Application of the Magnetic Filtration to the Removal of Radioactive Corrosion Products Using Permanent and Electric Magnets

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1. Introduction

The novel magnetic filter that would remove corrosion products is developed to reduce the risk of occupational radiation exposure and to help meet the increasing demand for higher safety requirements in nuclear power plants. The permanent magnet filter (PMF) generated a relatively strong magnetism and demonstrated the removal efficiency of over 80% for corrosion particles. The cohesive device using electric magnets, which causes the corrosion particles to flocculate into larger aggregates, about 5 μm in diameter, was set up before the PMF, improving the corrosion product removal rate to over 90%. This paper focuses on the application of magnetic filtration to radioactive corrosion products and presents the results of several experiments that show how the novel magnetic filter using permanent and electric magnets results in the filtration of corrosion products.

2. Principles of Magnetic Separation System

Open gradient magnetic separation (OGMS) utilizes the field gradient of the external magnetic field produced by the magnet itself to deflect the magnetic particles from the main stream. In contrast to high gradient magnetic separation (HGMS), OGMS has neither a magnetic filter matrix made of fine ferromagnetic wires nor iron beads for generating the strong magnetic field, but it is possible to apply for a continuous process. Since the outlets for concentrates and filtrates are divided, no particle accumulation takes place inside the magnetic separator.

High gradient magnetic separation takes advantage of large magnetic forces around fine ferromagnetic wires or iron beads in the magnetic filter to collect the magnetic particles in matrices. The matrix locally distorts the magnetic field produced by surrounding solenoid magnets and creates large magnetic field gradients in the vicinity of the ferromagnetic surfaces. These surfaces then become trapping sites for magnetic particles. For HGMS, the removal of captured particles by flushing the filter matrix is necessary to avoid blockage of the filter matrix, since the accumulation of particles sometimes occurs inside the separator.

3. Magnetic Filtration using Permanent and Electric Magnets

3.1 Design of the Magnetic Filter using Permanent and Electric Magnets

The novel magnetic filter using permanent and electric magnets was devised to improve the corrosion product removal rate. The magnetic filter is composed of two main devices: the permanent magnet filter (PMF) and the cohesive device. The PMF was manufactured to separate metallic particles from the main stream. The cohesive device was developed to cause the very fine suspended magnetic particles to flocculate into larger aggregates that can be separated easily in the PMF. The mechanism of the magnetic filter is shown in Fig. 1.

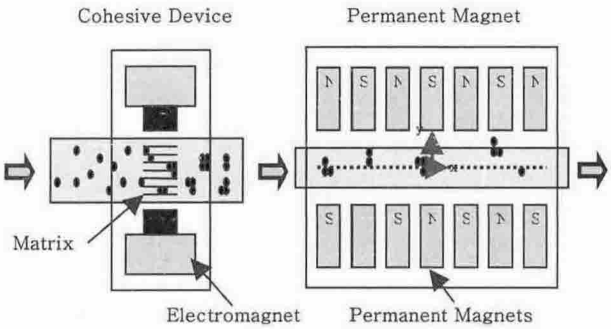

Figure 1. Mechanism of magnetic filter

The PMF devised in this research adopts the wiggler configuration, applying the principle of OGMS [1]. In this wiggler configuration, there are two rows of magnets arranged parallel to one another and separated by a certain distance. Once inside the wiggler configuration, the particles are influenced by a spatially varied magnetic field that causes them to oscillate back and forth in a plane perpendicular to the magnetic field [2]. Finally, the corrosion products are accumulated at the bottom corner of the fluid channel and are separated from the fluid stream at the boundary wall of the vessel.

The cohesive device, applying the principle of HGMS, is composed of three main parts: a vessel with inlet and outlet pipe connections, which are fitted to the inside with a solenoid to generate a background magnetic field and a structure to cool the magnet coils; the magnetizable matrix assembly; and the control panel [3]. The whole vessel is supported concentrically to an electromagnetic solenoid. As corrosion particles in the fluid pass through the matrix assembly along the pipe line, they are magnetized by the background magnetic field gradient generated by electromagnets and ferromagnetic matrices. This gradient in the background field causes the attraction of particles with positive susceptibility toward the surface. The very fine magnetized particles on the matrix surface eventually flocculate into larger aggregates by a process attributable to the potential differences between each particle while the power supply timer is on. Power is supplied for a specific interval, after which the timer turns off, and the magnetized corrosion aggregates flow out from the matrix assembly.

3.2 Experimental Results

To be consistent with previous experiments, the experimental environment is established similar to that of the PMF and the cohesive device, and experiments were usually performed under room temperature and atmospheric pressure. Various experiments were conducted with changes to the following parameters: the class of particles, the flow rates, and the concentration of the input solution. Nickel ferrite, cobalt ferrite, and magnetite were used to simulate corrosion products. The flow rates ranged from 1 litter/min to 5 litter/min, and the concentration of the input solution is within the range of 20 to 1 ppm. To prevent the residual aggregates from taking place on the matrix assembly, the operation minute of electromagnets was set up as 1 minute at 10 seconds shut-off intervals. The typical rotating velocity of permanent magnet assembly was 50 rotation/minute (rpm).

The novel magnetic filter composed of the PMF and the cohesive device displays the very satisfactory filtration ability that the removal efficiency for all corrosion products is highly improved. Figure 2 illustrates a sharp decrease in the number of corrosion particles between input and output solution for nickel ferrite at 10ppm in spite of some differences between the high and low flow rates. The experimental data in Fig. 2 also indicates that most corrosion particles are within the range of 2 or 3 ㎛ in diameter, and the number of these corrosion products rapidly decreases after magnetic filtration.

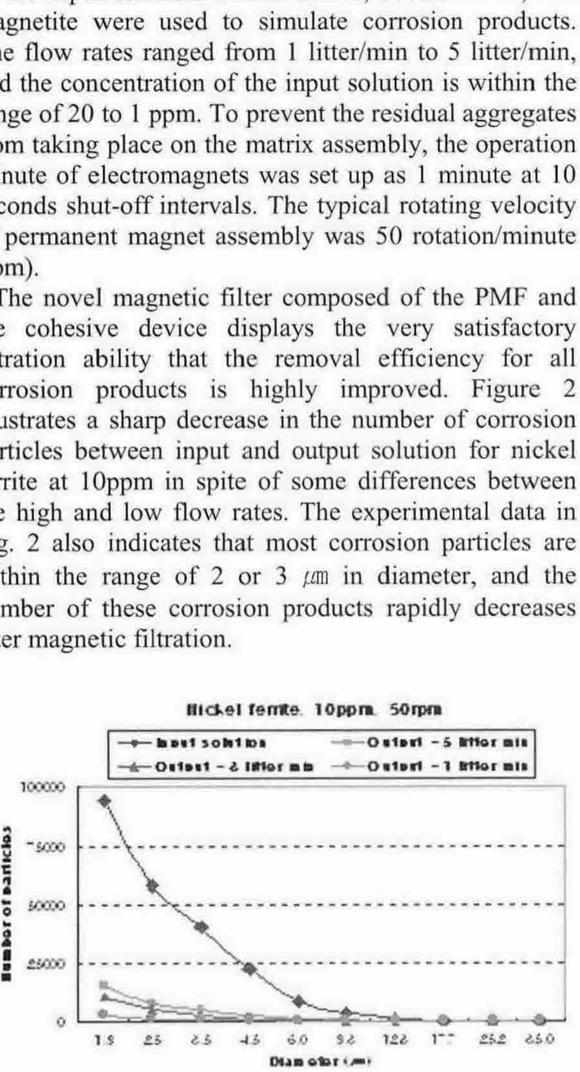

Figure 2. Particle distribution of input and output solution

The flow rate plays a dominant role in magnetic filtration. As the flow rate is decreased, the removal efficiency for corrosion products is increased. In particular, the corrosion removal rate reaches over 90 % for all particles with a 1 litter/min flow rate and a 50 rpm rotating velocity of the magnet assembly. Figure 3 demonstrates the removal efficiency for magnetite according to the flow rates, respectively. To compare the experimental results of combined magnetic filter with the previous results of the PMF, both results are plotted in the same figure; a solid and dotted line indicates the results of combined magnetic filter and the PMF only, respectively.

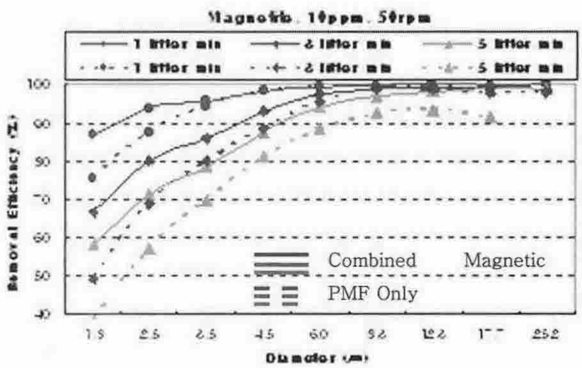

Figure 3. Removal efficiency according to the flow rates

4. Conclusion

The cohesive device was set up before the PMF to increase the corrosion product removal rate. Experiments with the novel magnetic filter using permanent and electric magnets showed the highly improved removal efficiency for corrosion products. The removal efficiency of the PMF for very fine corrosion products was increased from under 80 % to over 90 %, under various flow rates and concentrations. The flow rate played an important role in the magnetic filtration for particles, and the removal efficiency increased for a lower flow rate of the fluid stream. In general, the corrosion removal rate is over 90% regardless of the concentration of the input solution with a lower flow rate. In conclusion, the novel magnetic filter using permanent and electric magnets can be applied to an active method of improving the water quality of the primary coolant.

5. Acknowledgement

This research was carried out with the financial support of the Ministry of Science and Technology, Republic of Korea.

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