EFFETS OF IMPURITY IONS ON CORROSION BEHAVIOR OF STEAM TURBINE MATERIALS FOR THERMAL POWER PLANTS

Masayoshi Hirano*, Satoshi Itaba*, Toshio Sakurada**, Yukio Imaizumi**, Noboru Kawai***, Hideo Hirano***, Takao Minami**** and Hiroshi Takaku*****
* Energy Applications R&D Center, Chubu Electric Power Co., Inc.
** Research Laboratory, Kyushu Electric Power Co., Inc.
*** Central Research Institute of Electric Power Industry
**** Sumitomo Metal Technology, Inc.
***** Faculty of Engineering, Shinshu University
* 20-1, Kitasekiyama, Ohdaka, Midori-ku, Nagoya, 459-8522 Japan
** 2-1-47, Shiobara, Minami-ku, Fukuoka, 815-8520 Japan
*** 2-11-1, Iwado- kita, Komae, Tokyo, 201-8511 Japan
**** 1-8, Fusoh-cho, Amagasaki, Hyogo, 660-0891 Japan
***** 4-17-1, Wakisato, Nagano, 380-8553 Japan

OBJECTIVE
The corrosive impurities present in boiler water operated with the combined water treatment (CWT) in thermal power plants are maintained at an extremely low level by using the ultrapure water and also by controlling the strict operation of the condensate demineralizers. However, it is known that the concentration of impurities may induce the corrosion of turbine materials at the alternating dry and wet parts and also at the crevices in the steam condensation regions of low-pressure turbines1,2. In this work, the effects of impurity ions and the dissolved oxygen concentration on the corrosion of steam turbine materials are investigated mainly under the alternating dry and wet conditions.

EXPERIMENTAL METHODS
Test pieces (3.5NiCrMoV steel used for rotors, and 12Cr steel and 17-4PH steel used for blades) were placed in an autoclave test container, and simulated boiler water (with the pH, dissolved oxygen concentration, impurity ion concentrations, etc. adjusted beforehand) was pumped into the test container. Then, corrosion tests were conducted under alternating dry and wet conditions. One cycle of the dry and wet tests consisted of alternation of the dry conditions (at 110°C, for 6 hours, and at <5% humidity) and the wet conditions (at 90°C for 18 hours). The tests were continued for specified cycles. After the tests, investigations were conducted for stress corrosion cracking, uniform corrosion and crevice corrosion.

RESULTS
Effects of Impurity Ions on Corrosion Behavior
Figure 1 shows the effects of the impurity ions on the maximum pitting corrosion depth in a crevice. The tests on 3.5NiCrMoV steel resulted in a corrosion behavior similar to that of uniform corrosion. The 12Cr steel was subjected to the pitting corrosion when the SO$_4^{2-}$ ions and Cl$^-$ ions were added, while the 17-4PH steel had no pitting corrosion when these ions were added. From these test results, it may be suggested that the corrosion behavior of steam turbine materials with a relatively low content Cr (3.5NiCrMoV steel and also 12Cr steel) is influenced more severely by the SO$_4^{2-}$ ions than by the Cl$^-$ ions.

The corrosion film formed on the 3.5NiCrMoV steel was composed mainly of Fe$_3$O$_4$ with a small content of the condensed Ni and Cr. On the other hand, the corrosion film on 12Cr steel in the crevice free areas contained the approximately 65% Cr, and that in the crevice areas consisted of the duplex structure of the enriched Fe in the outer layer and the enriched Cr in the inner layer. These facts on the properties of corrosion films could sufficiently explain the corrosion behaviors shown in Figure 1.

Effects of Dissolved Oxygen on Corrosion Behavior
Figure 2 shows the effects of the dissolved oxygen concentration on the maximum pitting corrosion depth formed in the crevice. The 3.5NiCrMoV steel with no crevices showed no pitting corrosion when the dissolved oxygen concentration was approximately 15 μg/l. However, even in such a low dissolved oxygen concentration range, the 3.5NiCrMoV steel with crevices was subjected to the pitting corrosion. On the other hand, when the dissolved oxygen concentration was relatively high up to 60 μg/l, the 12Cr steels both with and without crevices had the high corrosion resistance with the extremely small pitting corrosion depth.

From the view point of the fundamental corrosion characteristics such as pitting corrosion depths mentioned above, it is suggested that the corrosion of the typical LP steam turbine materials under the alternating dry and wet conditions will be more severe than that under the continuous immersion conditions3.

REFERENCES
1) O. Jonas and N.F. Rieger, EPRI Report TR-10378, 1994
2) B. Dooley et al., EPRI Report TR-108184-V1, 1999

![Diagram](image-url)

**Fig. 1** Effects of a Cr content and impurity ions on the maximum pitting corrosion depth after 2000 hours tests.

![Diagram](image-url)

**Fig. 2** Effects of a dissolved oxygen concentration and crevices on the maximum pitting corrosion depth after 2000 hours tests.