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Laser welding of NiTi shape memory alloy: Comparison of the similar and dissimilar joints to AISI 304 stainless steel

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ABSTRACT

The unique properties of NiTi alloy, such as its shape memory effect, super-elasticity and biocompatibility, make it ideal material for various applications such as aerospace, micro-electronics and medical device. In order to meet the requirement of increasing applications, great attention has been given to joining of this material to itself and to other materials during past few years. Laser welding has been known as a suitable joining technique for NiTi shape memory alloy. Hence, in this work, a comparative study on laser welding of NiTi wire to itself and to AISI 304 austenitic stainless steel wire has been made. Microstructures, mechanical properties and fracture morphologies of the laser joints were investigated using optical microscopy, scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), X-ray diffraction analysis (XRD), Vickers microhardness ($HV_{0.2}$) and tensile testing techniques. The results showed that the NiTi–NiTi laser joint reached about 63% of the ultimate tensile strength of the as-received NiTi wire (i.e. 835 MPa) with rupture strain of about 16%. This joint also enabled the possibility to benefit from the pseudo-elastic properties of the NiTi component. However, tensile strength and ductility decreased significantly after dissimilar laser welding of NiTi to stainless steel due to the formation of brittle intermetallic compounds in the weld zone during laser welding. Therefore, a suitable modification process is required for improvement of the joint properties of the dissimilar welded wires.
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1. Introduction

Owing to unique properties like super-elasticity, shape memory effect and biocompatibility, nickel titanium (NiTi) alloy is one of the most popular and new smart materials used in many fields such as aviation and space-flight, ocean development, mechanic-electronic and medical devices [1–3]. However, successful applications of any novel material not only hinge on its intrinsic characteristics, but also depends on problem solving and development of processing technologies. As a result, the usage of this material may be limited to specific conditions unless joining of this material to itself and to other materials is facilitated. The possibility of joining this material would expand its applicability to many new circumstances. However, joining of NiTi has been considered as a difficult task because of its high sensitivity to the thermo-mechanical treatment and the deteriorations of super-elasticity and shape memory effect in the weld zone as compared with the base metal due to metallurgical changes. Falvo et al. [4] reported a marked reduction in mechanical and shape memory performance of the NiTi welded joint. Same results were presented by Chan et al. [5] in a later study that showed the onset of transformation temperatures of the weld shifted to the very negative side as compared with the as-received NiTi and also a reduction in pseudo-elastic property in the NiTi welded foil. In recent years, great attention has been given to the influence of the joining method and procedure on microstructure and properties of similar NiTi alloys joints, but joining of NiTi to other materials has not sufficiently been considered [4–7]. Stainless steels (SSs) are one of the dominant materials which are widely used in different applications especially in medical devices owing to their mechanical properties, workability, low cost and corrosion resistance [8]. Therefore, joining of NiTi to stainless steel would be desirable for widening of its applications. It should be noted that, making dissimilar joints between these materials is a rather difficult procedure due to the large differences in their physical and chemical properties. It was shown that the brittle intermetallic phases such as $TiFe_2$ made the resulting weld equally brittle [9]. Li et al. [10,11] showed that laser welding using Ni interlayer and Co filler metal could greatly improve the mechanical performance of TiNi–SS fusion welds. Recently, the particular behavior of cracks, which nucleate and propagate in dissimilar welds, was observed in

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