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Review study of Mechanical properties under Friction Sir Welding of Titanium Alloy (Ti-6Al-4V)

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Abstract—*Friction Stir Welding was invented in early 90's at TWI (The Welding Institute in Cambridge, UK) which is a solid state welding process; early used to weld aluminum alloys, now adopted for high resistant materials. Joining titanium alloys by conventional fusion welding processes resulted in several difficulties because of high material reactivity with nitrogen, oxygen and hydrogen along subsequent embrittlement of the joint. However FSW serves high quality and cost effective solution. Mechanical properties of joints are stringently associated to the microstructural evolutions, with respect to phase change, occurring during the process. Here a 3mm plate of Ti-6Al-4V having yield stress of 920 MPa, ultimate tensile stress of 1050MPa and micro hardness 351 HV is welded by FSW with W25Re tool. The Micro hardness and Ultimate tensile stresses are observed at different rotational speeds of tool.*

Keywords—Friction Stir Welding, Yield Strength, Elongation, Ultimate Tensile Strength and Stir Zone.

I. INTRODUCTION

Titanium and titanium alloys finds a huge demand in aerospace industry due to their high strength- weight ratio and also their good corrosion resistance. Yet, titanium alloys has lower ductility with respect to steels and are among the materials whose welding is difficult. Presently titanium and titanium alloys are welded by tungsten arc welding (TIG), metal arc welding (MIG) along with laser beam welding and plasma arc welding. It is impossible to avoid development of residual stresses, large distortion, and brittle cast structures, using these conventional fusion welding techniques. Also, there is possibility of contamination of such alloys by air, hydrogen, forming brittle compounds by absorbing oxygen and nitrogen. Friction Stir Welding (FSW) of titanium alloys serves as a high quality and cost efficient solution. Following figure 1 shows schematic representation of friction stir welding.

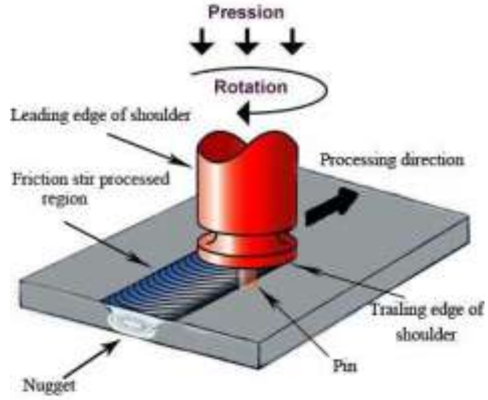

FIGURE 1: Schematic of FSW [1]

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II. MATERIAL AND METHOD

1.1 Material

Titanium alloy Ti-6Al-4V are joined by friction stir welding process.Ti-6Al-4V titanium alloy is difficult to be welded by fusion welding processes which lead to several weld defects. Table 1 shows the chemical composition of Ti-6Al-4V titanium alloy.

TABLE 1
CHEMICAL COMPOSITION OF TITANIUM ALLOY (TI-6AL-4V)

Chemical Composition.	Al	V	C	Fe	N	O	H
Weight in %	6.09	4.02	0.011	0.14	0.008	0.14	0.0023

Yu Zang [2] performed friction stir welding of 3mm Ti-6Al-4V plates using a molybdenum based alloy tool having convex shoulder with step spiral patterns on surface to enhance stirring effect. Argon gas used as shielding gas. M Ramulu [3] evaluated friction stir welded (FSW) and friction stir welded-superplastically formed Ti–6Al–4V alloy sheets having thickness ranging between 2 to 2.5 mm. The titanium sheets were welded and tested (in both stress relieved and superplastically formed condition.Jianqing Su[4] performed friction stir processing on 2mm thick Ti-6Al-4V sheets using various processing parameters including tool rotational speed and tool traverse speedwith W–1%La2O3 tool to produce defect-free friction stir processed materials. Paul Edwards [5] investigated properties of 6mm thick Ti-6Al-4V alloy plateby FSW processing tool made of tungsten lanthanum (W-La) alloy carrying all the welds at constant rotational and welding speeds. A.Steuwer [6] reported welding of 3mm thickness of Ti-6Al-4V alloy in a mill annealed condition, i.e. soaked for 2 h at 750 ^{o} C and air cooled.

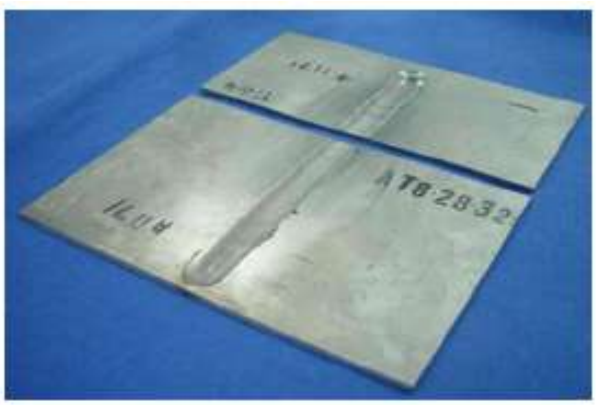

FIGURE 2: Typical Ti-6Al-4V FSW Joint [3]

1.2 Method

Friction stir welding technique is used to join Ti-6Al-4V alloy due to its solid state method of joining utilizing friction between the material being joined, and a rotating non-consumable tool which generate the needed heat to plasticize and mix material. The high speed of rotational tool causes friction and heat in base metal and joins the plates. As it provides defect free weld due to absence of fusion welding FSW has got tremendous demand in market. The tool has some major parts like shoulder and pin/plunge which penetrates into the weld joint during welding process. Argon gas is used as shielding medium while welding which is supplied around the tool during process.According to Yu Zang [2] test specimens are cut in bone like shape byas shown in figure 3. As per M .Ramulu [3] 250 kN capacity 5585 Instron Load used for testing specimen for calculating tensile strength, yield strength, Young's modulus and elongation. In the paper by Jianqing Su [4] samples were examined by optical microscopy (OM) and scanning electron microscope (SEM), FEI Nova Nanosem 230 equipped with EDAX-TSL orientation imaging micro-scopy (OIM) system for electron backscatter diffraction (EBSD) analysis.

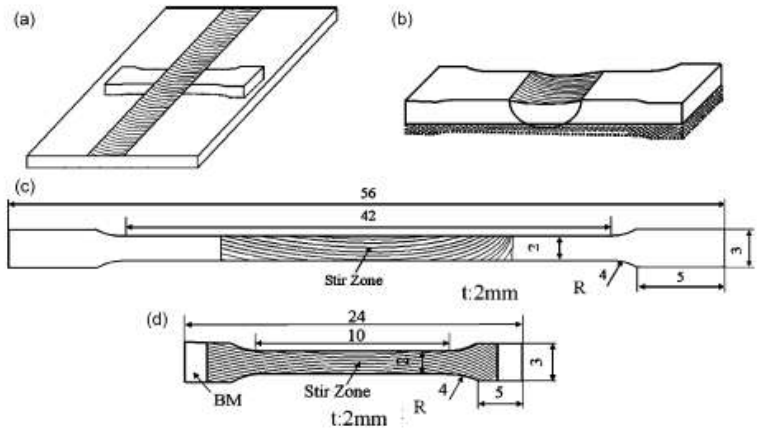

FIGURE 3:(a) and (b) illustrates the procedure for cutting tensile specimens. (c) Shows configuration of the transverse tensile specimen and (d) show the smaller tensile test specimen [2]

III. RESULT

As noted by Yu Zang [2] the SZ exhibited much higher mechanical properties than the base material, while the HAZ was the weakest in the weld, and its properties were representative of the transverse tensile properties of the weld. By M. Ramulu [3] friction stir welds in Ti-6Al-4V alloy possess higher ultimate tensile and yield strengths compared to the properties of parent material. According to Jiaquing Su [4] when compared with the base material, the stir zones of friction stir processed samples showed superior tensile strength and comparable ductility. As per noted by Paul Edwards [5] heat treatment temperatures under 870 C improving higher tensile strengths and elongations with good fatigue life.

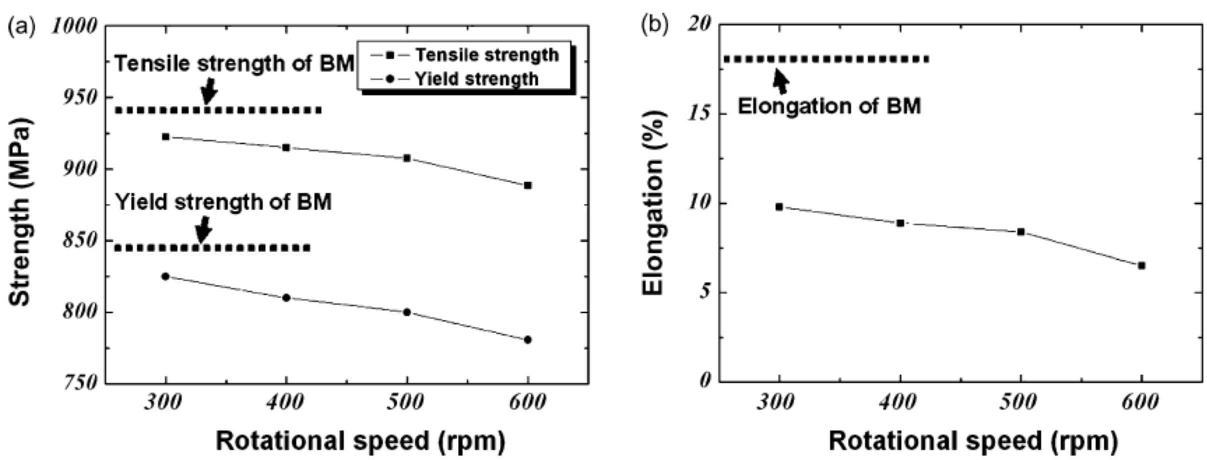

FIGURE 4: Rotational speed effect on transverse tensile properties:
(a) tensile strengths and (b) elongation [2]

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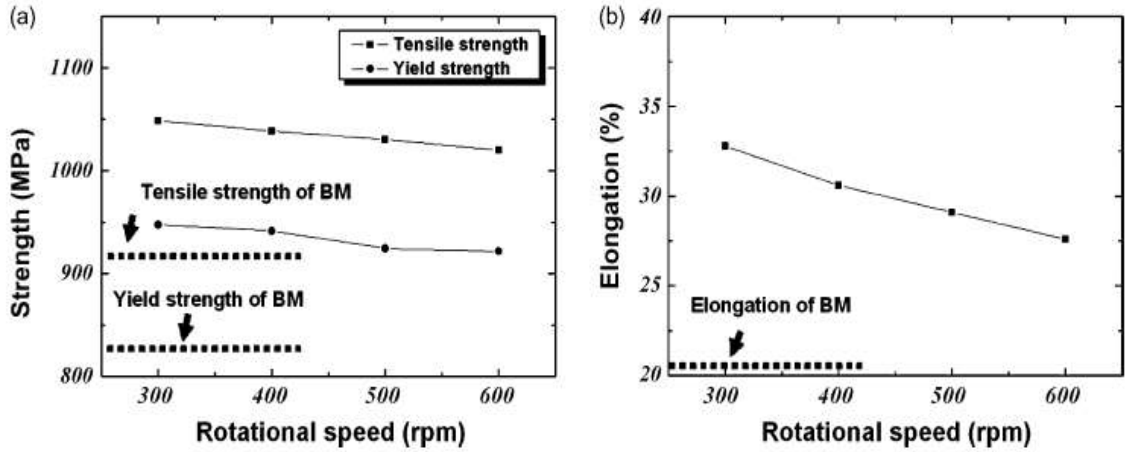

FIGURE 13: Rotational speed effect on tensile properties of the SZ: (a) tensile strengths and (b) elongation. [2]

Table 2 represents the mechanical properties exhibited by Ti-6Al-4V after FSW application. It shows the evaluations done by different authors in investigation of tensile strength, yield strength, and elongation along with the tool material and tool dimension specifications.

TABLE 2
MECHANICAL PROPERTIES EXHIBITED BY Ti-6Al-4V

W/p Thic-kness(mm)	Tool Mat.	Tool Pin Length in mm	Tool Pin Dia. (mm)	Tool Shoulder Dia. in mm	Tool Rotational Speed (rev/min)	Tool Travel speed (mm/min)	Tensile Strength (MPa)	Yield Strength (MPa)	Elong. in %	Ref.. No.
3	Mo alloy	-	5.1 to 3	15	300 to 600	60	BM-978, SZ 1025 to 1050	BM-845, SZ-920 to 950	BM = 18, SZ-27.5 to 33	2
2 to 2.5	-	-	-	-	150 to 490	75 to 150	BM- 1149 ± 58.7	BM- 1103 ± 39.5	BM = 9.3 ± 1.5	3
2	W–1% La2O3	1.7	6.3	10.1	800 to 1000	25.4 to 101.6	BM-1014.7 ± 4.55, SZ- 1156.2 ± 0.0 to 1042.9 ± 15.0	BM-941.8 ± 24.7, SZ-1067.4 ± 31.4 to 936.8 ± 20.5	BM = 23.1 ± 1.3, SZ- 23.6 ± 0.7 to 19.9 ± 0.5	4
6	W-La	-	-	-	250	100	BM= 994 to 1045, SZ= 980 to 1016	BM - 939 to 978, SZ= 923 to 971	BM= 9 to 16, SZ=7 to 17	5
3	-	2.9	8	14	300 to 600	45 to 165	BM= 1000, SZ= 1002 to 1059	BM - 962	BM= 18, SZ= 3 to 12	6

IV. CONCLUSION

From this review it can be concluded that the mechanical properties carried by base metal in as received condition gets changed in the stir zone or weld nugget after friction stir welding process. The stir zone exhibited improvement in mechanical properties with higher tensile strength and yield strength.

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