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Changes in nitrogen, hydrogen and oxygen gas contents in γ -iron on oxidation

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abstract

Nitrogen, hydrogen and oxygen contents affect the chemical properties of iron and steels. It seemed that there are no studies on changes in gas contents γ -iron on oxidation. Therefore, the contents gas on oxidation were determined.

γ -iron was oxidized under atmospheric pressure at 1000℃. Treatment times were 1.5, 3, and 5 hours. Nitrogen content increased to about 12% after for 3 hours of oxidation, while hydrogen and oxygen contents slightly decreased with time. Nitrogen content in γ -iron might have been affected by the amount of humidity.

Keywords: oxidation, γ -iron, nitrogen, hydrogen, oxygen

1. Introduction

There have been many studies on the subject the oxidation mechanisms. However, those studies seem not to consider of inclusion gases in iron[1)2)3)]. Carbon diffusion coefficient have been measured for steels subjected to oxidation with decarburization[6)]. However, these oxidation or diffusion experiment did not investigate the behaviors of nitrogen, hydrogen and oxygen. If on oxidation, there were same studies to compare this report with the other person paper, the other report must have mentioned inclusion gases in γ -iron .

In steels, the nitrogen content dose not change in an oxidizing atmosphere. The oxides prevent steels from absorbing nitrogen[4)]. This may be due to the presence some carbon or a thin oxides layer on steels.

Nitrogen, hydrogen and oxygen gases are present in iron and steel materials. These gases are affected the properties of iron and steel materials. In automobile exhausts and boilers, iron and steel parts are exposed to an oxidation atmosphere for long periods of time and high temperature. As a result, the chemical properties of the materials change according to the contents of gases.

Experiments of nitrogen absorption by pure iron have been conducted in the presence of high levels of nitrogen with hydrogen and low humidity in the atmosphere[5)]. It was reported that oxygen prevents the γ -iron from absorbing nitrogen.

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2. Experimental procedure

γ -iron was oxidized at 1000℃ in an electric furnace for 1.5, 3 and 5 hours. The specimen composition was C,0.009%; Si,0.2%; Mn,0.24%; P,0.04%; S,0.016%; Cu,0.03%; Ni,0.03%; Cr,0.05%; and Pb,0.13%. The 30-mm-diameter rods were machined to 20 mm and then polished with 320 grade emery papers. Before oxidation, the rods were cleaned with alcohol. Their length was 125mm. One end of each rod was machined to 30 degrees. The specimens were suspended vertically with stainless steel wire in an electric furnace.

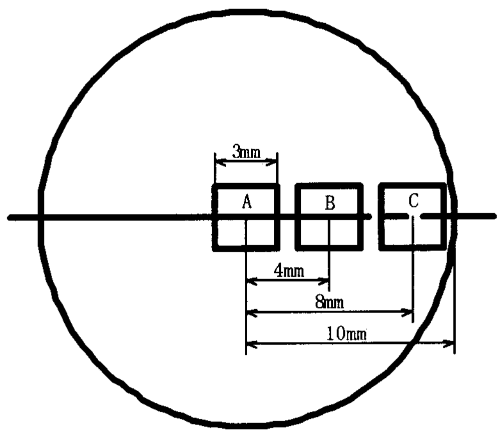

Figure1. Specimen size and position for analysis. A, center, B, middle and C, surface part.

Fig. 1 shows the cross section of the analyzed parts. A is the center part, B; the middle part, and C; the surface part, respectively. The sample for the analysis used transverse center part about 50 mm. And then, for hydrogen and oxygen tests piece were machined to 3×3×10 mm, from the center, middle, and surface parts of the cylinder cross section. For nitrogen content specimen used 3 mm φ the drilled waste product, same part of cylinder cross section. Analyzed oxygen gases amount to oxides. The machining and specimen analyses were carried out at Nippon Steel Techno Research Corporation. Analysis of oxygen and nitrogen were inert gas melting infrared absorption method and heat conductivity method, while hydrogen was inert gas melting heat conductivity method. The gases analysis were conducted more than two months after the oxidation treatment.

Fick's second law is $\partial C/\ \partial t=D\partial^2C/\partial X^2$, for boundary condition $C=C_0$, $x=0$, $t>0$, the solution of which is $C=C_0(1\text{-erf}x/\ 2\sqrt{Dt}\ )$ (1), and where D is the diffusion coefficient. Fig.2, 3 and 4 of the calculated broken line were plotted using equation (1), where equation (1) used x=0.15cm, diffusion coefficient, experiment time and primary concentration. These calculated broken line evaluated in order to compare experiment result.

3. Results and discussion

γ-iron was oxidized under atmospheric pressure at 1000℃ for 1.5, 3 and 5 hours. Fig.2 shows the increase in nitrogen content with time at the surface part. The nitrogen content in γ-iron increased to about 12% in 3 hours. The nitrogen content of the center and middle parts did not change after each treatment time.

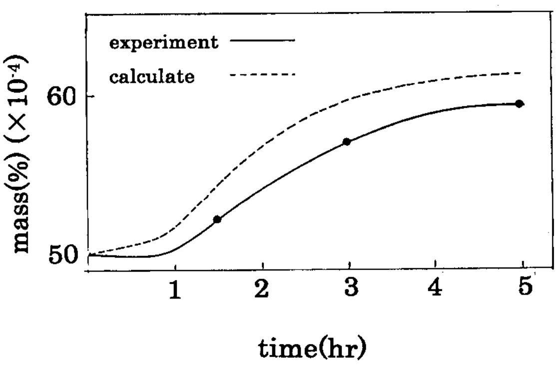

Fig.2 Nitrogen content at surface part with time.

The broken line represents the calculated results, whereas the solid line represents the experimental results. For the calculated results, used to absolute humidity and thickness of oxides instead of Fick's solution x. $C=C_0[1\text{-erf}(\ \sqrt{p+T}\ /\ 2\sqrt{Dt}\ )]$, where p is the absolute humidity and, T is the thickness of the oxides. The absolute humidity was 9.2 and the oxides thicknesses were 0.25, 0.33, and 0.40 mm. These oxides thickness measured from photograph of oxides films. This 9.2 value is vapor pressure of wet bulb temperature. Nitrogen diffusion coefficient D[6] is 1.3×10^{-7} cm²/s at 1000℃. Nitrogen absorption may be affected by the amount of humidity and thickness of oxides. The experimental values for nitrogen were lower than the calculated ones because of little amount of nitrogen in the atmosphere.

Fig.3 shows the relationship of the hydrogen contents with treatment time. Hydrogen content was observed in small amounts in γ-iron. Approximately three hours oxidation time results the lowest hydrogen contents in γ-iron.

Calculated value of Fig.3 used equation (1), where the hydrogen diffusion coefficient D[6] is 1.4×10^{-4} cm²/s at 1000℃.

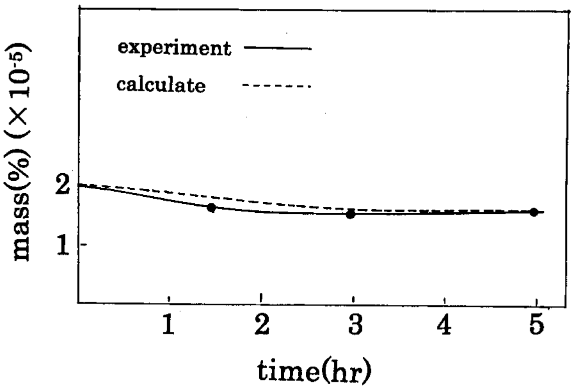

Fig.3 Average of the hydrogen contents of the three parts with time.

Hydrogen diffusion distance is calculated using equation $x=2\sqrt{Dt}$ [7], where D is the diffusion coefficient and t is time. Diffusion time is 5.4×10^3s. Diffusion distance x was 1.7cm.

As shown in Fig.4, the oxygen gas content decrease with time in γ-iron. During the first stage, there is little change in gas oxygen content because there is much humidity on the iron surface. It seemed that there may be much oxygen at first stage oxidation on the iron surface. After five hours oxidation time there is little high oxygen content in γ-iron because it may contain oxides. Oxygen in its pure form was observed small amounts in the γ-iron.

Approximately three hours oxidation time results in the smallest oxygen gas content in γ -iron of the surface part.

The oxygen diffusion coefficient is $D^{6)} = 6.7 \times 10^{-7}$ cm^2/s at 1000℃. Diffusion distance was 0.12cm.

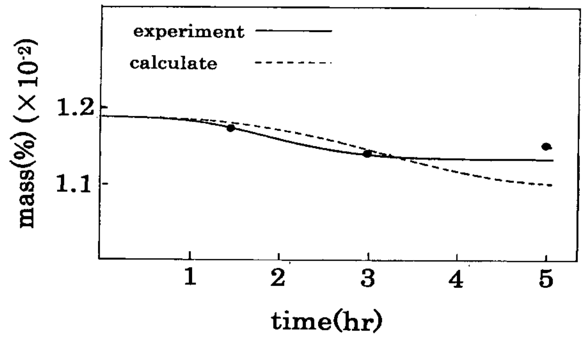

Fig. 4 Oxygen content of the surface Part with time.

Both hydrogen and oxygen contents decreased at three hours treatment time, whereas nitrogen content increased however, the nitrogen and oxygen contents were plotted for the surface part, whereas the hydrogen content were the average result of three parts.

4. Conclusion

γ -iron was oxidized at 1000℃ under atmospheric pressure. As a result,

1. The nitrogen contents increased with time in γ -iron. Nitrogen content in γ -iron might have affected with the amount of humidity.

2. The oxygen and hydrogen contents in γ -iron decreased with time.

3. The oxygen and hydrogen contents in γ -iron were at their lowest at three hours oxidation time.

The nitrogen, hydrogen and oxygen gas contents in γ -iron changed with oxidation at 1000℃. At three hours oxidation treatment time nitrogen absorption occurred with a decreased in hydrogen and oxygen.

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