Effect of Load on Joint Efficiency and Hardness in Friction Stir Welding of AA6061 & AA6063 Aluminium Alloys

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Abstract— Aluminium Alloys have been used in various applications owing to its high mechanical properties such as Hardness, Tensile Strength, Impact Strength and etc. These mechanical properties are directly and indirectly affects by various parameter. Load given during the friction stir welding process can also be affecting the mechanical properties of the welded joints. In this study, the Hardness and Joint Efficiency of dissimilar Aluminum alloys namely AA6061 and AA6063 are studied with reference to the Load applied during the process.

Key words: Friction Stir Welding, Hardness, Joint Efficiency, Load, Tensile Strength

I. INTRODUCTION

The Friction Stir welding was invented by Wayne Thomas in 1991at TWI in UK. FSW is not consuming electrode which was the major pitfall of other conventional welding process and it is done by specially designed non-consumable rotational tool pushed in to work piece. The Transverse Motion is given to rotating tool by which friction is created. The Tool is made to withstand the high thermal behaviors.

II. WORKING PRINCIPLE

Friction Stir welding is working on the principle that when a rotating tool which has a pin is inserted between the very small gaps of the dissimilar aluminium plates. Thereby generating frictional heat, which creates the immersed probe and the interface between the shoulder of the tool and the work piece, the joining process will be start and corresponding load is applied for the perfect joining, the rotational speed and travel speed are the major influencing factor. The computer numerical controlled vertical milling machine is preferred for the better result.

III. MICROSTRUCTURE

The Fig. 1 describes the solid state structure of the friction stir welding. This structure will be created the after the welding of similar and dissimilar aluminium alloys. The microstructure can be categorizes into the following Four Zone.[1].

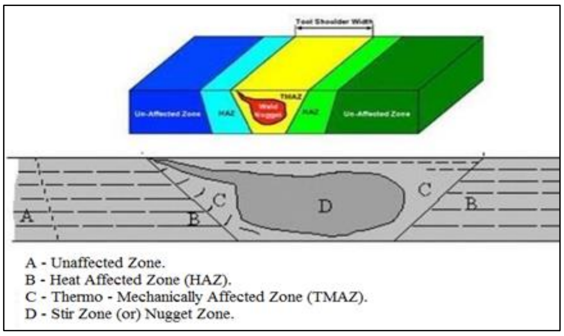

Fig. 1: Microstructure of FSW Plate

Stir Zone: (also called as Weld Nugget or dynamically recrystallized zone). The region of highly deformed material which is forcefully affected by the area of the pin during welding.

Thermo-Mechanically affected zone (TMAZ): This region is also affected during welding process and has a minimal deformation as compared with Stir Zone.

Heat Affected Zone (HAZ): During all the working process, there will be the Heat Affected Zone due to intermolecular movement of materials. As name implies this zone will not affect by molecular deformation.

Unaffected Material Zone(UZ): The parent materials in this zone doesn't affected by process and its consequences.

IV. EXPERIMENTAL PROCEDURE

The Chemical Composition of AA6061 [1] and AA6063 [2] are represented in Table 1.

Element	AA6061 % (By Weight)	AA6063 % (By Weight)
Si	0.4 - 0.8	0.2 – 0.6
Fe	Max 0.7	Max0.35
Cu	0.15-0.40	Max 0.1
Mn	Max 0.15	Max 0.1
Mg	0.8-1.2	0.45– 0.9
Cr	0.04 - 0.35	0.05– 0.25
Zn	Max 0.15	Max 0.1
Ti	0.15	Max 0.1
Al	Bal	Bal

Table 1: Composition of AA6061 & AA6063

AA6061 and AA6063 Aluminum Alloys plates of dimension 100mm*50mm*6mm were taken for study. The Properties of AA6061 and AA6063 are listed below in Table 2.

Property	AA6063	AA6061
Proof stress	160MPa	276MPa
Tensile strength	195MPa	310MPa
Elongation	0.1	0.17
Shearstrength	152MPa	207MPa
Rockwell Hardness	68HRB	85 HRB

Table 2: Properties of AA6061 & AA6063

The special non consumable tool is designed using the material H13 hardened tool Steel. The Specification of the Tool is presented in Fig.2.

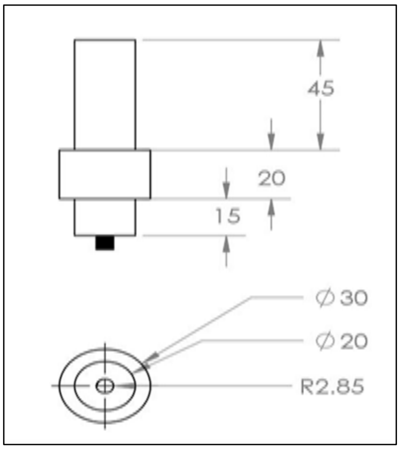

Fig. 2: Tool Specification

The aluminium alloy plates were welded in vertical milling machine with FSW attachment. The fixture and collar is prepared for the dimensions of work piece and tool to hold the same respectively. The Process of FSW is shown in Fig.3


Fig. 3: FSW Process.

The Welding has been done at various load conditions of 3000N, 4000N, 5000N, 6000N and 7000N. The Rotational Speed and Travel Speed of the tool are fixed constant at 900rpm and 3mm/sec respectively. The welded joints of AA6061 and AA6063 dissimilar alloys are represented in Fig. 4.

Fig. 4: Welded Joints

V. Hardness Test

The welded joints were analyzed for hardness at various zones and for its tensile strength. The Rockwell Hardness test was taken into account for finding the Hardness value of welded Joints. Rockwell hardness was carried out using the ASTM E8 – 17e1 standards. The Center of the weld is taken as Stir Zone and 10mm from the Centre on the both side are taken as Thermo mechanically affected zone and 15mm from the centre on both side are taken as heat affected zone and remaining portion are taken as Unaffected material zone.[4]. The Values of Rockwell Hardness test is as shown in Table 3.

SL.NO	LOAD (N)	Rockwell Hardness Value B - Scale (Average of 3)						
		AA6063 (Advancing Side)				AA6061 (Retreating)		
		Unaffected Material Zone (AA6063)	HAZ (15mm from the SZ)	TMAZ (10mm from the SZ)	Stir Zone	TMAZ (10mm from the SZ)	HAZ (15mm from the SZ)	Unaffected Material Zone (AA6061)
1	3000	66	63	59	56	62	69	78
2	4000	63	62	61	61	64	69	74
3	5000	60	63	67	64	66	71	75
4	6000	65	66	72	79	80	81	79
5	7000	63	65	69	75	75	74	74

Table 3: Rockwell Hardness test

The Comparative Graph between Hardness Value and Plate Positions at various loads has been drawn in Fig. 5.

Fig. 5: Plate Positions Vs Hardness @ Various Loads

VI. Tensile Test

Tensile Test specimen of welded joints was made as per the standard ASTM E8 – M04 for sub-specimen. The welded joints were cut down as per the standards for tensile test. The specimen for test is represented in the Fig. 6.


Fig. 6: Specimen for Tensile Test.

The tensile strength of the welded joints was carried out in universal testing machine as shown in Fig.7.


Fig. 6: UTM - Tensile Test

The Recordings of the Tensile Test is Tabulated and Joint Efficiency is also calculated by using the Formula.

η = T.S (Joint)/ T.S (Base)

η = Joint Efficiency

T.S (Joint) = Tensile Strength of the joint T.S (Base) = Tensile Strength of the lower strength base metal (AA6063)

The Recordings are displayed in Table 4.

LOAD (N)	Tensile Strength (Mpa)	Joint Efficiency η (%)
3000	85	43.59
4000	88	45.13
5000	104	53.33
6000	126	64.62
7000	119	61.03

Table 4.Tensile Strength & Joint Efficiency

The Comparative Graph is shown in Fig. 7.

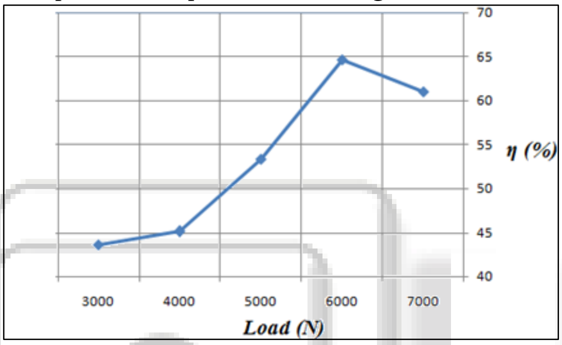

Fig. 7: Load Vs Joint Efficiency

VII. Result and Discussion

From This study, The Effect of Load which is given during the process of friction stir welding on the Hardness and Strength of the Joint between AA6061 & AA6063 were studied and the conclusions are find as follows,

- The Load has high influence on the Hardness of the Joint. The Weld which has been carried under 6000N Load has posses the high hardness value at the nugget zone.
- Microstructure of the welded plate was also affected due to different load condition.
- The Weld Under 6000N load Condition yields the higher strength weld and the corresponding weld joint efficiency is 64.62%
- The Joint Efficiency of the Weld exhibits the behavior of the intermetalics. The Study reveals the weld quality is good when the weld is carried between 6000N to7000N load conditions.

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