STRUCTURE AND MECHANICAL PROPERTIES OF MULTILAYER METAL-INTERMETALLIC COMPOSITES FABRICATED BY EXPLOSIVE WELDING AND ANNEALING

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Abstract. To meet the demand of aerospace industry and anti-armor technique, scholars paid much attention to metallic–intermetallic laminate (MIL) composites to get some materials with higher properties like high performance and low specific gravity. In this work, Ti-$TiAl_3$-Ti multilayer composites were obtained using explosive weld method and annealing. The microstructure of the composites are investigated with optical microscopy, scanning electron microscopy (SEM) and X-ray diffraction (XRD). Microhardness measurement was carried out using a Vickers microindenter testing machine. Quasi-static tensile test and bending test were carried out with universal testing machine.

1. Introduction

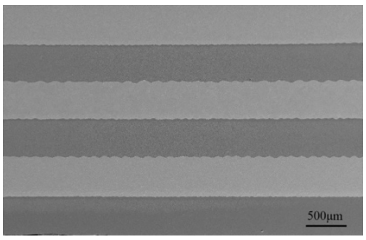
Ti-$TiAl_3$ metallic–intermetallic laminate (MIL) composites have attracted many scholars attention for its advantages of low specific gravity, high strength, heat and corrosion resistance [1]. But many of the multilayer composites are obtained through sintering process which will take more time for the foils to react [2]. Explosive welding is an effective one-step welding method to fabricate multilayer composites. The aim of this work is to study the fabrication of Ti-$TiAl_3$ MIL by explosive welding and following annealing, and its microstructure and mechanical property is also investigated.

2. Experimental procedure

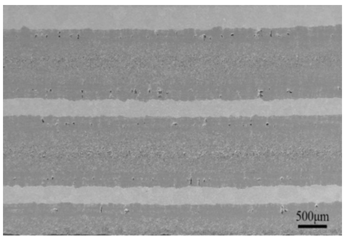
The Ti alloy (grade TA1) and pure Al plates in dimension of 150mm×100mm×0.5mm were used as initial materials in this study. The Ti and Al plates were stacked alternately in a parallel scheme. Two kinds of powder explosives were used; and the detonation velocities are 2.5 km/s and 3.2 km/s, respectively. The as-received composites were annealed at 640 °C for 4 h in the air atmosphere without pressing. The microstructures of the welded samples before and after heat treatment were observed using optical microscopy and scanning electron microscopy. The EDS tests were carried out to characterize the elements distribution and diffusion thickness at the interface between Ti and Al. The phase composition at the interface after heat treatment was analyzed by x-ray diffraction. The mechanical properties of Ti-$TiAl_3$ MIL were measured to estimate the effect of various microstructures and heat treatment. The microhardness distribution from top to bottom was investigated using a Vickers microindenter testing machine, with a loading of 50g and the dwell-time of 15 s. The tensile and three point bending tests were carried out using universal testing machine (INSTRON-5985) with a loading rate of 5mm/min.

3. Results and discussion

The microstructures of the cross-section of composites before and after heat treatment are shown in Fig.1. The morphology shown in Fig.1a presents that Ti-Al multilayers were successfully fabricated with a typical wavy interface [3]. The wavelength and amplitude decreased from the top to bottom and no voids or cracks were observed along the interfaces. Fig.1b shows the cross-section of Ti-$TiAl_3$ MIL, which was obtained from the heat treated Ti-Al multilayers. It shows that the Al layers have been completely consumed during the induced reaction between Ti and Al. Voids were observed at the intermetallic layers. The XRD result shows that only $TiAl_3$ phases were formed at the interface, as shown in Fig. 2.



(a)



(b)

Fig. 1 Microstructure observation images on the cross section of the composite obtained by SEM (a) TA1-Al composite after explosive weld; (b) composite after heat treatment at 640°C for 4h

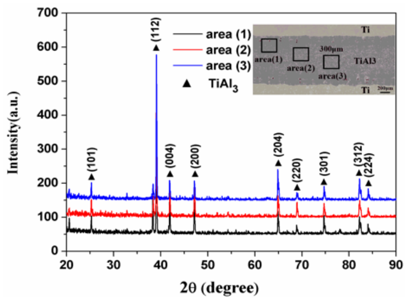


Fig. 2 XRD result of $TiAl_3$ from the top area to the middle area

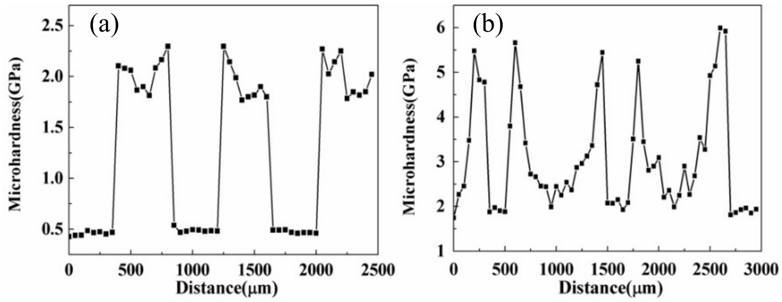


Fig. 3 Microhardness across the layers of the composite (a) TA1-Al composite after explosive weld; (b) composite after heat treatment at 640°C for 4h

The microhardness profiles at cross-section of Ti-Al multilayer was presented in Fig 3a. It shows that the hardness of Al plates throughout the cross-section is constant while the TA1 plates present higher hardness near the interface, which results from the dislocations and fine grains due to the extreme high pressure and severe deformation at the impact surface. The microhardness profiles at cross-section of Ti-$TiAl_3$ MIL, was presented in Fig. 3b. The distribution along each intermetallic layer is not uniform, showing a high hardness of 5.5 GPa at the interface and low one of 2 GPa at the center. The microstructure of intermetallic shows a dense morphology near the interface and voids at the center, which is mainly responsible for the low hardness. It is noticed that the grain size of $TiAl_3$ near the interface is smaller than the one at center; the reason for its formation will be discussed in detail.

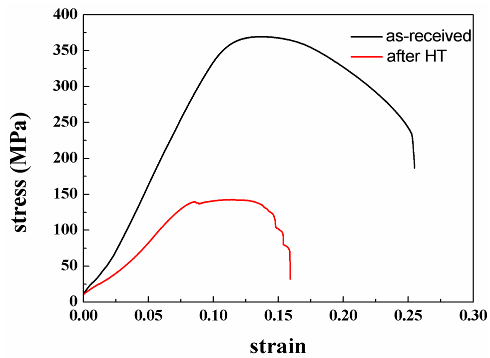


Fig. 4 Strain-stress curve of the sample before and after heat treatment

The tensile test result was presents in Fig.4. It shows that the tensile strength of this Ti-Al composite plate is 369MPa, with an elongation rate of 24%, and after heat treatment the tensile strength and elongation are lower than the sample without annealing.

Conclusions

The Ti-Al multilayer and Ti-$TiAl_3$ MIL were successfully fabricated by explosive welding and subsequent heat treatment. After heat treatment, all the Al were consumed and only TiAl3 were generated. The TiAl3 layers shows a high hardness of 5.5GP and an inhomogeneous structure due to the existence of voids. Tensile strength and elongation of the Ti-$TiAl_3$ MIL are lower than that of as received Ti-Al clad plate.

References

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