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Experimental Investigations of Mechanical Properties of Weld Joint of Aluminium Alloys (6XXX Series) Welded by Friction Stir Welding

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Abstract: **-- Aluminium alloys are extensively used in the field of manufacturing because of its immense range of applications. Friction stir welding is one of the major processes which are used for joining alloys of aluminium. This type of welding technique has shown very positive results in welding of aluminium alloys. In this research, variation in mechanical properties of friction stir welded aluminium alloys (6000 series) is observedconcerning variation in their input parameters, i.e., feed rate, tool rpm and tool tipcross-section. Conical, square and triangular tool tip cross sections are used in this research paper for friction stir welding of aluminium alloys. Variation in mechanical properties of hardness & roughness is observed in this research study and are calculated with the help of Taguchi's approach.**

Keywords: Friction stir welding (Al alloy-6XXX series), Hardness, Roughness, Taguchi Method.

I. INTRODUCTION

In the field of production engineering the main motive is to develop cancurate, easy and efficient method of welding processes that are ecofriendlyin nature. Friction stir welding is the most modern technique in which the non consumable tool generates heat because of friction between the workpiece and tool, due to this plastic deformation takes place at the welding position which forms the joint. This type of welding is a solid-state welding technique. It was invented in 1991. Many researchers did investigations on friction stir welding process. Thomas, JC. Murch and WM. Niclolas (1997) analyzed this new technology,i.e., friction stir welding. The studyresulted t thatto join aluminium alloys and surface oxide, friction stir welding is an effective method and for fabrication of lightweight materials which are suitable for various industrial applications can be done by a friction stir welding technique. Nakata and Y.C. Chen (2009) studied friction stir welding of 2-mm AZ91D thixo-moulded sheet. The study resulted that there is an enhancement of 38-50% of tensile strength in the weld could be obtained over base metal with rpm between 1240-1750 rpm and a feed rate of 40-50 mm/min.Park S.H.C, Sato Y.S and Kokawa (2003) studied friction stir welding on 6mm AZ31 plates at rpm of 1220 and a feed rate of 90mm/min.The study showed a much inferior yield strength and elongation and from transverse tensile test compared with the base metal, a slightly lower ultimate tensile strength of the weld is obtained.Lakshminarayananet al.,studied on AA2219 aluminium alloy at rpm between 500-1600 and frictional speed range between 0.37-2.25 mm/sec. The study showed that on AA2219 metals, defect-free friction stir welding is produced under a broad range of rotational and welding speeds. .Karthikeyan, S. Natarajan, V. Balasubramanian and V.S. Senthil Kumar (2009) in this research, cast aluminium alloy of 2285 grade was the base metal. Three different feed rates,i.e. 10mm/min, 12mm/min and 15mm/min and two different tool rotational speeds were taken,i.e. 1400 and 1800. Investigation gave hopeful results as there wasan increase in mechanical properties that are: - tensile strength, yield strength and ductility.Neeraj et al. (2016) studied and experimented on joining the aluminium alloy of AA5083 and AA6082. Conversation is done on how there exists the effect on various process parameters. The various flow of heat and other aspects are also discussedin this research paper.

II. EXPERIMENTAL SETUP

Friction stir welding of aluminium alloys (6XXX series) was done at vertical milling machine. A totalnumber of 10 joints was fabricated with the help of this machine.

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The chemical composition of aluminium alloys of series 6XXX is given in table1.

Table I. Chemical Composition of aluminium alloys

aluminium	95.8-98.6 %
chromium	0.04 – 0.34 %
copper	0.15 – 0.4 %
ferrous	Maximum 0.7 %
manganese	Maximum 0.15 %
silicon	0.4 – 0.8 %
magnesium	0.8 – 1.2 %
tin	Maximum 0.15 %
zinc	Maximum 0.25 %

Table II. Process Parameters

rpm	1000	1200	1400
Feed Rate	16	20	25

Tool material which is used for this operation is mild steel. A total number of 6 tools specimen, 2 of each different cross-sectiontip (Conical, Square,and Triangular) were fabricated on a lathe machine. Tool summarization is given in Table III.

Table III. Tool Summarization

Summarization	Conical	Square	Triangular
Tip/pin dimension	Depth-4mm, Inner Dia-4mm, Outer Dia-9mm	Sides-6mm, Depth-4mm	Sides-7mm, Depth-5mm
Tool holder dimension	Length-44mm, Dia-16mm	Length-44mm, Dia-16mm	Length-44mm, Dia-16mm
Tool shoulder dimension	Length-25mm, Dia-20mm	Length-25mm, Dia-20mm	Length-25mm, Dia-20mm

There are total 6 tools which are fabricated on a lathe machine as shown in figure I, i.e. 2 conical, 2 triangular and 2 squares. Designs of 6tools are shown in figure II.

Figure I. Lathe Machine

Figure II. Tool designs

Variation in mechanical properties(hardness & roughness) of friction stir welded aluminium alloys are experimentally investigatedconcerning variation in their input parameters like feed rate, tool rpm and tool tip cross section(Conical, Square, and Triangular). With the help of the Taguchi method, input parameters are addedin it andnumerical outcomes of hardness and roughness are shown in figure III. Graphical representation of hardness and roughness concerninga change in their input parameters are shown in figure IV.

	C1-T	C2	C3	C4	C5
	TOOL TIP	RPM	FEED	ROUGHNESS(Ra)	HARDNESS
1	T	1000	16	1.29	45
2	T	1200	20	1.13	51
3	T	1400	25	3.70	54
4	C	1000	20	1.35	59
5	C	1200	25	0.55	41
6	C	1400	16	0.66	61
7	S	1000	25	1.19	46
8	S	1200	16	2.60	47
9	S	1400	20	1.25	63

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Figure III. Input parameters and Numerical Outcomes of hardness and roughness.

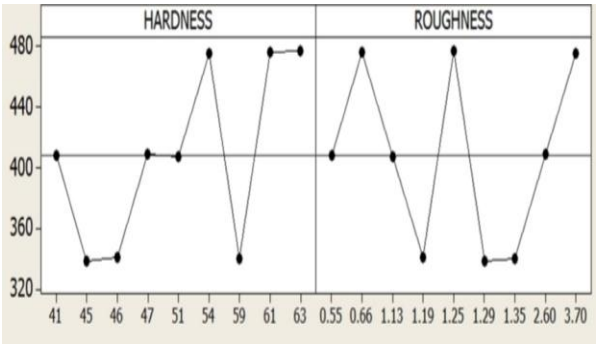

Figure IV. Graphical representationof hardness and roughness.

III. CONCLUSIONS

i) ANALYSIS OF HARDNESS

Hardness is the property of a material; it is the resistance of a material to indentation, lesser the indentation, more hard is the material. Rockwell scale is a hardness scale and surface hardness experiments are done in Rockwell hardness testing machine. Mean result of hardness as per the Taguchi Analysis is better for 6th 8th and the 9thwork piece,i.e. Conical cross section tool tip at 1400rpm with a feed rate of 16mm/min, Square cross section tool tip at 1200rpm and 1400 rpm with a feed rate of 16mm/min and 20 respectively. The experiment of hardness is done on Rockwell Hardness Machine as shown in figure V.

Figure V. Rockwell Hardness Machine.

ii) ANALYSIS OF ROUGHNESS

Roughness is the property of a material,and it indicates the surface texture of a material, more the irregularities of a material surface, more will be the roughness. Mean result of roughness as per the Taguchi Analysis is better for 2nd, 5th and 9thwork piecei.e., Triangular, Conical and Square cross-sectionaltool tip at 1200rpm, 1200rpm and 1400 rpm with a feed rate of 20mm/min, 25mm/min and 20mm/min.

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