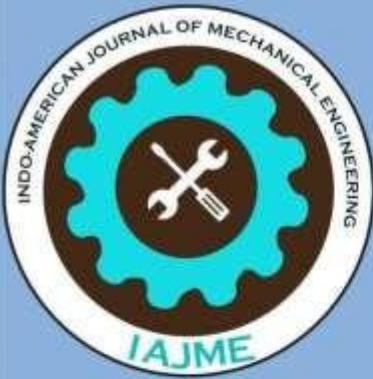




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Impact Strength in Friction Stir Welded Aluminum 6101 T6 Alloy: The Role of Welding Speed and Tool Pin Geometry

Dr. B. Ravi, Dr. G. Raja Kumar, B. Shankar, K. Rambabu

Abstract.

The material being welded does not melt and recast during the friction stir welding (FSW) process, making it a solid state joining technique. Here, a consumable tool is used to produce heat by friction between the mating surfaces. Welding settings are crucial in determining the final joint performance. This study examines the impact of friction stir welds of aluminum alloy, focusing on the effects of welding velocity and tool pin shape. Strips of 6mm thick Aluminum alloy AA 6101 T6 with a variety of tool pin profiles (cylindrical, tapered cylindrical, square, and tapered square) were used to create the welded connections. All welding was completed at ambient temperature.

1 Introduction

Aluminum alloys are increasingly being used in the transportation and aerospace industries because to their low density and ease of casting. Aluminum requires welding. Use castings alone or in combination with wrought alloys in a wide range of products. Because of issues including porosity, hot cracking, and distortion while welding, these alloys are difficult to fuse using standard fusion welding methods. An developing solid state joining technique, friction stir welding (FSW) does not need melting and recasting the material being welded [1]. The idea behind the FSW procedure is straightforward. In this case, the non-replaceable tool is a shoulder and a pin [2]. Moving ahead along the weld line, the pin of the rotary tool is inserted into the plates being welded until the shoulder makes solid contact. The rotating

tool generates frictional heat, which warms and pliable the material. The pliable material beneath the shoulder is extruded by the tool's rotating and traverse motion, carried from the front to the rearward side of the joint, and consolidated into a single piece there [3]. The weld junction is made by FSW without the need for bulk melting. Furthermore, dynamic recrystallization and recovery, brought on by the substantial thermal mechanical deformation, enhance the microstructure of the stir zone. Thus, it is shown that FSW welds have much better mechanical qualities than their comparable fusion welds. Since FSW is a solid-state process, the material must be correctly agitated under the rotating action of a non-consumable tool in order to produce high-quality

Assoc. Prof^{1,3,4}, Professor²
bravi1234@gmail.com, rajkumardotcom@gmail.com, shankarbanothu3@gmail.com
kasimallarambabu@gmail.com

Welds devoid of defects [4]. Even in aluminum alloys that were assumed to be non weldable, defect-free welds with acceptable mechanical qualities have been created [5]. Alloys undergo solid-state phase transitions during the cooling cycle of a friction stir weld. Due to FSW is preferred over fusion welding since it does not need the parent metal to be melted [6]. Frictional heat generated by the thermal cycle during welding varies throughout the weld's cross section. Because of the high temperatures and the mixing of the plasticized material, the distribution of any precipitates in the base material is altered in the FSW zone. Welding's heat and temperature distribution variations affect the joints' durability and malleability [7].

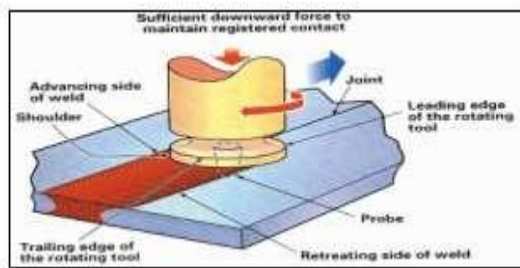


Figure 1. FSW Process

The tool's pin/shoulder shape controls the process forces and ensures a consistent microstructure and joint characteristics. An MX Triflute and Whorl Instrument higher heat output and decreased displacement volumes of the softened materials allow welding forces to be reduced in geometries [8]. The rate of rotation of the tool, and hence the rate at which the material surrounding the pin is heated and stirred and mixed, is given by the equation [9].

The highest temperature produced during welding and the amount of time the material is exposed to the welding is controlled by the welding speed or tool traverse speed [10]. Moving the tool back and forth over the pin moves the agitated material from the front to the rear, where it may be welded [11]. The great productivity of friction stir welded joints is made possible by the fast welding speed.

However, while welding at a constant rotational speed, going too fast might cause voids to develop under the weld's top surface or on the leading edge of the weld nugget. The more the welding speeds, the larger the wormhole faults [12]. So, the purpose of

this experiment is to measure the impact strength of welded joints made from AA6101 aluminum alloy at different welding speeds.

2 Experimental works

For this experiment, we utilized 6 mm thick plates of extruded AA6101 in T6 condition as our foundation material. The necessary dimensions for the plates were dimensions (300 mm 150 mm) by cutting with a powered hacksaw and grinding down to size. Different tool pin geometries were fabricated for each of the four tools (cylindrical, taper cylindrical, square, and Taper Square). Lathe machines were used to make pins with a square form and tapered square pins, while Milling machines were used to make pins with a cylindrical shape. The tool's pin is 6mm in diameter and the shoulder diameter is 18mm. The length of the pin should be just under the thickness of the material being worked on. There is a 6mm thickness to the work piece and a 5.90mm pin length. FSW joints were fabricated using a square butt joint design. After positioning the plates using mechanical clamps, the basic joint arrangement was established. Welds were done at right angles to the rolling direction. The joints were made using a single-pass welding technique. High carbon high chromium steel, non-consumable tools were utilized to make the joints. Table 1 displays the results of an analysis performed at IMTT Batala on the elemental makeup of the base metal.

Table 1. AA 6101 T6's Constituent Chemicals.

Element	Percentage
Al	97.6 min
Si	0.60 max
Fe	0.35 max



Cu	0.10 max
Mn	0.10 max
Mg	0.90 max
Cr	0.10 max
Zn	0.10 max
Ti	0.10 max
Others	0.15 max

The joints were manufactured using the R & D centre, Ludhiana's HAAS Super VF2 (12000 rpm) Vertical Milling machine. The joints were made at a steady the translation rates were assumed to be 40 mm/min, 55 mm/min, 70 mm/min, and 85 mm/min with a rotational speed of 1100 rpm. Each tool was used to create four different joints. Table 2 displays the process parameters, their values, and the sizes of the associated tools.

Table 2: Parameters for the FSW procedure

Process parameters	Values
Tool rotation speed (rpm)	1100
Welding speed (mm/min)	40, 55, 70, 85
Pin Length (mm)	5.90
Tool shoulder Diameter (mm)	18
Pin diameter (mm)	6
D/d ratio of tool	3
Tool pin geometry	Cylindrical
Tool material	High carbon steel

Welded joints were cut using a band saw and then machined to the appropriate sizes for testing. The Material Testing Association of America the specimens used in the tests were prepared according to (ASTM) standards. The impact resistance of several specimens was determined using the Charpy test. The first step of Friction Stir Welding is seen in Figure 2. Figure 3 shows the welded Specimen



Figure 2. Starting Stage of FSW Process



Figure 3. Welded Specimen at 1100 rpm, 70mm/min

3 Results and discussion

Charpy tests on transverse tensile samples with a weld nugget zone at the impact zone were used to determine the impact strength of friction stir welded joints. Impact strength of friction stir welded AA 6101T6 aluminum alloy joints generated at different welding speeds and with varying tool pin shapes is shown in Table 3. Demonstrates that AA 6101T6 friction stir welds have lower impact strength than the starting material. When compared to other joints, those made using a Taper square tool have higher



impact strength. However, joints made with a cylindrical pin shaped tool are weaker. Impact strength for a cylindrical pin profiled tool rises linearly from 31 J at a rotating speed of 1100 rpm to 34 J at a welding speed of 40 mm/min, and then declines to 32 J at a welding speed of 85 mm/min (Figure 2). For a tool with a cylindrical pin shape, the maximum weld joint impact strength was 34 J. Taper cylindrical pin contoured tools have higher impact strength than their cylindrical pin counterparts. As welding speed is increased from 40 mm/min to 85 mm/min, the impact strength also rises, from 33 J to 38 J. Square pin profiled tools have less impact strength than their cylindrical and tapered cylindrical pin counterparts, but more strength than their Taper square pin counterparts. For a taper square pin profiled tool, the impact strength rises from 41 J at low welding speeds to 48 J at high welding speeds, falling down to 40 J at medium welding speeds.

Strength of Fabricated Joints against Impact, Table 3.

Sample No.	Welding Speed	Shape of Tool	Impact Strength
1	40	Cylindrical	31
2	55	Cylindrical	33
3	70	Cylindrical	34
4	85	Cylindrical	32
5	40	Taper Cylinder	33
6	55	Taper Cylinder	35
7	70	Taper Cylinder	36
8	85	Taper Cylinder	38
9	40	Square	34
10	55	Square	36
11	70	Square	39

12	85	Square	35
13	40	Taper Square	41
14	55	Taper Square	42
15	70	Taper Square	48
16	85	Taper Square	40

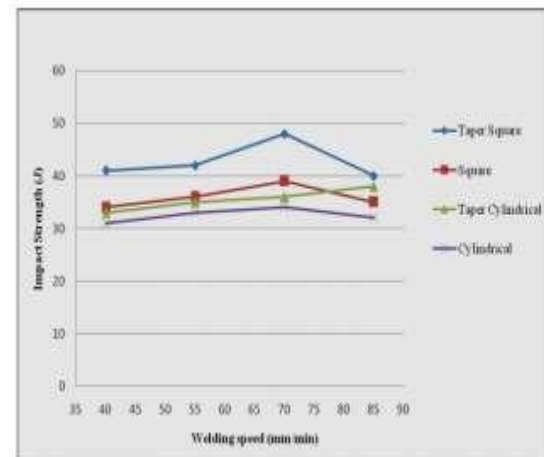
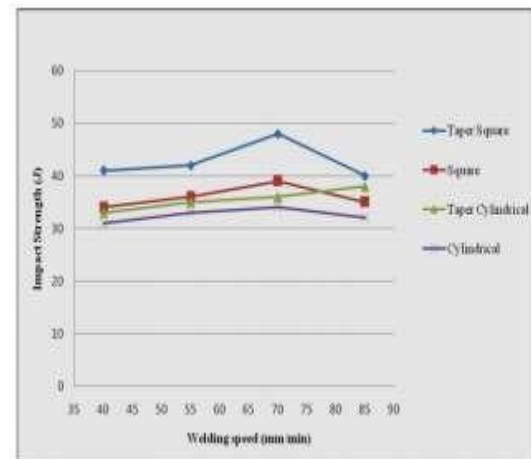


Figure 4: Impact Strength as a Function of Welding Velocity and Pin Profile

The profile of the pin is crucial to the smooth flow of materials and production. Friction stir welding is controlled by a turntable, which determines the welding rate. Eccentric people tend to choose pins with square or tapered-square shapes. Because of the pin's irregularity, even incompressible materials may flow around it. A dynamic orbit is connected to the eccentricity of the object that is revolving. The route followed by plasticized material as it flows from the leading edge to the following edge of a rotating tool is determined by the relationship between the static volume and the dynamic volume. The square tool, the taper cylinder tool, and the cylindrical pin profiled tool all have lower ratios than the taper square tool. Because of their flat sides, tools with a taper square or square pin shape may also provide a pulsing stirring motion in a fluid. For a tool with a cylindrical or tapered cylindrical pin profile, this pulsing motion is not present. Taper Square pin shaped tools provide the strongest pulsing action in the stir zone, which

results in fine grains and the maximum impact strength.

4 Conclusions

Research was conducted to determine how welding Velocity impacts the development of a friction stir processing zone in aluminum alloy AA 6101T6. Important findings from this inquiry are as follows: It is possible to create a flawless weld out of AA 6101T6 by using the friction stir welding method. The analysis found that the taper square pin profiled tool outperformed the cylindrical, taper cylindrical and square pin profiled tools when it came to joint strength. Impact strength of friction stir welded connections is affected by (iii) the profile of the tool pin and the welding speed. Welding faster enhances the impact strength of the joints, but only up to a certain limit. The strongest impact resistance was found in the joint that was manufactured at 1100rpm rotating speed and 70mm/min welding speed using a taper square pin shaped tool.

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