INFLUENCE OF PROCESS PARAMETERS ON FRICTION STIR WELDED 6063-T6 ALUMINIUM ALLOY: AN EXPERIMENTAL INVESTIGATION

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ABSTRACT

The welding of heat treatable Aluminium alloys has always introduced a difficulty since heat given by welding process tends to mechanical properties of the welded material. Current research work is done to evaluate tensile strength, hardness and microstructure of friction stir welded 6063 T6 aluminium alloy at different process parameters like tool feed, frequency etc. Friction stir welding is done of 6mm thick al 6063 plates that were 100mm long and 50 mm wide. Various readings are taken at different rotational speeds and tool penetration. Percent elongation and % reduction in area are calculated in tensile test. Tensile strength for different tested specimen ranged between 0.065 to 0.125 KN/mm^2. After cross checking the results of friction stir welding as compared to other conventional types of welding it can be said that friction stir welding is the basic need of manufacturing industry to meet the ever increasing demands of compatibility and need of higher tensile strength limit.

KEYWORDS : Friction stir welding (FSW), Heat affected zone(HAZ), and Aluminium Alloy.

1. INTRODUCTION

Friction stir welding (FSW) is a new joiningprocess.It is done by moving the workpieces with respect to each other by applying compressive force to the joint to provide heating to the welding zone.Induced heat softens the metal and due to which it extruded and welding of the workpiece takes place. Aluminium plates of desired dimensions are fixed to the supportive plate to eliminate the defects due to vibrations during work and a mechanical tool is made to rotate at adequate speed to provide the well finished joint.

This welding technique provides critical merits over fusion welding which incorporates welding of aluminium alloys. Aluminium alloys are comparatively difficult to join but by using FSW it can be done with much ease and at reasonable value

Solid state welding of metals will be in demand sooner rather than later for cutting edge automotive and in aeronautical applications.In this research FSW is applied to join 6063-T6 aluminium alloys of 6mm thickness. Then, the metallographic structure along with the mechanical and thermal properties of tested specimen with different rotational speeds of tool were analysed.

2. LITERATURE

Kulekci et al. , 2008(5), decided the effects of the tool diameter, tool pivot on strength of solid state welded lap joints.Weld joints of AA 5754 aluminium plates were made by a conventional milling machine. It was found that by increasing tool pivot for a tool diameter will increase the tensile strength and vice-versa.

Liu et al. ,1997(6) mulled over microstructural parts of the friction stir welding of 6061-T6 aluminium. They expressed thatLight Microscope andTransmission Electron Microscope wereapplied to depict the microstructures in weld area, they differentiated them andinitial 6061T6 aluminium plate. They have also evaluated the related hardness profile. A progression of the butt welds and recreated welds in the solid plate zones were also driven, at rpm ranging from300 rpm to 1000 rpm. Principle comes to fruition were procured prescribes that friction stir weld area in the 6061-T6 aluminium is depicted by what has every one of the reserves of being dynamicrecrystallization microstructure. Next stage particles among work piece were fundamentally stirred intoweld zone in which the remaining hardness shifts from 55 WHN nearmost astounding purpose of the weld to 65 WHN near the base, rather than a work piece hardness which changes between around 85 and 100 WHN. The weld zone grain estimate found the centre estimation of 10 μm instead of 100 μm for the work piece.Rhodes et al. ,1997(9) pondered the effects of FSW on the microstructure of 7075 aluminium alloy. They expressed thatmethodology, in perspective of frictional heaton faying areas of plates to be joined, achieved a joint made by the interface dissemination, heat induced, and the solid-state dissemination. Benavides et al. ,1999(1) thought about low value temperature FSW of 2024 al. It was shown to incorporate dynamic recrystallization making ultra fine and equiaxed grain structures to energize super plastic failure. The 2024 Al mix was FS joined at 30 °C, and most prominent weldtemperatures did not outperform around 140 °C. It differences and a focal weld grain sizearound 10 μm, where the most outrageous weld zone temperature were 330°C.

Fazel–Fajafabadi et al., 2010 (4), proposed that by making modifications in process parameters , zero defected lap joints of CP-Ti with 304 stainless steel can be achieved.

Rajakumar et al., 2011 (8), established relationships to find hardness and grain size of AA 6061-T6 welds by incorporating process parameters and FSW tool.

Elangovan et al. , 2008 (2), worked on AA 6061 aluminium alloys , he examined impact of axial power and tool pin profiles on FSP zone. Maximum axial force applies was 7 KN and superior tensile properties were attained by using square pin profilated tool.

Elangovan et al., 2009 (3), this time he used mathematical model to predict tensile strength of AA 6061 alloys and axial force was taken 7 KN , rotational speed was 1200 rpm with welding speed of 1.25 mm/s. Superior tensile properties were given as compared to other joints.

Moreira et al. , 2008(7) analyzed Fatigue split advancement in the friction stir joints of 6061-T6 and 6082-T6 aluminium compounds. Here, a close report between fatigue split formation direct of friction stir welds of aluminium composites was finished. Fatigue split advancement graphs were settled for breaks developing in different territories of the weldments in addition with base material, heat affected zone and welded metal. For the most part, friction stir material displayed cut down quality and the ductility properties compared to base material.These base metalsdisplayed on a very basic level the same as break propagation conduct. again the friction stir 6061-T6 aluminium alloy showed cut down the crack spread rates as compared to 6082-T6 aluminium alloy.

TABLE NO. 1: COMPARISON TABLE OF VARIOUS RESEARCHERS

S.NO	RESEARCHERS	MATERIAL USED	METHOD USED	PARAMETERS	RESULT
1.	Liu et al. (1997)	AA 6061-T6	Light microscope and transmission electron microscope	Rotational speed 300- 1000 rpm Interpretation speed 0.15-0.25 cm/s	Grain size of weld was 10 µm
2.	Rhodes et al. (1997)	AA 7075	Friction heating of faying surfaces	Rotational speed of 700- 1350 rpm	Recrystallised nugget of 2-4 µm grain size
3.	Benavides et al. (1999)	AA 2024	Dynamic recrystallisation	Temp 30^0-140^0 C grain size 0.8 µm	Most extreme weld zone temp. was estimated 330^0 C
4.	Moreira et al. (2008)	AA 6082-T6 & AA 6061-T6	Fatigue crack development in FS welds	Rotational speed 700-1250 rpm	AA 6061-T6 shows low crack propagation than AA 6082-T6 alloys
5.	Elangovan et al. (2008)	AA 6061	Impact of axial power and tool pin profiles on FSP zone	Axial power was 7 KN	Superior tensile properties by using square pin profilated tool
6.	Elangovan et al. (2009)	AA 6061	Used mathematical model to predict tensile strength	Axial force was 7 KN , rotational speed was 1200 rpm & welding speed of 1.25 mm/s	Superior tensile properties as compared to other joints

3. EXPERIMENTAL SETUP

The examinations were completed on conventional friction stir welding machine with a range of 7.5 hp and 1800 rpm as appeared in Figure 3.1.

Figure 3.1 - FSW Machine

The FSW machine provides the tool rotational speed, the welding speed by spindle speed and the table feed. In FSW, the tool penetration induce the force. When the tool feed increases, then axial force also increases by the resistance offered between the tool shoulder and material to be welded with backup plate.

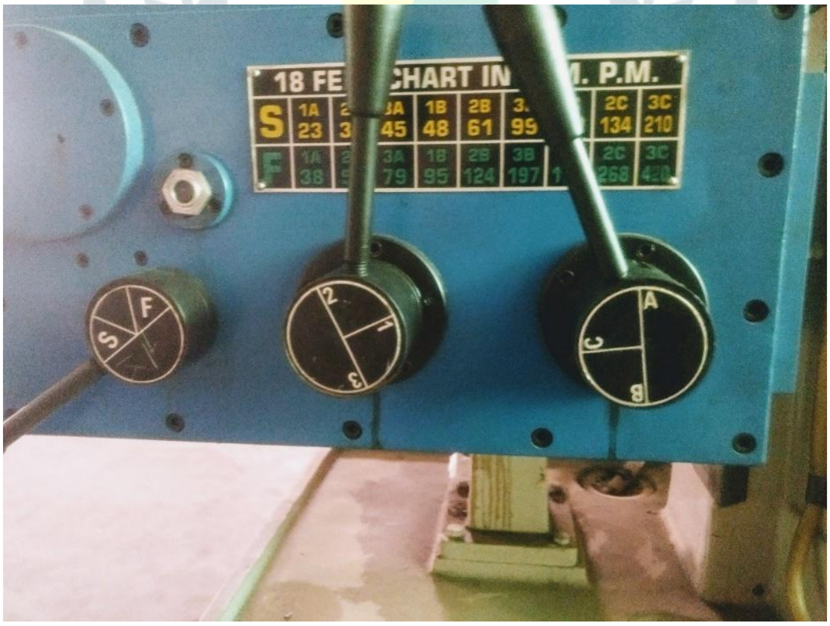

Figure -3.2 Tool feeding mechanism of FSW Machine

In figure 3.2 tool feeding mechanism is shown by which operator can give deliberate tool penetration depending on the other process parameters. Tool penetration plays a vital role in providing the desired tensile strength to the weld.

Before conducting the real work some trial runs were conducted by varying the process parameters. Process parameters were changed one by one such that by changing one variable at a time and keeping the other constant.

Range of the tool moving speed and welding pacehave been taken from 700-1300 rpm and 0.8 mm/sec to 4 mm/sec respectively (Minton and Mynors 2006). Finishing of this welded specimen is not upto mark after friction stir welding. To get properly finished surface it is rubbed to both faces to remove the chips

Further after doing work on this welded specimen drawing is made with proper dimension as indicated by the ASTM-E8 standards .While working on the welded specimens some cutting irregularities were faced due to slight hand movement and drawing error.

4. MATERIAL AND ITS PROPERTIES

The 6xxx-seriescontain manganese to expand the ductility as well as strength. Aluminium composite 6063 has the most elevated strength among the 6000 series alloys with astounding corrosion resistance property. Alloy 6063 is known as a basic alloy. The expansion of substantial measure of manganese controls the grain structure which thus brings about a more hard alloy. The 6063 alloys have manganese to build ductility and strength. The T6 phase is achieved by counterfeit maturing at180°C by **Ericsson and Sandstorm 2003(31)**.

TABLE NO.2 : INGREDIENTS OF THE 6063 ALUMINIUM ALLOY BY WEIGHT%

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
0.2–0.6	≤0.35	≤0.10	0.1	.45–0.9	≤0.10	≤0.10	≤0.10

Testing of weld is done on UNITEK 94100 testing machine as shown in figure 3.3. Test specimen were mounted precisely at zero load reading on the reading scale of testing machine.

Figure 3.3 – UNITEK 94100 Testing Machine

Tensile test data might be helpful in examinations of materials, composite improvement, quality control, and design in specific situations. The consequences of pressure trial of examples machined to standard measurements from chose segments of a section or material may not thoroughly represent the strength and ductility properties of the whole final result or its satisfactory conduct in various conditions. These test techniques are viewed as satisfactory for acknowledgment testing of commercial shipments. The test strategies have been utilized widely in the exchange for this reason. The tensile testhas been set up according tostandard values and the base metal and also the welded joints has been tried on the UNITEK 94100 Testing Machine.

During the tensile test a limit will come when the test specimen undergoes failure. Breaking of the specimen takes place at the yield point and the reading along with the graph between Load and Displacement is plotted with the help of printer attached to the UNITEK 94100 machine.

The Vickers micro hardness technique depends on optical framework. This strategy, enables us with a scope of moderate loads by using a diamond indenter by producing a identation that is estimated but changed over to a hardness range. It is exceptionally valuable to test a large range of metalsfor the time the test tests are deliberately arranged. Ordinarily the used loads keptsmall, in range of few grams reaching to few kilograms, but Vickers "macro" loads can touch 30 kilograms. Micro Vickers hardness testing machine is shown in figure 3.4.

Figure 3.4- Microvickers Hardness Tester

Specimen of desired dimensions is prepared according to the analyser size to fit the specimen in the analyser. Sample surface must be finished very smoothly for the proper readings and it should looks like a mirror in appearance. Generally, readied specimen are situated on a medium to encouragetesting.The test method was liable to issues of operator impact on the test results. Microhardness of the welds was estimated at a test load of 5 N for a short period of 10 sec.

RESULT AND DISCUSSION

While testing friction stir welded specimen of width 12mm and thickness 6mm to obtain tensile strength of the welds of aluminium 6063 alloys on UNITEK 94100 testing machine various values were obtained depending upon the provided parameters such that spindle speed ,tool penetration and the heat produced nearby the weld nugget. These values of specimen elongation and final area of the specimen are interpreted by the computer attached with the tensile test machine.

Tensile test gives the values of various variable parameters for specific friction stir welding conditions. Maximum force (FM), maximum displacement ,percent elongation and percent reduction in area are those important variables which were given by the tensile test machine.

Let us take example of a specimen XA that was tested in the UNITEK 94100 TENSILE TEST MACHINE .This was a rectangular bar of thickness 6mm,width 12 mm. Gauge length was 40 mm here at a maximum force of 6.570. Displacement at maximum force was 3.110mm and max displacement was 3.900mm . Under these conditions the rectangular bar finally breaks at a point after 17.500 % elongation . Graph obtained from the machine indicated that tensile strength of XA specimen was 91 N.

In this way total 12 specimen were tested with graphs and their values are given in the table 4.1 and their means are in table 4.2 and mean values of utm and % elongation are given in table 4.3

TABLE NO. 3: TENSILE TEST RESULTS OF VARIOUS PROCESS PARAMETERS

SAMPLE NO.	TENSILE STRENGTH (KN/MM^2)	% ELONGATION	% REDUCTION IN AREA
XA	0.091	17.500	51.389
XB	0.079	15.000	58,333
XC	0.125	20.000	46.667
XD	0.090	12.500	66.278
XE	0.078	17.000	50.889
XF	0.088	10.000	72.222
XG	0.086	16.250	53.454
XH	0.057	15.000	58.075
XI	0.100	10.000	60.555
XJ	0.072	11.250	55.775
XK	0.106	13.000	52.545
XL	0.064	15.000	58.784

The Vickers micro hardness technique depends on an optical estimation framework. The Micro hardness test strategy, ASTM E-8, determines a scope of light loads utilizing a diamond indenter to make a identation which is estimated and changed over to a hardness value. It is exceptionally valuable for testing a wide sort of materials as long as the test tests are deliberately arranged. A square base pyramid formed diamond utilized for testing in the Vickers scale. Ordinarily loads are light, extending from a couple of grams to one or a few kilograms, although "macro" Vickers loads can run up to 30 kg or more. The Micro hardness techniques are utilized to test metals, ceramics, and composites.

TABLE NO. 4: MEAN VALUE OF HARDNESS

SAMPLE NO.	MEAN HARDNESS
1	61.0667
2	61.6000
3	62.5000
4	60.9667
5	61.5000
6	61.7667
7	60.5333
8	61.0667
9	61.3333

CONCLUSION

The optimization of process parameters was done utilizing design of investigations approach. The strength of the joint was investigated by tensile test. Metallographic investigations and Micro hardness survey over the weld was performed. From these tests and investigation the accompanying conclusions are determined:-

1. Bigger plate thickness or bigger tool diameter alludes to the lower spindle speed and weld speed to get great weld. Likewise the lower plate thickness or the littler tool diameter alludes to higher spindle speed and higher weld speed to get the great weld.
2. The cross segment region or plunge territory of the tool is higher for the bigger tool which requires bigger power to hold up under the compressive plunge pressure.
3. Henceforth the higher shoulder penetrations are required.
4. Bigger plate size requires a higher number of sides of polygon for compelling stirring procedure. Thus the smaller plate size requires less number of sides of polygon to the stirring. The quantity of sides of the polygon makes the comparing beats per upset. The comparing ideal spindle speed got for various plate thicknesses alludes 105 heartbeats/sec to 110 heartbeats/sec is the ideal to accomplish the defect free great weld.

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