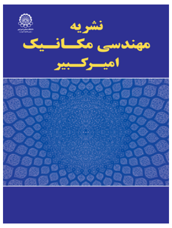

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Microstructure and Mechanical Properties of Inconel 738LC Joint by Wide Gap Brazing Using Inconel 718

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ABSTRACT: In this research, Inconel 738LC as the base metal was joined by wide gap brazing using the mixture of Inconel 718 as high-temperature particle and BNi-2 as low-temperature particle. By using Inconel 718, the brazing temperature can be increased and porosity reduced significantly due to higher melting point temperature than the base metal. The effect of mixture ratio on the microstructure and the mechanical properties was studied. The amount of the low-temperature particle in the mixture was 30, 40, and 50 percent. By decreasing the low-temperature particle ratio, the amount of eutectic phase and the blocky boride in the solid diffusion zone decreased markedly. The joint width increased by increasing the amount of low-temperature particles. There were two distinct regions in the joint/base interface. Due to the diffusion of boron into the base, adjacent to the joint, the grain boundary melted and created a region including both the isothermal solidification zone and solid diffusion zone. By getting away from the joint, the content of boron reduced by the grain-boundary diffusion. It was observed that aging did not have a significant effect on the amount and distribution of eutectic phases and blocky borides, however, the morphology of these phases changed slightly. Moreover, aging had a small effect on hardness making the hardness of different phases more uniform.

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1- Introduction

High-temperature brazing widely used as a cost-effective technology to produce high-performance joints with excellent static and dynamic load resistance as well as high corrosion resistance [1]. For conventional brazing, the joint gaps to be brazed are generally required to be below 200 μm to provide the capillary attraction.

For brazing of a wider joint, excessive Melting Point Depressant (MPD) elements form brittle intermetallics such as borides and silicides in the centerline. The presence of these phases provides a path for crack propagation and reduces fracture strength of the joint. To overcome these limitations, Wide Gap Brazing (WGB) was developed. In this case the Low-Temperature Particle (LTP) is blended with High-Temperature Particle (HTP) of similar composition to the base metal [2, 3]. HTP in WGB has the following functions: (i) to provide capillary force to draw molten filler alloy into the cavity, (ii) to act as MPDs sink, and (iii) to further alloying the joint and increase its ductility [4, 5]. The mechanical behavior of mixed powder brazed joint is always determined by its inherent microstructure. The presence of eutectic product and large intermetallic in mixed powder brazed joint has been found to promote crack initiation and provide low resistance to cracks propagation during deformation, deteriorating the mixed powder brazed joint's mechanical behavior [6].

In this study, polycrystalline cast Inconel 738LC superalloy is used as the base metal. The purpose of this research is to use alternative filler alloys to develop and characterize a braze repair process for this alloy. Therefore, Inconel 718 is used to reach better mechanical properties. However, the microstructure and mechanical properties of WGB joints involving dissimilar alloys and brazing alloys containing boron and silicon have not been studied.

2- Experimental Procedure

The parent metal chosen in the present study was Inconel 738LC. For brazing, BNi-2 was selected as the LTP, while Inconel 718 was used as HTP. 30, 40, and 50 percent LTP was selected to study the effect of mixing ratio. Brazing was carried out in a vacuum furnace at about 5×10-5 torr at 1230 oC for 10 min and was held at 1109 °C for 2 hr. To study the effect of heat treatment, some samples were aged under standard aging conditions of Inconel 738LC (845oC/24hr). A microhardness test was performed using 50 g load. The shear test was carried out on samples with dimensions of 10×10×10 mm3.

3- Results and Discussion

Fig. 1 shows the microstructure of regions and zones in 50% BNi-2. During the brazing cycle, the LTP melts and fills the gap. By reducing the amount of MPD from the liquid due to the diffusion of B and Si to the HTP, the liquid solidifies isothermally.

Fig. 2 shows that Athermally Solidified Region (ASR) has a hardness value of about 1280 HV. This is higher than the hardness values of other regions remarkably. This region contains eutectic structure which is rich in Cr and Mo. Other regions mostly contain γ matrix and hence they have a similar

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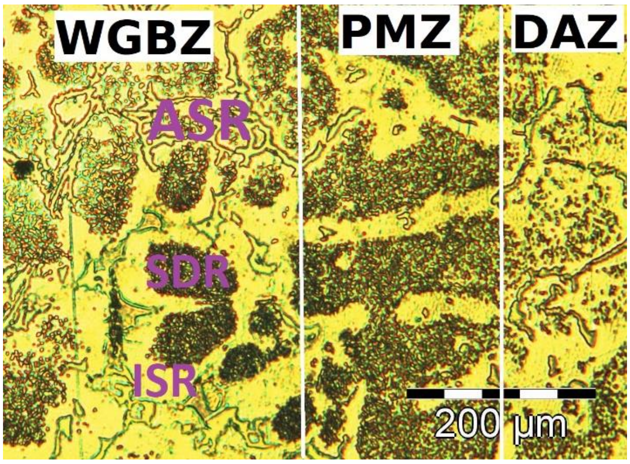

Fig. 1. the microstructure of the sample brazed with 50% LTP

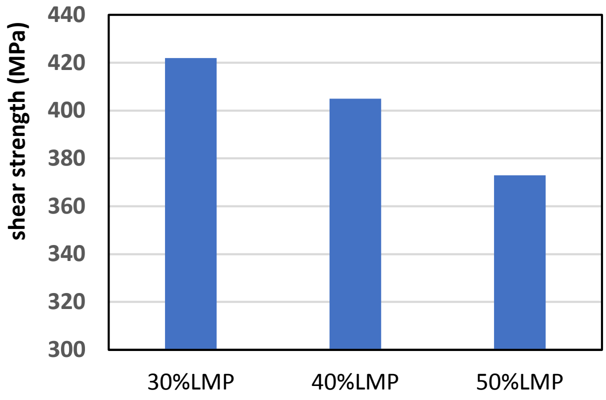

Fig. 3. Shear strength of the joints

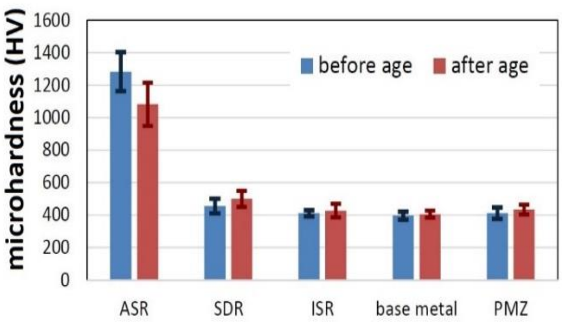

Fig. 2. Microhardness of solidification regions of WGBZ and interface in 50% LMP sample

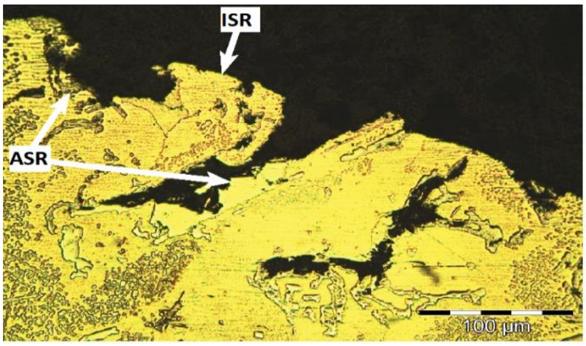

Fig. 4. Fracture surface of 50% LMP sample after aging

hardness. By heat treatment, the hardness does not change noticeably. During brazing, the alloying elements are depleted from the matrix. Thus, during heat treatment, formation of γ" is not possible in the matrix and hence the hardness does not change significantly. In WGBZ, during heat treatment, the hardness of the ASR reduces and the hardness of the Solid Diffusion Region (SDR) increases. Therefore, the hardness of the joint becomes more uniform. During aging, B diffuses from eutectic Cr-rich boride to the matrix and the hardness at the eutectic structure reduces. However, the hardness in this region does not change significantly, because, at aging temperature, Cr23C6 forms due to lower Gibbs free energy and this carbide is very brittle. The diffusion of B from the ASR to the Isothermal Solidification Region (ISR) is very low because the γ matrix is depleted from elements that form borides. Moreover, γ has low solubility of B according to Ni-B binary diagram.

The shear strength of the brazed samples at different mixing ratios is shown in Fig. 3. As can be seen, the strength decreases from 422 MPa to 373 MPa by increasing LTP ratio from 30 to 50 percent. Fig. 4 shows the cross-section of the fractured sample by optical microscope. It can be seen that fracture mostly occurs at the ASR. The brittle structure of this region beside interlink network shape makes this region a suitable location for crack propagation and thus the mechanical properties decrease significantly. By increasing the LTP ratio, the eutectic volume fraction increases and ductile area decreases; thus the fracture strength decreases. However, in all samples, the crack mostly propagates in the ASR due to network shape of this area.

4- Conclusions

During WGB of Inconel 738LC using Inconel 718, the eutectic structure has a detrimental effect on mechanical properties due to brittle structure and interlinked network shape. By heat treatment, the hardness of eutectic decreases slightly. During aging, brittle Cr23C6 forms and hence the hardness after heat treatment does not change significantly.

References

[1] X.W. Wu, R.S. Chandel, H.P. Seow, H. Li, Wide gap brazing of stainless steel to nickel-based superalloy, Journal of Materials Processing Technology, 113(1) (2001) 215-221.

[2] X. Huang, W. Miglietti, Wide Gap Braze Repair of Gas Turbine Blades and Vanes—A Review, Journal of Engineering for Gas Turbines and Power, 134(1) (2011) 010801.

[3] T. Henhoeffer, X. Huang, S. Yandt, P. Au, Fatigue Properties of Narrow and Wide Gap Braze Repaired Joints, Journal of Engineering for Gas Turbines and Power, 133(9) (2011) 092101.

[4] D. McGuire, X. Huang, D. Nagy, W. Chen, Effect of Tungsten Addition on the Nucleation of Borides in Wide Gap Brazed Joint, Journal of Engineering for Gas Turbines and Power, 132(6) (2010) 062101.

[5] Y.H. Kim, K.T. Kim, I.H. Kim, Effect of Mixing Ratio on Mechanical Properties of Wide-Gap Brazed Ni-Based Superalloy with Ni-Si-B Alloy Powder, Key Engineering Materials, 306-308 (2006) 935-940.

[6] G. Wang, Y. Sun, X. Wang, J. Liu, J. Liu, J. Li, J. Yu, Y. Zhou, T. Jin, X. Sun, X. Sun, Microstructure evolution and mechanical behavior of Ni-based single crystal superalloy joint brazed with mixed powder at elevated temperature, Journal of Materials Science & Technology, 33(10) (2017) 1219-1226.