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STRENGTH VS. TOUGHNESS RELATION IN Fe-HIGH MANGANESE ALLOYS

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INTRODUCTION

Charpy impact tests were performed on the 16 to 36 wt% Mn steels whose tensile properties have already been reported [1]. The effect of Mn content on the ductile-brittle transition behavior was basically identical with other workers' results [2,3]. However, since the reasons for these phenomena are quite unclear, advanced experimental facts are presented for further discussion.

EXPERIMENTAL PROCEDURE

The alloy preparation has been described in the previous report [1]. After solution treatment at 1000°C for 1 h followed by water quenching, the ASTM standard Charpy V-notch impact test specimens were machined. The tests were carried out at various temperatures from -196°C to 250°C. Chemical information at the grain boundaries was investigated by Auger electron spectroscopy (AES).

RESULTS AND DISCUSSION

The impact energy is plotted against test temperature in Fig. 1. The following three conclusions may be obtained from this figure:

(1) the ε (hcp) martensite existing in the as-quenched condition and/or formed during deformation, deteriorates the toughness, as typically seen in the 25 Mn alloy. The ductile-brittle transition (DBT) of this alloy at around 150°C to 20°C and below is attributed to the reverse ε → γ transformation at elevated temperatures. Although the specimens containing large amounts of ε show lower impact energies, the fractured surfaces consist of shallow dimples (see Fig. 2b). For the phase compositions of each alloy see Ref. 1.

(2) The deformation-induced α' martensite in 16 to 20% Mn alloys enhances the toughness but much α' formation leads to the DBT associated with the fracture mode change from transgranular (dimple) to intergranular (Fig. 2a).

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(3) The alloys with more than 36 wt% Mn also show intergranular fracture at low temperatures (Fig. 2c), although the impact energy at -196°C is not so low.

The reason for intergranular fractures of the above (2 and 3) is now under investigation. The AES study thus far has shown no clear evidence of the segregation of any impurity elements at grain boundaries, while the tendency of Mn enrichment has been observed.

Figure 3 exhibits the relation between yield strength and Charpy impact energy where data obtained at different temperatures are plotted. The best combination in the Fe-high Mn binary system would be obtained in stable austenite or martensite alloys not containing e martensite. However, those two alloys have a common drawback of the possibility of intergranular fracture at low temperatures.

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REFERENCES

1. Y. Tomota and J.W. Morris, Jr., presented at the 107th ISIJ annual meeting.

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Fig. 1. Ductile-brittle transition curves of Fe-Mn alloys.
Fig 2. SEM fractographs of Charpy specimens tested at -196°C. A) 15 hr - intergranular fracture, B) 25 hr - dimple, and C) 26.5 hr - intergranular dimple mode.
Fig. 3. Relationship between yield strength and Charpy impact energy.
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