

Westinghouse Modular Grinding Process - Enhancement of Volume Reduction for Hot Resin Supercompaction – 13491

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ABSTRACT

In nuclear power plants (NPP) ion exchange (IX) resins are used in several systems for water treatment. Spent resins can contain a significant amount of contaminants which makes treatment for disposal of spent resins mandatory. Several treatment processes are available such as direct immobilization with technologies like cementation, bitumisation, polymer solidification or usage of a high integrity container (HIC). These technologies usually come with a significant increase in final waste volume. The Hot Resin Supercompaction (HRSC) is a thermal treatment process which reduces the resin waste volume significantly. For a mixture of powdered and bead resins the HRSC process has demonstrated a volume reduction of up to 75 % [1]. For bead resins only the HRSC process is challenging because the bead resins compaction properties are unfavorable. The bead resin material does not form a solid block after compaction and shows a high spring back effect. The volume reduction of bead resins is not as good as for the mixture described in [1]. The compaction properties of bead resin waste can be significantly improved by grinding the beads to powder. The grinding also eliminates the need for a powder additive. Westinghouse has developed a modular grinding process to grind the bead resin to powder. The developed process requires no circulation of resins and enables a selective adjustment of particle size and distribution to achieve optimal results in the HRSC or in any other following process. A special grinding tool setup is used to minimize maintenance and radiation exposure to personnel.

INTRODUCTION

In nuclear power plants (NPP) ion exchange (IX) resins are used in several systems for water treatment. The resins are available in bead or powdered form. In PWR normally bead resins are used. BWR often use powdered resins.

For waste treatment of spent IX resins basically two methods are used:

- Direct immobilization (e.g. with cement, bitumen, polymer or High Integrity Container (HIC))
- Thermal treatment (e.g. drying, incineration, oxidation or pyrolysis)

The final waste volume increases by direct immobilization with technologies like cementation, bitumisation, polymer solidification or usage of a HIC. The Hot Resin Supercompaction (HRSC) is a thermal treatment process which reduces the resin waste volume significantly. But the bead resin HRSC process is challenging because the bead resins compaction properties are unfavorable. The bead resin material does not form a solid block after compaction and shows a high spring back effect. The volume reduction of bead resins is not as good as for powdered resins.

The addition of a powder additive to spent bead resins is one option to overcome the unfavorable bead resins compaction properties. The additive positively affects the compaction properties of bead resins to form a solid block after compaction. However, the efficiency of compaction and volume reduction is lowered by the additive addition and it is not comparable to the efficiency of a HRSC process of powdered resins. The compaction properties of bead resin waste can be significantly improved by grinding the beads to a powder. The grinding also eliminates the need for a powder additive .

Westinghouse Electric Company has developed a modular grinding process to grind the bead resin to powder. The developed modular grinding process is designed for flexible use and enables a selective adjustment of particle size and distribution to achieve optimal results in the HRSC or in any other following process.

DESCRIPTION OF THE MODULAR GRINDING PROCESS

The equipment consists of two separate grinding equipment modules: a pre crusher integrated in the process tank and a colloid mill. The grinding process is divided into the process steps pre crushing and grinding. The whole process is operated in wet conditions.

The resins are processed batch wise in the system. The described grinding system is designed for processing approx. 400 L resin waste per batch but can be scaled up to approx. 2000 L per batch.

Resin/water ratio adjustment

At first the resins are sluiced into the process tank. This is conducted by flushing and simultaneously dewatering until the required amount of resins is loaded into the process tank.

To adjust the proper resin/water ratio the sluice water is first removed, collected and reused to adjust the resin/water ratio.

The adjustment of the resin / water ratio is important because it affects the grinding process itself as well as the later drying process. Mixtures with high water content have poor grinding properties and lead to higher cost in the later drying process. Whereas mixtures with low water content can have poor flow properties which can result in pipe clogging.

All loading is carried out by volume. To control the loading volumes, simple level switches are used. The level switches can be adjusted in height to adapt the whole process to plant specific conditions (e.g. used resin type or distances the resin slurry needs to be transferred).

Pre crushing module and process

When the process tank is filled with the proper mixture of resins and water the pre crushing in the tank is started. It reduces the bead resins particle size and converts the resin water mixture into a pump able suspension with much lower sedimentation properties. The d50 of particle size distribution is $< 400 \mu\text{m}$ after pre crushing. The pre crusher (shown on Fig. 1.) is integrated in the process tank from the bottom of the tank. The designed rotor / stator geometry generates a directed flow towards the pre crusher. The resin beads are sucked into the pre crusher, crushed and pushed out. The pre crusher operates at high speed which also generates a good blending of the resin water mixture. In order to ensure proper resin particle size reduction a special design of the rotor / stator geometry has been developed. Without this special design the resins would just flow through the pre crusher without any size reduction. Once the resin water mixture is turned into slurry the pre crushing is finished. An additional stirrer in the tank supports the pre crushing process and ensures that the resin slurry stays in motion after the pre crusher is stopped, preventing sedimentation while keeping the thixotropic resin slurry at low viscosity.

Depending on the requirements of the installed waste treatment equipment the slurry can either be processed directly by any other equipment or as it is the case for the HRSC process, further ground.

A pump transfers the pre crushed resin slurry to the next process step.



Fig. 1. Pre crusher for in tank batch processing

Grinding module and process

For the HRSC the resins particle size is further reduced using a special colloid mill. The mill operates with a conical shaped rotor and corresponding stator (shown on Fig. 2.). These tools have two different zones for grinding. The first zone has gear cutting tools which serve for feeding and pre-milling and the second zone is coated with an extremely hard and rough surface. The grinding elements are made from metal or ceramics.

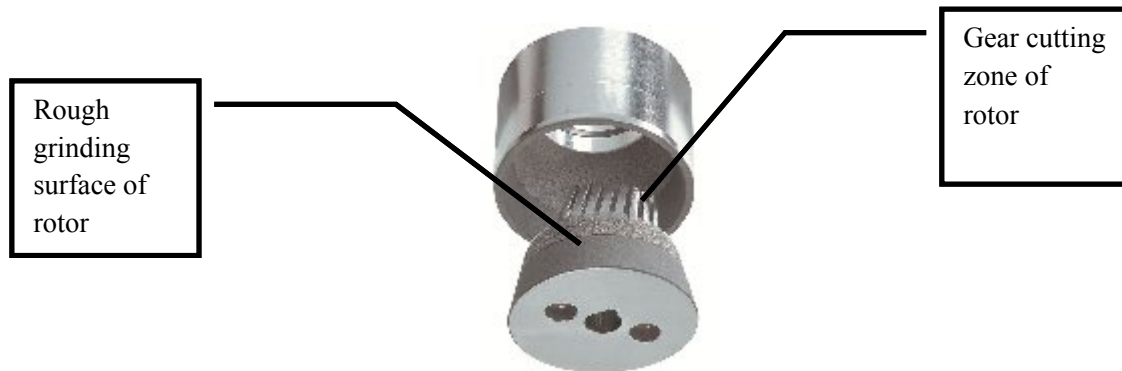


Fig. 2. Grinding elements

The pump pushes the resin slurry through the mill where it is ground within a single passage. The particle size and its distribution can be controlled with the adjustable gap between rotor and stator. Due to the single passage through the mill the gap has to be adjusted only once. With a single passage it is possible to reach a $d_{50} < 30 \mu\text{m}$.

The ground resins are directly transferred to the next process equipment (which is a dryer in case of HRSC). The grinding is completed when the process tank containing the resin slurry is empty. Now, a new batch can be prepared or the system is flushed directly. The water used for flushing is transferred to the same process equipment as the ground resins. This ensures that all resin waste and flushing water is processed and no secondary waste is generated.

DISCUSSION

The separation and modularization of pre crushing and grinding in two process steps with two piece of equipment has several advantages towards using a single mill system with circulation.

Benefits from modularization

The grinding modules can be used independently from each other which allow an easy adaption to any plants waste processing needs.

The space saving integration of the pre crusher into the process tank enables using the pre crusher without the mill for every process where very fine ground resins are not required e.g. enhancing

transportation properties for long transportation or reducing floatation of resins in a cementation process.

In case finer particle are required for further processing, the mill can be easily added to the system. Because the operations pre crushing and grinding are separated (in location and equipment) no manual grinding gap adjustment of the mill is necessary when switching from pre crushing to grinding.

Benefits from the single passage design

Due to the fact that the modular grinding process abstains from any resin circulation in the grinding process the particle size distribution can be much better controlled. Circulation of grinding material back to the feed tank comes with statistical uncertainties on the number of passages each particles runs through the mill. This can result in a longer process time to ensure the target particle size distribution is reached and each particle has passed the mill with a specific statistic certainty.

Using a single passage design these uncertainties are removed. In fact it allows tailoring the particle size distribution by mixing specific amount of resin material because each process step delivers repeatable results.

Benefits from using a colloid mill

The mill operates with robust metal or ceramic based grinding elements. These grinding elements have a non porous body. Compared to other processes which use porous and brittle corundum disk elements the contamination in metal or ceramic based grinding elements is significantly reduced. The porous structure of a corundum disk usually gets clogged by fine resin powder (see Fig. 3.). Once the pores are filled with fine resin powder they cannot be cleaned completely. The porous corundum disks become a hot spot.

Furthermore, a corundum disk has brittle properties which increase the risk of broken disk element. This leads to shorter maintenance intervals and higher radiation exposure to personnel for exchanging broken grinding elements and overall increased operational cost.



Fig. 3. Corundum disk from a corundum disk mill with a crack after 1 h of testing

Benefits from using ground resin in combination with HRSC

The main reason for applying a grinding process is because of its beneficial effect on volume reduction for bead resin waste in HRSC.

This enhancement of volume reduction by grinding has several reasons:

1. Eliminate the use of costly inactive, additive material . Additive material occupies valuable space in the crumble drum and therefore reduces the waste loading.
2. The shape of the ground resin is much rougher and not ideally round compared to bead resins. This property improves the compaction significantly because the single particles can adhere together whereas round beads do not. This leads to a solid block when compacting ground resins. Bead resins do not form a solid block after compaction.
3. The particle size distribution is optimized for compaction. The different particle sizes in a mixture lead to a more dense packing, because the void space in between the bigger particles is filled with finer resin material, whereas bead resins have a narrow particle size distribution and thus the voids are filled with air.
4. With ground resins or powdered resins a much higher compaction force is possible, compared to bead resins only or bead resins with additive. The possible compaction force for ground resins is more than twice the force used for bead resins only. The volume reduction is directly linked to the compaction force.

The described volume reduction enhancement is achieved by mechanical operations like grinding and compaction. With these simple mechanical processes the volume reduction of ground resins compared to pure bead resins is improved up to 30 % and compared to bead resins with additive it is improved up to 40 %.

The volume reduction using these mechanical operations is limited by the material density of the resins itself. Further volume reduction is achieved by increasing the drying temperature above 110 °C and thermal modification of the resin material and its density.

Additional positive effects by using ground resin to the overall process are:

- Improved heat transfer in the drying process due to the reduced particle size and increase in particle surface.
- Higher possible compaction force without damaging the crumble drum.

Limiting factor using ground resin in combination with HRSC

A limiting factor using the described grinding system compared to a HRSC with bead resins only, is the required extra water for the grinding process.

This extra water has to be removed either by evaporating in the following drying process or a mechanical dewatering using centrifuges. A simple mechanical dewatering with a filter as used for bead resin is not possible for ground resin due to their fine particle size.

The best suitable solution depends on the infrastructure of the plant and has to be carefully considered. Evaporation comes with an increase in energy consumption for the drying process whereas a mechanical dewatering using centrifuge technology is connected to higher investment and maintenance cost.

The small extra energy needed for grinding and evaporation is usually compensated by significant savings due to much lower disposal volumes.

CONCLUSIONS

Compared to existing grinding systems the described modular grinding equipment minimizes radiation exposure of workers during operation and maintenance by minimizing the contamination and increasing durability of grinding elements as well as making any in-process grinding gap adjustment redundant. The modular design improves the availability of the grinding system itself.

The reduced radiation exposure, improved availability as well as the decreased maintenance frequency in combination with less demand of spare parts results in significantly reduced operational costs.

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The combination of grinding, drying below 200 °C and high force compaction can achieve a volume reduction for bead resins of 60 – up to 70 % (depending on resin type).

REFERENCES

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