Development of High Efficient Hybrid System for Dissolved Oxygen Removal

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1. Introduction

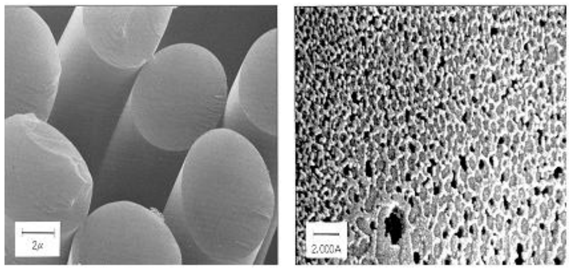
Since dissolved oxygen (DO) accelerates the metal corrosion of pitting and denting in a steam generator system, the DO concentration level of make-up water should be kept below 100 ppb. There are several removal methods of DO, such as vacuum degasification, thermal deaeration, and reductive removal by oxygen scavengers[1]. Although the operation principles of vacuum degasification and thermal deaeration are simple, these methods require a lot of energy for operation and show lower efficiency. The reductive removal of DO by hydrazine or hydrogen needs a highly active catalyst to obtain sufficient reduction rate at an ambient temperature[2]. The development of low cost and high efficient catalysts and a hybrid-type oxygen removal system was tried in this study, using membrane[3] and activated carbon fiber (ACF) having good characteristics as a catalyst support[4,5]: a high surface area, a variety of catalyst shapes, a small resistance for mass transfer and high oxygen activation function.

2. Experimental

The experiment was conducted to see if low-cost, high-efficient degasssing performance can be achieved by a combination of Hollow fiber membrane and Pt catalyst impregnated in ACF that uses H_2 as its reducer. It aimed to prove if Pt catalyst impregnated in ACF continues to show high activity even after it is raised to the level of commercialization.

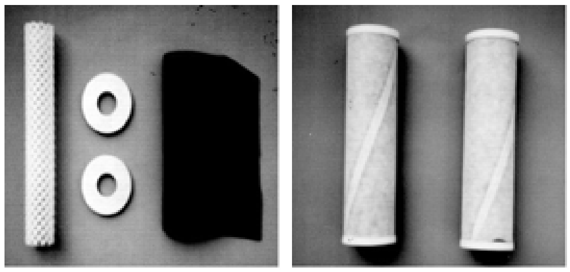
2.1 Production of Prototype of Pt cartridge catalyst

Heesung Engelhard Corp, a major catalyst maker, was asked to make a prototype of Pt catalyst impregnated in ACF. Support was Kuraray's ACF(FT300-15), which is famous for its excellent mechanical strength. Pt precursor was Pt compound dissolved in ethanolamine. Figure 1 describes pore distribution of Rayon ACF, which consists of small pores with sharp peaks near 10Å of pore diameter. Pt catalyst impregnated in ACF in cartridge form was processed to make it easy to install and replace it. Figure 2 describes cartridge components and after-processing form.



(a) (b)

Figure 1. Enlarged picture of Activated Carbon Fiber
(a) Picture of cross-section of Activated Carbon Fiber (×4,800), (b) Enlarged picture of profile of pore (×60,000)



(a) (b)

Figure 2. Picture of Pt(2.0)/ACF cartridge catalyst components(a) and finished catalyst (b)

2.2 Conditions for DO's catalyst reduction removal process

High pure water(≅18MΩ·cm) was used as Feed water and chiller was used to maintain Feed water in the tank at ambient temperature of 25℃. Sintered filter with pore of 0.5 μm was used as hydrogen sparger to mix H_2 and water. Pressure regulating valve was attached to the back pipe of reactor vessel to maintain pressure inside the pipe at 105 psig. The flow of high pure water being supplied to Pt catalytic reactor vessel was maintained at 100 $L\cdot min^{-1}$ by controlling the number of Feed pump rotations with inverter.

2.3 pilot equipment for Pt catalytic reaction

Figure 3 describes the structure of pilot Hybrid-type degassing equipment. Installing DH meter helped control the concentration level of H_2 going from H_2 generator to Pt catalytic reactor vessel. Also, DO concentration changes before and after going through membrane and Pt catalytic reactor vessel was observed by setting up DO meter with 1 ppb precision in Inlet and Outlet.

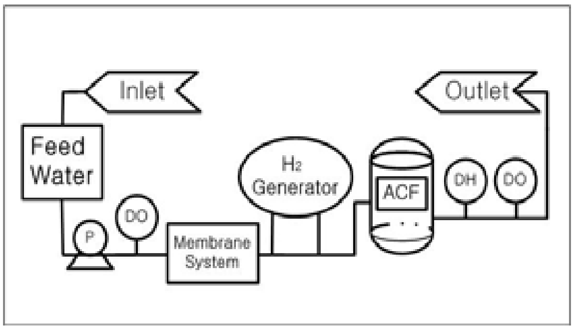


Figure 3. Schematic diagram of pilot Hybrid-type degassing equipment.

3. Conclusion

After going through Hollow fiber membrane, initial DO concentration of 7.5 ppm was lowered to about 1.5ppm, which was lowered again to less than 1 ppb by dissolving H_2 in more than the equivalent ratio of DO and running it through catalytic layer. All of which proves that the prototype of Pt catalyst has high activity in removing DO.

Table 1, describes DO removal rate by pilot equipment according to DH concentration when initial DO concentration of high pure water is 1.5 ppm after going through Hollow fiber membrane. When DH concentration was lower than the equivalent ratio, DO removal rate was low. However, DO removal rate was 99.9% when DH concentration was controlled to be about 120% of the equivalent ratio at 225 ppb. DO was completely removed when DH concentration was controlled to be about 150% of the equivalent ratio at 270 ppb.

Table 1. Removal rate of DO by Hybrid-type degassing equipment according to DH concentration

Concentration (ppm)			DO removal (%)	pH
Inlet DO	Inlet DH[a)]	Outlet DO		
7.5	0.050	1.100	85.3	7.8
7.5	0.100	0.605	91.9	7.5
7.5	0.225	0.008	99.9	6.9
7.5	0.270	-[b)]	100.0	6.1

* Test condition: temperature 25 ℃, catalyst weight 37.6 g, flow rate 100 L min^{-1} , system pressure 105 psig.
[a)] Dissolved hydrogen [b)] Non-detectable

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