Global Journal of Researches in Engineering: J
General Engineering
Volume 17 Issue 1 Version 1.0 Year 2017
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Friction Stir Welding of Austenitic NiTi Shape Memory Alloys

Lima, J. S., Neto, A. C. W. & Melo, R. H. F
Federal Institute of Education, Science and Technology

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 austenitc state after welding, achieved ultimate tensile strength of 700 MPa and 13% strain the main fracture mode was ductile.

Keywords: NITI shape memory alloy, friction stir welding process, mechanical properties.

GJRE-F Classification: FOR Code: 291899

FRICTIONSTIRWELDINGOFAUSTENITICNITISHAPEMEMORYALLOYS

Strictly as per the compliance and regulations of :

Friction Stir Welding of Austenitic NiTi Shape Memory Alloys

Lima, J. S. [α] , Neto, A. C. W. [σ] & Melo, R. H. F. [ρ]

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 austenitc state after welding, achieved ultimate tensile strength of 700 MPa and 13% strain the main fracture mode was ductile.**

Keywords: NITI shape memory alloy, friction stir welding process, mechanical properties.

I. 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 [1-3], 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 [6-10]. 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].

Author α: bachelor's in Industrial Automation.
Author σ: Mechanical Engineer. Occupational Hygienist.
Author ρ: Mechanical Engineer. Occupational Hygienist. Professor of Materials Science and Manufacturing Process. Electromechanics Department. Federal Institute of Education, Science and Technology.
e-mail: raphael.melo@ifpb.edu.br

II. Materials and Methods

In this paper an austentic NiTi shape memory thin sheet was used. Table 1 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.

III. Results and Discussion

Fig.1 shows the percentage variation curves of the electrical resistance as a function of temperature (ERT), using the temperature of 100°C as the austenitic reference state. The profile of the curve in the friction stir welded condition indicates, qualitatively, that the material will be in the austenitic state at room temperature (about 25°C). It is only possible to identify a slight inflection of the ERT curve, indicating possible temperature of beginning of the R phase transformation (Rs) from austenite phase. This behavior is similar to that of NiTi SMA alloys that have been subjected to cold or hot rolling, which phase transformation are blocked due to the characteristic hardening of this manufacturing process [2, 11]. The R phase is a transition state

Global Journal of Researches in Engineering (J) Volume XVII Issue I Version I Year 2017

between the austenitic and martensitic phases of NiTi SMA characterized by a trigonal crystalline structure with rhombohedral distortion [12].

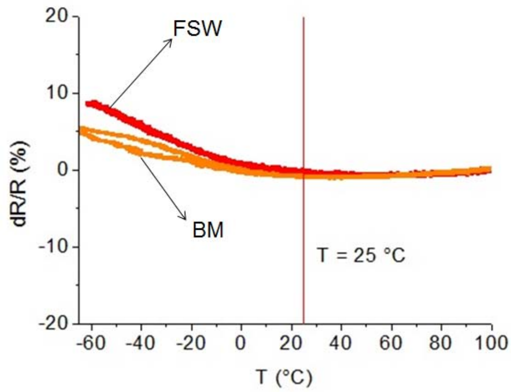

Fig.1: Variation of electrical resistance as a function of temperature (ERT) in NiTi FSW condition and the base metal (BM)

Fig.2 shows the Vickers microhardness profile of the welded joint. It is possible to verify that the hardness in the stir zone is higher than the base metal, due to the mechanical work of the FSW process, which promotes grain refining and consequent increase of resistance [11].

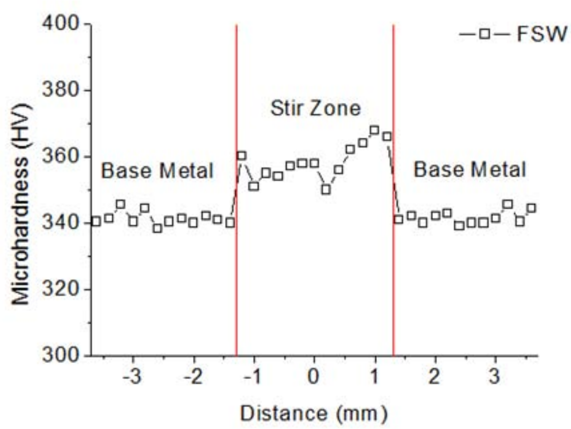

Fig.2: Vickers microhardness profile of the welded joint

In Fig. 3 it is possible to observe the stress-strain behavior of NiTi SMA welded joint. The welded joint showed satisfactory mechanical resistance [13, 14, 15], reaching a ultimate tensile strength of 700 MPa and 13% strain, higher than those observed by other authors that utilized fusion welding processes [5, 7, 16, 18, 19, 20, 21, 22-26] and equal to those who used solid state welding processes [11, 27] except Shinoda et al [28].

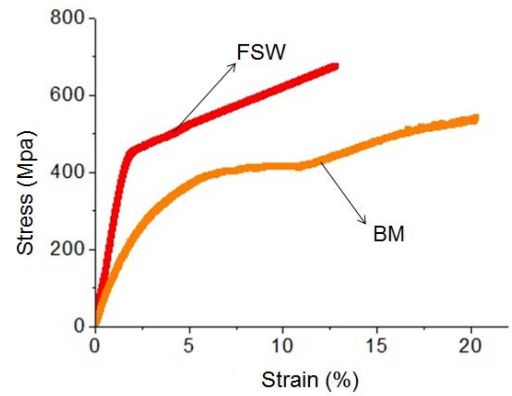

Fig.3: Stress-strain behavior for NiTi SMA friction stir welded joint

Fig.4 shows the aspect of the fracture surface of the welded joint. The fracture occurred near the center of the stir zone presenting ductile characteristics, such as dimples due to large deformations achieved.

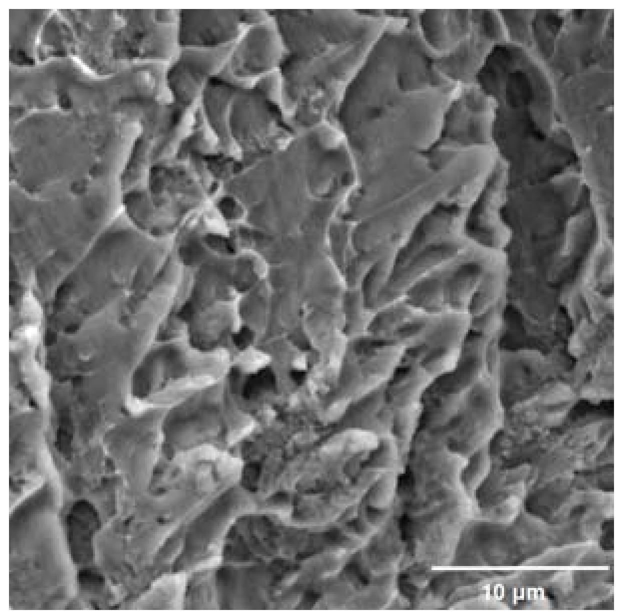

Fig.4: Fracture surface of the friction stir welded joint

IV. Conclusion

In this paper thin sheets of NiTi SMA were welded by FSW process. The welded joint obtained by this process presented good mechanical properties and it was capable of achieve 700 MPa ultimate tensile strength and 13% strain. The welded joint remained in the austenitc phase state after welding, differently of fusion welding process. The stress induced martensite occurs at 450 MPa in the welded condition, 50 MPa above the base metal. The 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.

Global Journal of Researches in Engineering (J) Volume XVII Issue I Version I Year 2017

References Références Referencias

1. Lagoudas DC. Shape Memory Alloys: Modeling and Engineering Applications 2008 Texas: Springer.
2. Otsuka K, Wayman CM. Shape Memory Materials 1998 Cambridge University Press, Cambridge, UK.
3. Jani JM, Leary M, Subic A, Gibson MA.. Mater Des 2014; 56:1078-113.
4. Rao A, Srinivasa AR, Reddy JN. Design of Shape Memory Alloys (SMA) Actuators 2012 Texas: Springer.
5. Gugel H, Theisen W. Microstructural investigations of laser welded dissimilar nickeltitanium-steel joints. In: Proceedings 8th European symposium on martensitic transformations 2009; 7–11.
6. Van der Eijk C, Fostervoll H, Sallom Z, Akselsen OM. Plasma Welding of NiTi to NiTi, Stainless Steel and Hastelloy C276, Int. Conf. Joining of Specialty Materials VI Program, ASM Materials Solutions Conf. & Exposition. 2003 Pittsburgh, PA, USA.
7. Falvo A, Furgiuele FM, Maletta C. Mat Sci Eng A 2005; 412:235-40.
8. Ikai A, Kimura K, Tobush H. Journal of Intelligent Material Systems and Structures 1996; 7:646-55.
9. Gong WH, Chen YH, Ke LM. Trans Nonferrous Met Soc China 2011; 21:2044-8.
10. Vondrous P, Kolarik L, Kolarikova M. Annals of DAAAM for 2012 & Proceedings of the 23rd International DAAAM Symposium. Vienna 2012; 1039-42.
11. London B, Fino J, Pelton A R, Mahoney M. Friction Stir Processing of Nitinol. Friction Stir Welding and Processing III. Warrendale 2005; 67-74.
12. Lukás P, Sittner P, Lugovoy D, Neov D, Ceretti M. Appl. Phys. A. 2002, 74:1121-23.
13. Amorim, Fernando Andrade et al. Avaliação das Propriedades Termomecânicas de Fios de Liga com Memória de Forma NiTi Soldados por Pulsos de Micro TIG. Soldag. insp., Dez 2015, vol.20, no.4, p.423-433.
14. Mirshekari GR, Saatchi A, Kermanpur A, Sandrnezhaad SK. Optics & Laser Technology; 54:151-8, 2013.
15. Oliveira JP, Barbosa D, Braz Fernandes FM, Miranda RM. Tungsten Inert Gas (TIG) welding of Ni-Rich NiTi plates: functional behavior. Smart Materials and Structures, v 25, p 1-7.
16. Van der Eijk C, Fostervoll H, Sallom Z, Akselsen OM. Plasma Welding of NiTi to NiTi, Stainless Steel and Hastelloy C276, Int. Conf. Joining of Specialty Materials VI Program, ASM Materials Solutions Conf. & Exposition. 2003 Pittsburgh, PA, USA.
17. Chan CW, Man HC, Cheng, FT. Mat Sci Eng A 2012; 559;407-15.
18. Zheng, Y, Jiang, F, Li, L, Yang, H, Liu, Y. Effect of ageing treatment on the transformation behavior of Ti-50.9 at.% Ni alloy. Acta Materialia, v. 56, 736-745, 2008.
19. Vondrous P, Kolarik L, Kolarikova M. Annals of DAAAM for 2012 & Proceedings of the 23rd International DAAAM Symposium. Vienna 2012; 1039-42.
20. Zeng, Z, Yang, M, Oliveira, JP, Song, D, Peng, B. Laser welding of NiTi shape memory alloy wires and tubes for multi-functional design applications, Smart Materials and Structures, v 25, 2016.
21. Vieira, L. M. A. Laser welding of Shape Memory Alloys. Dissertação de mestrado submetida a Lisboa, Universidade Nova de Lisboa, Portugal, 2010.
22. Schlossmacher, P, Haas, T, Schussler, A. Laser welding of Ni-rich TiNi shape memory alloy: mechanical behavior. Journal de Phsyique 4, v 7, p 251-256, 1997.
23. Song YG, Li WS, Li L, Zheng YF. Mat. Let. 2008; 62:2325-28.
24. Sevilla, P, Martorell, F, Libenson, C, Planell, J, Gil, F. Laser welding of NiTi orthodontic archwires for selective force application, Journal of Materials Science: Materials Medical, v 19, p 525-529, 2008.
25. Khan MI, Panda SK, Zhou Y. Mater T Jim 49:2702-8, 2008.
26. Zhao XK, Lan L, Sun H, Haung JH, Zhang, H, Wang, Y. Materials Letters; 64:628-31, 2010.
27. Meir S, Gordon S, Karsh M, Wiezman A, Ayers R, Olson DL. Review of Progress in Quantitative Nondestructive Evaluation, v. 30, 2011.
28. Shinoda T, Tsuchiya T, Takahashi H. Transactions of the Japan Welding Society, v. 22, 1991.