Development of a Novel Spent Fuel Chopper for PHWR fuel

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ABSTRACT

Decladding of spent PHWR fuel is achieved by mechanically chopping the spent fuel employing special purpose shearing machine. Spent Fuel Chopper based on progressive feeding, clamping and chopping has been in operation in the present operating reprocessing plants located in Tarapur and Kalpakkam. Valuable experience has been gained in operation and maintenance aspects of this equipment over the years. In order to increase the productivity and reduce the maintenance down time, a new spent fuel chopper based on gang chopping concept has been developed incorporating the good features of the existing model. The first spent fuel chopper designed and manufactured as per new concept has undergone cold commissioning in ROP Tarapur and hot commissioning is in progress.

INTRODUCTION

India has adopted closed fuel cycle strategy in its nuclear program for efficient management of available resources to meet the long term energy requirement of the nation. Closing the fuel cycle by reprocessing the spent fuel enables recovery of material that can be recycled. The technology for reprocessing has been developed and established indigenously on an industrial scale. Presently reprocessing facilities are in operation in Trombay, Tarapur and Kalpakkam.

Spent fuel dissolution is the initial step of reprocessing during which, the core of spent fuel is exposed to leach acid, which calls for decladding of spent fuel. The Aluminum clad fuel used in the research reactor is decladded using chemical process. The PHWR fuel with zircaloy cladding, however, is subjected to mechanical decladding. Development of high throughput equipment for our reprocessing program has been the priority for last few years and development of a rugged and reliable Spent Fuel Chopper has been the first step in this regard.

SPENT FUEL CHOPPER (SFC)

Spent Fuel Chopper is used for shearing the fuel bundle or pins into small pieces thereby exposing the fuel for chemical dissolution making it amenable for further extraction process. The SFC used in present operating plants is based on a concept of progressive feeding, clamping and cutting of fuel with a single shear blade. The spent fuel chopper based on this concept was first installed in PREFRE, Tarapur. This chopper was imported from France. A similar SFC with minor modifications was later indigenously manufactured and installed in KARP, Kalpakkam. A SFC essentially consists of:
The spent fuel which is loaded into the fuel magazine is pushed into shear unit using fuel pusher drive mechanism operated from outside the cell. The chain magazine which houses the chain for the fuel pusher is connected to the fuel magazine with its actuating devices from outside the cell. In shear unit the fuel is pre-clamped by auxiliary gag and then rigidly clamped by main gag prior to the shearing the fuel in set lengths. The chopped fuel is fed into the distributor with the distributor door in open condition and then the chopped fuel is diverted to dissolver limb 1 or 2 using the clapper door. A typical layout of the spent fuel chopper housed in a dissolver cell is shown in Fig. 1.

**GANG CHOPPING - A NEW CONCEPT**

Gang cutting is an operation involving multiple cutting blades in order to save time and labour. It was seen that the shorter length of PHWR fuel (compared to LWR/BWR fuel) can be utilized to our advantage by adapting the concept of gang chopping. Mock trials were conducted with simulated fuel (Zircaloy cladded fuel filled with heavy density concrete) to assess the tonnage of the hydraulic system and quality of cut. These were found to be within practical and acceptable ranges. As the gang chopping involved cutting of a complete fuel bundle in single stroke, the requirement of gagging (clamping) system could be eliminated, thus simplifying the shear internals. Similarly a single actuator in place of multiple actuators (for gagging and cutting) also meant easier and reduced maintenance requirements.

**SPENT FUEL CHOPPER BASED ON GANG CHOPPING**

Based on the studies and the experience gathered with the existing SFC, a new spent fuel chopper has been developed to suit the existing site layout of ROP, Tarapur and P3A Kalpakkam. It has been designed to receive and handle a batch of 10 (220 MW) PHWR fuel bundles. A brief description of the features of SFC is given below.

Valuable experience has been gained through operation and maintenance of these SFC’s over the years. These experiences helped in conceiving a novel SFC based on a new concept, while retaining the proven aspects of the existing design for higher throughput and lower down time for maintenance.

![Fig. 1: Typical layout of spent fuel chopper in dissolver cell](image)

- Fuel Feed System,
- Fuel Shearing System,
- Fuel Distribution,
- Hydraulic System and
- Control system

a) Fuel Shear Unit: A single module of fixed and moving blades assembled on carrier plates in a guided fashion which on actuation by the hydraulic ram, shears the complete fuel bundle into multiple segments of desired length (Fig. 2).
b) Hydraulic actuator for fuel feed: Fuel pushing is actuated by hydraulic motor accompanied with pressure sensor and rotary encoder for precise control of torque and position (Fig. 3).

c) Fuel positioning unit: Also known as Component Transfer Assembly, it is a new addition to the existing design for receiving the complete fuel when pushed by the fuel feed system and positions it between the cutting tools (Fig. 4).

d) The hydraulic ram design: A single hydraulic cylinder assembly with moving cylinder and stationary piston arrangement for transmitting the force to moving tool assembly via a pusher rod. (Fig. 5)
e) Controls with safety features: Introduction of PLC based controls with safety interlock based on the feedback from the field sensors like reed switches and limit switches.
f) Provision for remote viewing of SFC: Introduction of transparent windows on the shear zone, fuel feed and distribution system for facilitating the viewing through CCTV camera for continuous monitoring of the functioning of components in order to have visual feedback.
All the components within the hot cell like the shear module components transfer system, pneumatic cylinders for distributor and distributor doors etc have been designed for remote handing employing equipment such as in-cell crane, master slave manipulator, power manipulator etc. The hydraulic actuators and power packs, PLC and control panel are located in operating area freely accessible for maintenance. All the major components employed for the new SFC has been sourced indigenously.

**MANUFACTURING, TESTING AND INSTALLATION**

Based on the in house design, a new SFC with a capacity of 200 Te was manufactured by M/s HMT Ltd under an MoU with BARC. The manufacturing activity was completed as per an elaborate quality assurance plan. Extensive testing of individual subassemblies and complete assembly with and without loads were carried out (Fig. 6). Simulated fuel using cold worked SS 304 tubes as clad material filled with Alumina cement/steatite pellets were used for carrying out load trials. Verification of the control logics for simulated accidental conditions considering the safety aspects were also carried out. Subsequent to the final acceptance of SFC, it was installed and commissioned at ROP Tarapur. Remote maintenance trials of individual subassemblies were also carried out as a part of commissioning trials (Fig. 7). The SFC has undergone cold commissioning with non-reactor grade, PHWR fuel bundle and is presently under hot commissioning.

**SUMMARY**

Indigenous development of the spent fuel chopper based on this new gang chopping concept should help in planning new reprocessing plants for higher throughput. The modular design of individual sub system will enable easy maintenance and reduced down time. The newly developed SFC will significantly improve the capacity of head end process of reprocessing and the availability of machine for longer duration without failure.