ABSTRACT

In the recent past, considerable concern is shown towards manufacturing titanium parts by cold extrusion techniques highlighting the aspects of conservation of these expensive material. Cold forging of titanium and its alloys generally demand high magnitude of forming stresses. The possible approach in reducing the tool stresses can be thought in terms of temperature. Though the higher temperatures lower the forming stresses, the problems such as formation of oxides, depletion of lubricants and phenomenon of dynamic strain ageing cannot be overruled at elevated temperatures, while working titanium and its alloys. The extension of warm working technique to these materials thus deserves some reservation.

A portion of forming energy is converted into heat commonly termed as adiabatic heating. The low heat capacity and low thermal conductivity of titanium lead to enormous rise in temperature of the billet, while working. The simple solution to minimise the tool stresses can be in terms of exploiting the adiabatic heating of the work material during cold extrusion. If the heat generated during deformation has to be effectively utilized for reducing the forming stresses, it becomes necessary to shorten the time of contact between the work metal and tool material, i.e. higher strain rate of working, in view to reduce the conduction heat loss from the billet. The excessive temperature rise at high strain rates may introduce dynamic strain ageing and attendant problems.

The present work aims at enumerating the interaction of deformation ratio and strain rate with the adiabatic heating which would establish lower forming stresses for cold extruding commercially pure titanium.

Solid and ring compression tests have been performed on the commercially pure titanium from 303 to 573 K in the strain rate range of 0.07 to 32 s⁻¹, to document the flow properties. The findings of compression tests are consulted for reasoning and selecting optimal strain rate of cold extrusion. Cold (at room temperature) solid forward and Hooker extrusions have been performed in hydraulic press and crank press, with a special tooling adaptable for the above two machines. The process parameters such as force, displacement and temperature were measured with suitable transducers and recorded with appropriate recorders. Post extrusion tests such as radiographic, ultrasonic
and dye-penetrant examinations and room temperature tensile, impact and hardness tests were carried out to assess the properties and soundness of the extrudes. The influence of deformation ratio on corrosion resistance was also studied on the extrudes for meaningful inferences.

The present investigation leads to the following results:

True stress data under compressive state of stress are generated in the temperature range of 303 to 573 K and in the strain rate range of 0.07 to 32 s\(^{-1}\). Analysis of the true stress data indicates that at 303 K, the true stress is lower at higher strain rates than that in lower strain rates, due to the effective utilization of adiabatic heating. The sudden increase in specimen temperature causes the occurrence of dynamic strain ageing phenomenon in the investigated strain rate and temperature regime. Due to the onset of dynamic strain ageing warm working seems to offer no advantage in reducing forming stress.

The extrusion pressure and hence the tool stress is observed to be lower for any reduction with the crank press (higher strain rate) than with hydraulic press (lower strain rate). The extrudes are sound and healthier for engineering applications and the corrosion properties are unaffected by cold work.

Cold working with higher strain rates establish the lowest forming stresses. The effect of adiabatic heating is beneficial at these situations.