

Friction Stir Welding of Austenitic NiTi Shape Memory Alloys

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Abstract

This prospective work aims to evaluate the weldability of thin sheets of NiTi shape memory alloy by friction stir welding process. The phase transformation temperature was determined by ERT, the mechanical properties were evaluated by Vickers microhardness and tensile test. The fracture surface was investigated by SEM. The welded joints remained in the austenitic state after welding, achieved ultimate tensile strength of 700 MPa and 13

Index terms— NITI shape memory alloy, friction stir welding process, mechanical properties.

1 Introduction

NiTi shape memory alloys (SMA) are a unique class of metals that show non-diffusional phase transformation in the solid state induced by temperature changes and/or mechanical loads [1][2][3], differently of conventional engineering metals. The shape memory properties combined with the good corrosion resistance and biocompatibility of the NiTi shape memory alloys make them high attractive to smart engineering applications, such as Micro-Electro-Mechanical-Systems (MEMS). On the other hand, these alloys present great problems of machining and conformability that limit their applications. Thus welding techniques appears as a viable technological alternative to obtain complex geometry components made of shape memory alloys [4,5].

Joining NiTi SMA by fusion welding processes is a technological challenge due to the formation of fragile intermetallic compounds, which leads to a intense loss of tenacity in the welded joints, due to solidification cracks associated with the dendritic microstructure of the weld metal. In addition, precipitation of deleterious phases in the thermally affected zone and in the weld metal can result in severe reduction of mechanical resistance [6][7][8][9][10]. Solid state welding processes, like friction stir welding (FSW), are a technical alternative to join these alloys because no precipitation of brittle intermetallic compounds occurs [11].

2 II.

3 Materials and Methods

In this paper an austenitic NiTi shape memory thin sheet was used. Table ?? shows the chemical composition of the sheet, according to Sunrise Titanium Technology Co. Ltd.

Tab.1: Chemical composition of thin sheets (wy.%)Ti (%) Ni (%)
44,09 55,91

After previous studies, the FSW process parameters used was 180 mm/min welding travel speed and rotation of tool tip of 1500 rpm. A 4-axis HOMI machining center was used to fabricate the welded joints. The tool shoulder diameter is 17 mm and the tip diameter is 2mm.

The phase transformation temperature was determined by variation of the electrical resistance as a function of the temperature (ERT) [2] with an average heating or cooling rate of 4°C/min cooling from 100°C to -60°C and then heating to 100°C. The microhardness measurements were performed using a microindenter model FM-700 from Future Tech, applying a load of 50 gf for 15 seconds with a distance between the indentations approximately of 200 μm. Tensile tests were performed on an MTS 810 testing machine with a displacement rate of 0.05mm/min at room temperature. The fracture surfaces were observed by scanning electron microscopy (SEM) using a TESCAN microscope, VEGA 3 SBH model.

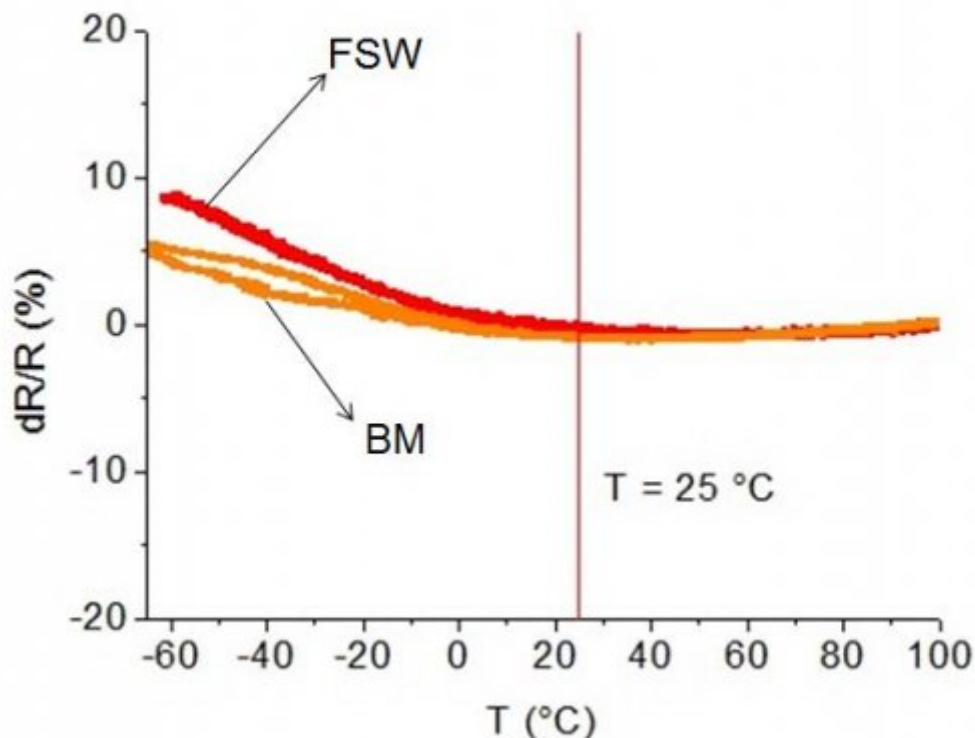
4 III.

45 5 Results and Discussion

46 Fig. 1 shows the percentage variation curves of the electrical resistance as a function of temperature (ERT),
 47 using the temperature of 100°C as the austenitic reference state. The profile of the curve in the friction stir
 48 welded condition indicates, qualitatively, that the material will be in the austenitic state at room temperature
 49 (about 25°C). It is only possible to identify a slight inflection of the ERT curve, indicating possible temperature
 50 of beginning of the R phase transformation (Rs) from phase. This behavior is similar to that of NiTi SMA alloys
 51 that have been subjected to cold or hot rolling, which phase transformation are blocked due to the characteristic
 52 hardening of this manufacturing process [2,11]. The R phase is a transition state between the austenitic and
 53 martensitic phases of NiTi SMA characterized by a trigonal crystalline structure with rhombohedral distortion
 54 [12]. Fig. 2 shows the Vickers microhardness profile of the welded joint. It is possible to verify that the hardness in
 55 the stir zone is higher than the base metal, due to the mechanical work of the FSW process, which promotes grain
 56 refining and consequent increase of resistance [11]. In Fig. 3 it is possible to observe the stress-strain behavior
 57 of NiTi SMA welded joint. The welded joint showed satisfactory mechanical resistance [13,14,15], reaching a
 58 ultimate tensile strength of 700 MPa and 13% strain, higher than those observed by other authors that utilized
 59 fusion welding processes [5,7,16,18,19,20,21,[22][23][24][25][26] and equal to those who used solid state welding
 60 processes [11,27] except Shinoda et al [28].

61 6 Conclusion

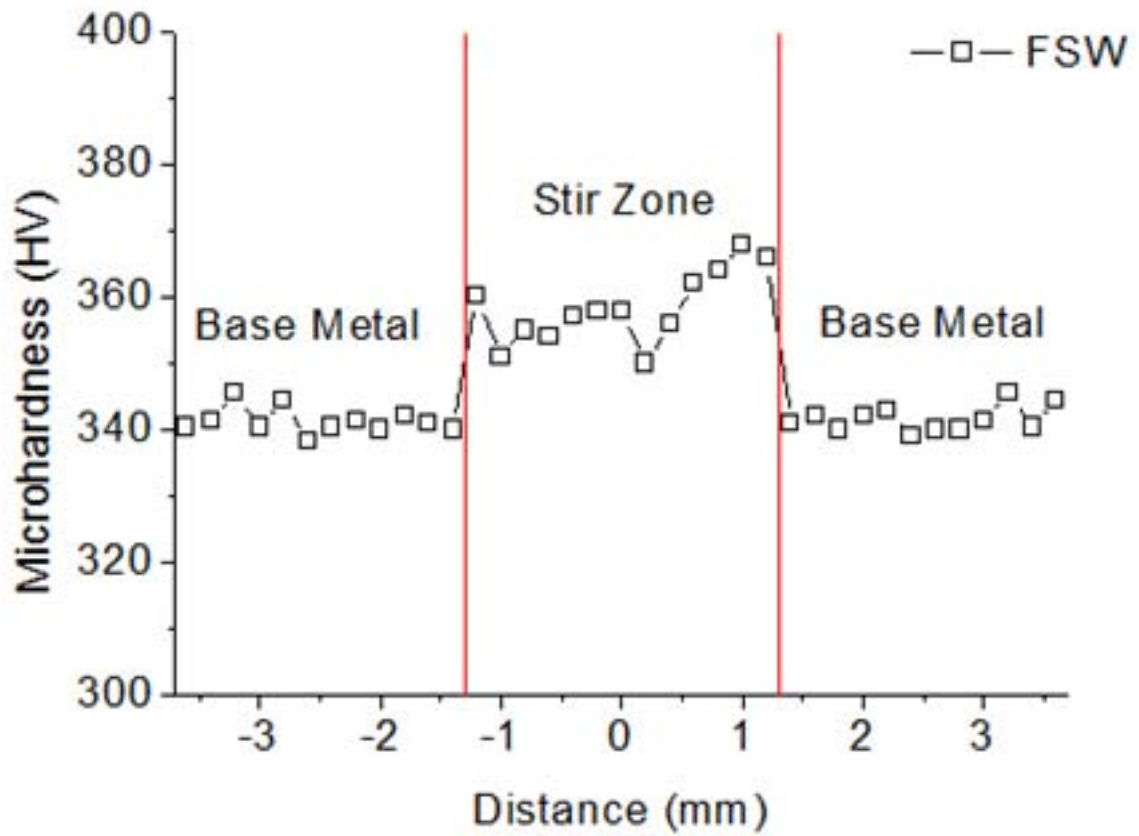
62 In this paper thin sheets of NiTi SMA were welded by FSW process. The welded joint obtained by this process
 63 presented good mechanical properties and it was capable of achieve 700 MPa ultimate tensile strength and 13%
 64 strain. The welded joint remained in the austenitic phase state after welding, differently of fusion welding process.
 65 The stress induced martensite occurs at 450 MPa in the welded condition, 50 MPa above the base metal. The
 66 increase in mechanical resistance in detriment of ductility observed indicates that hardening occurs in function
 of the mechanical work of the friction stir welding process. ¹



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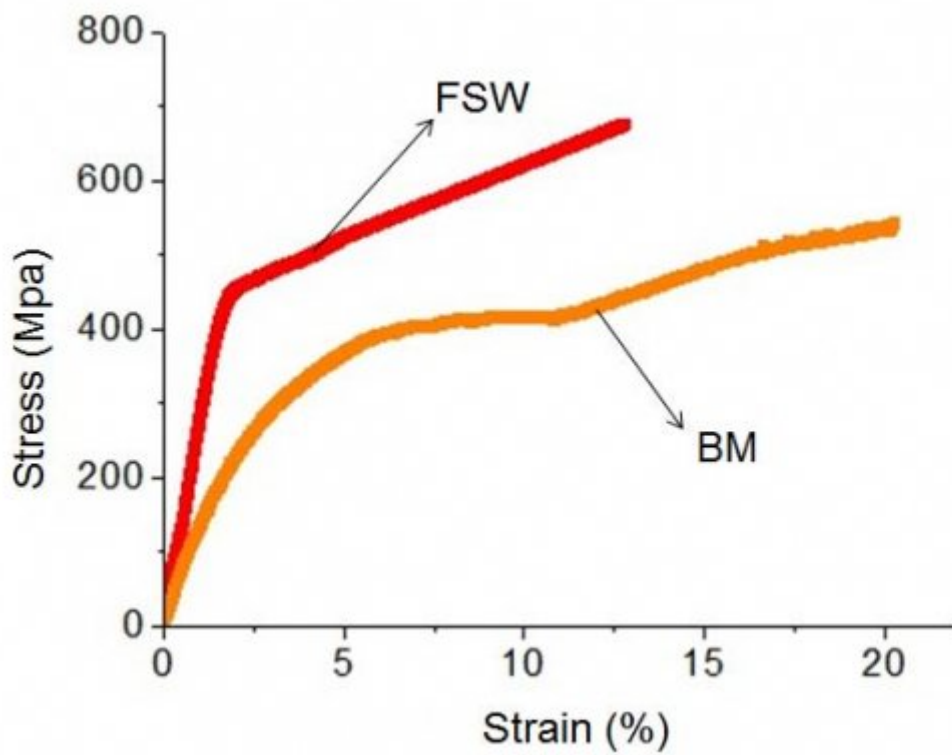
Figure 1: Fig. 1 :

67



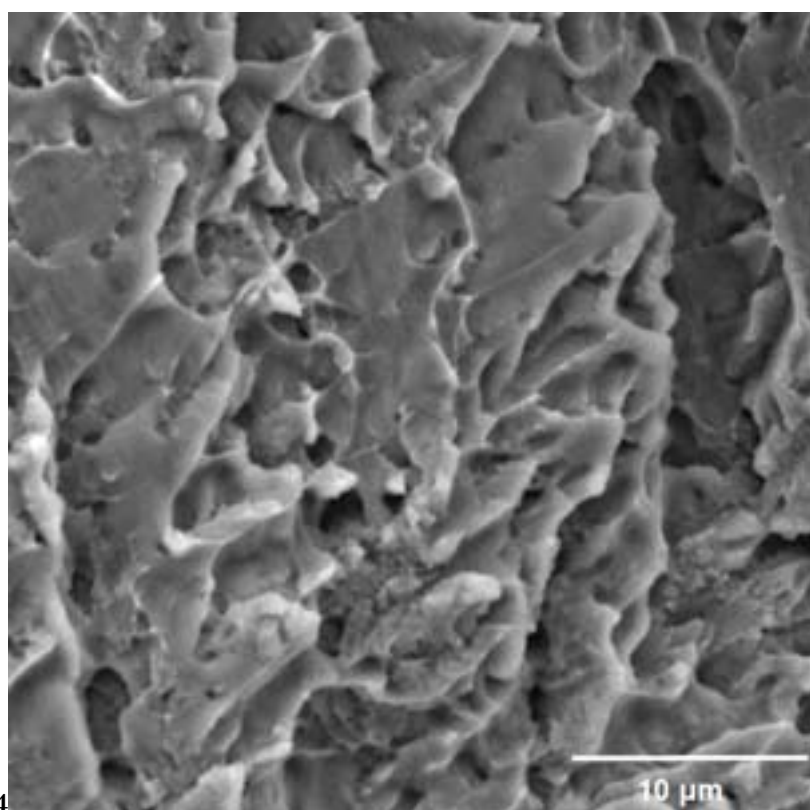
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Figure 2: Fig. 2 :



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Figure 3: Fig. 3 :



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Figure 4: Fig. 4 :

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