Single Pin Chopper

EXECUTIVE SUMMARY

Single pin chopper (SPC), compared to bundle chopper, is the ideal choice for fast reactor fuels to avoid crimping. This is because of the slender nature of the fuel, SPC for FBTR spent fuel is designed, manufactured, tested and commissioned at COmpact Reprocessing of Advanced fuel in Lead Cell (CORAL). This is compact and amenable for remote maintenance. SPC consists of fuel pin feeding, magazine rotation, gripping and cutting mechanisms. Since this rich Pu bearing carbide fuel is used first time in the world, many experiments and simulations were done to validate the design. The machine is operating successfully for past five years achieving a bench mark of chopping spent fuel irradiated up to 100 GWd/t.

OUTLINE

CORAL (COmpact Reprocessing of Advanced fuel in Lead Cell) is a versatile radioactive research facility for the development of special purpose machines with remote operation and maintenance features apart from serving as the pilot plant for establishing the process flow sheet for FBR fuels.

In fast reactor fuel reprocessing chop leach process is adopted. Chopping is done to expose the surface of the fuel to the dissolvent. In this process the fuel alone is dissolved leaving the clad as hull.

While, in thermal reactor reprocessing plant, bundle shearing machine is used, but in fast reactor reprocessing plant single pin shearing is preferred, in order to reduce the crimping of fuel pin due to slender nature of the pin with the thin clad. Also generation of fines will be less.

The chopper machine as shown in Fig.1 consists of fuel pin feeding, magazine holder indexing, gripping and cutting mechanisms. Feeding mechanism consists of rack and pinion driven by stepper motor. The push rod moves the pin to the required length for shearing. Magazine holder indexing is by an advanced pawl & ratchet mechanism actuated by pneumatic cylinder that rotates the magazine for feeding the next pin. Gripper consists of stationary and movable grippers actuated by a pneumatic cylinder and cutter consists of cutting tool and spring-loaded shunter actuated by a pneumatic cylinder for chopping the pin.

The magazine containing 10 pins in an array on its circumference is aligned to the equipment, locked and its doors are opened. The chopper operation consists of fuel pin feeding, gripping and cutting. After cutting the pin cutting tool moves along with the shunter and in return stroke pin falls in to the dissolver chute and cutting tool returns to its original position, which prevents flying of cut bits. The sequence of operation follows till one fuel pin is completely chopped, then the push rod retracts to its original position, indexing of magazine takes place to align the next pin. A microprocessor based control unit carries out the sequence of operation automatically as per the logic diagram given in Fig. 2. In order to view the cutting operation carried out in side the chopper box there is provision for fixing camera remotely inside the chopper box. Argon gas is purged in to the chopper unit during chopping to avoid fire hazard, as carbide fuel is pyrophoric in nature and it is exhausted through the dissolver off gas system.

Based on the experimental data on rate of dissolution and powder generation the cut pin length is optimized to 25-30 mm. Several campaigns of chopping have been conducted in this machine with spent fuel from FBTR. Fuel pins with burn ups varying from 25, 50, 100 GWd/t have been chopped without any problems. With this machine 10 pins are chopped in less than 2 hours.

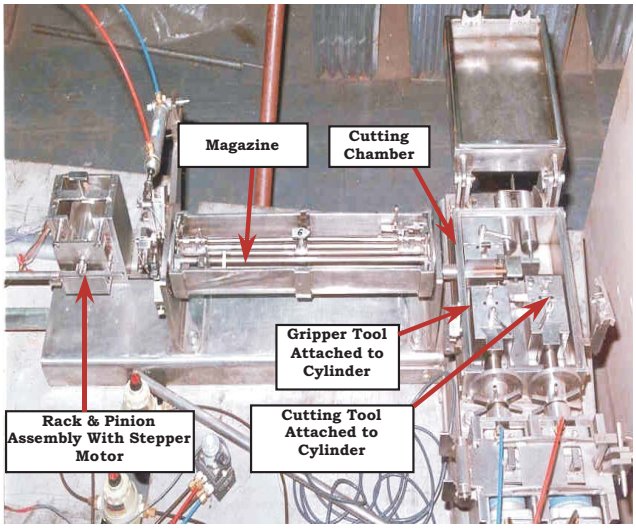

Fig. 1 : Single Pin Chopper

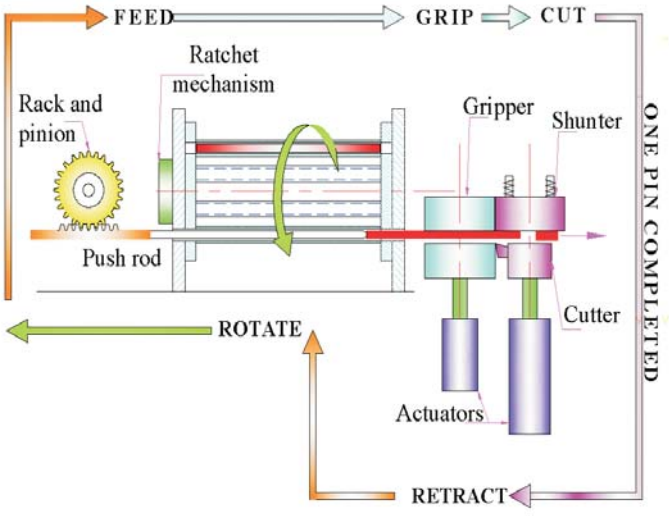

Fig. 2 : Working logic – a schematic Diagram

■ SINGLE PIN CHOPPER

In Reprocessing of fast reactor fuels, Chop-Leach process is usually adopted. This involves cutting of the spent fuel pins into small pieces inside shielded cells, remotely. Various types of choppers are employed based on the fuel pin characteristics and the throughput requirements. Single pin chopper is one such design, employed for chopping of the slender pins of fast reactor fuels. In this design, a single pin is fed and cut at a time, which enables to avoid crimping of these pins. Crimping of pins reduces the reaction rate as the dissolvent will not be contact with the fuel surface.

■ GENERAL EXPLANATION RELATED TO THE DESCRIPTION

The SPC as shown in Fig.3 is made modular in design such that any package like feed, rotate, grip and cut with respective drives can be remotely replaced or maintained. Even the magazine containing of fuel pins is also aligned and replaced from the equipment remotely. All the parts are manufactured and aligned in such a way, remote maintenance can be carried out by general-purpose manipulator with the special gadgets. All the operations are viewed through CCTV.

Mostly pneumatic actuators are chosen for radiation and toxic environment. The material of construction of the parts is either Stainless steel(SS)304 or SS410 depending on strength, corrosion and wear resistance requirements.

A spacer wire is helically wound over the fast reactor fuel pins for flow of coolant, in the sub assembly. During first campaign of spent fuel chopping this spacer wire having very high tension got entangled and posed difficulties in fuel pin feeding and cutting mechanism. These issues were analysed, addressed successfully by suitable modifications in gripping and cutting tool. The feed back and experiences gained with the SPC at CORAL was very much useful in development of various types of choppers required to meet the capacities of future fast reactor reprocessing plants.

The material specimens including pressurised capsules are kept in irradiation capsules, which are in turn locked in special steel subassemblies. These special sub assemblies are loaded in Fast Breeder Test Reactor for irradiation.

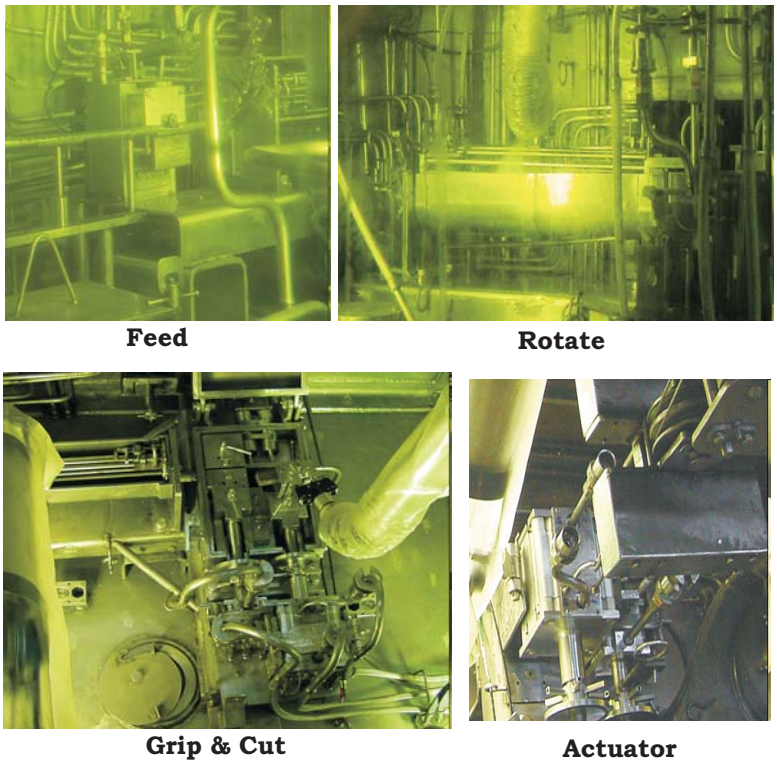

Fig. 3: SPC Mechanism

■ BRIEF DESCRIPTION OF THEORETICAL BACKGROUND

a) Cutting Tool: T-42 (10% Cobalt) of hardness 65RC is used to cut irradiated 20% CW SS316 fuel pin having hardness in range of 18-20 RC. The shear force required to cut is estimated to be 1200 kgf. The optimum velocity of the cutting tool was arrived based on spent fuel characteristics, fuel dislodgment, and wear resistance of tool. The clearance between the cutting tool and stationary blade is kept low to reduce the crimping.

b) Gripper: The gripper profile is designed such that pinching will not occur. Gripping system is designed to balance the excessive force while gripping.

c) Magazine Holder: Magazine holder indexing is by advanced pawl and ratchet mechanism, which provides accurate positioning, self-locking and maintenance free operation.

■ ACHIEVEMENT

The equipment is manufactured to strict interchangeable tolerances by special machining techniques. Rigorous simulation was carried out using different types of simulated fuel rods and performance found satisfactory. The equipment was commissioned at CORAL and is operating successfully for past 5 years. This machine is first of its kind in the world, which has handled rich Pu bearing carbide fuel irradiated up to 100 GWd/t. This experience with this machine enables scaling up the capacities for future plants.

Further inquiries:
Shri A.Ravisankar, Reprocessing Plant Design Division
Reprocessing Group, IGCAR, e-mail: aravish@igcar.gov.in