Oxidation Behavior of Fe-Ni Alloy at High Temperature

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Introduction

Steel for automobile has generally been fabricated using by hot-rolling process. A small amount of nickel is easy to be contained into steel, causes oxidation on the surface and then makes surface roughness higher.

In this study, iron steel containing less then 5 wt.% Ni was fabricated and its oxidation behavior at high temperature was examined.

Experimental

Fe-Ni alloys containing 0.05, 0.1, 0.5, 1.0 wt.% Ni were fabricated using by a vacuum arc furnace. The specimen was normalized at 1100℃ for 24 hours, polished with a diamond paste (1㎛), and then measured its surface area and weigh.

The specimen was exposed at 1000, 1050, 1100, 1150, 1200℃ for 5~120 seconds in air and weighed after exposure. Surface roughness was observed using by a laser microscope and a marker test was performed to investigate interface movement between the matrix and the oxidation layer. A Surface and cross-section structure were observed using by a scanning electron microscope (Hitachi S2050) and chemical composition of oxide layer was evaluated using by EPMA and WDX (JOEL JXA-8900). Chemical composition in the iron oxide layer was measured using by X-ray diffraction (JDX 3500) through analyzing of the surface of the specimen before/after removing an oxidation layer.

Results and Discussion

The relationship between the mass change and the oxidation time, when the specimen was exposed at 1100, 1150, 1200℃, is shown in Fig. 1. Mass has increased rapidly during 10~30 seconds and increased slowly after 30 seconds. Mass gain due to the oxidation increased with increasing the contents of nickel as well as the oxidation temperature. This means that oxidation is preceded fast, even though it is early stage of oxidation, because the steel used in this study doesn't contain alloying elements that help formation of high-resistant oxide layer against oxidation at high temperature.

Mass gain obtained in-situ measurement with oxidation time is given in Fig. 2. Gradient, which represents an oxidation rate was 1 or 2 till 20 seconds and it decreased to 1/2 after 20 seconds to be a parabolic type. Temperature at the initial stage of oxidation increased more quickly at the furnace inside than at the surface of the specimen and its behavior was reversed due to oxidation heat after 20 seconds later.

Many cracks were observed in the oxide layer and black particles were also mixed inside. Oxide layer was mainly composed of FeO. And particles of Fe_3O_4 and Fe_2O_3 were distributed in FeO layer. Ni was concentrated a little bit the interface area between the matrix and the oxide layer. Spike-type oxidation behavior, which tip area of an oxide layer is penetrated into the matrix, has not observed in Fe-Ni alloys containing 0.05, 0.1, 0.5, 1.0 wt.% Ni even though they are exposed at high temperature. The order of the composition ratio for the oxide was $Fe_2O_3 \gg Fe_3O_4 \gg FeO$ at the oxide surface, $FeO \gg Fe_3O_4 \gg Fe_2O_3$ at the internal oxide, and $FeO \gg Fe_3O_4 \gg Fe_2O_3$ at the surface of metal after stripping oxide layer.

Surface of the specimen was uniform during 5 seconds, at early stage of oxidation, and it has got rougher with the oxidation time, but back to uniform at 60~120 seconds. It is thought that the oxide scale, which has grown with orientation at an early stage of oxidation, has got to unite and to be uniformed with oxidation time.

Conclusion

Oxidation behavior of Fe-Ni alloys added by small amount of Ni was studied, when they were exposed rapidly up to 1100℃, 1150℃, and 1200℃, respectively. Gradient, which represents an oxidation rate, obtained from mass change curve was 1 or 2 till 20 seconds and it decreased to 1/2 after 20 seconds to be a parabolic type.

Temperature at the initial stage of oxidation increased more quickly at the furnace inside than at the surface of the specimen and its behavior was reversed due to oxidation heat after 20 seconds later. Oxide layer was mainly composed of FeO. And particles of Fe_3O_4 and Fe_2O_3 were distributed in FeO layer. The order of the composition ratio for the oxide was $Fe_2O_3 \gg Fe_3O_4 \gg FeO$ at the oxide surface, $FeO \gg Fe_3O_4 \gg Fe_2O_3$ at the internal oxide, and $FeO \gg Fe_3O_4 \gg Fe_2O_3$ at the surface of metal after stripping oxide layer.

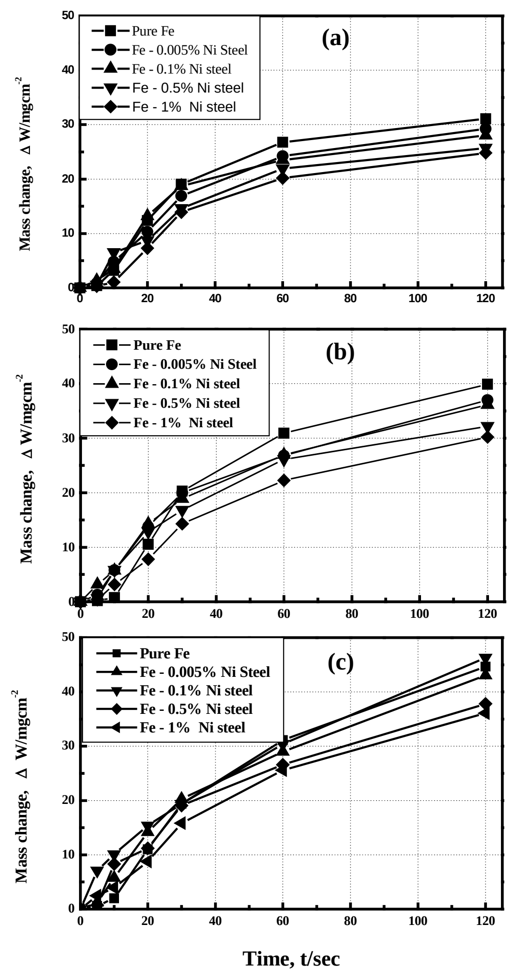

Fig. 1 Variation of mass change of Fe-Ni alloy at high temperature of (a) 1100°C (b) 1150°C (c) 1200 °C.

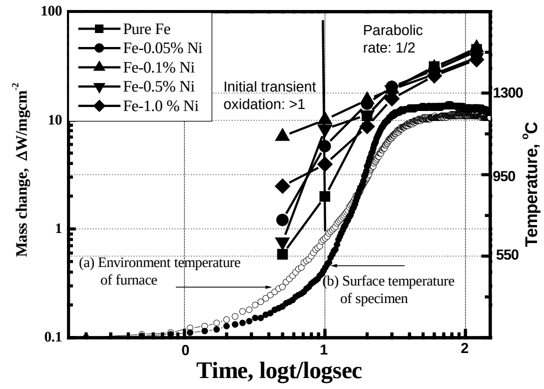

Fig. 2 The mass change of Fe-Ni alloy at temperature of 1200 °C in air.