. S. Yadav***  
*Department of Metallurgical Engineering, B.I.T. Sindri, Dhanbad  
**Department of Met. Engg. & Material science, N.I.T. Jamshedpur  
***Research and Development Division, Tata steel.  
Email: mkagrawal_nit@yahoo.co.in

All integrated steel plants generate large amount of waste materials in the iron making and steelmaking processes. These wastes materials are basically different type of ferroginous oxides and fluxes. Most of these materials contain high iron, carbon, calcium and magnesium values and can, therefore, be recycled.

**LIFE PREDICTION OF PIPELINE STEEL IN CO2/H2S ENVIRONMENT**

G.S. Das and A.S. Khanna  
Corrosion Science & Engineering  
Indian Institute of Technology Bombay  
Powai, Mumbai- 400076  
Email: gsdas@met.iitb.ac.in ; gsdnifft@yahoo.com

API grade low carbon steels are generally used in the petroleum industries for the transportation of crude oil and gas. These steel suffers from the corrosion in carbon dioxide and hydrogen sulphide medium. The service life of these steels can be predicted by determined corrosion rate in these corrosive medium. Four types of steels API X-52, API X-56, API X-60 and L-80 were used for the corrosion studies in 3.5 % NaCl. The severity of their corrosion rates were measured in the laboratory scale by with simulating actual field conditions in a closed autoclave loop system with liquid flow rate of 2.5 m/s. It has been observed that as temperature and partial pressure of CO2 increases the corrosion rate increases. The performance of API X-60 grade steel shows better corrosion resistance when compared to all the steels used. The corrosion products formed on the metal surface were analyzed by SEM and XRD techniques.

**PHASE-PURE ANATASE TiO2 NANOCRYSTALS FROM MULTI-METAL WASTE CHLORIDE LIQUORS BY SOLVENT EXTRACTION COMBINED WITH HYDROTHERMAL SYNTHESIS**

Jesty Thomas, M.L.P Reddy and G.D Surender  
Process Science & Engineering Division, Regional Research Laboratory, CSIR Thiruvananthapuram - 695 019, India.  
Email: mlpreddy@yahoo.co.uk

A novel process for the synthesis of phase-pure anatase TiO2 nanocrystals from multivalent metal chloride solutions has been proposed by solvent extraction combined with low temperature hydrothermal synthesis. The process comprises the steps of i) Selective extraction of TiCl4 from multivalent metal chloride solutions by solvent extraction using tributylphosphate as an extractant; ii) Precipitation of amorphous titania from the loaded solvent; iii) Separation of amorphous titania, dispersion in deionized water and adjustment of the pH; iv) Hydrothermal synthesis by using the above precursor; v) Separation of the synthesized products by filtration, drying and characterization. The results demonstrate that phase-pure anatase nanocrystallites (5-20 nm) possessing photocatalytic activity can be synthesized hydrothermally at relatively low temperatures and reaction times.

**4-ACYLBIS(1-PHENYL-3-METHYL-5-PYRAZOLONES) AS HIGHLY SELECTIVE EXTRACTANTS FOR VANADIUM(V) FROM TITANIA WASTE CHLORIDE LIQUORS**

P.N. Remya, Rani Pavithran and M.L.P. Reddy  
Ion-specific Separation Science & Technology Group  
Regional Research Laboratory, CSIR Thiruvananthapuram-695 019  
Email: mplreddy@yahoo.co.uk

The more our economy recovers and recycles useful metals from its wastes, the less mining will be needed and less
environmental damage will result from waste disposal. Hence, in the present study efforts have been made for the recovery of vanadium from waste chloride liquors of titania industry by employing 4-acylbis(1-phenyl-3-methyl-5-pyrazolones) as extractants. The extraction behavior of Mg(II), Al(III), Ti(IV), V(V), Cr(III), Mn(II), Fe(II) and Fe(III) has been studied using various 4-acylbis(1-phenyl-3-methyl-5-pyrazolones) from hydrochloric acid solutions. The results demonstrate that V(V) is selectively extracted into the organic phase leaving behind all the other associated metal ions in the raffinate. It can be concluded from these investigations that 4-acylbispyrazolones can be used as selective solvent extraction reagents for the separation and recovery of vanadium from the waste chloride liquors of titanium minerals processing industry.

IMPROVEMENTS IN PREBAKED ANODES AND CO₂ EMISSIONS IN ALUMINIUM ELECTROLYSIS CELL

R.N. Jena, M.K.B. Nair and Binuta Patra
Smelter Plant, National Aluminium Co.Ltd, Angul (Orissa)

Prebaked anodes emit green house gases while they are consumed in the Aluminium electrolysis process. These gases are being considered harmful for global environment. To minimize the CO₂ emissions, carbon consumption in pots is to be reduced by improving anode quality. This paper relates the carbon anode quality and emission of CO₂ gas.

THIN LAYER CHROMATOGRAPHIC SEPERATION AND QUANTITATIVE DETERMINATION OF COEXISTING Al, Fe AND Ti IN BAXITE AND RED MUD

P.A. Mohamed Najar, J.U. Jeurkar and K.V. Ramana Rao
Jawaharlal Nehru Aluminum Research Development and Design Centre Amaravati Road, Nagpur-440 023

Thin layer chromatographic (TLC) separation of the three major metallic constituents viz. Al, Fe, Ti and silicon in bauxite and red mud were presented in an attempt to develop rapid analytical procedures for bauxite and red mud. Quantitative determinations of these separated species were carried out by coupling chromatography using appropriate analytical techniques such as spectrophotometry and titrimetry.

RECYCLING OF METALLURGICAL WASTES AT ROURKELA STEEL PLANT

A.L. Kundu and B. Rai
R&C Lab, SAIL, RSP, Rourkela-769011

Rorkela steel plant consumes large quantities of raw materials and generates substantial quantities of solid and other waste materials during iron and steel making. Presently, RSP is very keen to improve solid waste management as business opportunity and all round efforts have been made to reuse and recycle them gainfully. The paper deals with how RSP has been able to use LD slag (fine & lump), Nut coke, BF flue dust, Mill scale and BOF sedge for various metallurgical applications inside the plant.