Development of Hull Waste Batching System for Integrated Nuclear Recycle Plant

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Abstract
Hull compaction facility is being designed for the first time in India. Hull batching is the first processing step in hull compaction facility of Integrated Nuclear Recycle Plant (INRP). As INRP is a high throughput plant, the generation of hull waste will be in large quantity. The hull waste is associated with high level radioactivity having long lived radio isotopes. Hence, there is a need for volume reduction of these wastes to minimise the long term storage space requirement at geological repository and at in-plant engineered storage.

Various types of feeder designs have been studied before finalising the type of basic feeder equipment for batching system. As the batching system handles high level of radioactivity associated with alpha contaminations, it is required to be highly reliable and amenable for easy maintenance in addition to performing its primary batching functions. A gravimetric vibratory feeder based hull batching system has been developed after extensive mock up trials.

Introduction
Hull waste is a structural part of un-dissolved fuel assembly that is separated during dissolution process of chopped spent fuel in reprocessing facilities. They are associated with high level of radioactivity along with alpha contaminations which contains zircloy fines, residual fission products and heavy metals. The hulls are hollow cylindrical waste, which occupy huge volume. A presently operating plant typically generates hull waste in the order of 30 cubic meters per year, which are being stored in storage facility without any compaction. As the upcoming INRP is a large capacity plant; the volume of hull waste generated will be very high, in the order of 160 cubic meters per year. Therefore, compaction of these hull wastes was felt necessary.

Hull batching is an important part and the first step in hull processing. An objective of the hull batching process is to use standard canister as container for hull wastes that is finalised for Vitrified Waste Product so as to have identical design for storage locations and material handling/ remote handling systems for different high active solid waste products at engineered storage facilities as well as at geological repositories. The hull batching system is designed to transfer hull wastes from a hull drum, containing one batch of spent fuel hulls into 8 nos. of smaller sized cans. The basis of selection of dimensions of the can is to accommodate compacted discs into the standard sized canisters.

As the batching system is being designed for this application for the first time, mock ups trials were carried out to establish their reliability and performance of the system.

Studies of Various Bulk Solid Feeders
The equipment for batching system of this kind was being developed for the first time indigenously. This required design innovations, literature survey and trial mock ups for the equipment before finally being considered for inducting in INRP. Various types of feeder designs, which are commercially available for bulk solids, have been studied in detail. Also, feedbacks from different types of commercial bulk solid feeders were taken from industries/ users. They are also studied with respect to their suitability in adopting in radiation environment. High system reliability and easy maintenance are the critical requirements of the feeder system in addition to performance of conventional feeder functions. Important criteria for selection of feeders for hull batching system are briefly listed below:

a) Uninterrupted and reliable flow of hull pieces from the feeder tray
b) Achieving desired flow rate and accuracy of the flow
c) Reliability of system
d) Immediate start/stop after switching
e) Easy/remote replacement for maintenance prone parts
f) Suitability in high radiation environment
g) Design for control of contamination spread
h) Easy to decontaminate
i) Sizes and type of hull waste

Various commonly used feeders in the industries are screw feeders, rotary valves, vibratory feeders, belt feeders, flexible wall hoppers, etc. Basically, feeders are used to modulate and control the mass flow rates of solids. The pros and cons of each type of feeder were analysed. Finally, a gravimetric electromagnetic vibratory feeder was selected for detailed studies for incorporating it in a batching system and its amenability for remote maintenance. The electromagnetic vibratory feeder has several advantages over other types of bulk solid flow equipment. First, it is extremely rugged and simple in construction. Second, it can be enclosed to eliminate contamination spread from hulls. Third, it can be made amenable for remote maintenance.
Design Concept

Feeder is used to control discharge from a system. Control involves not only stopping and starting flow but also metering the rate of discharge. Vibratory feeder controls the discharge using vibrator. An electro-magnetic vibrator is selected for hull batching system owing to its high reliability and accuracy of flow. This vibrator is a spring-mass oscillation system using electro-magnets that exploit the resonance of the oscillation. If the system is stimulated, it continues to oscillate with its natural frequency, with decaying amplitude depending on its attenuation properties.

A gravimetric vibratory feeder used for the batching system provides closed loop feedback information about the actual weight of the hull pieces being discharged into the destination container and modulate the feed for coarse and fine feed accordingly. It uses vibrations and gravity both to move the materials. Gravity determines the direction of the flow and vibrations controls the feed rate of the materials. The bulk hull pieces are delivered into the hopper from the top and pour the hull pieces from exit hopper through feeder in a controlled fashion. Basic principle of the feeder is that when the magnet receives power, vibration occurs because a pulsating magnetic field is established between the armature and the magnet. There are leaf springs provided in the feeder which permit the armature to move toward and away from the magnet, which imparts the vibration to the tray that ultimately moves the materials.

Hull compaction facility comprises of facilities for hull receipt, hull batching, hull drying, compaction of cans, compacted discs filling into standard canisters, welding of canisters with lids, contamination check/decontamination of canisters, and interim storage in shielded vaults. The block diagram depicting major process steps in the facility is shown in Fig.1 below:

The batching system is planned to be installed inside a shielded cell, called batching cell. The cell is provided with various remote viewing and handling arrangements to carry out the batching operation remotely. Hull waste drums are received in hull compaction facility from reprocessing block. The drum is brought to the batching cell through underground shielded tunnel by a remotely operated trolley. Empty cans are feed to the cell through external transfer drawer through remotely operated can transfer trolley. A load cell based weighing is inbuilt in the trolley trough, which is integrated with the batching system for closed feedbacks through controller. Position accuracy of the trolley is achieved by a shaft encoder/proximity switches. These cans are provided with corrugations on shells for easy compaction. The cell is provided with in-cell crane, master slave manipulators, radiation shielding windows, cameras, grapples, electrically operated can transfer trolleys and external transfer drawers for remote viewing and handling of cans. All the drives are kept outside the cell through stepped plugs type embedded parts in shielded walls. The batching cell is surrounded by operating galleries for operation within the cell.

Design Features

The vibratory feeder type batching system consists mainly of 1) Main hopper 2) Drum tilting assembly 3) Electromagnetic Vibration 4) Vibratory tray 5) Exit hopper drain 6) Outer casing. The drum tilting assembly has rotating cage structure, which receives hull drum from top. It has a locking strip for locking in position of the hull drum. The tilting of the drum at desired angle is achieved by means of an electrical motor drive. The hull pieces are poured from the drum directly into the hopper unit. The main hopper bottom exit diameter is chosen to avoid arching of hull pieces. At the exit of the hopper, there is a vibratory tray, which will feed the hull pieces into the can through exit hopper drain. A tapered guided feeder tray of overall size 400mm (W) x 1400mm (L) x 200mm (H) is provided. The feeder tray size is worked out based on the requirement of buffer storage capacity for 1 batch operation of hull pieces. An electromagnetic vibrator is directly attached to the feeder tray with standard below deck mounting arrangement. The vibrator motor rating is 0.4 KW. The vibrator is variable amplitudes and fixed vibration frequency type. The feeder tray oscillates 3000 oscillations per minute at 50 Hz-mains. Working stroke of the vibrator and hence the throughput can be adjusted during operation from very low to 100 % by changing the voltage from the controller. The normal working stroke for 100% operating flow is adjusted at 2 mm where 90% of the flow takes place, while last 10% of the flow is with low amplitude for finer flow to achieve desired batching accuracy of less than 0.5%. One cycle of batching is corresponding to 30 Kg of hull pieces. Coil spring isolators are planned between the support and feeder tray. Discharge mass flow rate of the hull pieces of the batching system is 400 Kg/hr. Main-stay material of construction for various parts of the batching system is austenitic stainless steel grade 304L. Major parts of the vibrator are also constructed from stainless steel material. A Schematic of the hull batching system is given in Fig.2.
This system is a low-maintenance, continuous duty, no-wear operation and high reliability type. The vibrator unit consisting mainly of electromagnet, leaf springs and masses, which are housed in a stainless steel casing with ingress protection rating as IP 65 class. The vibrator unit is attached with the feeder tray by means flange connection. In case of failure of the vibrator module, it can be detached remotely from the feeder tray with the help of remote gadgets specifically designed for this purpose like special guide tools, impact wrench, etc. and using in-cell crane available in the cell. Electrical cables to the vibrator are having quick connection type connectors. An active maintenance area is provided adjacent to the batching cell for any contact maintenance.

Hull drum is brought to the hull tilting arrangement by in-cell crane and grapples. A drum tilting frame with drum locking arrangement is provided. With the help of mechanised lever arrangement, the drum is locked in the position. The hopper lid will be closed before tilting and off-gas is turned-on to maintain a negative pressure inside the hopper. The drum is tilted in a controlled fashion into the hopper so that the bulk hull pieces will fall into the hopper as per the quantity of the batch size. The drum tilting is done by using an electric motor with sector gear arrangement, which is kept outside the cell. A pour point of the tray has been provided with open/close type gate, having diameter of 175mm. This gate will avoid any unwanted fall of the hull piece from pour point by gravity after the system is switched off. The hopper angle and size of outlets of batching system are finalised based on the hull material properties. Hopper design is carried out achieve mass flow mode. Bottom opening is sized to prevent mechanical interlocking of hull pieces. A floor tray is also planned below the batching unit, where any accidental fall of hull pieces will be collected.

Inactive dummy hull pieces have been used in the trials. An existing commercial feeder of similar capacity has been used for the purpose. The feeder was tested extensively for studying its performance. Around 6000 nos. of dummy hull pieces, corresponding to 30 Kg of hulls of 1 batch were used for the testing purpose. The feeder was operated in a batch mode. The feeder tray vibration frequency was 3000 oscillations per minutes. It was observed that the hulls of one can quantity, i.e. 30 Kg were collected inside the existing box within 5 minutes. During trials, a batching accuracy of better than 0.5 % by weight was achieved.

**Control Logics and Safety Interlocks**

The system operation is controlled by stand-alone Programmable Logic Control system, which is kept at operating gallery outside the cell. The control access is provided from local control panels at PLC within the plant and also important signals are duplicated at central control room of INRP. Various safety interlocks are provided to ensure availability of empty can on the trolley, Positioning of can trolley below pour point, Closure of drum locking strip & hopper lid, Start of Off-gas system etc. Also fine and coarse flow by Vibrators will be based on feedback from load cell based weighing system. Close of batching operation will be based on feedback of the weight of hulls being filled in the can from load cell.

**Conclusion**

Various commercially available bulk solid feeders have been studied and feedbacks from industries have been taken for selecting a type of feeder to be incorporated in the batching system. A gravimetric electromagnetic vibratory feeder based batching system has been developed. Flow parameters have been arrived after extensive mock up trials on the existing commercial feeder, carried out at vendor’s works. Issues of maintenance and spread of contamination have been taken care in design of the system.

**References**