Materials Science Research India Volume 01 No. **(1)** 03-08 (2003)

MICROSTRUCTURE AND FORMATION MECHANISM OF DIFFUSION-BONDED JOINT OF Fe3AITO Cr18-Ni8 STAINLESS STEEL

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(Received, May 04, 2003)

ABSTRACT

Microstructures and formation mechanism of Fe_3Al/Cr18-Ni8 joint, which was obtained by diffusion-bonding with 1333K for 3.6ks at a pressure of 17.5 MPa, were analyzed by means of Scanning electron microscopy (SEM), Electron probe microanalysis (EPMA) and X-ray diffraction (XRD).The results indicated that new phases including FeAl, Ni_3Al and a-Fe (Al) solid solution were formed during the diffusion-bonding of Fe_3Al intermetallic to Cr18-Ni8 steel. And the microstructure of diffusion-bonded Fe_3Al/Cr18-Ni8 joint is Fe_3Al/(Fe_3Al+FeAl)/Ni_3Al/a-Fe(Al)/Cr18-Ni8.

Key words: Microstructure; formation mechanism; Fe_3Al/Cr18-Ni8 joint; diffusion-bonding.

INTRODUCTION

In recent years, Fe_3Al intermetallic has attracted the attention of many researchers due to its distinctive properties, such as high strength at elevated temperature and excellent resistance to oxidization and corrosion[12]. But the toughness of Fe_3Al intermetallic is low so that it is easy to crack when welded with electron beam welding (EBW) or gas tungsten arc welding (GTAW)[3-4]. The study of surfacing Fe_3Al intermetallic on Cr18-Ni8 stainless steel indicated that the oxidation and corrosion resistance Fe_3Al intermetallic was more excellent than that of Cr18-Ni8 stainless steel[5]. The joining of Fe_3Ai intermetallic and CM 8-Ni8 stainless steel is a-key technology to enlarge the application of Fe_3Al intermetallic in. electronics and petrochemical lindustries.

With the development of vacuum and computer technology, the increasingly advanced diffusion-bonding technology is widening the application field of intermetallic. There have been some reports on the diffusion-bonding of intermetallic such-as TiAl, Ti_3Al and Ni_3Al[6-8]. But the study on the diffusion-bonding of Fe_3Al intermetallic is few[9-10]. In this paper, Fe_3Al intermetallic and Cr18-Ni8 stainless steel were diffusion-bonded *and* the microstructures and formation mechanism of diffusion-bonded Fe_3Al/ Cr18-Ni8 joint were studied by means of SEM, EPMA and XRD. The experimental results provide theoretical and practical base and open a new way to broaden the

Application of Fe_3Al intermetallic as high temperature structural material.

EXPERIMENTAL

Materials and Methods

Materials used in the experiments were Fe_3Al intermetallic and Cr18-Ni8 austenitic stainless steel. Fe_3Al intermetallic sample was machined into the size of 100mmx20mmx20mm and Cr18-Ni8 steel sample was 100mmx20mmx8mm. The chemical compositions and physical performances of above samples are shown in Table.1 and Table 2.

The oxide film on samples surface should be eliminated. The treatments of samples surface including: ground by sand paper →acetone dipped →alcohol c leaned →water flushed →dried. Diffusion- bonding was conducted immediately after above treatments. The technology parameters used in the diffusion-bonding were: heating temperature 1333K, holding time 3.6ks, pressure 17.5MPa, vacuum degree 4.8×10^{-4} Pa.

After the diffusion- bonding, the sample was cut for the metallography specimens. These specimens were polished and etched with a solution

Table-1: Chemical compositions and physical performances of Fe_3Al intermetallic

Chemical compositions/wt, %						
Fe	Al	Cr	Mn	Zr	B	Ce
80.3	17.3	1.9	0.13	0.25	0.02	0.10

Physical performances								
Structure	Order Critical Temperature /K	Young's modulus /GPa	Melting Point /K	Coefficient of thermal expansion $/10^{-6} \cdot K^{-1}$	Density $/g \cdot cm^{-3}$	Tensile strength /MPa	Elongation /%	Hardness (HRC)
DO_3	813	140	1813	11.5	6.72	455	2	29

Table -2 : Chemical composition and physical performances of Cr18-Ni8 stainless steel

Chemical compositions/wt, %						
C	Mn	Si	Cr	Ni	Ti	Fe
0.10	2.0	1.0	18	8.5	0.5	Ban

Physical performances								
Melting point /K	Coefficient of thermal expansion $/10^{-6} \cdot K^{-1}$	Density $/g \cdot cm^{-3}$	Specific heat $/J \cdot (g \cdot K)^{-1}$	Thermal Conductivity $/J \cdot (cm \cdot s \cdot K)^{-1}$	Electrical resistivity $/10^{-6}\ \Omega \cdot cm$	Tensile strength /MPa	Elongation /%	Hardness (HRB)
1703	16.7	8.03	0.50	0.16	74	520	40	90

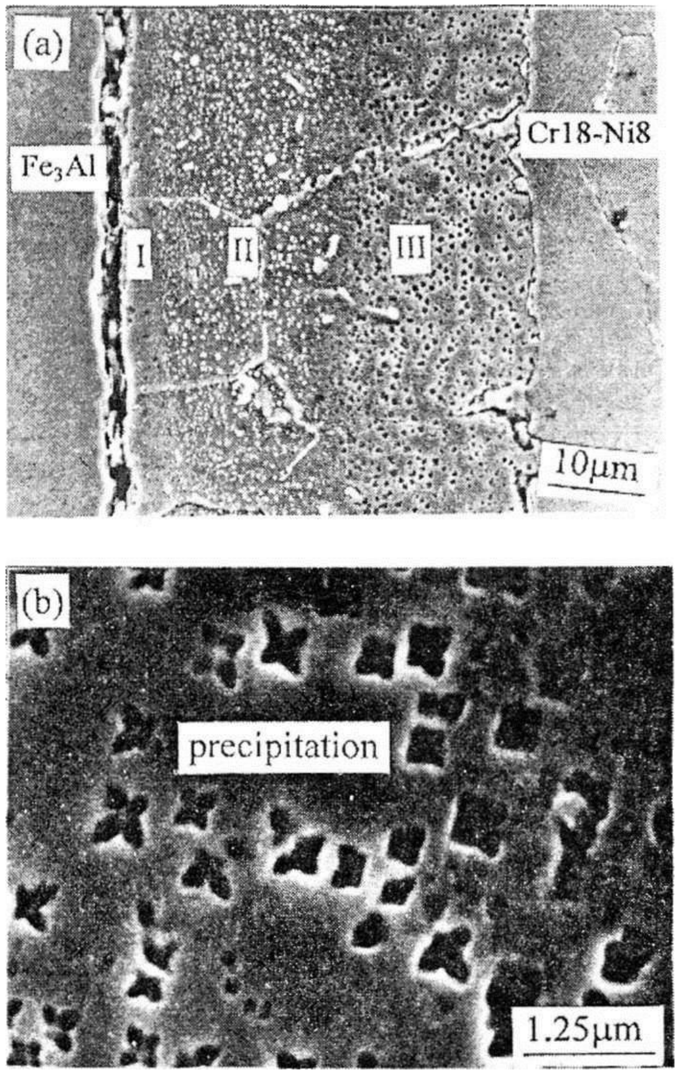

Fig.1 Microstructure morphology of the diffusion-bonded Fe_3Al/Cr18-Ni8 joing: (a) Reaction layers; (b) Morphology of the spot dispersion precipitations

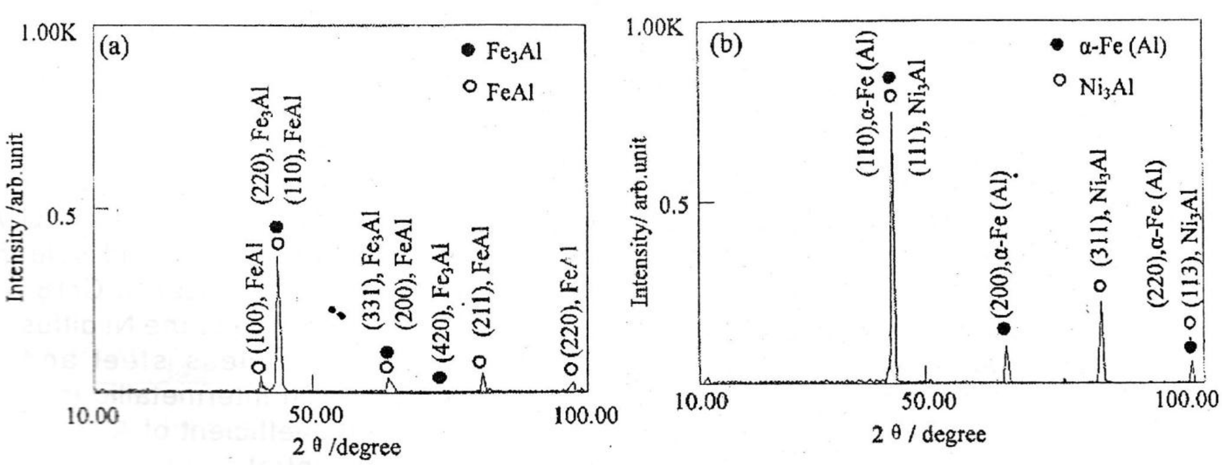

Fig.2 X-ray diffraction patterns of the diffusion-bonded Fe_3Al/Cr18-Ni8 Joint: (a) Region near to Fe_3Al intermetallic; (b) Region near to Cr18-Ni8 steel.

Table -3 :The EPMA analysis results on element concentrations of the reaction layers /Wt.%

Reaction layer	Al	Fe	Ni	Cr	Ti
I	22.5	69.9	3.5	3.8	0.3
II	8.7	72.0	6.8	14.1	0.4
III	2.6	71.6	8.0	17.3	0.5

consisting of 70 % HCI and 30 % HNO_3 . Microstructures, of diffusion- bonded $Fe_3Al/Cr18-Ni8$ joint were observed by means of JXA-80 scanning electron microscopy (SEM). The new formed phases in the reaction layers were determined by X- ray diffractometry (XRD) with copper target with 40 kV voltage and 150 mA current. The element concentrations of the diffusion- bonded $Fe_3Al/Cr18-Ni8$ joint were analyzed with JXA- 8800 R electron probe microanalysis (EPMA).

RESULTS AND DISCUSSION

1. Microstructure of diffusion-bonded $Fe_3Al/Cr18-Ni8$ joint

Fig.1 shows the microstructure morphologies of the cross- section of the $Fe_3Al/Cr18-Ni8$ joint bonded at 1333K for 3.6ks. It can be found that three kinds of reaction layers with different microstructure have clearly occurred between Fe_3Al intermetallic and Cr18-Ni8 steel (see fig. 1 a). Every reaction layer is labeled with I, II and I I I in Fig. 1 a. And there are spot precipitations dispersive distributed in the reaction layers. The morphology of the spot precipitations is shown in Fig.1b.

Microstructure in the reaction layers is complicated because of the diffusion *oi* Al, Fe, Ni and Cr from matrixes. Layer I is the narrow region near to Fe_3Al intermetallic and microstructure in the layer is even. Layer III is the region near to Cr 18-Ni8 steel and microstructure in the layer has lots of black spot precipitations. Layer II is the region between layer I and III and microstructure in the layer has white precipitation.

2. XRD analysis

The diffusion-bonding produces new phase, which was investigated by X- ray diffractometry(XRD) for the shear fracture surface of the dif fusion- bonded $Fe_3Al/Cr18-Ni8$ joint. The XRD profiles are shown in Fig.2.

It can be found that three new phases were formed during the diffusion-bonding of Fe_3Al intermetallic to Cr18-Ni8 steel. They are determined to be Fe Al, Ni_3Al! and cc-Fe (Al) solid solution. This is because the elements (Al, Fe and Ni) from matrixes diffuse each other and when element concentrations rise to certain amount, they can react to form new phases in the diffusion-bonded $Fe_3Al/Cr18-Ni8$ joint.

Table.3 shows element concentrations of the reaction layers analyzed by EPMA. In layer I near to Fe_3Al intermetallic, Al diffusion is affected by Ni and Cr elements to assemble and form (Fe Al+FeAl) intermetallic, Ni_3Al intermetallic and a-Fe(Al) solid solution are found in the^ region near to Cr18-Ni8 steel. It is probably due to the Ni diffusion from Cr18-Ni8 stainless steel and Al diffusion from Ni_3Al intermetallic in layer II. The diffusion coefficient of Al is small, so that the concentration of Al in layer III is quiet low (2.6 %). Finally α-Fe(Al) solid solution can be formed after cooling in the region near to Cr18-Ni8 steel.

The synthetically analysis to Fig. 2 and Table. 3 indicates that microstructure of the diffusion-bonded Fe_3Al/Cr1 8-Ni8 joint is Fe_3Al/(Fe_3Al+ FeAl)/ Ni_3Al/ a- Fe(Al)/ Cr 18 - Ni 8 . Moreover, the microstructure is product at certain temperature and it will not change with bonding time once it forms, but the thickness of the reaction layers will increase with bonding t ime.

2. Formation mechanism

Fig. 3 is the interface reaction model for diffusion- bonded Fe_3Al/ Cr 18 - Ni 8 joint. Fig 3a shows the original state of. atoms in Fe_3Al intermetallic and Cr18-Ni8 steel. Fig.3b shows the state of the diffusion of atoms during diffusion- bonding. The whole reaction process can be divided into three stages.

In the first stage (see fig.3c), Al from Fe_3Al intermetallic diffuses to the original Fe3Al/Cr 18 - Ni 8 interface and the concentration of Al is much. So Fe Al intermetallic is formed and a duplex- phase (Fe_3Al+ FeAl) layer occurs on the Fe3Al Intermetallic side according to reaction 1. At the same time, Fe from Cr18-Ni8 steel reacts with few Al into a- Fe(Al) according to Reaction 2, thus a single- phase a- Fe(Al) layer occurs on the Cr18-Ni8 steel side.

$Fe_3Al \rightarrow FeAl + 2Fe$ (1)

Fe+Al -» α-Fe(Al) (2)

In the second stage (see Fig. 3 d) with the continuous reaction of the first stage, the amount of Ni from Cr 18 - Ni 8 steel diffuses through a- Fe(Al) layer and gathers at the (Fe_3Al + FeAl)/ α-Fe(Al) interface. When the concentration of Ni r ises to a certain amount, Ni reacts with Al into Ni_3Al intermetallic, thus a single- phase Ni_3Al layer occurs at the (Fe_3Al+ Fe Al)/ α- Fe(Al) interface.

In the third stage (see f ig. 3 e), Fe Al continues to grow at the (Fe_3Al+FeAl) interface, and the thickness of the (Fe_3Al+ FeAl) layer extends to the Fe_3Al side, α- Fe(Al) continues to grow at the α- Fe(Al) Cr 18 - Ni 8 interface and the thickness of the α- Fe(Al) extends to the Cr18-Ni8 steel

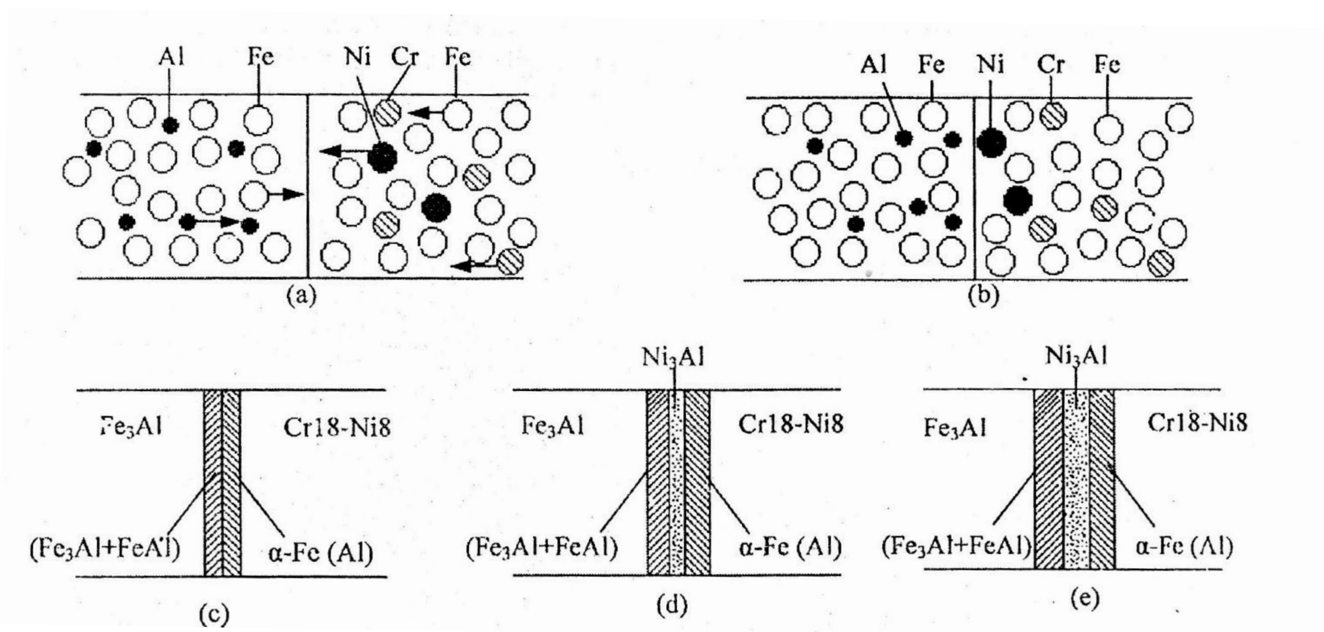

Fig.3 Interface reaction model for diffusion-bonded Fe3Al/Cr18-Ni8 joint: (a) original state; (b) diffusion state; (c) first stage; (d) second stage; (e) third stage.

side. Ni_3Al continues to grow at the Ni_3Al/α-Fe(Al) interface and the thickness of the Ni_3Al layer extends to the α-Fe(Al) side.

During the whole diffusion- bonding, Cr diffuses from Cr 18 - Ni 8 steel to Fe_3Al intermetallic across the Fe_3Al/Cr18-Ni8 interface and it is not reacted. But it is dispersed to the reaction layers into Cr spot precipitation phase.

ACKNOWLEDGEMENTS

This work supported by the Foundation of the National Key Laboratory of Advanced W elding Production Technology, Harbin Institute of Technology, P. R. China. The authors express the heartfelt thanks here.

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