Design of Metal Cored Wire for Erosion Resistant Overlay Welding

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Abstract

Erosion is a common failure mode of materials frequently encountered in plant and power industry. Although the erosion resistance of Fe-base alloy has been inferior to the other expensive materials, it is expected that the strain-induced martensitic transformation can impart high erosion resistance to Fe-base alloy. The key technology to develop Fe-base metal cored welding wire for erosion resistant overlay welding may include the strain-induced metallurgy for hardening rate control and the welding flux metallurgy for dilution control. Sophisticated studies showed that the strain-induced martensitic transformation behavior was related to the critical strain energy which was dependent on the alloy composition. Dilution and bead shape of overlay weld were proved to be affected by metal transfer mode during gas tungsten arc welding and elements in welding fluxes. It was considered that the highly erosion resistant Fe-base overlay weld could be achieved by precise control of alloy composition to have proper level of critical strain energy for energy absorption and welding flux formulation to have small amount of deoxidizing metallic elements for dilution.

Key Words : metal cored welding wire, overlay welding, erosion resistance, strain induced metallurgy, strain induced martensitic transformation, critical strain energy, welding flux metallurgy, dilution

1. Introduction

Erosion is a common failure mode of materials frequently encountered in plant and power industry. Despite its economic importance, little attention has been made to the erosion loss especially in viewpoint of materials. Dense ceramic coatings, such as WC and B_4C, are known to have excellent erosion resistance but they are not easy to apply[1,2]. Among metallic materials, Co-base and Ni-base alloys are known to be superior to Fe-base alloys but their erosion resistance is not cost effective for overlay welding.

Although the erosion resistance of Fe-base alloy has been inferior to the other expensive materials, it is expected that the strain-induced martensitic transformation can impart high erosion resistance to Fe-base alloy[3]. The key technology to develop Fe-base metal cored welding wire for erosion resistant overlay welding may include the strain-induced metallurgy for hardening rate control and the welding flux metallurgy for dilution control. In this paper, the strain-induced martensitic transformation behavior of Fe-based alloy and the dilution behavior of gas metal arc overlay welding are summarized by reviewing recent studies of the authors.

2. Experiments

To investigate the strain-induced martensitic transformation behavior, Fe-10Cr-10Ni-xC (x= 0.3, 0.4, 0.5 and 0.6 wt.%) alloys were prepared by vacuum induction melting. Tensile tests were performed at room temperature and strain rate of 1.667×10-3s-1 with tensile test specimen as shown in Fig. 1. The volume fraction of martensite formed during tensile test was measured by Feritscope which was attached to the center of tensile specimen. The critical strain energy which is defined as the strain energy necessary to initiate strain-induced martensitic transformation was measured as the area below 0.3 vol.% martensite in stress-strain curve for each alloy compositions.

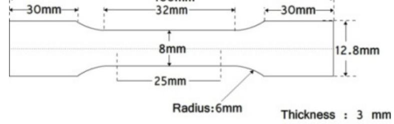

Fig.1 Dimension of tensile test specimen

Cavitation erosion tests were performed using vibratory cavitation testing equipment according to ASTM G32-03. The amount of martensite volume fraction on the eroded surface was measured by

Feritscope for the erosion test times.

Metal cored welding wire having alloy composition of Fe-20Cr-1.7C-1Si were prepared with the addition of various welding fluxes containing Mn, Al, Ti, Si, ZrO_2, NaF and MgF_2. The variation of welding current and voltage was recorded to identify the metal transfer mode during gas tungsten arc welding. Dilution was measure as Ap / (Ar + Ap) from cross section of overlay weld shown in Fig. 2.

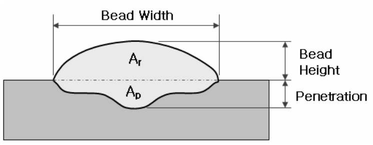

Fig.2 Geometry of overlay weld bead

3. Results and discussion

The critical strain energy as a function of carbon content is shown in Fig. 3. It can be known from Fig. 3 that the critical strain energy increased with carbon content. It means that the strain-induced martensitic transformation is hard to occur with increasing carbon content.

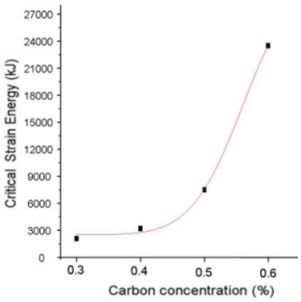

Fig.3 Critical strain energy of Fe-10Cr-10Ni-xC alloys

Fig.4 shows the volume fraction of martensite of Fe-10Cr-10Ni-xC (x= 0.2, 0.5, 1.0) alloys as a function of erosion test. It can be known from Fig.4 that the higher carbon content resulted in the large volume fraction of martensite during erosion test.

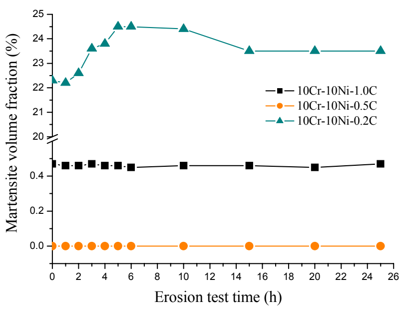

Fig.4 Volume fraction of Fe-10Cr-10Ni-xC alloys as a function of cavitation erosion test time

However, the erosion loss, as shown Fig.5, didn't corresponded to the critical strain energy and the amount of strain-induced martensite. 0.5C alloy showed lowest erosion loss rather than 0.2C and 1.0C alloys. It was considered that there existed the proper level of critical strain energy at which the energy absorption during erosion became maximized

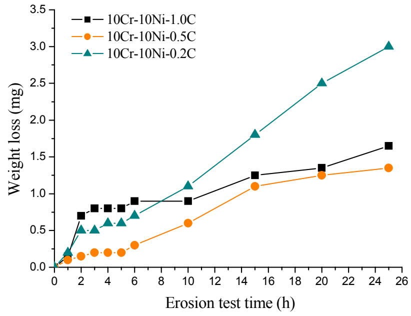

Fig.5 Weight loss of Fe-10Cr-10Ni-xC alloys as a function of cavitation erosion test time

The dilution of overlay weld bead with the addition of various weld flux elements was shown in Fig.6. It can be known that the small addition of deoxidizing metallic elements was effective compared to oxide, fluoride and Si. It was considered to be due to that the additions of metallic elements affected metal transfer mode and Marangoni flow by reducing oxygen contents.

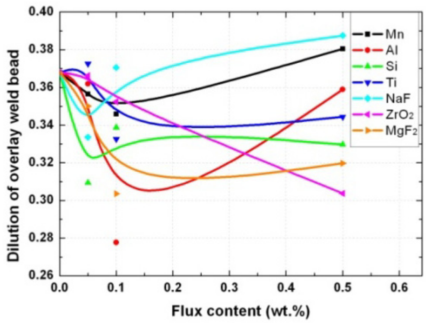

Fig.6 The variation overlay weld bead dilution with the addition of various weld flux elements.

4. Conclusions

The strain-induced martensitic transformation behavior was related to the critical strain energy which was dependent on the alloy composition. Dilution and bead shape of overlay weld were proved to be affected by metal transfer mode during gas tungsten arc welding and elements in welding fluxes. It was considered that the highly erosion resistant Fe-base overlay weld could be achieved by precise control of alloy composition to have proper level of critical strain energy for energy absorption and welding flux formulation to have small amount of deoxidizing metallic elements for dilution.

Acknowledgements

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