COMPARISON OF EFFECTS OF TRIANGULAR AND HEXAGONAL TOOL PIN PROFILES ALONG WITH OTHER WELDING PARAMETERS ON MECHANICAL PROPERTIES OF FRICTION STIR WELDED JOINT OF AS41A

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ABSTRACT

In recent times, there are numerous requirements for the material having properties like better strength, light weight, better chemical properties and other merits. Here, the Friction Stir Welding is considered and the effects on the result of the quality of the weld joint. The welding parameters of tool pin profiles, rotational speeds and welding speeds are considered for the effects on the results. The results obtained here of the weld joint are of mechanical properties like ultimate tensile strength and hardness. The base material considered for the current research is Mg AS41A alloy. Besides the base material considered, the tool material considered here is HCHCr D2 Tool Steel. There are two different tool pin profiles selected here in this research work: Triangular tool pin profile and Hexagonal tool pin profile. The best result is obtained in the weld joint manufactured at 1500 rpm rotational speed and 17 mm/minute with hexagonal tool pin profile. The weld joint formed by the triangular tool pin profile gave poor results. This research paper discusses the mechanical properties like ultimate tensile strength and hardness of the weld joints obtained in this research. Also, the comparison between the hexagonal tool pin profiles and triangular tool pin profiles is made in this research work.

KEYWORDS: *Friction Stir Welding (FSW), welding parameters, mechanical properties, hexagonal, triangular.*

1. INTRODUCTION[1-5]

Friction Stir Welding (FSW) was invented by Wayne Thomas at The Welding Institute (TWI) Ltd in 1991. It would beat the issues connected with customary welding methods, for example, shrinkage, cementing splitting and porosity. FSW is a solid state process which produces welds of high caliber in materials which are hard to weld.

1.1 PRINCIPLE OF OPERATION[4]

The customary FSW process comprises of the insertion of a rotational apparatus, framed by a pin and a shoulder, into the adjoining surfaces of pieces to be welded and interpreted along the weld joint, as showed in Fig. 1.1. Amid the procedure, the pin situated inside the weld joint produces heat through both contact and plastic twisting and deforming which diminishes the material and empowers plastic stream, bringing on the blend of materials. In the meantime, the shoulder set on the surface of the adjoining line heats and drags material from the front to the rear of the apparatus, averting spillage of material out of the welding joint and framing a smooth surface.

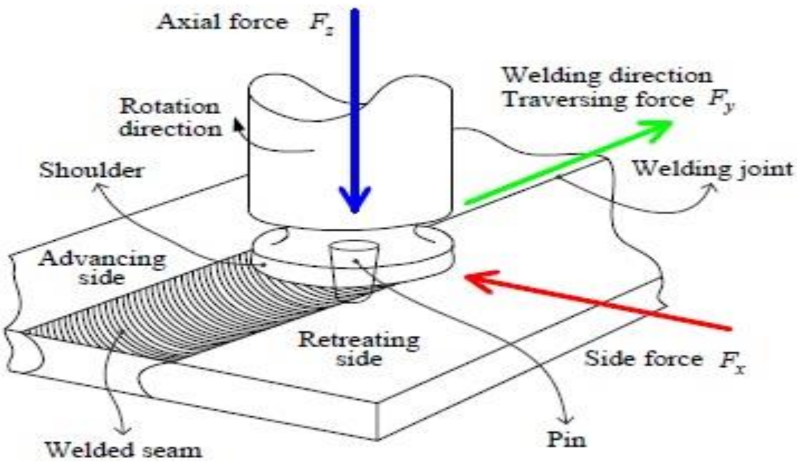

FIGURE 1.1: PRINCIPLE OF OPERATION[4]

1.2 ADVANTAGES[1]

- Good mechanical properties
- Improved safety due to the absence of toxic fumes or the spatter of molten material.
- No consumables like filler material or gas shield.
- Easily automated on simple machine tools like milling machine .
- Lower setup costs and less training.
- Can operate in all positions (horizontal, vertical, etc.), as there is no weld pool.
- Generally good weld appearance and minimal thickness under/over-matching, thus reducing the need for expensive machining after welding.
- Low environmental impact.

1.3 DISADVATAGES[1]

- Exit holes are left when tool is withdrawn.
- Large down forces required with heavy-duty clamping necessary to hold the plates together.
- Less flexible than manual and arc welding processes (difficulties with thickness variations and non-linear welds).
- Often slower traverse rate than some fusion welding techniques, although this may be offset if fewer welding passes are required.

2. EXPERIMENTAL PROCEDURE

Here, in this research work, the experimental procedure consists of an overall setup of universal milling machine with vertical tool attachment, FSW tool, base plates on which welding will be done, fixture which holds the plates rigidly, T bolts and Stepped clamps.

2.1 UNIVERSAL MILLING MACHINE

In this research work, universal milling machine was used for the experimental work. Machine has work table size 1250mm × 300mm, with variable spindle speeds ranging from 220 rpm (min) to 1500 rpm (max) along with feed rate range of 17 mm/min (min) to 240 mm/min (max).

FIGURE 2.1: UNIVERSAL MILLING MACHINE

2.2 MATERIAL SELECTED – Mg ALLOY AS41A

For the purpose of our investigation, plates of magnesium alloys AS41A-F with 6 mm thickness and 300 mm × 300 mm, are taken into consideration. It is shown in the diagram below. These plates will be cut according to the fixture size in either in universal milling machine or vertical milling machine. The size of the fixture selected here is 200 mm × 150 mm. Thus, the plates are cut to fit in the size of the fixture. Here, in order to arrange the plates to be welded together, each individual plate is cut into the size of 96 mm × 150 mm.

Chemical composition of AS41A-F is as follows:

ELEMENT	Mg	Al	Si	Mn	Zn	Cu	Ni
CONTENT(%)	94.6	3.5-5	0.5-1.5	0.2-0.5	<0.12	<0.06	<0.03

TABLE 2.1: CHEMICAL COMPOSITION OF AS41A

The physical properties of AS41A are as follows:

MELTING POINT	570-615 ^{o}C
DENSITY	1776 kg/m^3

TABLE 2.2: PHYSICAL PROPERTIES OF AS41A

The mechanical properties of AS41A are as follows:

Tensile strength	214 MPa
Yield strength	138 MPa
Compressive yield strength	138 MPa
Shear modulus	17 GPa
Elastic modulus	45 GPa
Poisson's ratio	0.35
Elongation at break(50 mm)	6-15%
Thermal conductivity	68 W/Mk

TABLE 2.3: MECHANICAL PROPERTIES OF AS41A

2.3 TOOL MATERIAL SELECTED

The tool material selected is HIGH Carbon High Chromium (HCHCr) D2 Tool Steel. The chemical composition of the tool material is as follows:

ELEMENT	C	Si	Mn	P	S	Cr	Mo	V
CONTENT(%)	1.4-1.6	0.6 max	0.6 max	0.03 max	0.03 max	11-13	0.7-1.2	1.1 max

TABLE 2.4: CHEMICAL COMPOSITION OF HCHCr D2 TOOL STEEL

The following two tool pin profiles are manufactured by lathe and precision grinding machine and then heat treated up to 57-62 HRC. Hexagonal and triangular tool pin profiles are compared in this research work.

1) Hexagonal tool pin profile:

Here, the dimensions of the profile are:
Diameter of shank = 15 mm
Length of shank = 25 mm
Diameter of shoulder = 18 mm
Length of shoulder = 20 mm
Diameter of pin = 6 mm
Length of pin = 5.8 mm

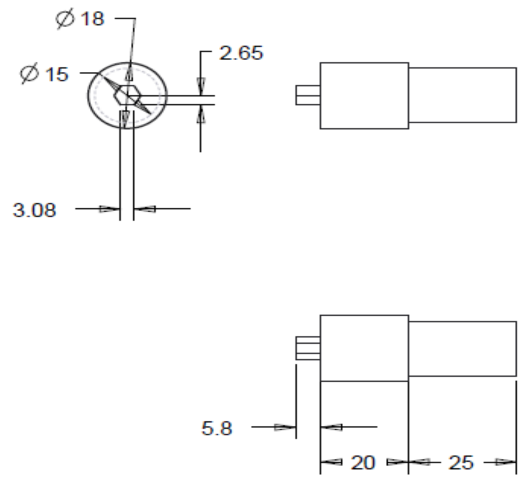

FIGURE 2.2: HEXAGONAL TOOL PIN PROFILE

2) TRIANGULAR TOOL PIN PROFILE:

Here, the dimensions of the profile are:

Diameter of shank = 15 mm
Length of shank = 25 mm
Diameter of shoulder = 18 mm
Length of shoulder = 20 mm
Diameter of pin = 6 mm
Length of pin = 5.8 mm

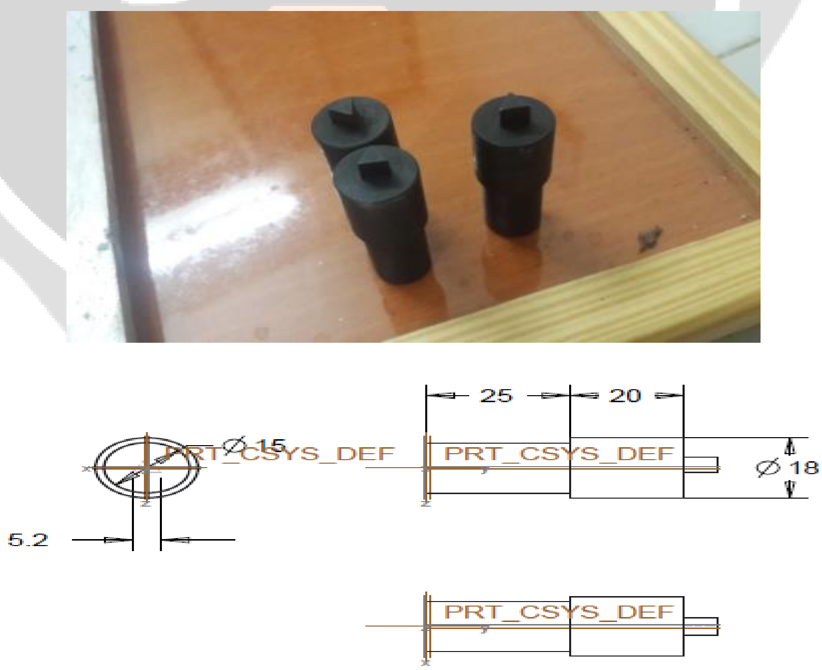

FIGURE 2.3: TRIANGULAR TOOL PIN PROFILE

3. RESULTS AND DISCUSSIONS

Here, in this research work three welding speeds and three rotational speeds are taken in to consideration and their success is also discussed in the same table given below.

TRIAL	TOOL PIN PROFILE	ROTATIONAL SPEED (rpm)	WELDING SPEED (mm/min)	RESULT
1	TRIANGULAR	880	17	SUCCESSFUL
2	TRIANGULAR	1140	24	FAILED
3	TRIANGULAR	1500	32	SUCCESSFUL
4	HEXAGONAL	880	24	SUCCESSFUL
5	HEXAGONAL	1140	32	SUCCESSFUL
6	HEXAGONAL	1500	17	SUCCESSFUL

TABLE 2.5: EXPERIMENT DETAILS WITH RESULTS

3.1 HARDNESS RESULTS

The results of the hardness of above experiments are shown in the table below.

SAMPLE	TOOL PIN PROFILE	ROTATIONAL SPEED (rpm)	WELDING SPEED (mm/min)	HARDNESS(HV)	Hardness(BHN)
1	TRIANGULAR	880	17	Not possible	-
2	TRIANGULAR	1140	24	FAILED	-
3	TRIANGULAR	1500	32	Not possible	-
4	HEXAGONAL	880	24	87	81
5	HEXAGONAL PROFILE	1140	32	77	-
6	HEXAGONAL	1500	17	88	81

TABLE 2.6 HARDNESS RESULTS OF WELDS

The welds of the triangular tool pin profile were in a very poor condition. The weld plate from the second trial failed instantly. Also, the plates welded from the first and the second trials are not properly welded and thus they have a very poor condition. The plates could not be examined in the Vicker's Hardness Testing machine. The plates needed a particular surface finish which was not there. Thus, due to improper or poor welding, the surface finish was rough and also not up to the marks for the hardness testing machine.

The welds of the hexagonal tool pin profile were in a better condition than the triangular tool pin profile. The best result from the plates welded with hexagonal tool pin profiles were in the trial '6'. Also, the weld finish in these weld joints is very good.

3.2 TENSILE TEST RESULTS

The results of the tensile tests are shown in the table below in terms of ultimate tensile strength.

SAMPLE	PROFILE	ROTATIONAL SPEED (rpm)	WELDING SPEED (mm/minute)	UTS (MPa)
1	TRIANGULAR	880	17	0.0000
2	TRIANGULAR	1140	24	0.0000
3	TRIANGULAR	1500	32	16.2847
4	HEXAGONAL	880	24	39.9305
5	HEXAGONAL	1140	32	13.6111
6	HEXAGONAL	1500	17	51.0416

The sample '1' failed during the manufacturing of the specimen, and sample '2' had failed instantly after welding. Thus, only sample '3' was successfully manufactured into specimen and then tested. The result of ultimate tensile strength is very poor. Result is found to be 16.2847 MPa in terms of ultimate tensile strength.

The results with hexagonal tool pin profile in terms of ultimate tensile strength are better in comparison to triangular tool pin profile. The values of ultimate tensile strength for hexagonal tool pin profile are shown in the table above.

Thus, hexagonal tool pin profile is better than the triangular tool pin profile in terms of ultimate tensile strength.

4. CONCLUSION

It is found from the above results that the mechanical properties of the weld joints using hexagonal tool pin profile are better than triangular tool pin profiles. Also, in hexagonal tool pin profiles, the result of the weld in which the rotational speed is higher and the welding speed is low, has better mechanical properties. Sample '6' from the experimented trials had parameters of hexagonal tool pin profiles having rotational speed of 1500 rpm and welding speed of 17 mm/minute.

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