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Microstructure and mechanical properties of resistance-welded NiTi/stainless steel joints

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Abstract

Resistance welding was employed to join NiTi and stainless steel (SS), with the aim to fabricate a NiTi/stainless steel joint for biomedical applications. The effects of welding current and post-welding cold drawing with 30% area reduction on the joint microstructures and mechanical properties were investigated. At a welding current of 40 A, a NiTi/SS joint with a reaction layer of several microns in size was obtained. The tensile strength of this joint reached 440 MPa, with 7.9% rupture elongation and a fracture on the NiTi side that occurred via micro-void coalescence mechanism. Good plasticity and bending performance of the joint were verified by the bending test. After cold drawing, the microstructures in the heat-affected zones (HAZs) were refined and the microhardness in the HAZs increased. The tensile strength of the joint increased to 830 MPa, with 6.2% elongation. The 40-μm-thick weld obtained at the welding current of 45 A consisted of a reaction layer and a NiTi molten zone. Local embrittlement occurred near the NiTi fusion line owing to grain coarsening, the existence of re-solidified grain boundaries in the HAZ and eutectics in the molten zone. The tensile strength of the joint was established as 340 MPa, with 5.8% rupture elongation and a cleavage-mediated fracture on the NiTi side. This type of joint could not be drawn as a result of its reduced ductility.

Keywords: NiTi; Stainless steel; Resistance welding; Microstructure

1. Introduction

In biomedical sphere, joining of NiTi and stainless steel (SS) enables the fabrication of composite guidewire, venous catheter and orthodontic arch wire. Reliable joining techniques that can prepare NiTi/SS joints with good mechanical properties, especially bending performance, are thus of great importance. The joining methods reported currently, however, are not satisfactory.

The brittle nature of the NiTi/stainless steel (SS) joint was described for the first time by Eijk et al. (2003) in a preliminary study on plasma welding of NiTi and SS. Li et al. (2005) employed capacitor discharge upset welding to join NiTi and SS. The authors reported that while both of the base metals melted, the liquid phase was not removed from the NiTi/SS interface completely, thus resulting in low strength (150 MPa). Fukumoto et al. (2010) used friction welding to prepare NiTi/SS joints, demonstrating that welding without Ni interlayer results in the formation of brittle Fe_2Ti phase at the weld interface. This outcome suggested that the solid-state bonding over several seconds failed to inhibit the formation of brittle phases. Gugel et al. (2008) reported the mechanical behaviour of laser-welded NiTi/SS joints, with strengths of up to 623 MPa, but failed to provide any microstructural information.

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