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Joining Tensile Strength and an Analysis of the Joining Interface of Ni-based Superalloys by using a High Temperature Brazing Process

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1. Introduction

Nickel-based superalloys possess excellent properties at elevated temperatures and have thus been commonly used in the manufacture of aerospace components and next generation nuclear power plants as an intermediate heat exchanger(IHX) material because of their superior high temperature performance, oxidation and corrosion resistance. In a number of applications of these alloys, their high performance relies on an adequate joining technique. High temperature brazing process with a nickel-based filler metal has proven to be one of the most flexible joining techniques, as it can be adjusted to a variety of base materials by changing the filler metal compositions. In a traditional brazing, the filler metal is distributed between the closely fitted surfaces of the joint gap by a capillary attraction. The success of a capillary brazing depends largely on the capillary forces of the joint gap to draw and retain the molten filler metal within the joint clearance. For a conventional brazing, the joint gaps to be brazed are generally required to retain about 0-1.5 mm to provide a capillary attraction[1]. Furthermore, one essential property of this process is a strong metallurgical reaction between the brazing alloy and the base metal that results in joints of a high strength and toughness. However, it is necessary for this reaction to provide a small clearance of about 50-100 μm in order to prevent a precipitation of brittle intermetallic phases such as silicides, borides and phosphides due to the relatively high contents of the respective metalloids in the brazing alloy. The metalloids serve as melting point depressants and improve the wetting ability of a filler metal[2]. Unfortunately, as the necessary joint clearance must not exceed 50-100 μm, high production costs arise and the size of the joining partners is also limited. The present study is aimed at joint tensile strength characterization, analyzing the interfacial microstructure, elements analysis and a hardness of brazed joints such as Inconel 617, Haynes 230, Hastelloy-X, and Alloy 800H Ni-based superalloys with MBF-15(Ni-13Cr-4,.2Fe-4.5Si-2.8B-1.0Co-0.03C wt.%) filler metal at 1190°C, using Instron 4465, SEM, EDS and a Vickers hardness tester respectively.

2. Methods and Results

Table 1 Chemical compositions of Ni-based superalloys and MBF 15

Material	Compositions(wt.%)														
	Ni	Cr	Co	Mo	Fe	W	Al	Ti	C	Mn	Si	Cu	S	La	B
Haynes 230	Bal.	22	5	2	3	14	0.3	-	0.1	0.5	0.4	-	-	0.02	0.005
Inconel 617	Bal.	22	12.5	9	1.5	-	1.2	0.3	0.07	0.5	0.5	0.2	0.008	-	-
Hastelloy-X	Bal.	22	1.5	9	18.5	0.6	-	-	0.1	0.5	0.5	-	-	-	-
MBF 15	Bal.	13	-	-	4	-	-	-	0.03	-	4.5	-	-	-	2.8

The brazing alloy is nickel base MBF 15. The nominal compositions of the base metal and the braze alloy are given in Table 1. The foil had a thickness of 35μm, which was used for the all experiments. The experimental brazing was carried out by a brazing process in a vacuum of approximately 2 x 10^{-5} Torr, an applied pressure of about 0.74Mpa and the brazing temperature was 1190℃ for a brazing time of 5 minutes. Microstructural observations were made on the cross-sectional samples by using an optical microscope(OM), scanning electron microscope(SEM), and an energy dispersive X-ray spectrometer(EDS). The tensile tests were performed at room temperature with a cross head speed of 1.5 mm/min according to ASTM E8M.

2.1 Joint cross-section examinations

Quality of a joining was inspected by using SEM micrographs of the joint cross-sections. The SEM micrographs of the joint cross-sections are shown in Fig. 1. These microstructural photos reveal that all the brazed bonds exhibit a good wetting between the filler alloy and both base materials, however some joints contain a few small voids. Microstructure in the centre-line region of a joint brazed with MBF-15 shows a typical ternary eutectic of γ -nickel, nickel boride and chromium boride. The elemental distribution in the joint was analysed on the joint cross-section by EDS as seen in the X-ray maps of Fig. 2. Major elements detected included Ni, Cr, Fe, and Si. Results from EDS reveal that the agglomerates along the centerline of the joint were Cr, Ni and Si. These results suggest a possible formation of intermetallic compounds such as Ni and Cr silicides and possibly borides.

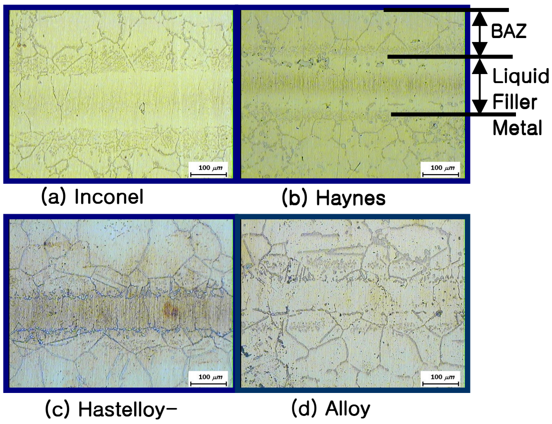

Fig. 1 Microstructures of a brazed joint and brazing affected zone(B.A.Z.) at the brazing temperature 1190℃.

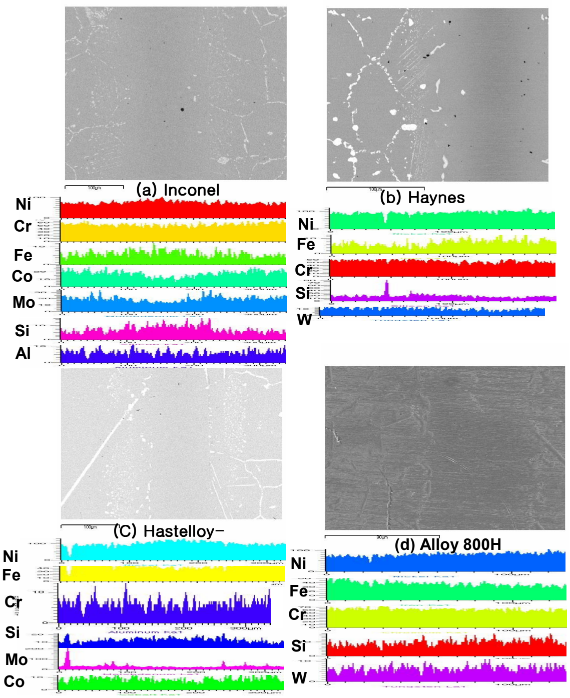

Fig. 2 Element distribution line scan across the brazed joint at the brazing temperature 1190℃: (a) Inconel 617, (b) Haynes 230, (c) Hastelloy-X, and (d) Alloy 800H.

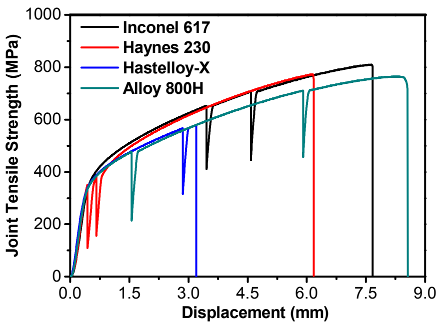

Fig. 3 Tensile strengths of brazed specimens with Ni-based Superalloys at room temperature.

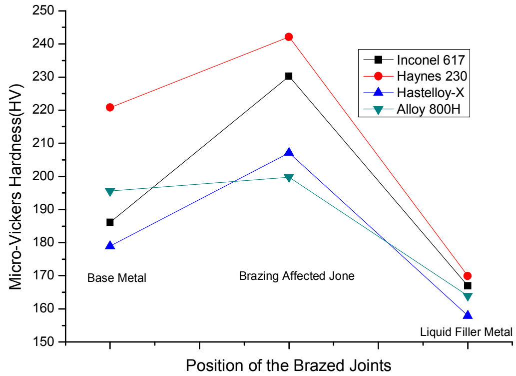

Fig. 4 Micro-Vickers hardness of a brazed joint with brazed positions.

2.2 Joint tensile strength and Hardness

In all the specimens, the joint tensile strengths revealled that excellent joint tensile strengths of as high as 547-810 MPa were obtained when processed at 1190℃ for 5 minutes as shown in Fig. 3. Micro-Vickers hardness of a brazed joint with brazed positions is shown in Fig. 3. The highest hardness of the joint zones exhibited a brazing affected zone(BAZ).

3. Conclusion

Joining of Ni-based superallys have been studied by applying a vacuum furnace brazing process at 1190℃ for a joining time of 5 minnutes with an applied pressure of about 0.74MPa. Excellent joints were obtained by using MBF-15, a Ni-base alloy, as the brazing material. The results show that joint tensile strengths of as high as 547-788 MPa were obtained when processed at 1190℃ for 5 minutes. X-ray analysis reveals that the agglomerates along the centerline of the joint are rich in Cr, Ni, Fe and Si. These results suggest the possible formation of intermetallic compounds such as Ni and Cr silicides and possibly borides.

Acknowledgement

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REFERENCES

[1] E. Lugschcheider, Th. Schitty, E. Halmoy, Metallurgical aspects of additive-aided wide-clearance brazing with nickel-based filler metals, Weld. J. 9s-13s, 1989.
[2] E. Lugschcheider, Th. Schitty, Production of high strength and tough joints by wide gap brazing,, Proceeding of the International Conference Welding '90 Technology Material, Fracture, pp. 21-29, 1990.