Application of the Electric and Permanent Magnets for the Removal of Radioactive Corrosion Products

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1. Introduction

Accumulation and transportation of particulate corrosion products in a primary coolant system can result in serious problems necessitating unanticipated maintenance shutdowns and heavy waste disposal costs. In particular, the corrosion products deposited on the fuel surface are activated by neutron flux in the reactor core and finally become the radioactive corrosion products contributing to occupational radiation exposure (ORE). In the previous study, a permanent magnetic filter (PMF) was developed to separate the metallic corrosion particles from the coolant stream. The PMF was found to achieve a high removal efficiency of over 90% for particles with diameters of 5 ㎛ and over. This finding let to the construction of the cohesive device that causes the metallic particulates to flocculate into larger aggregates of about 5 ㎛ in diameter. This study places emphasis on the application of magnetic filtration to radioactive corrosion products and presents the results of several experiments of magnetic filter.

2. Design and Operation

The magnetic filter using electric and permanent magnets was devised to improve the corrosion product removal rate. The magnetic filter is composed of two main devices: the cohesive device and the permanent magnet filter (PMF) [1, 2]. 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 [3].

The principle behind the operation of the magnetic filter is simple. First, the input particles are mixed homogeneously in the water tank by the bypass pump and then flow into the cohesive device. As corrosion particles in the cohesive device 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 and into the PMF. Corrosion aggregates in the PMF are magnetized as they pass through the channel between the magnet assemblies, due to the strong magnetic field; the particle aggregates then move in the direction of the permanent magnets, rotated by a driving motor connected to the separator. 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.

3. Experiments and Results

Several experiments were conducted with changes to the following parameters: the class of particles, the flow rates, the rotating velocity of permanent magnet assembly, the concentration of the input solution, and the particle size. The detailed experimental parameters are presented in Table 1.

Table 1. Conditions of Experiments

Conditions	Classes and values
Particles	Nickel ferrite ($NiFe_2O_4$) Cobalt ferrite ($CoFe_2O_4$) Magnetite (Fe_3O_4)
Flow rates	1ℓ/min, 3ℓ/min, 5ℓ/min
Rotating velocity of magnet assembly	30rpm, 50rpm, 70rpm
Particle concentrations	1ppm, 10ppm, 20ppm
Particle size	1 ~ 35 ㎛
Operation minutes of electromagnets	1 min-ON and 10 sec-OFF (Fixed parameter)
Applied magnetic fields	5K Gauss (Fixed parameter)

The magnetic filter demonstrates the good filtration performance that the removal rate for all corrosion products is highly improved. Figure 1 illustrates an increase of removal rate of the magnetic filter compared with that of the PMF only. The increased removal rate reaches over 90 % for all particles with a 1 liter/min flow rate and a 50 rpm rotating velocity of the magnet assembly [2]. Consistent with the results of the PMF only, the flow rate plays a dominant role in magnetic filtration of the combined filter. As the flow rate is decreased, the removal efficiency for corrosion products is increased. This result also indicates the higher flow rate, the higher increase of removal rate (Fig. 2). This phenomenon is attributed to the flocculation of particles; the particles, which are not separated in the PMF due to the high flow rate, flocculate into lager aggregates passing through the cohesive device and these larger particles are easy to be removed in the PMF. The particle size made great contribution to the removal rate. Corresponding to the result of PMF only, the removal efficiency increases for a lager particle size. Figure 3 shows the increased removal efficiency on the average for nickel ferrite, magnetite, and cobalt ferrite.

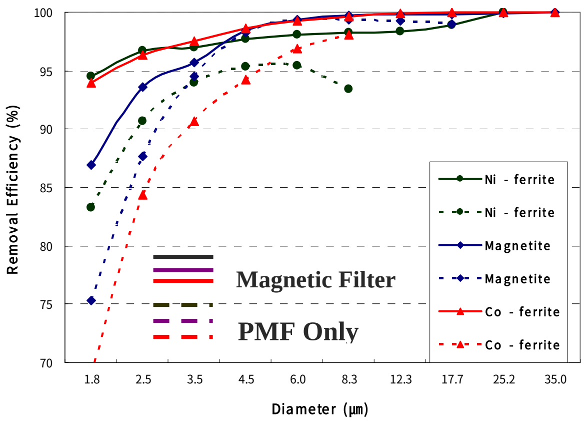

Fig.1. Removal efficiency (Class of Particles)

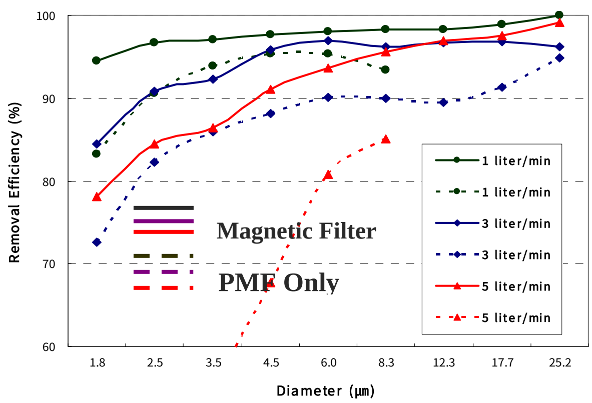

Fig.2. Removal efficiency (Flow Rates)

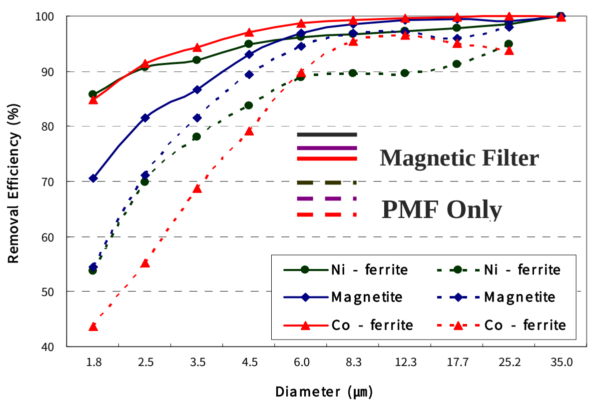

Fig.3. Removal efficiency (Particle Size)

Incidentally, the rotating velocity of permanent magnet assembly and the concentration of the input solution were not important parameters for determining the removal rate for corrosion particles. To compare the experimental results of 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 magnetic filter and the PMF only, respectively.

4. Conclusion

The magnetic filter composed of the PMF and the cohesive device is a novel magnetic filter system which can flocculate the very fine colloidal particles and then separate them from the fluid stream. This device also shows the remarkable removal rate of various corrosion products. The potential of utilization for nuclear power plants is very high due to the several advantages of the novel filter system: no pressure drop, the possibility of application under high temperature and pressure, and no back flushing. Thus, the magnetic filter using permanent and electric magnets, developed in this study, can be applied to an active method to improve the water quality of the primary coolant in nuclear power plants. This filter is especially worthy of consideration from the standpoint of reducing reactor corrosion iron input.

5. Acknowledgement

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