A CHROMATE-FREE METHOD OF CORROSION PROTECTION FOR MILD STEEL IN AMMONIA/WATER ABSORPTION HEAT PUMPS

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Ammonia/water (A/W) absorption heat systems have regained their popularity in the industry of heating, ventilation and air conditioning because ammonia is a low-cost, environmentally safe refrigerant with excellent thermodynamic properties. Another advantage has been the flexibility to use almost any energy source, especially natural gas or industrial waste heat sources. In order to be competitive, A/W absorption systems have to be constructed with inexpensive materials such as mild steel and have a long lifetime with little maintenance. Due to corrosion of steel in the high-temperature working fluid and the build-up of hydrogen gas as a corrosion product which reduces the efficiency of the system, chromate is added as inhibitor to the A/W working solution. Due to the environmental and health problems associated with the use of Cr^{6+}, it has become urgent to develop chromate-free, maintenance-free and environmentally friendly inhibitors or alternative corrosion protection methods for steel in A/W absorption systems.

A dual-protection strategy has been developed in which an inhibitor is added to the working fluid and a protective surface layer is formed on the steel. Various rare earth metal salts (REMS) have been evaluated as inhibitors. A cerating process has been evaluated in which a REM (hydr)oxide layer is formed during immersion in a REMS solution containing hydrogen peroxide. The efficiency of various inhibitor candidates has been evaluated in the A/W baseline solution (5 wt% NH_3 + 0.2 wt% NaOH) at 100°C using EIS and potentiodynamic polarization techniques. The optimum conditions for the cerating process on steel were determined using a factorial design approach with $CeCl_3$ concentration, H_2O_2 concentration and cerating time as factors at two or three levels. Since the cerated layers on steel have a cracked-mud appearance as revealed by SEM, sodium nitride as an oxygen scavenger and pH adjuster, a surfactant and lead acetate as solution stabilizer were added to the cerating solution. A final sealing treatment in a silicate or molybdate solution improved the corrosion resistance markedly. It was also found that aging of the cerating solution prior to use had a beneficial effect on corrosion resistance of the steel.

The concept of the dual corrosion protection strategy has been tested in a high-temperature test rig at Advanced Mechanical Technology, Inc. (AMTI) in Watertown, MA. This test rig simulates an A/W system. EIS data and hydrogen concentration data were collected in this rig for various inhibitors and cerating procedures.

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REFERENCES

1. C.L. Hannon, J. Gerstmann, Z. Sun and F. Mansfeld, "Corrosion Protection of Absorption Heat Pumps by Rare Earth Metal Salts", Research In Progress Symp., Corrosion/2001, NACE, (2001).