Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Joining Characteristics of Intermediate Heat Exchanger Candidate Materials in Very High Temperature Reactor(VHTR)

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1. Introduction

Worldwide studies have shown an increasing need for energy with the use of all energy sources, ranging from renewable sources through nuclear power, gas, to a limited extent oil and finally to the most prolific fossil fuel, coal. Although this increased need for generation capacity can met with different fuel sources, maybe the main fuel worldwide for next generation is hydrogen [1]. The very high temperature reactor(VHTR) can produce hydrogen from only heat and water by using thermochemical iodine-sulfur(I-S) process or from heat, water, and natural gas by applying the steam reformer technology to core outlet temperatures greater than about 950℃. An intermediate heat exchanger(IHX) is the component in which the heat from the primary circuit helium is transferred to the secondary circuit helium(about 950℃ at 1000psi), thus keeping the secondary circuit free of radioactive contamination. The IHX will be located with a pressure vessel within the reactor containment that will be attached to the reactor pressure vessel by the cross-vessel. Therefore, an intermediate heat exchanger(IHX) especially is a key component in a VHTR. The Status of the IHX design will probably be a compact, counter-flow heat exchanger design consisting of metallic plate construction with small channels etched into each plate and assembled into a module. This heat exchanger design is refereed to as a “printed circuit heat exchanger”. Printed circuit type heat exchanger are constructed from flat metal plates into which fluid flow channels are chemically milled. The milled plates are stacked and diffusion bonded together [2]. In this study, the effects of the brazing temperature and homogenizing time for brazed specimens on the joint and base material microstuctures, elemental distribution within the microstructures and the resulting joint tensile strength and micro hardness of Ni-based superalloy such as Haynes 230 were investigated.

2. Methods and Results

The base metal used in this study is Haynes 230 Ni-based superalloy. 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 were performed for all experiments. The experimental brazing was carried out at brazing process in a vacuum of approximately 2 x 10^{-5} Torr, an applied pressure of about 0.74Mpa and the three kinds of brazing temperatures were 1100, 1150, and 1190℃ with holding time 5 to 1440 minute. Microstructural observations were made on cross-sectional samples using an optical microscope(OM), scanning electron microscope(SEM), and electron probe X-ray microanalyzer(EPMA). The tensile tests were performed at room temperature with cross head speed 1.5 mm/min according to ASTM E8M.

Table 1 Nominal compositions of base materials and the brazing alloy

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
MBF 15	Bal.	13			4				0.03		4.5				2.8

2.1 Joint cross-section examinations

Quality of joining was inspected using SEM micrographs of joint cross-sections. The SEM micrographs of joint cross-sections are shown in Fig. 1. These microstructural photos reveal that all brazed bonds exhibit good wetting between the filler alloy and both base materials, some joints contain a few small voids, the thickness of the joint zone increased with increasing joining time, and a zone of agglomerates along the centerline of the joint was observed to decrease in width as the joining time increased. Microstructure in the centre-line region of a joint brazed with MBF-15 show 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 EPMA as seen in the X-ray maps of Fig. 2. Major elements detected included Ni, Fe, Cr, Si and B. Results from EPMA reveal the agglomerates along the centerline of the joint were in Cr, Ni and Si. These results suggest possible formation of intermetallic compounds such as Ni and Cr silicides and possibly borides.

2.2 Joint strength

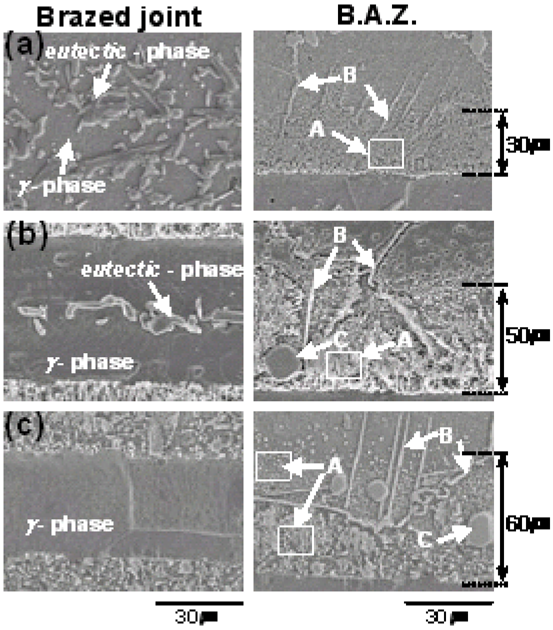

Fig. 1 Microstructures of brazed joint and brazing affected zone(B.A.Z.) at brazing temperatures : (a) 1100℃, (b) 1150℃, and (c) 1190℃.

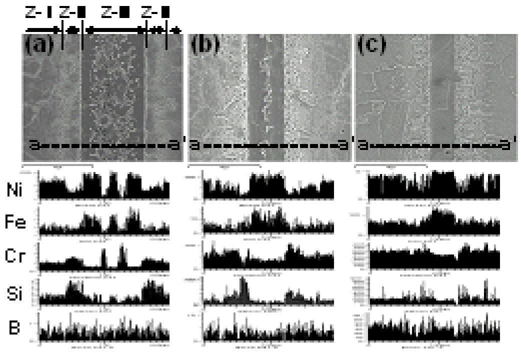

Fig. 2 Element distribution line scan across the brazed joint at brazing temperature (a) 1100℃, (b) 1150℃, and (c) 1190℃.

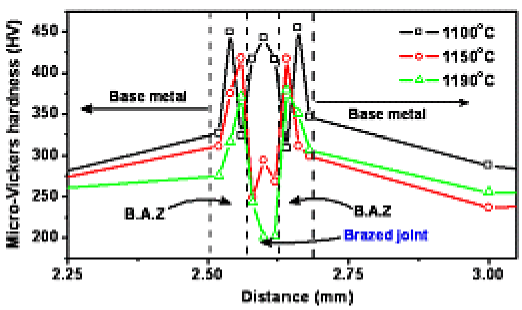

Fig. 3 Micro-Vickers hardness of brazed joint as a function of brazing temperature.

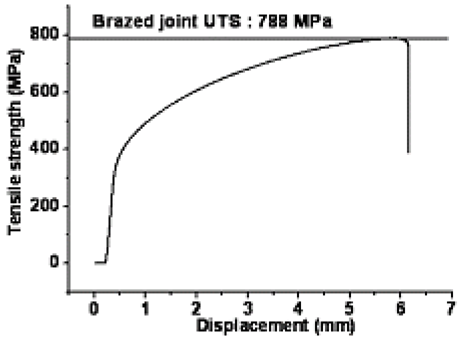

Fig. 4 Tensile strength of brazed specimen at room temperature.

Micro-Vickers hardness of brazed joint as a function of brazing temperature as shown in Fig. 3. The hardness of the joint zone decreased with increasing brazing temperature. The average joint tensile strength reveal that excellent joint tensile strengths of as high as 788 MPa were obtained when processes at 1190℃ for 5 minute as shown in Fig. 4.

3. Conclusion

Joining of Haynes 230 has been studied applying a vacuum furnace brazing process at 1100℃, 1150℃, and 1190℃ for joining holding time 5 to 1440 minute with an applied pressure of about 0.74MPa. Excellent joints were obtained using MBF-15, a Ni-base alloy, as the brazing material. The results show that joint tensile strengths of as high as 788 MPa were obtained when processes at 1190℃ for 5 minute. Microstructure in the centre-line region of a joint brazed with MBF-15 show a typical ternary eutectic of γ -nickel, nickel boride and chromium boride.

REFERENCES

[1] S. Issler, A. Klenk, A.A. Shibli and J.A. Williams, Weld Repair of Ferritic welded materials for High Temperature Application, International Materials Reviews, Vol.49, No. 5 p. 299, 2004.

[2] Guido Baccaglini, Syd ball, Tim Burchell, Bill Corwin, Tom Fewell, Malcolm LaBar, Philip MacDonald, Philip Rittenhouse, Eric Shaber, Finis Southworth, Russ Vollman, Very High Temperature Reactor(VHTR), Survey of Materials Research and Development Needs to Support Early Deployment, INEEL/EXT-03-00141, 37-39, 2003.