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Influence of Tool Pin Profile on Microstructure and Mechanical Properties of Friction Stir Welded 6351 Aluminium Alloy.

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Research Article

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ABSTRACT

The objective of this investigation is to study the effect of five tool pin profiles, namely straight, cylindrical, taper cylindrical, threaded cylindrical, square and triangular on the mechanical properties and microstructure of friction stir welded aluminium AA6351 alloy. The defect free FSW butt joints were produced on the alloy sheet at a constant rotational speed 900 rpm and traverse speed of 65mm/ min with different tool profiles. The results indicate that the triangular tool produced mechanically sound and metallurgically free, defect weld joints compared to other tool pin profiles.

INTRODUCTION

Aluminium alloys are more attractive for applications of automotive, aerospace and marine industry due to their high specific strength, corrosion resistance and weldabilty. Friction stir welding is a new solid state welding technique developed by The Welding Institute (TWI) for joining of aluminium alloys and other metallic materials [1]. It is a continuous process in which a rotation tool pin moves along the joint interface and a tool shoulder applies a severe plastic deformation [2].The main advantages of this method are fewer weld defects, low distortion , high quality, lower residual stresses etc. The welding parameters such as rotational speed, welding speed, axial force and tool pin profile influence the mechanical properties of the joints [3].The effect of some important parameters such as rotational speed, traverse speed and axial force on weld properties of aluminium alloys has been investigated[4-6] . Sakthivel explained the influence of welding speed on microstructure and mechanical properties of friction stir welded aluminium alloy. The results indicated that good correlation existed between mechanical properties and welding speed [4]. Peel et al. [7] investigated the effect of tool traverse speed and tool design on mechanical properties of friction stir welded aluminium 5083 alloys. Jayaraman et al [8] studied the influence of process parameters on tensile strength of friction stir welded cast A319 aluminium alloy joints. Zhang et al [9] investigated the effect of shoulder diameter on the temperature rise and material deformation in friction stir welding and found that grain growth near the welding line can be restricted by controlling the temperature variation. Mathematical models were developed between friction stir welding process parameters and mechanical properties of aluminium alloys [10]. Elangovan et al [11] studied the influence of tool pin profile and shoulder diameter on the formation of friction stir processing zone in AA 6061 aluminium alloy. They found that the joints made by square tool pin profile with 18 mm shoulder diameter showed better mechanical properties. Literature indicated that most of the research work has been carried out on FSW of AA 6061, AA 6082, and AA 2219 aluminium alloys [11-13]. Limited work has been carried out on friction stir welding of aluminium AA 6351 alloy. Hence, it required to study the influence of tool pin profile on the mechanical properties of joints.

In this investigation, an attempt has been made to understand the influence of various types of tool pin profiles on mechanical properties of friction stir welded aluminium AA 6351 alloy.

EXPERIMENTAL WORK

In this present investigation, a rolled sheet of 4mm thickness aluminium AA 6351 alloy sheet was used as the base material. The samples of size 150 mm × 75 mm were cut from the sheet using a milling machine. The nominal chemical composition of the base material was tested using spectral analysis. The mechanical properties of the base material such as tensile properties and hardness were tested using tensile test and Vickers micro hardness test, respectively. The chemical composition and mechanical properties of the material is shown in Table 1 and 2 respectively. Before starting the friction stir welding, the samples that need to be friction stir welded were firmly clamped to the backing plate using holding clamps which were bolted to the work table of the machine. The rotating FSW tool was pressed against the joint interface. The single pass welding procedure was adopted in the rolling direction at a constant load for fabricating the joints as shown in the Fig.1. Non consumable tools made of high carbon steel, H13 with shoulder diameter 18 mm was used to fabricate joints. Five different tool pin profiles were used to fabricate joints shown in Fig 2. The FSW processing parameters and tool dimensions are presented in Table3.

Table 1 Chemical composition of AA6351 (Wt %)

Element	Si	Fe	Mn	Mg	Cu	Zn	Ti	Cr	Al
% Wt	0.91	0.5	0.54	0.71	0.02	0.005	0.004	0.05	Balance

Table 2 Mechanical properties of base material

Ultimate tensile strength (MPa)	Yield strength (MPa)	Elongation (%)	Hardness (H_V)
360	269	12	59.7

Table 3 FSW process parameters and tool dimensions

Process parameters	Values
Rotational Speed (RPM)	900
Traverse Speed (mm /min)	65
Tool Inclined angle (°)	3
Tool shoulder diameter, D (mm)	18
Pin diameter, d (mm)	6
D/d ratio of tool	3
Pin length, L (mm)	3.8

Figure 1: Friction stir welding experimental set-up

Tensile testing was carried out on a universal testing machine and an average of three test results were done to analyse the strength of the samples that were cut along the processing direction as per ASTM E8M-04 guidelines. Vickers microhardness measurement was done using Vickers micro hardness tester with a load of 5 kgf and a dwell period of 20s. The microstructure of the base material and welded samples was examined by optical microscope. The specimens for microstructural analysis were sectioned to the required size and then polished using different grades of emery papers and etched with a standard Kellers reagent made of 1ml hydrofluoric acid, 1.5 ml hydrochloric acid, 2.5 ml nitric acid and 95 ml diluted water.

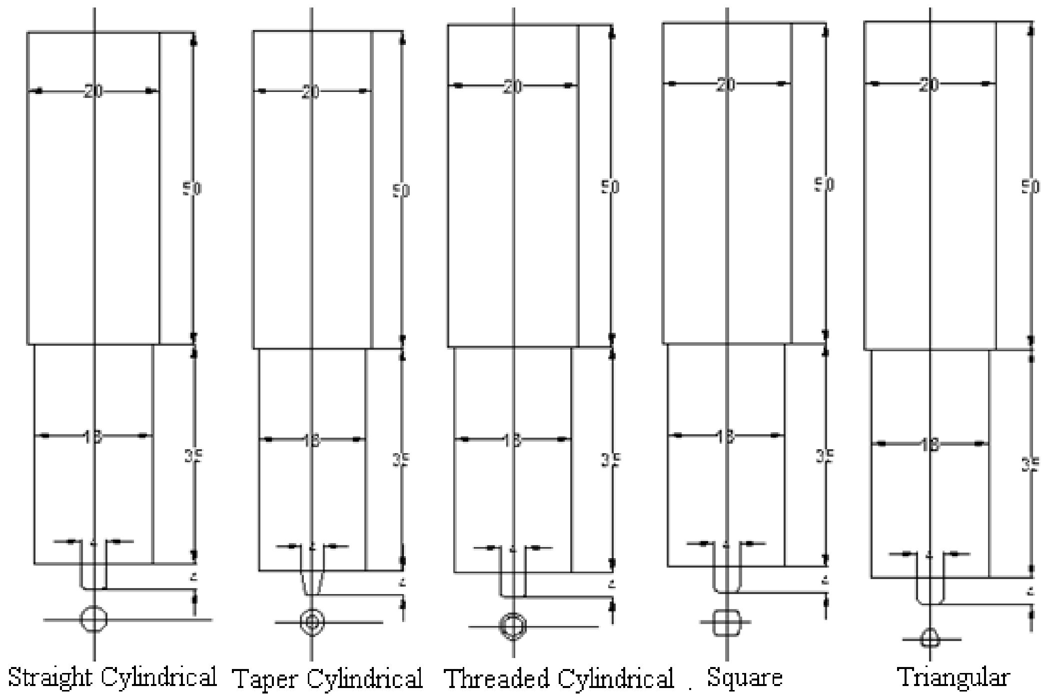

Figure 2: FSW tool pin Profiles

RESULTS AND DISCUSSION

Mechanical properties

Table 4. Mechanical Properties of FSW aluminium AA 6351 alloy

Tool pin profiles	UTS (MPa)	YS (MPa)	% Elongation	Micro hardness (Hv)
Straight cylindrical	168	100	9.3	40
Taper Cylindrical	170	80	7.56	44
Threaded Cylindrical	166	127	6.56	42
Square	161	77	10.66	39
Triangular	174	117	9.3	48

Mechanical properties of friction stir weld joints fabricated by different types of pin profiles are shown in Table 4. From the Table 4, it is observed that the joints made by triangular tool show better mechanical properties with the higher joint efficiency compared to all other joints. This is due to the more grain refinement and annealing during the welding process. The joints fabricates by the taper cylindrical tool also showed better properties. This is due number of optimal heat generation. The joints fabricated by square pin profile exhibited lower mechanical properties compared all the samples. This is due to grain growth during process causes the higher amount of heat generation due to the larger contact area.

Microstructure Analysis

The optical microstructures of base material and FSW samples are shown in Fig 3. The optical microstructure of base material and FSW samples are taken at the nugget region. The base material consists of an inhomogeneous coarse grain structure. The FSW samples exhibited homogeneous fine grain structure compared base material. The sample fabricated by triangular tool produced better microstructure having uniform grains. This is the reason for obtaining better mechanical properties of FSWed by triangular tool. The joint made by square tool

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is shown in homogenous microstructure having large grains due to grain growth during the process resulting poor mechanical properties.

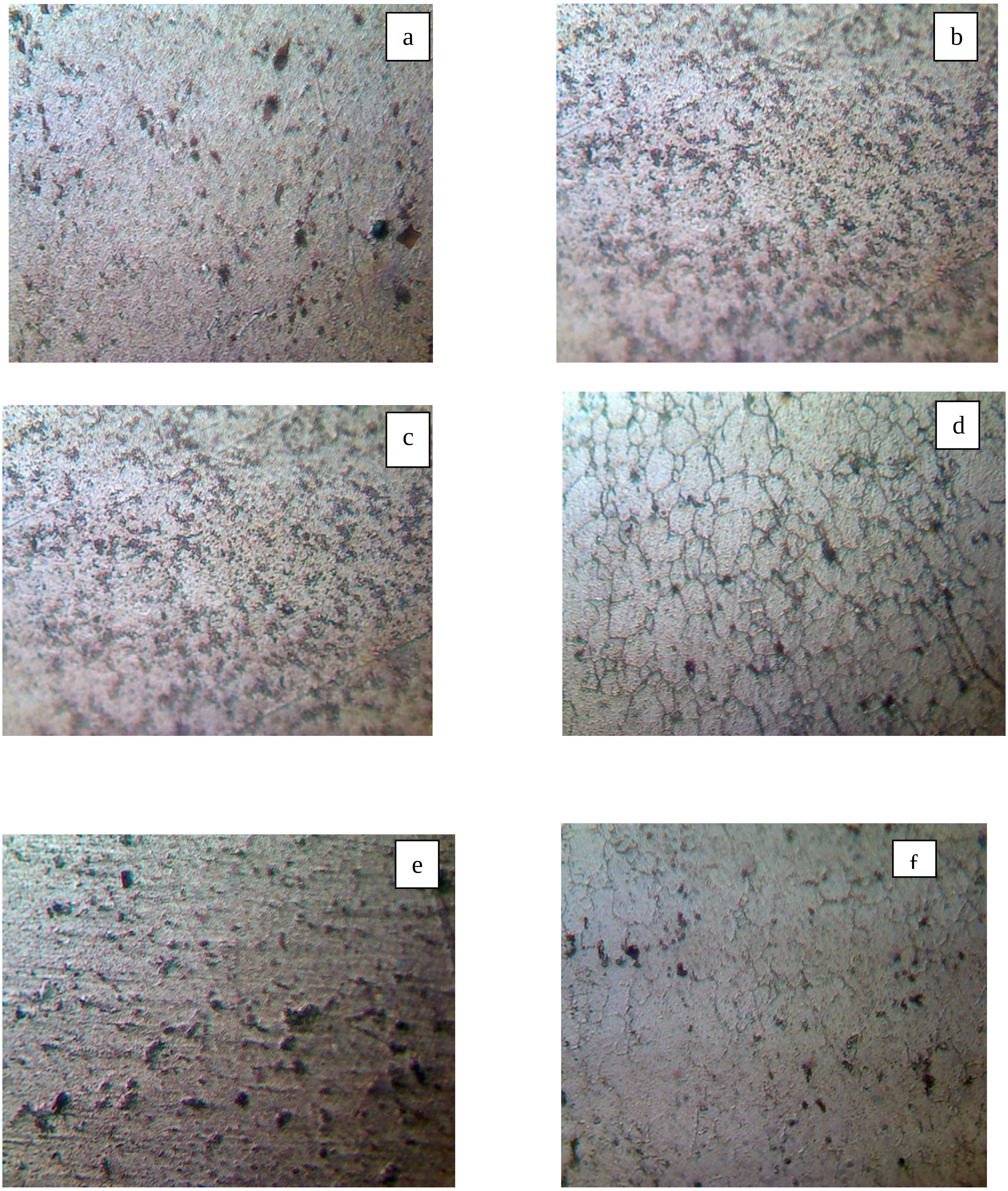

Figure 3: Optical microstructures of (a) base material (b) FSW samples of straight cylindrical tool, (b) taper cylindrical tool (d) threaded cylindrical tool (e) square and triangular tool

CONCLUSION

The influence of various tool pin profiles on mechanical properties and microstructures has been evaluated. The results indicate that the joints made by triangular tool exhibited superior mechanical properties than others due to more grain refinement during the process.

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