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Improving interfacial reaction nonhomogeneity during laser welding–brazing aluminum to titanium

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ABSTRACT

Heterogeneous interfacial reactions were easily found along the Ti/Al interface due to high temperature gradient during laser welding–brazing of Ti/Al dissimilar alloys. To improve the nonhomogeneity, relative uniform energy distribution of laser beam and appropriate groove were attempted. The effects of these attempts on the nonhomogeneity of interfacial reactions were investigated by finite element method (FEM) numerical simulation and experimental validation. The results indicate that the V-shaped groove can make the interface roughly parallel to the isotherm of the temperature field. Moreover, the rectangular spot laser can further improve homogenization of the interfacial reaction along the interface in comparison with circular spot laser. Tensile test results show that the combination of rectangular spot laser welding–brazing and V-shaped groove can effectively control the fracture of Ti/Al joints in the seam in a wide processing parameters window, and the average tensile strength reaches 278 MPa.

1. Introduction

Lightweight hybrid structures of Ti/Al dissimilar alloys have great prospect in aerospace and automotive industry applications [1,2]. It is necessary to join aluminum with titanium to achieve this structural design. However, welding of Al/Ti dissimilar alloys is rather difficult due to their large difference in thermophysical and thermochemical performances. The formation of large amount of brittle intermetallic compounds is a big problem during the joining of Ti/Al. Therefore, diffusion welding [3], brazing [4] and friction stir welding [5–7] were investigated to control the formation of brittle intermetallic compound, but these methods were restricted by vacuum environment or joint configuration.

In recent years, arc welding–brazing [8–10] has been developed for partners with large difference in melting point. Compared with the arc, laser was regarded as desirable heating source for joining dissimilar alloys [11–13], such as high energy density and high heating/cooling velocity. Laser welding–brazing has shown good prospect in application of the joining of Fe/Al dissimilar alloys [14,15]. The thickness of brittle reaction layer can be limited to the level of just a few microns in laser welding–brazing of Al/Ti, which can significantly enhance the mechanical property of the joint [16–21]. Moreover, laser welding–brazing is a very flexible manufacturing technique and it is convenient for industrial application.

However, there is an enormous gradient inside the joint because laser welding–brazing is a local heating, which can result in a series of problems, such as interfacial reaction nonhomogeneity, poor welding process and poor spreadability of brazing filler metal. In order to solve these problems, laser brazing with hot filler wire [22], dual beam laser brazing [23] and diode laser brazing [24] have been developed. Unfortunately, interfacial reaction nonhomogeneity along the interface from the top to the bottom of the joint is still not solved. Interfacial reaction nonhomogeneity may induce the fact that interfacial reaction is overly performs at the top of the joint, whereas it is insufficient at the bottom of the joint. Therefore, this nonhomogeneity is unfavorable for enhancing the controllability of interfacial reaction and the controlling of mechanical properties, especially for butt welding of dissimilar alloys.

The goal of this paper is to improve the nonhomogeneity of interfacial reaction of Al/Ti joint by laser welding–brazing. Both rectangular spot laser beam with relative uniform energy distribution and V-shaped groove with 45° angle were used to decrease the temperature gradient along the interface. The temperature field, distribution of intermetallic compounds, tensile strength and fracture behavior of joints were described.

2. Materials and experimental procedure

Ti–6Al–4V alloy and 5A06 Al alloy plates with a thickness of 1.5 mm were selected as the laser joining materials. 5A06 Al alloy

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