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Short communication

Investigation of joining Al–C–Ti cermets and Ti6Al4V by combustion synthesis

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ABSTRACT

The paper has addressed a route for the welding of titanium alloy (Ti6Al4V) and Al–C–Ti powders by the combustion synthesis (CS) method. Al–C–Ti powders were compressed in the titanium alloy pipes with relative densities of 65%, and then the powder compact was sintered by two reaction mode at the same time as the annulus of titanium alloy and the synthesized product were joined. The paper has studied the effects of reaction mode and Al content in starting powders on the structure and property of the welded joints. And it has also discussed the microstructure of welded joints by laser-induced combustion synthesis (LCS). The mechanical properties of the welding seam have been also tested. The results show that LCS welding has realized fusion welding and the welding seam has good mechanical properties. Furthermore, SEM analysis has indicated that nano-size grains of TiC were formed in the joint layer.

1. Introduction

Titanium carbide is a well-known material with high melting point, extreme hardness, low density, excellent mechanical properties at high temperature as well as resistance to wear, erosion, oxidation and corrosion [1–3]. Joining of TiC cermet to titanium alloy is significant for its high-temperature applications. Traditional fusion weld is difficult for joining due to the mismatch in the based materials properties [4]. Brazing and diffusion bonding are almost low in efficiency, and are mostly carried out in a vacuum or protective atmosphere [5–7]. Clearly, innovative methods are needed for joining of TiC cermet to titanium alloy.

Combustion synthesis (CS) welding is a technology in which exothermic reaction heat serves as welding heat source and reaction product serves as welding agent. CS in powder compact provides rapid bursts of energy and these reactive compacts can act as local heat sources to join materials [8–10]. Since heating is localized to the interface during reactive joining, materials with different coefficients of thermal expansion can be joined by this method. It has been shown that a wide variety of materials including titanium [11], stainless steel [12,13], high-temperature alloy [14], as well as silicon nitride [15] and NiAl/FCD [16] pairs have been successfully joined using this novel technique. According to the different reaction mode, the CS reaction can be divided into two kinds of mode: the CS by heating ignition and thermal explosion mode.

The purpose of this work was to investigate joining of TiC cermet to Ti6Al4V by CS. In particular, the effects of reaction mode and Al content on the structure and property of the welded joints were studied. Then, the mechanical properties of the welding seam were tested.

2. Experimental procedures

The powder, blended in three different composition ratio of Ti, C and Al, is pressed inside Ti6Al4V titanium alloy ring in order to make full use of the quantity of heat released in the reaction of the powder compact [17,18]. To achieve the joint of TiC/Ti6Al4V in uniform ability and integrated structure, two modes (laser-induced combustion synthesis and thermal explosion) are carried out in the experiment.

All joined inner surfaces of Ti6Al4V titanium alloy ring were polished by SiC papers up to grit 1200 and ultrasonically cleaned by acetone prior to reactive joining. High purity Ti, C and Al powders with an average particle size of 45 μm were used as the starting materials. Ti and C powders with an atomic ratio of 1:1 were mixed with 20–40 wt% Al. The powders were dry-mixed thoroughly in a tumbler ball mill and pressed into titanium alloy ring under a pressure of 20 kN to form cylindrical compacts with the diameter of 10 mm and height of 10 mm. Powder compacts were formed with 65% theoretical maximum density of the reactant mixture.

In laser-induced combustion synthesis (LCS) mode, the compacts were ignited at one end by laser irradiation using 5 kW CO_2 laser (HJ-4) with a fixed wavelength of 10.6 μm. The laser processing parameters in this study are selected as follows: laser power 1.2 kW, laser beam diameter 0.2 mm. The LCS process was carried

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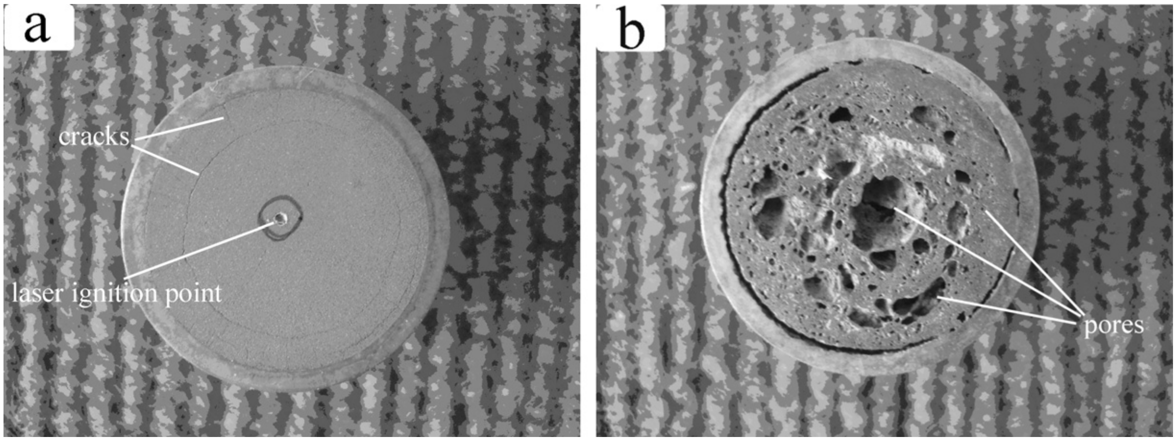

Fig. 1. Combustion synthesis of intermetallic compounds conducted in (a) laser-induced combustion synthesis mode (b) thermal explosion mode.

out in an argon-shielding chamber so as to prevent oxidization. In the thermal explosion mode, the process was carried out in a high temperature vacuum furnace at heating rate 5 K/s. The vacuum was about 8.5×10^{-3} Pa.

The burnt samples were then prepared in accordance with standard procedures for metal samples and etched with 2 vol.% HF + 3 vol.% HCl + 5 vol.% HNO_3 + 90 vol.% H_2O solution for 5–10 s at 25 °C. Microstructures of welded joints were investigated by

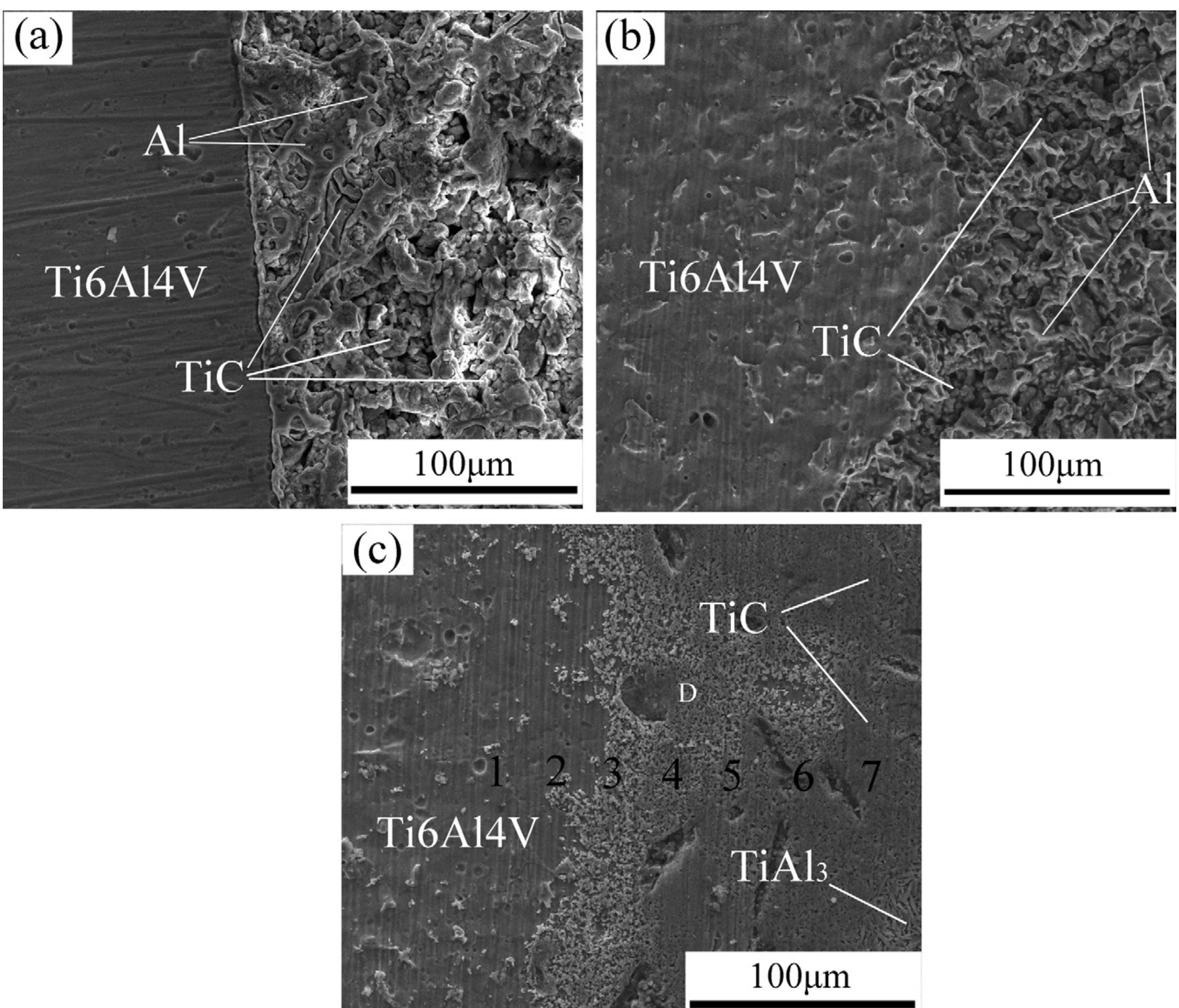

Fig. 2. Microstructure (SEM) of the specimens with different Al content: (a) 20 wt% Al (b) 30 wt% Al (c) 40 wt% Al.