Dissolution characteristics of magnetite in an inorganic acidic solution for the decontamination of heat transport system

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1. Introduction

The heat transport system (HTS) in pressurized heavy water reactor (PHWR) circulates pressurized D_2O coolant through the fuel channels to remove the heat produced by fission in the nuclear fuel. The coolant transports the heat to steam generators, where it is transferred to light water to produce steam to drive the turbine shown in Figure 1. The HTS piping is fabricated from corrosion resistant carbon steel. In PHWRs, magnetite is the major corrosion product as the primary heat transport (PHT) system made up of carbon steel. Many previous studies also showed the presence of thick magnetite layer during the operation time. In the PHWR system, typical film thickness of oxide layer is 2-3μm on stainless steel (SS) surface but on carbon steel surfaces is about 75μm. The PHT system of 220 MWe PHWR, such as Douglas Point nuclear power plant, formed very thick magnetite oxide of 30~35 mg/cm^2[1,3].

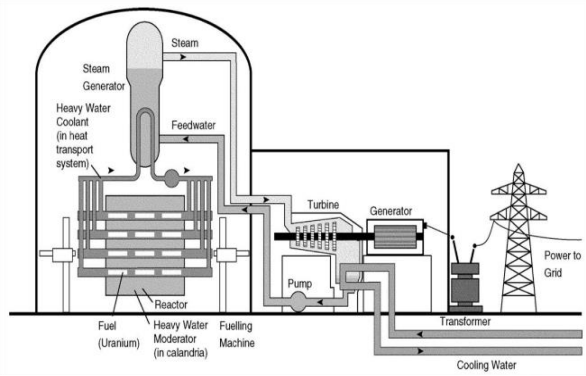

Figure 1. Schematic diagram of PHWR system

A new chemical decontamination technology for domestic CANDU type reactors will be applied for the commercial operation of PHWR decontamination in near future. For the purpose of applying a new chemical decontamination technology for PHWR system, we tested many experimental parameters to investigate the characteristics of magnetite dissolution in an inorganic acidic solution for removing thicker oxide film.

2. Materials and methods

Experiments on the magnetite dissolution were carried in a stirred batch glass reactor using HyBRID solution. Typical HyBRID solution contains 50 mM of hydrazine and 0.5 mM of Cu ion. Hydrazine is basic, so H_2SO_4 is used to meet pH 2.6(±0.5), the condition of an acidic HyBRID solution.

In order to understand the behavior of magnetite dissolution with time, the effects of initial input amount of magnetite and Cu ion concentration were varied in the experimental conditions as listed in Table 1.

Table 1: Experimental conditions

Parameters	Fe_3O_4 conc. (g/l)	Cu conc. (mM)	N_2H_4 conc. (mM)	pH
Fe_3O_4 conc.	0.5~2.5	0.5	50	2.6 (adjusted by H_2SO_4)
Cupper conc.	1.25	0~1.5		

Periodic samples were taken during entire experiment period and analyzed the dissolved concentration of Fe ion in the solution by using atomic absorption spectrophotometer(AAS, Perkin Elmer). The dissolution experiments have been done in a stirred batch glass reactor controlled with rotation speed of 500 rpm and the solution temperature of 95°C.

3. Results and Discussion

Fig. 1 showed the dissolution characteristics of the effect of initial amount of magnetite added in the solution, in three different hours. This is considered that magnetite in solution was able to dissolve much more at 6 hour than 3 hour as increase magnetite at initial time. However, magnetite dissolution doesn't show significant difference in between 6 hours and 9 hours.

It is reported that Cu ion in inorganic acidic solution plays a key role to enhance the magnetite dissolution

rate as an assistant [2]. In this study, in order to set the more effective Cu ion concentration in magnetite dissolution, the effect of the Cu ion concentration on the magnetite dissolution behavior was investigated as shown in Fig. 2. The dissolution rate of magnetite was increased with increase in Cu ion concentration in an inorganic solution. Based on this experimental condition in which up to 900 ppm of Fe ions can be dissolved, it can be seen that almost complete dissolution of magnetite takes place after 9 hours under Cu ion concentration of 1.0 mM or more.

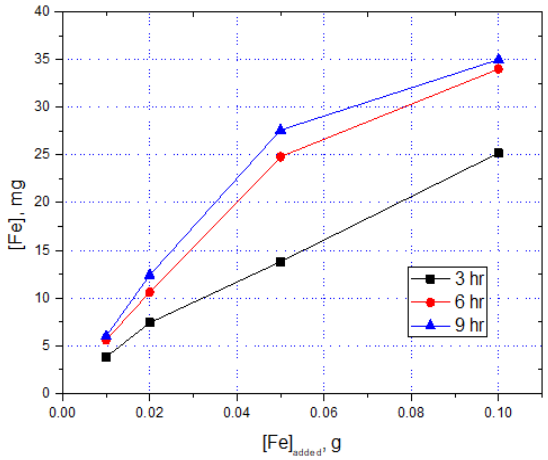

Fig 1. Amount of magnetite dissolved in solution according to the initial concentration of magnetite, in three several hours.

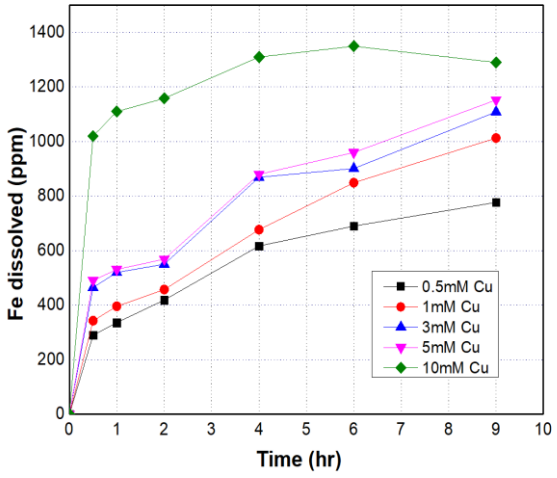

Fig 2. Dissolution behavior of magnetite according to the concentration of Cu ion.

4. Conclusion

The main function of chemical decontamination for the reactor system of PHWRs is high dissolution capability enough to remove radioactive corrosion products. From experimental results it was evaluated that magnetite can be dissolved up to about 1,000 ppm under the condition of in an inorganic solution. In case of high Cu concentration up to 1.0mM, it was very effective magnetite dissolution. As a results, it is considered that the dissolution behavior of magnetite in an inorganic solution is applicable to the chemical decontamination of PHWRs system, which is formed very thick oxides. Further study will be continued to investigate the reaction mechanism and the optimum condition for a new chemical decontamination technology for PHWRs.

5. References

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