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Vacuum brazing of super-Ni/NiCr laminated composite to Cr18–Ni8 steel with NiCrP filler metal

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ABSTRACT

Vacuum brazing of super-Ni/NiCr laminated composite and Cr18–Ni8 steel was performed using NiCrP filler metal. Microstructure, elemental distribution, microhardness and shear strength were investigated by means of scanning electron microscopy (SEM), energy-dispersive spectroscopy (EDS) and electromechanical universal testing machine. An excellent joint was obtained at 1040 °C for 20 min and the shear strength was as high as 137 MPa. The brazed region was divided into solid solution zone and eutectic zone. Elemental distribution indicated that P mainly concentrated in the eutectic zone in the form of Ni_3P. Ni_2Cr particles precipitated in NiCr base layer under the influence of thermal cycling.

1. Introduction

Super-Ni/NiCr laminated composite is a newly developed material composed of super-Ni cover layer and NiCr base layer. Kim and Yu (1997) reviewed the structure advantages of laminated and sandwiched sheet metals. Super-Ni cover layer is featured with resistance to high-temperature and corrosion. NiCr base layer has some unique properties, such as lower density, higher strength and less cost compared with super-Ni cover layer. Super-Ni/NiCr laminated composite combines the merits of the above two layers, so it is an attractive candidate for the lightweight, high performance structures. And super-Ni/NiCr laminated composite has a vast application prospect in the aerospace, energy and power industries for its special advantages.

Usually, only a part of the component will withstand the effect of high temperature or corrosion. So joining the laminated composite with Cr18–Ni8 stainless steel to form a composite structure will not only make full use of their respective performance advantages but also reduce the component weight. A key to develop the engineering applications of super-Ni/NiCr laminate is welding. Both super-Ni cover layer and NiCr base layer should have good bonding with weld metal. Moreover, it is important to keep the structure integrity of super-Ni/NiCr laminate after welding. The joining of super-Ni/NiCr laminate to Cr18–Ni8 steel was conducted by pulsed current gas tungsten arc welding (PC-GTAW) when the technological parameters were strictly controlled (Xia et al., 2010). The pulsed current in this process produced a finer weld metal structure due to the melt pool agitation (Correa et al., 2009).

Vacuum brazing is a joining technique without flux, using ultra high vacuum condition instead of protective gas atmosphere. Therefore, minimum joint contamination without oxidation can be obtained (Sánchez et al., 2011). Ni-based filler metals provide joints with excellent corrosion resistance and strength at elevated temperature (Severin, 1993). Phosphorus in NiCrP filler metal reduces the melting point and improves the wettability while chromium provides high oxidation resistance (Maciel et al., 2006). Thus, vacuum brazing with NiCrP filler metal was used for joining super-Ni/NiCr laminated composite to Cr18–Ni8 steel in this study. The current investigation attempts to characterize the microstructure, elemental distribution and bond strength of the brazed joints.

2. Experimental procedures

Materials used in this study were super-Ni/NiCr laminated composite and Cr18–Ni8 stainless steel with the thickness of 2.6 mm. The laminated composite was a sandwich plate composed of super-Ni cover layers (0.3 mm) and NiCr base layer (2 mm).

Table 1
Chemical composition of NiCrP filler metal (wt.%).

Ni	Cr	P	Si	B	Ti	Co	C
75.0–78.0	13.0–15.0	9.7–10.5	≤0.1	≤0.02	≤0.05	≤0.10	≤0.06

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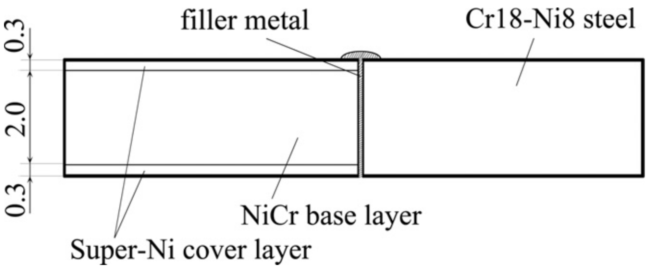

Fig. 1. Schematic diagram of joint assembly (unit in mm).

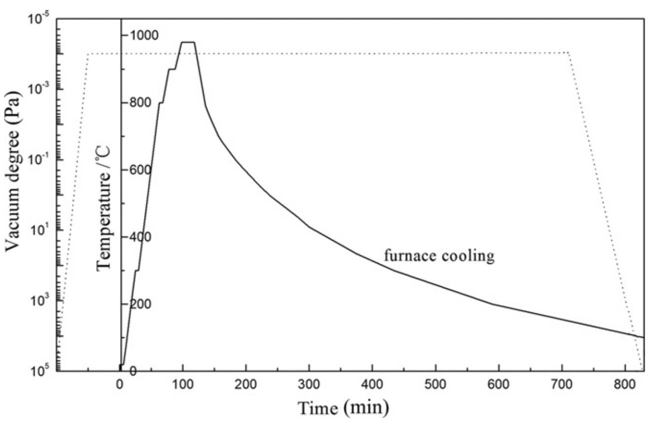

Fig. 2. Technological parameters of brazing cycle.

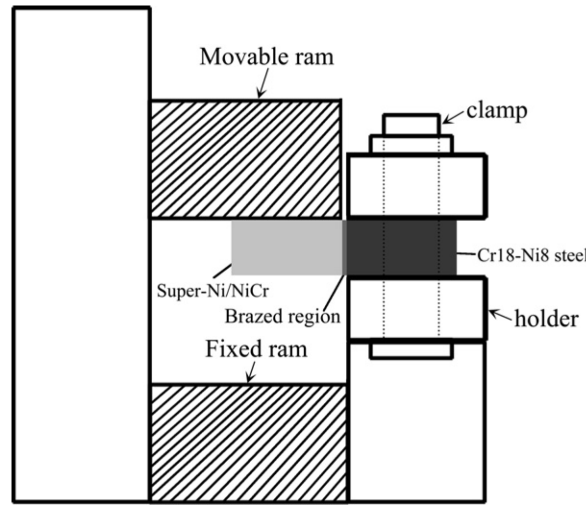

Fig. 3. Clamping fixture for shear strength testing.

NiCrP filler metal used in brazing was in the form of powder and its chemical composition is given in Table 1. The liquidus temperature is about 890 °C. The sizes of super-Ni/NiCr laminate and Cr18–Ni8 steel plate were 30 mm × 10 mm × 2.6 mm. The faying surfaces were prepared by grinding with 360# and 800# SiC paper, cleaning in alcohol. The specimens were arranged in butt joint. Schematic diagram of joint assembly is shown in Fig. 1. An excessive amount of filler metal was used regarding the joint gap volume.

Technological parameters of brazing cycle are illustrated in Fig. 2 (technological parameters: brazing temperature 940 °C, 980 °C, 1040 °C; holding time 20 min; vacuum degree 1.33×10^{-4} Pa). The

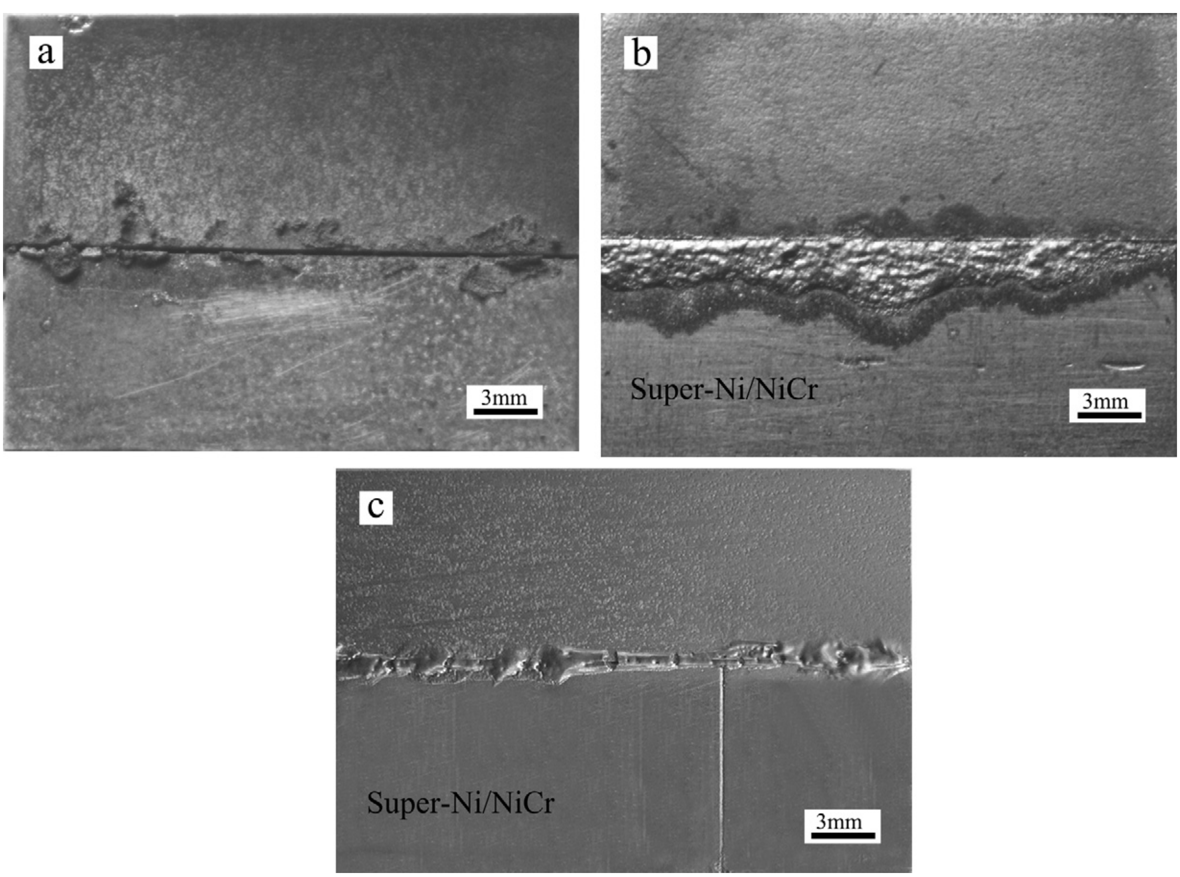

Fig. 4. Macrograph of brazed joint made with NiCrP filler metal at various temperatures: (a) 940 °C, (b) 980 °C and (c) 1040 °C.