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STUDY PROPERTIES ON FATIGUE PROPERTIES OF WELDED JOINTS WITH FERROUS ALLOYS AND SEM APPORACH

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ABSTRACT:

The construction industry has for many years shown interest in opportunities offered by the welding of dissimilar metals. The need for appropriate and effective techniques has increased in recent decades with efforts to meet wide disparities constraints in services. Fatigue design of welded structures is primarily based on a nominal stress; hot spot stress methods or local approaches each having several limitations when coupled with finite element modeling. An alternative recent structural stress definition is discussed and implemented in a post-processor. It provides an effective means for the direct coupling of finite element results to the fatigue assessment of welded joints in complex structures. The applications presented in this work confirm the main features of the method: mesh-insensitivity, accurate crack location and life to failure predictions.

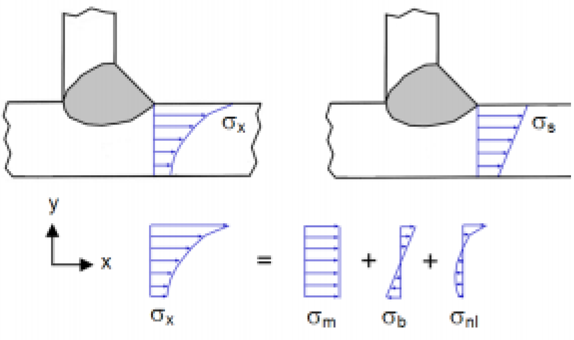
Keywords: *Welded joints; Structural stress; Fatigue assessment, ferrous alloys*

1.0 Introduction:

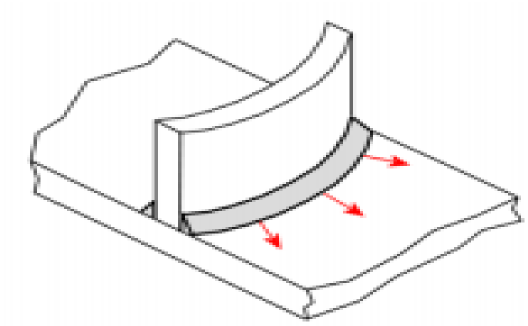
Dissimilar weld is attracting increasing attention because it can take advantage of specific attributes of each material to enhance the performance of a product or introduce new functionalities. They are applied in various fields such as thermal power station, nuclear industries, automobile, aerospace, etc. A number of dissimilar joints with aluminum, titanium, ferrous and many kinds of materials have been successfully formed by various methods from fusion welding to friction welding process. With high strength to weight ratio, corrosion resistance, and good strength sustainability at high temperatures, titanium alloys are important in aerospace applications. As design complexity and service demands increase, dissimilar welds with titanium alloys become a particular interest in the field of aerospace industry. The principal failure mode in welds is fatigue cracking, therefore many efforts have been put in the study of the strength of welded joints and in the definition of design guidelines. As the finite element method has become the favorite tool in structural analysis, there is an unquestionable need for a direct connection of the fatigue assessment approaches to the simulations. In this work, after a brief review of some well established techniques in Section a novel approach developed at Battelle Institute, and recently entered in the ASME standards, is described in Sections. Some applications to experimental tests are then presented in Section. This method allows a relaxation of some finite element modeling difficulties, mainly the mesh sensitivity, and grants the possibility of using alternatively solid and shell elements to model welded joints. The results of the FE analysis are then used in combination to a fatigue master curve that consolidates a large number of welded joint configurations. The structural stress approach is suited for the assessment of fatigue failures occurring at the weld toes;

accordingly it is the stress component normal to the crack plane, i.e. normal to the weld line that is the driver for crack propagation.

It must be emphasized that the finite element simulations have to be linear elastic therefore a fatigue assessment of the welded joints in the components can be a precious additional outcome of a standard stress analysis. The only specific requirement concerns the modeling of the welds because the fillets must be explicitly included to correctly represent the stiffness of the joints. This can be done using inclined elements, as shown in Fig. 2a which reports an example of a T-joint connection between two tubular parts.



Decomposition of the through thickness stress at the weld toe

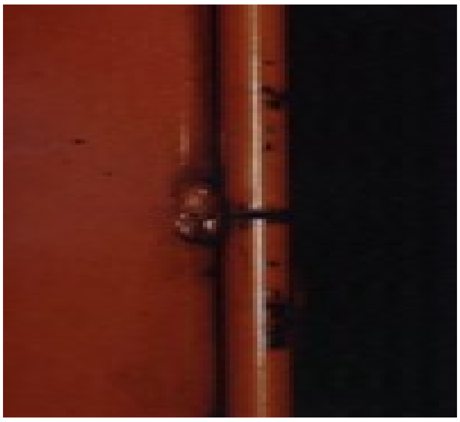


Stress component acted to the normal weld fillet

PROBLEMS DUE TO FAULTY DESIGNS AND POOR MATERIAL QUALITY:

It must be able to perform its specified functions as efficiently as possible. 2. It must be capable of being fabricated economically. 3. It must be capable of providing an adequate service life. As a direct result of the first and second of these conditions the factors of safety must be reduced to a bare minimum, in order to reduce weights and costs, and to increase the speed of operations of machines and production processes. Unfortunately this result tends to work against the designer in his efforts to obtain an adequate service life, particularly in cases where fatigue failure is likely to occur. Perhaps it is therefore not so surprising that it has been estimated that 90% of the failures which occur in engineering components can be attributed to fatigue.

Crack in fillet welds



Crack in weld joint

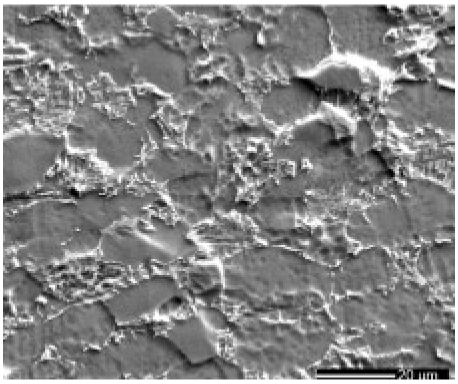
2.0 Literature review:

Masubuchi [1] and Connor [2] discussed various types of welding induced distortions, residual stresses in thin walled structures and the respective control and mitigation techniques. Distortions are considered as the most common defects that occur during welding, which can adversely affect the dimensional accuracy and thus lead to expensive corrective work. Hence, it is very essential to forecast the distortions in advance in order to minimize the negative effects, so that it helps in improving the quality of welded parts and finally to reduce the manufacturing costs as well. Deo et al. [3] presented a panel with angular distortion, that is transverse to the welding direction and caused by shrinking near the fusion zone resulting in a change in the angle of the parts. 21 Chin-Hyung Lee et al. [4] have carried out three dimensional FE analysis to estimate the residual stresses in circumferential welds of steel pipes with inside radius to wall thickness ratio ranging from 10 to 100. They have also illustrated the variation in residual stresses at different circumferential locations and the effects of diameter on residual stress distributions. Shim Y et al. [5] considered a ramp heat input and included the effect of moving arc in their analysis. They also investigated the effect of various ramp times and observed that 20% of the actual heat input time is the best ramp time. Liang Wang et al. [6] have investigated the effect of laser travel velocities with constant power and the laser powers with constant velocity on the distribution of residual stress during laser welding of thin wall plates. In this study, net heat input during welding process was also varied. Spina et al. [7] evaluated the effect of welding speeds on the weld profiles and distortion of the components during laser welding of AA 5083 sheets using numerical simulations. This study revealed that as the welding speed reduced the net heat input increased and vice versa. Brickstad et al. [8] numerically simulated a multi-pass circumferential butt-welding of stainless steel pipes using a non-linear thermo-mechanical Finite element analysis (FEA) to study the variation in weld heat inputs. They also studied the variation in the through-thickness of the weld and HAZ on the axial and hoop stresses for austenitic stainless steel pipe welds and their sensitivity against weld parameters. Kazuo Ogawa et al. [9] investigated the residual stress in penetration nozzles by considering different nominal heat inputs and weld speeds at constant weld power for different weld passes. Chaowen Li et al. [10] carried out three dimensional FEA of temperatures and stresses for increasing weld speeds with constant power on different samples. The above study reveals that increase in weld speed at constant power, increases the net heat input. Kermanpur et al. [11] studied the effect of variation in net heat input for a GTAW circumferentially butt welded pipes. The study revealed that 22 increasing the heat input resulted in a wider weld pool along with a higher maximum temperature in the HAZ. Wu. C.S et al. [12] used different levels of heat inputs with different welding currents by keeping welding speed and voltage as constant for two different arc welding processes (double sided and plasma) in the numerical simulation. They also carried out numerical analysis to predict the temperature field and weld pool shape as a function of welding speed with constant laser power and current. Gery et al. [13] investigated the effect of variable welding speeds and energy inputs on the transient temperature distribution, shape and boundaries of fusion zone and HAZ.

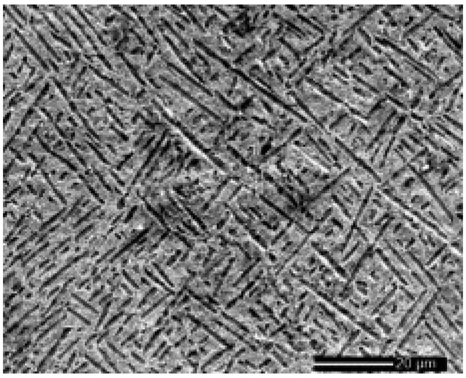
Dean Deng et al. [14] examined the influences of heat input on the size of HAZ, welding residual stress and distortion during numerical simulation of electro slag welding process. Dean Deng et al. [15] performed four different cases of welding simulations with constant weld current, voltage and speed to clarify the influence of phase transformation on the residual stress and welding deformation. Teng et al. [16] carried out welding simulations on T±shape fillet welding plate and discussed on buckling strength of welded joints and the effect of flange thickness, penetration depth and restraint conditions on distortions and residual stresses. Long et al. [17] predicted the temperature variations, fusion zone and HAZ as well as longitudinal and transverse shrinkage, angular distortion and residual stress for various welding speeds and plate thicknesses. Díaz et al. [18] carried out the comparative analysis on distortion of TIG welding of austenitic and duplex stainless steels by considering two different net heat inputs for both the stainless steels. Jiang et al. [19] studied the effect of different welding heat inputs and layer numbers on residual stresses and deformation in repair welds of stainless steel clad plate. Yanhong Tian et al. [20] investigated the effect of heat input and welding speed on the temperature field, especially on the shape and dimensions of the weld pool. It can be observed from the above detailed literature survey that no focused studies had been undertaken 23 to study the effect of different conditions of weld speeds and powers with constant heat input on the variation in temperature distributions and residual stresses. Further, literature survey also reveals that no studies have been reported on the variation in longitudinal and circumferential residual stresses along the radial distance from the outer surface as a function of different weld speeds and powers with constant heat input. The relationship between weld speed and power versus residual stress and their distributions at constant heat input can be established, through FE modeling. Further, these FE models can be used for optimizing the weld parameters for obtaining sound welds. There have been numerous investigations that pertain to the numerical analysis with experimental validation to understand the temperature distribution, distortions and the residual stresses. During welding, the weld component may undergo severe thermal cycles because of high concentrated heat source in the region of weld centre, which in turn results in distortion and residual stresses in the weld metal in longitudinal as well as in circumferential directions. There are a few studies that deal with the measurement of thermal cycles and optimizing the important welding process parameters such as welding speed, heat input, weld sequence and clamping conditions etc for butt welding of plate. Sattari-Far I., et al. [21] presented a three-dimensional thermo-mechanical analysis to investigate the effect of welding sequence on welding deformations in pipe±pipe joints and showed that a suitable welding sequence can substantially decrease the amount of welding distortions for a particular geometry. Rybicki E.F., et al. [22] developed a mathematical model for predicting transient temperature distributions, residual stresses, and residual deflections for girth-butt welds and compared temperature profiles for a two-pass welded pipe. They validated their predicted residual stresses and residual deflections based on a FE representation against individual passes,

3.0 Materials and Methods:

The typical microstructures of the as-received materials revealed by scanning electron microscopy (SEM) are shown

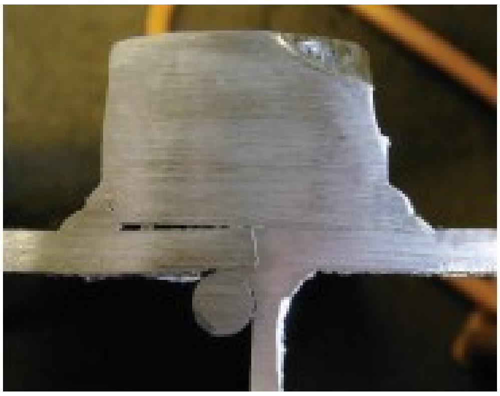


Microstructure of fe64



Microstructure of Fe17

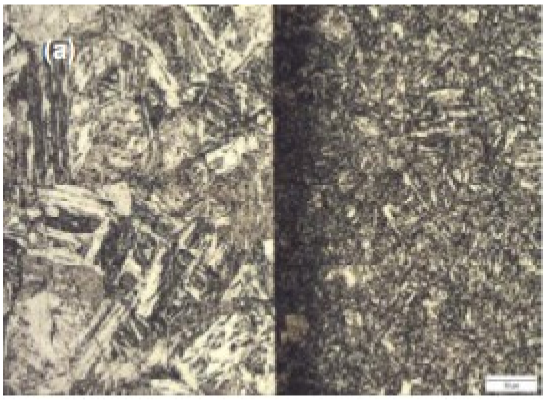
Attempts were made to weld samples of geometry 130 ˆ 75 ˆ 20 mm with a weld interface of 75 ˆ 20 mm. Fe64 and Fe17 titanium alloys were used for the dissimilar LFW trials. Welds were produced on a homemade linear friction welding machine of LFW-20T. The Ti64 sample was reciprocated, while the Ti17 sample was held stationary. Prior to welding, the welding surfaces of the samples were ground and cleaned in an acetone bath. The welding parameters were selected as follows: amplitude of oscillation of 3 mm, frequency of oscillation of 50 Hz, friction force of 4.8 kN and friction time of 3 s. Post weld heat treatment was carried out at 630 ˝C for 3 h in vacuum to relieve residual stress. The welded specimens for investigation were free from surface defects and internal defects



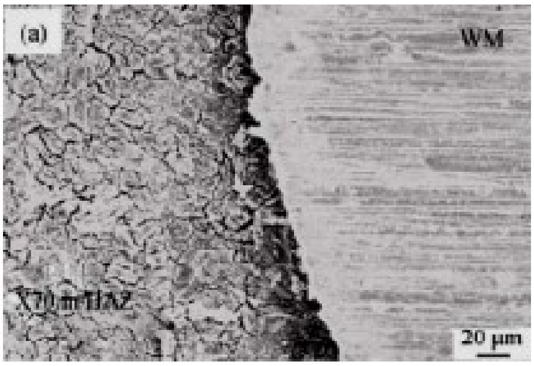
Deformations and cracks provoked by residual stresses

Dissimilar welding of two typical ferrous metals involves a different base metal and a filler metal. In this section, the difficulties involving dissimilar ferrous metals are presented and their weldability dis- cussed. It is possible to achieve successful dis- similar ferrous metal joints if proper procedures are followed.

- Problems with dissimilar ferrous metal welding
- Process weldability with dissimilar ferrous metals

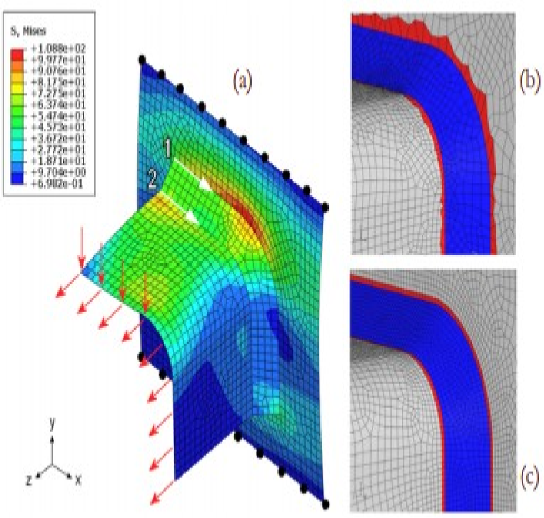


Welded interface joint

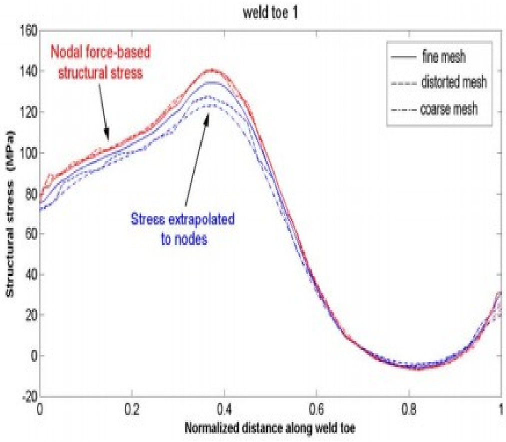


Micrograph of weld after 30days

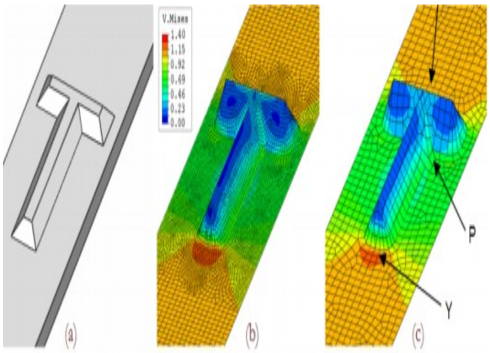
4.0 Results:



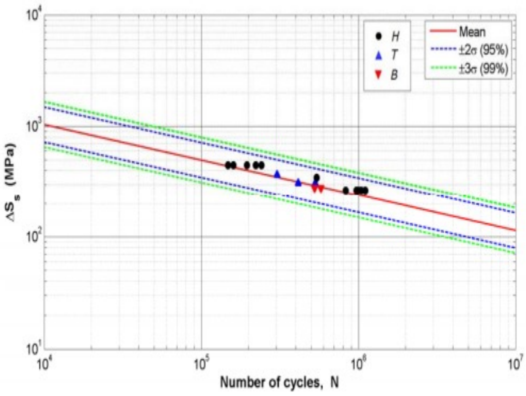
Curved profile welded to a flat plate: a) shell model using a coarse regular mesh at the toes; b)-c) close views of the fillet for the irregular mesh and the refined regular mesh



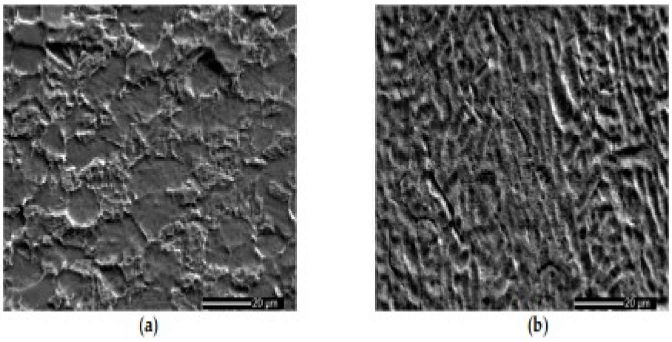
Comparison of the normal stress to the weld calculated from nodal stresses and the structural stress obtained from nodal forces



a) Specimen with the T-shaped attachment; b)-c) shell models with different mesh size. The V.Mises stress is normalized by the nominal tensile stress.



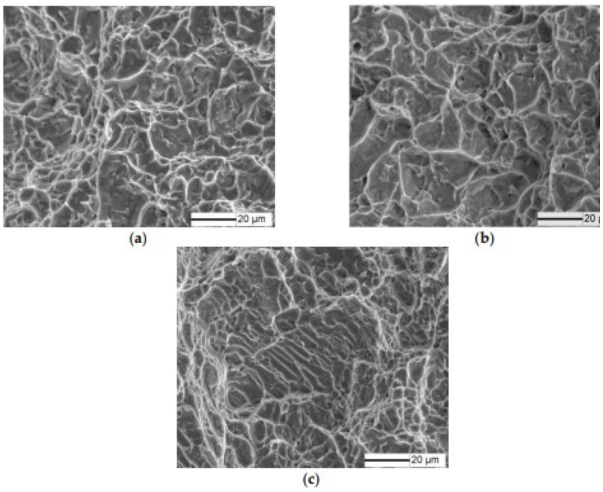
S-N curve and experimental results



(a)

(b)

(a) Fe64-heat affected zone (HAZ); (b) Fe64-thermo-mechanically affected zone



Fracture surface of (a) Fe64; (b) joints and (c) Fe17.

Conclusions:

The micro-structural evolution, micro-hardness, tensile properties and impact toughness of LFW dissimilar welds with Fe64 and Fe17 alloys were investigated. The following conclusions were drawn. (1) The microstructure across the linear friction welding dissimilar joints with titanium alloys displayed marked change, mainly consisting of a re-crystallized grain zone in the weld center, deformed grains and partial re-crystallization in the thermo-mechanical affected zones, and dissolved secondary α in the heat affected zones. (2) The maximum hardness is located in the weld metal, which may result from the fine grains arising from the rapid cooling during the welding process. (3) The linear friction welding dissimilar joints obtained higher tensile strength than base metal Fe64 with lower strength. The failure located in the Fe64 side approximately 1.2 mm away from the welding interface. (4) Base metals had superior impact toughness and fractured in a trans-granular mode, but weld zone exhibited decreased toughness and failed in a mixture of trans-granular and inter-granular fracture modes. The procedure was applied to three different specimen geometries subjected to constant amplitude loading and predicted the correct location of the fatigue cracks. Finally, the use of the ASME master S-N curve proved to give accurate fatigue life predictions..

References:

[1] D. Radaj Design and Analysis of Fatigue Resistant Welded Structures, Abington Publishing, Cambridge (1990).

[2] W. Fricke, Marine Structures, 16 (2003) 185

[3] D. Radaj, C.M. Sonsino, W. Fricke Fatigue Assessment of Welded Joints by Local Approaches (2nd Ed.), Woodhead Publishing, Cambridge (2006).

[4] A. Hobbacher, Recommendations of IIW Joint Working Group XIII – XV, Woodhead Publishing (1996).

[5] B. Atzori, P. Lazzarin, R. Tovo, Fatigue and Fracture of Engineering Materials and Structures, 22 (1999) 369

[6] M. Fermer, M. Andreasson, SAE Technical Paper 982311(1998)

[7] S. Zhang, DaimlerChrysler AG Research Report GR/VMB-07-001 (2007).

[8] P. Dong, Int. J. of Fatigue, 23 (2001) 865

[9] P. Dong, J. K. Hong, Z. Cao, Int. J. of Fatigue, 25 (2003) 811

[10] P. Dong, J. K. Hong, International Institute of Welding: IIW Doc. XIII-2036-04/XV-1173-04 [11] T. Gurney, Cumulative Damage of Welded Joints, Woodhead Publishing, Cambridge (2006)

[11] Martínez, L. L., Fatigue Behaviour of Welded High-Strength Steels (1997). Doctoral thesis from Royal Technical Institute, Stockholm, Sweden

[12] SSAB, Design with Weldox and Hardox (1991). Öxelösund. Sweden.

[13] The James F. Lincoln Arc Welding Foundation, Weld Cracking-An excerpt from The Fabricators' Guide to Welded Steel Construction.

[14] Heinrich, W., Good Condition. Hoist Magazine (December 2000/January 2001)

[15] Astarita, A.; Curioni, M.; Squillace, A.; Zhou, X.; Bellucci, F.; Thompson, G.E.; Beamish, K.A. Corrosion behaviour of stainless steel-titanium alloy linear friction welded joints: Galvanic coupling. Mater. Corros. 2015, 66, 111–117.

[16]. Grujicic, M.; Yavari, R.; Snipes, J.S.; Ramaswami, S. A linear friction welding process model for Carpenter Custom 465 precipitation-hardened martensitic stainless steel: A weld

microstructure-evolution analysis. J. Eng. Manuf. 2015, 228, 1887–2020.

[17]. Rotundo, F.; Marconi, A.; Morri, A.; Ceschini, A. Dissimilar linear friction welding between a SiC particle reinforced aluminum composite and a monolithic aluminum alloy: Microstructural, tensile and fatigue properties. Mater. Sci. Eng. A 2013, 558, 852–860.

[18]. Bhamji, I.; Moat, R.J.; Preuss, M.; Threadgill, P.L.; Addison, A.C. Linear friction welding of aluminium to copper. Sci. Technol. Weld. Join. 2012, 17, 314–320.

[19]. Bhamji, I.; Preuss, M.; Moat, R.J.; Threadgill, P.L.; Addison, A.C. Linear friction welding of aluminium to magnesium. Sci. Technol. Weld. Join. 2012, 17, 368–374.

[20]. Ma, T.J.; Zhong, B.; Li, W.-Y.; Zhang, Y.; Yang, S.Q.; Yang, C.L. On microstructure and mechanical properties of linear friction welded dissimilar Ti-6Al-4V and Ti-6.5Al-3.5Mo-1.5Zr-0.3Si joint. Sci. Technol. Weld. Join. 2012, 17, 9–12.

[21]. Wen, G.D.; Ma, T.J.; Li, W.Y.; Wang, S.Q.; Guo, H.Z.; Chen, D.L. Strain-controlled fatigue properties of linear friction welded dissimilar joints between Ti-6Al-4V and Ti-6.5Al-3.5Mo-1.5Zr-0.3Si alloys. Mater. Sci. Eng. A 2014, 612, 80–88.

[22]. Zhao, P.; Fu, L. Strain hardening behavior of linear friction welded joints between TC11 and TC17 dissimilar titanium alloys. Mater. Sci. Eng. A 2015, 621, 149–156.

[23]. Frankel, P.; Preuss, M.; Steuwer, A.; Withers, P.J.; Bray, S. Comparison of residual stresses in Ti-6Al-4V and Ti-6Al-2Sn-4Zr-2Mo linear friction welds. Mater. Sci. Technol. 2009, 25, 640–650.

[24]. Karadge, M.; Preuss, M.; Lovell, C.; Withers, P.J.; Bray, S. Texture development in Ti-6Al-4V linear friction welds. Mater. Sci. Eng. A 2007, 458, 182–181

[25]. Lang, B.; Zhang, T.C.; Li, X.H.; Guo, D.L. Microstructural evolution of a TC11 titanium alloy during linear friction welding. J. Mater. Sci. 2010, 45, 6218–6224.

[26]. Romero, J.; Attallah, M.M.; Preuss, M.; Karadge, M.; Bray, S.E. Effect of the forging pressure on the microstructure and residual stress development in Ti-6Al-4V linear friction welds. Acta Mater. 2008, 57, 5582–5592.

[27]. Corzo, V.; Casals, O.; Alcalá, J.; Mateo, A.; Anglada, M. Mechanical evaluation of linear friction welds in titanium alloys through indentation experiments. Weld. Int. 2007, 21, 125–128.

[28]. Schroeder, F.; Ward, R.M.; Turner, R.P.; Walpole, A.R.; Attallah, M.M.; Gebelin, J.-C.; Reed, R.C. Validation of a Model of Linear Friction Welding of Ti6Al4V by Considering Welds of Different Sizes. Metall. Mater. Trans. B 2015, 46, 2326–2331.

[29]. Turner, R.; Gebelin, J.-C.; Ward, R.M.; Reed, R.C. Linear friction welding of Ti-6Al-4V: Modelling and validation. Acta Mater. 2011, 59, 3792–3803.

[30]. McAndrew, A.R.; Colegrove, P.A.; Addison, A.C.; Flipo, B.C.D.; Russell, M.J. Modelling the influence of the process inputs on the removal of surface contaminants from Ti-6Al-4V linear friction welds. Mater. Des. 2015, 66, 183–195.