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A Brief Introduction of Dissimilar Welding Techniques for Aluminum Alloys and Steel

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Introduction

The manufacture of lightweight vehicle bodies is an effective way to conserve energy and reduce harmful gas emissions. It is a very popular area of research with the growing problems of energy and environment [1,2]. Al/steel hybrid structures are instrumental in the construction of components with lightweight designs that reduce energy consumption [3]. Low carbon steel DC 04 is the preferred material for great elongation, and 6016 aluminum alloy is known for its high fatigue limit [4]. Therefore, they are primarily used in the automotive industry. Thus, welding of the two metals to construct lightweight vehicle body is very popular in the automotive industry. Generally, traditional fusion welding results in the formation of brittle Fe-Al intermetallic compounds because of the direct contact of melted iron and aluminum. In addition, the high residual stress is also a problem which seriously affect the microstructure and mechanical properties of the joint [5]. The main problem of Al and steel welding is the formation of brittle aluminum-rich intermetallic compounds such as FeAl, Fe_3Al, Fe_2Al_5, and $FeAl_3$ [6]. These formations occur because of the different physical parameters and chemical compositions of DC04 steel and 6016 aluminum alloy. Another problem is the difference of the melting points of DC04 steel and 6016 aluminum alloy which induce the formation of the initial crack at the Fe-Al interface.

To avoid the direct contact of iron and aluminum during the melting welding process, some researchers propose the solid-state connection method such as friction stir welding, diffusion bonding and brazing method to realize the connection of steel and aluminum dissimilar material [7]. It is necessary to replace heavy steel components with light aluminum to meet the goal of lightweight design in vehicle manufacturing. Solid phase joining methods, such as friction stir welding, diffusion bonding, and brazing, were explored to obtain a sound joint between Al and steel. Watanabe et al. [8] obtained a visually acceptable friction stir-welded Al/steel dissimilar joint with a tensile strength as high as close to 90% of the Al base metal. However, the joint configurations welded with this technology were mainly limited to simple geometries, such as butt or overlapping. For diffusion bonding, the connection of Al to steel was achieved by mutual atomic diffusion under the effect of pressure at high temperatures. Howlader et al. [9] joined an Al bar to a steel sheet by diffusion bonding, achieving a joint strength of 60MPa. Nevertheless, the required pressure and high temperature would impose an extra cost on the practical industrial application. Zhang et al. [10] obtained a brazed Al/steel dissimilar joint with the highest shear strength of 260 MPa under a heating temperature of 850°C and heating duration of 720 s. Because brazing was performed in a furnace, the joining efficiency was relatively low, and the brazed workpiece had small dimensions. In fact, butt welding of Ti alloy to steel was convenient in technology. New laser welding methods have been increasingly utilized in industrial manufacturing for its great control of the intermetallic formation. It provides new connection methods for dissimilar materials [11]. Compared to other welding processes, laser beams can be precisely controlled to supply high-energy welding power within a narrow heat zone and with a high depth-to-width ratio. Therefore, laser was selected as the welding heat source of Al and steel.

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