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Gap-free fibre laser welding of Zn-coated steel on Al alloy for light-weight automotive applications

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ABSTRACT

As a result of new policies related to global warming announced by the European Union, avoiding unnecessary energy waste and reducing environmental pollution levels are becoming a major issue in the automotive industry. Accordingly, the lap welding of Zn-coated steels process, which is commonly used for producing car doors, has been gradually developed to lap welding of Zn-coated steel to light materials, such as Al alloy, Mg alloy and composite materials, in order to effectively reduce the vehicle weight. In certain part of car manufacture, organic glues are used to temporally join the Zn-coated steels and Al alloys before permanent welding takes place. The stability of such temporary joining by glues needs improving. Laser "stitching" or low strength welding could be considered as an alternative. However, challenges exist in joining Zn-coated steel on Al alloy by laser welding, due to significant differences of material properties between the two welding materials. Porosity, spatter and intermetallic brittle phases are readily produced in the weld. In this study, the effects of welding speed, laser power, number of the welding passes and type of shielding gas in gap-free welding of Zn-coated steel on Al alloy were investigated using a 1 kW single mode continuous wave fibre laser. Results show that a weld with higher shear strengths in the laser stitching application and less intermetallic phases could be obtained when nitrogen gas was used as the shielding gas. The corrosion resistance and the surface finish of the weld could be improved in double pass welding, especially when argon gas was used as the shielding gas.

1. Introduction

Laser welding has been widely used in industry owing to its benefits of high welding speed, high precision, reliability, high efficiency and high productivity. Among commercial laser systems, high power fibre lasers with excellent beam quality and high brightness have attracted increasing attention over the last few years. For certain applications, advantages of fibre lasers in energy, speed and processing quality have been demonstrated over the conventional CO_2 and Nd:YAG lasers [1,2]. High power fibre lasers have been successfully applied in the medical, military and telecommunications industries in the past few years [3–5].

Although laser welding of dissimilar materials is considered as a relatively complicated process in comparison with laser welding of similar materials, the demand for dissimilar materials welding has increased rapidly in industry due to the requirement for improving the flexibility in designing new generation products. The main issues with welding of dissimilar materials are differences of material properties leading to large stresses and the formation of intermetallic brittle phases that readily occur within the weld for certain alloys. Not only the presence of porosity in the weld, but the formation of intermetallic brittle phases in the laser welding of dissimilar materials process can induce the cracking in the weld and therefore reduce the weld strength [6]. Controlling the diffusion process was proposed as one approach to overcome these problems [7]. For this reason, laser welding is considered as having a potential in joining dissimilar materials because its high heating and cooling rates could restrict the formation of intermetallic phases [8].

Most research work associated with laser welding of automotive materials are relevant to lap welding of Zn-coated steels [9–12] or un-coated steel on Al alloys [8,13–21]. Hardly any work has been found on laser welding of Zn-coated steel on Al alloy without using a filler material. The main issues in laser welding of Zn-coated steel on Al alloy are the formation of porosity, spatter and intermetallic brittle phases [22,23]. An unstable melt pool resulting from Zn vaporisation readily occurs in laser welding of Zn-coated steel on Al alloy because the boiling point of Zn (907 °C) is lower than the melting point of Fe (1538 °C) and the boiling point of Al (2520 °C). Besides, intermetallic phases can

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