TREATMENT OF RADIOACTIVE SECONDARY WASTE FROM WATERJET ABRASIVE SUSPENSION CUTTING USING SEPARATION TECHNIQUES

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ABSTRACT

Water Abrasive Suspension Cutting (WAS) process is commonly used for the dismantling of a reactor pressure vessel and its internals. The cutting tool is capable of slicing metallic internals and other materials using a jet of water mixed with an abrasive substance at high velocity and pressure. The process offers numerous technical advantages, but it has a major disadvantage in producing secondary waste. Due to the addition of abrasive, the WAS process produces a waste mixture of inactive abrasive particles and radioactive steel particles (activated by neutron radiation) during the dismantling of steel components in nuclear facilities. The research project aims to separate the two fractions (abrasive and steel particles) with the help of magnetic separation and wet sieving. For this purpose, a prototype separation system with a magnetic filter has already been built and tested, which can separate up to 90% of the steel particles from the mixture.

INTRODUCTION

The water abrasive suspension cutting (WAS) technique is employed for the dismantling of nuclear facilities and has already been used for the segmentation of reactor pressure vessels (RPVs) and their internals. In this process, a high velocity water jet and a stream of solid abrasives (garnet) are introduced into a specially shaped abrasive jet nozzle from separate feed ports. A part of the water jet's momentum is transferred to the abrasives, whose velocity rapidly increases. During the cutting process, a suspension containing abrasive and a small amount of radioactive steel particles is produced as secondary waste. Presently, the entire particle mixture has to be disposed of as radioactive waste generating high disposal costs.

In the recent research project MASK, a separation process for the post-treatment of this steel/abrasive particle mixture was developed to reduce the amount of secondary waste. By this post-treatment, the abrasive particles were separated from the particle mixture through a combined sieving and magnetic filtering process. The separation process aimed to reduce the total amount of secondary waste by reusing abrasive particles for further WAS cutting. In this regard, a prototype separation system (MASK) with a sieve and magnetic filter has already been built and tested, which can separate up to 90% of the steel particles from the mixture.

In order to address issues related to the mode of operation, type of waste, and process optimisation in the MASK test plant; a new test plant will be designed and named ‘NAMASK’. In the new test plant, the mode of operation will be converted from a batch process to continuous operation. Moreover, the separation process will be tested and evaluated in the controlled area with a small-scale test setup employing activated materials for the suitability of the treatment for radioactive waste. In addition, the process optimisation considering major changes in the design of sieving equipment and magnetic separator will be implemented.

PRINCIPLE OF THE SEPARATION PROCESS

The separation process aims to reduce the total amount of secondary waste by reusing abrasive particles for further WAS cutting, see Figure 1. A steel component, e.g. RPV or its internals, are segmented by WAS during nuclear facilities decommissioning. This produces a particle mixture of non-radioactive abrasive and radioactive steel particles (called the original steel/abrasive particle mixture, OM). OM consists of large, intact abrasive particles, smaller steel particles and abrasive fragments. In the first step, the fine particle fraction is separated by sieving. This fraction contains the major steel mass fraction and small abrasive fragments (fine fraction FF) which have to be finally disposed of. In the second step, the coarse fraction (CF) is separated from large steel particles with a magnetic filter. These large steel particles are also finally disposed of. The remaining fraction of intact abrasive particles can be reused in the WAS process (reusable fraction, RF).

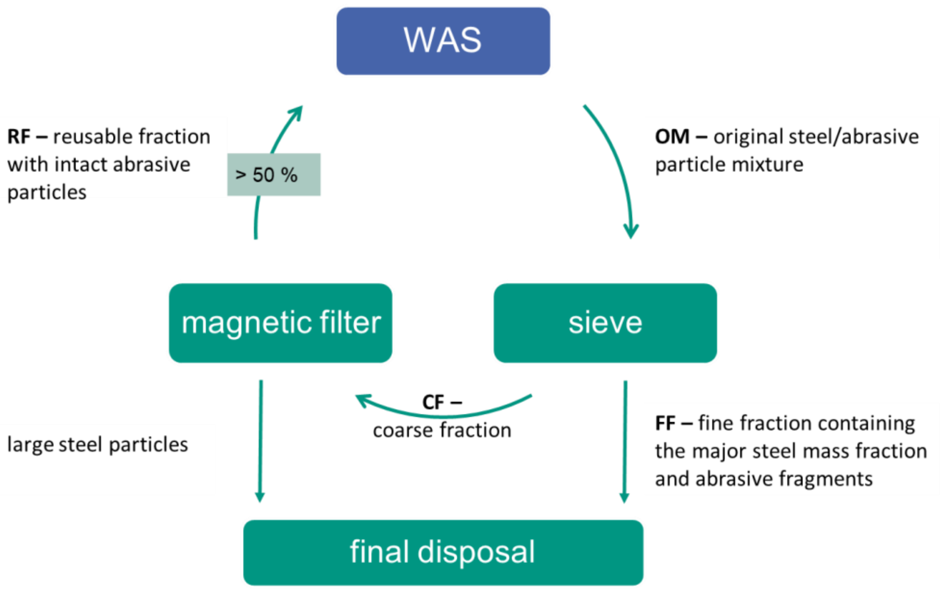

Figure 1: Principle of the reuse of abrasive and the separation process [1]

Analysis of the particle size distribution of the abrasive material before and after the WAS cut have shown, that between 50-75% of the abrasive after the cut is still suitable for reuse. A sieving process and magnetic separation removes abrasive fragments and activated steel particles and the treated abrasive can be used for a further cut in the WAS unit. In this way, between 50-75% of the abrasive generated by the WAS process can be reused.

In order to test the idea of reuse, a small-scale pilot plant (MASK test plant) was developed on a laboratory scale in which separation tests of abrasive and steel grain mixtures from the WAS process were carried out. The setup and operation of the MASK test plant can be seen in figure 2.

The goal of the test stand was to separate a fraction of abrasive particles for reuse from an abrasive and steel mixture. The steel concentration in the separated fraction and the amount of small abrasive fragments should be as low as possible. This separation was carried out in a batch process. The test plant is a modular construction, in which the process steps of wet sieving (size classification), magnetic filters and filters (solid/liquid separation) are implemented. Since the secondary waste contained water, all the process steps were carried out with a water-particle-suspension. The MASK separation unit is described briefly [1].

Figure 2: MASK separation test plant [1]

PROCESS OPTIMISATION

In the MASK test plant, a batch process was carried out and the sample material used for the experiments was not radioactive. In the new phase of the project named NAMASK, an optimised test plant will be designed where continuous operation can be implemented. That means, sieving and magnetic separation can be done continuously. Moreover, the separation process will be designed considering the setup being installed in a controlled area so that activated materials can be tested and evaluated.

Additionally, process optimisation in NAMASK also includes efficient designing of sieve structure and magnetic filter so that steel concentration in the reusable abrasive material will be reduced to further low levels than old MASK test plant. The arrangement of the sieve mounted with a vibrator in a glass housing can be seen in figure 3(a). The arrangement of the sieve is still under investigation to foresee the best separation results working in continuous operation. Similarly, figure 3(b) shows the preliminary selection of magnetic separator, that can provide fruitful result according to the new design and fulfil the required degree of separation.

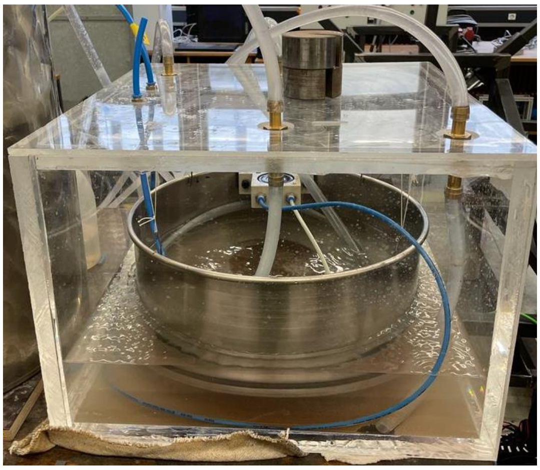

Figure 3(a): Sieve in glass housing (NAMASK)

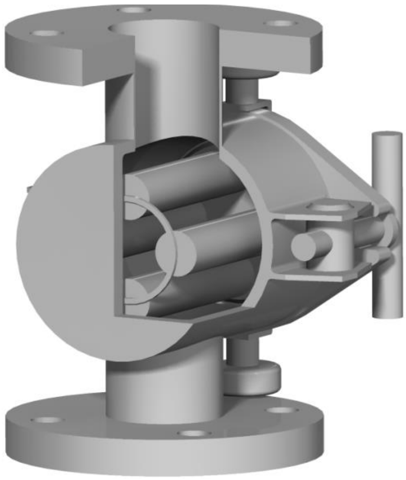

Figure 3(b): Sketch of selected magnetic filter [2]

As the project is in the commissioning phase, it requires continuous changes in the design parameters considering the optimal efficiencies and safe operations. To smoothly run the separation process, it involves a number of equipments including pumps, flow meters, flow controllers, bag filters, and a tank with agitator. A simple process flow diagram can be seen in figure 4 which provides an overview of the continuous operation.

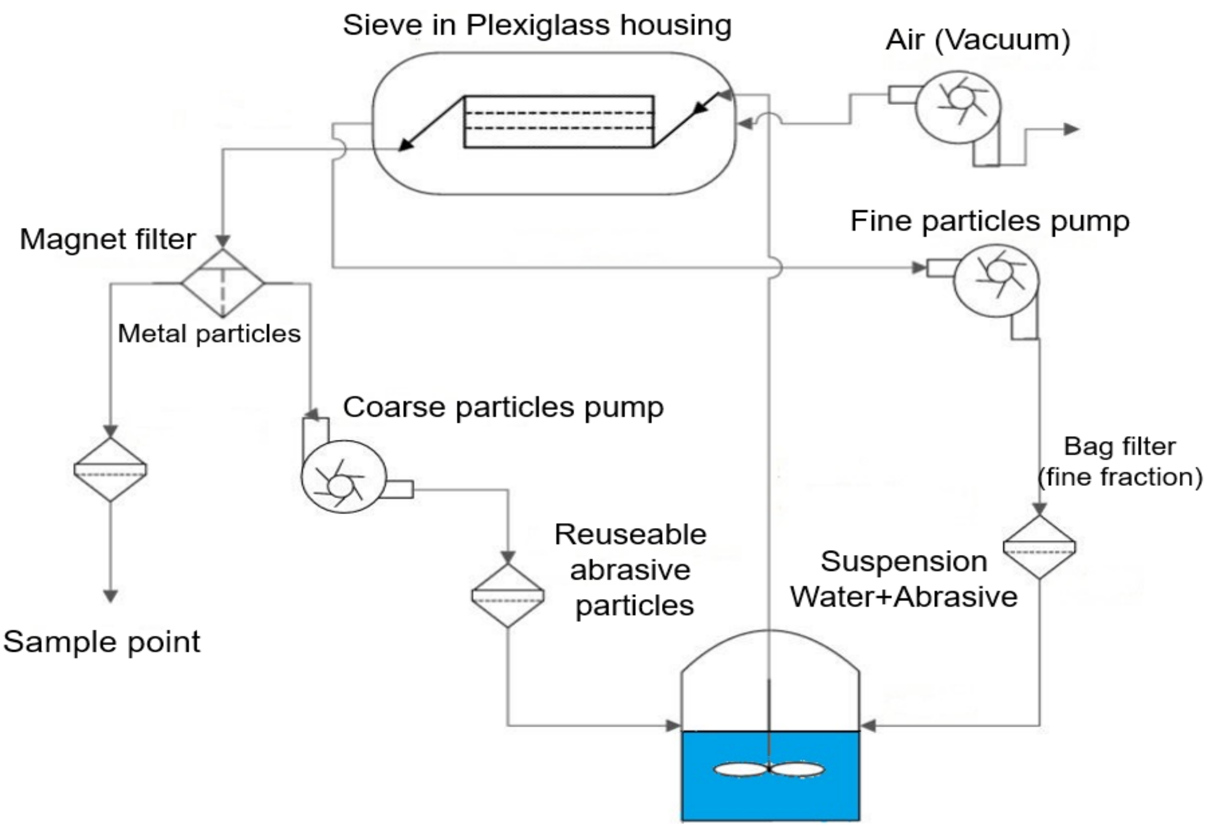

Figure 4: Process flow diagram for NAMASK test plant

CONCLUSION/ NEXT STEPS

The next phase in the project highlights continuous evaluation of sieve in different positions, vibration frequency, flow velocity, and positioning of the suction nozzle. Moreover, a magnetic filter will be installed with a possible configuration to achieve maximum removal of bigger steel particles, that might not be separated by the sieve. The NAMASK test plant is in the commissioning phase and the selection of suitable equipment material is also in consideration to accomplish the milestone of testing radioactive material in the controlled area.

REFERENCES

[1] Heneka, A.; Krauss, C.-O.; Becker, F.; Geckeis, H.; Gentes, S.; Lützenkirchen, J.; Plaschke, M.; Schild, D.; Tobie, W.; „A new technical approach for the minimization of secondary waste produced by water abrasive suspension cutting during disassembling of nuclear facilities", atw Vol. 66 (2021), Issue 1, Page 34

[2] https://www.goudsmitmagnets.com/solutions/magnetic-filtering-separating/pressure-filter-magnets