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PROCESS PARAMETER OPTIMIZATION FOR JOINING Ti 6Al-4V BY FSW USING VMC

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Abstract:
This research addresses the application of friction stir welding (FWS) of titanium alloy Ti–6Al–4V. Friction stir welding is a recent process, developed in the 1990s for aluminum joining; this joining process is being increasingly applied in many industries from basic materials, such as steel alloys, to high performance alloys, such as titanium. It is a process in great development and has its economic advantages when compared to conventional welding. For high performance alloys such as titanium, a major problem to overcome is the optimization of various parameters in order to obtain a uniform weld joint with high tensile strength. The samples were prepared by tungsten carbide tool of three different pin crossections and by varying the spindle speed and feed rate the results were then analyzed. Further various testing were performed in order to chose the most optimized solution
Key words: friction stirs welding, titanium, tungsten carbide

I. Introduction

Friction stir welding is an important new non-fusion technique for joining sheet and plate material. FSW was invented by Thomos Wanyne in 1991, and is a TWI licensed technology. The basic form of the process uses a cylindrical (non-consumable) tool, consisting of a flat circular shoulder, with a smaller probe protruding from its centre. The tool is rotated and plunged into the

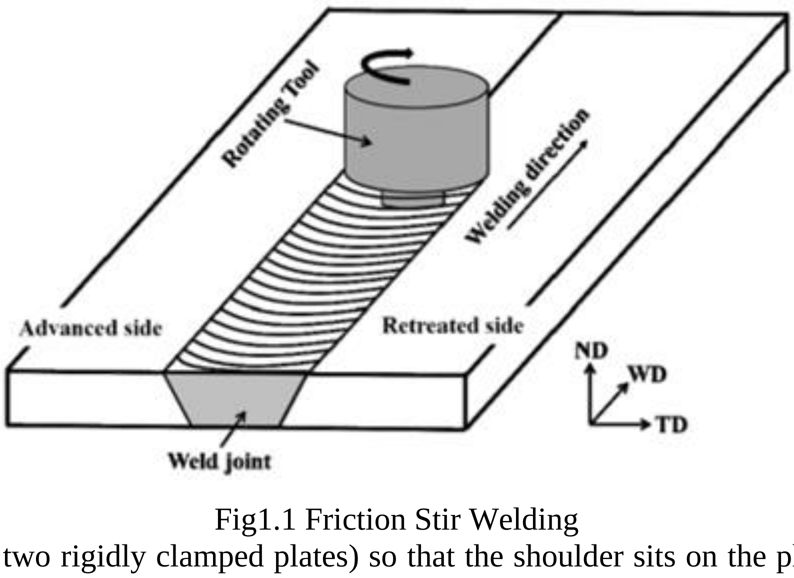

Fig1.1 Friction Stir Welding

Joint line (between two rigidly clamped plates) so that the shoulder sits on the plate surface and the work piece, as shown in Fig.1.1

Friction between the rotating tool and the plate material generates heat, and the high normal pressure from the tool causes a plasticized zone to form around the probe. The tool is then traversed, frictionally heating and plasticizing new material as it moves along the joint line. As the tool traverses, the probe stirs the locally plasticized area and forms a solid-phase joint. The FSW process has initially been patented by TWI in most industrialized countries and licensed for over 183 users. Friction stir welding and its variants – friction stir spot welding and friction stir processing – are used for the following industrial applications: shipbuilding and offshore, aerospace, automotive, railways, general fabrication, robotics, and computers.

II. Gaps In Literature

we came to know that, there is not much work done in the field of Friction Stir Welding of Titanium 6Al 4V.Though we came across a few studies which are done on conventional machines but till date there is no work published in the field of FSW of Titanium 6Al 4V with the help of VMC. As we know that we can vary various parameters and configurations in VMC moreover it is very much economical as compared to other conventional or non conventional machines. That's why we decided to perform FSW with the help of VMC.

III. Methodology

Titanium (Ti6Al4V) sheet of dimension 400 x110mm and thickness 4 mm was taken in order to create sample specimens for friction stir welding experiment .The sheet was further cut to 35x110mm in order to prepare specimens. Cutting of sheet was done via CNC wire EDM machining with a feed rate of 3mm/min and constant flow of deionized water was used as coolant which also helped in removing various small unwanted particles in the machining gap. Friction stir welding (FSW) is a solid-state joining process that uses a non-consumable tool to join two facing work pieces without melting the work piece material. Heat is generated by friction between the rotating tool and the work piece material, which leads to a softened region near the FSW tool. While the tool is traversed along the joint line, it mechanically intermixes the two pieces of metal, and forges the hot and softened metal by the mechanical pressure, which is applied by the tool.

	Tool 1	**Tool 2**	**Tool 3**
Tool Type	Conical	Cylindrical Threaded	Square
Material	Tungsten Carbide	Tungsten Carbide	Tungsten Carbide
Shank Diameter (mm)	15.8	16	16
Tool Length (mm)	50	50	50
Pin length (mm)	3.7	3.7	3.7
Pin Diameter (mm)	5-3	5	**….**

Table 1: Tool Specification

A rotating cylindrical tool with a profiled probe was fed into a butt joint between two clamped work pieces, until the shoulder, having a larger diameter than the pin, touched the surface of the work pieces. The probe is slightly shorter than the weld depth required, with the tool shoulder riding at top of the work surface. After a short dwell time, the tool was moved forward along the joint line at the pre-set welding speed.

Titanium 6AL 4V sheets with a thickness of 4mm were bonded by Friction Stir Welding using 3 tungsten carbide tools with different pin cross-sections, via CNC Vertical Milling Center. The parameters used for FSW were (tool rotation speed of 1000 rpm and a welding speed of 20mm/min). Using these conditions, no surface welding defects were observed. Friction stir welding was carried out at different feed rates and rpm and with variation of 3 different tools crossections, cylindrical

threaded, conical, and square tool shoulder plunge depth of 3.7 mm were considered for all the welds. A tungsten carbide tool with a 16 mm shoulder and a 30◦ conical pin, 3.7 mm in height and 3.5 mm in major diameter, was utilized.
Frictional heat was generated between the wear-resistant tool and the work pieces. This heat, along with that generated by the mechanical mixing process within the material, cause the stirred materials to soften without melting. As the tool was moved forward, a special profile on the probe forced plasticized material from the leading face to the rear, where the high forces assisted in a forged consolidation of the weld. The results were obtained with 3 different samples with different rpm (revolution per minute) from 900rpm to 1800 rpm and we obtained variation in strength.

IV. Results And Analysis

Titanium sheets were welded with variation of various parameters that resulted in different outcomes and quality of joints, the FSW joint obtained by conical tool at 1000 rpm resulted an average tensile strength of 429MPa, same tool at 1800 rpm resulted a FSW joint with tensile strength of 411Mpa. Then the tests were performed with cylindrical tool at 900 rpm the resulted Strength obtained was 418Mpa. After the tensile testing results various specimen were tested with similar values and the average strength results proved that successful joint can be created if set parameters are calculated precisely. Through the tensile test and the fractured specimens of FSW Ti6Al4V.overall highest average strength obtained was 49Mpa. Further the average transverse tensile strength of the joints obtained was 429 MPa. Fractures occurred only in the HAZ on the retreating side not on the advancing side. There were no significant micro structural differences. But there are some other factors which might influence the fracture behavior, which cannot be confirmed through the present study.

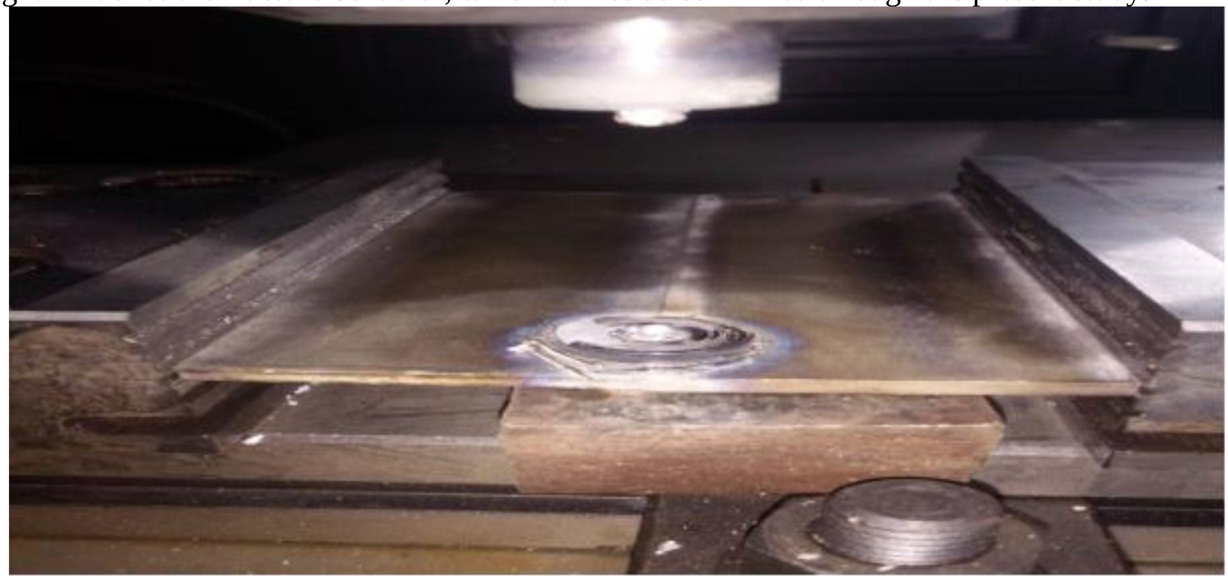

Fig1.2: Welding Operation

V. Conclusion

The various parameters tested in friction stir welding of titanium sheets provided us the information that even due to brittle nature and poor machinability of titanium and titanium alloys, successful friction stir welding can be performed on it which gives an adequate strength and through it necessary vital properties of welding joint can be obtained.

Fig1.3: FSW on Titanium Sheet

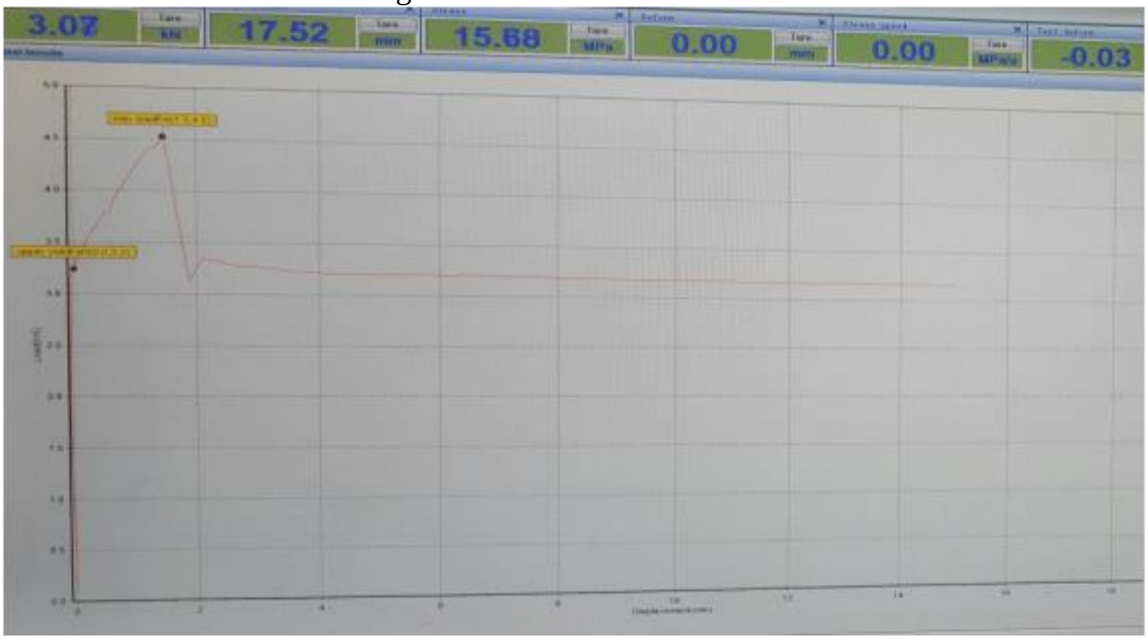

Fig1.4: Load v/s Displacement Curve

References:
[1] Kapil Gangwar1, M.Ramulu friction stir welding of titanium alloys ,University of Washington, 98195, Seattle, USA.
[2] A. Farias, G.F. Batalha , E.F.Prados , R.Magnabosco , S. Delijaicov University of Sao Paulo-Escola Politecnica-Loboratory of manufacturing Sao Paulo, SP ,Brazil
[3] W Song Z, Nakata K, Wu A, Liao J. Interfacial microstructure and mechanical property ofTi6Al4V/A6061 dissimilar joint by direct laser brazing without filler metal and groove. Mater Sci Eng A 2013;560:111-20.
[4] R. Boyer, G. Welsch, E.W. Collings, Materials Properties Handbook: Titanium Alloys ASM International, Materials Park (OH), 1994.
[5] Addison AC. Linear friction welding information for production engineering. TWI industrial members report - 961/2010. Cambridge, U.K; 2010.

[6] Hynes NR, Nagaraj P, Sujana JA. Investigation on joining of aluminum and mild steel by friction stud welding. Mater Manufacturing Process 2012;27(12):1409–13.[17] Rajesh Jesudoss Hynes N, Nagaraj P, Angela Jennifa Sujana J. Mechanical evaluation.
[7] Ji, S., et al., The effect of tool geometry on material flow behavior of friction stirs welding of titanium alloy. Engineering Review, 2013. 33(2): p. 107-113.
[8] S. Guo, Q. Meng, X. Zhao, Q. Wei, H. Xu, Design and fabrication of a meta stable β-type titanium alloy with ultralow elastic modulus and high strength, Scientific reports 5 (2015) 14688
[9] G.F. Miori, E.F. Prados, G.F. Batalha, Investigation of friction stir welding fsw processed AA5054 alloy, in :Friction Stir Welding and Processing FSWP'2012,2012,Saint-Etienne.Proceding Friction Stir Welding and Processing,2012,pp.89–91.
[10] Nandan R, DebRoy T, Bhadeshia HKDH. Recent advances in friction-stir welding – process, weldment structure and properties. Prog Mater Scienc2008;53:980–1023.
[11] C.Y. Yap, C.K. Chua, Z.L. Dong, Z.H. Liu, D.Q. Zhang, L.E. Loh, S.L. Sing, Review of selective laser melting:432 Materials and applications, ApplPhys Rev, 2 (2015) 041101.
[12] M. Fazel-Najafabadi, S.F. Kashani-Bozorg, A. Zarei-Hanzaki, Mater. Des. 31(10) (2010 4800-4807.
[13] Z. W. Ma, Y. Y. Jin, S. D. Ji, X. C. Meng, L. Ma, Q. H. Li, J. Mater. Sci. Technol. 35 (2019)97-99.
[14] Gao Y, Nakata K, Nagatsuka K, Liu FC, Liao J. Interface microstructural control byprobe length adjustment in friction stir welding of titanium and steel lap joint. Mater Des (1980-2015) 2015;65:17–23.
[15] Wu GQ, Shi CL, Sha W, Sha AX, Jiang HR. Effect of microstructure on the fatigue properties of Ti-6Al-4V titanium alloys. Mater Des 2013; 46:668–74.