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INVESTIGATIONS OF MECHANICAL PROPERTIES OFAA7075 JOINTS BY USING BOBBIN TOOL FRICTION STIR WELDING

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Abstract

Bobbin tool friction stir welding, a solid state metal joining technique, is being extensively used to join similar and dissimilar materials and alloys. In the present study, Bobbin tool is used to join 7075 aluminum alloy at a specific optimized tool rotational speed and tool travel speeds. The aluminum alloy coupons of size 75 x 150 mm are prepared. An exclusive welding fixture is designed to hold the specimens. With the optimized value of tool rotation speed and traverse speed the coupons are welded. The weld zone exhibits uniform texture and the mechanical properties are improved.

Key words: Bobbin tool Friction stir welding, Aluminium alloy, AA7075

I. Introduction

A solid-state welding technique called friction stir welding (FSW) welds two pieces of metal without melting them. The Welding Institute (TWI) in the UK created it and obtained a patent for it in 1991. In comparison to conventional welding techniques, FSW has several benefits including a lower chance of flaws, faster welding speeds, and superior mechanical qualities. In FSW, the joint between two metal components is penetrated by a rotating tool with a carefully designed shape. A solid-state bond can be created by stirring the metal together while it is softened by frictional heat produced by the tool. The softened metal is continually combined and agitated while the tool is pushed along the joint, creating a solid-state weld. Because of its capacity to combine high-strength alloys such as aluminium, titanium, and steel, FSW is frequently employed in the aerospace, automotive, and shipbuilding industries, among others. Moreover, it is employed in the production of pressure vessels, heat exchangers, and other parts requiring high strength and dependability. Overall, FSW is a promising technology with a wide range of possible uses, and current research is looking into methods to improve the procedure and increase its capabilities.

Due to its distinctive mix of characteristics, including as low density, high strength-to-weight ratio, resistance to corrosion, and outstanding formability, aluminium alloys are widely employed in a wide range of applications. There are various aluminium alloy series that can be found; they are categorized according to the alloying components they include. The most popular series of aluminium alloys and their uses are: 1000 series: These alloys have a minimum purity of 99.0% and are pure aluminium. They are frequently employed in products like electrical conductors and packaging where excellent electrical conductivity and corrosion resistance are necessary.2000 series: These copper-alloyed alloys are very strong and have great fatigue resistance. They are frequently utilized in aerospace applications for things like the elements of aircraft and missiles.3000 series: These alloys, which feature manganese as an alloying element, have acceptable formability and average strength. They are utilized in products including chemical apparatus, heat exchangers, and cooking utensils.4000 series: These alloys, which are silicon-alloyed, have good weldability. They are utilized in brazing alloys and welding wire. 5000 series: These alloys, which contain magnesium as an alloying component, exhibit great strength, good formability, and exceptional corrosion resistance. They are employed in a variety of applications, including structural components, automotive parts, and marine components.6000 series: These alloys, which combine silicon and magnesium, exhibit good formability, strength, and corrosion resistance. In architectural applications including windows, doors, and curtain walls, they are frequently employed.7000 series: These alloys, which feature zinc as an alloying component, exhibit great strength and good fatigue resistance. They are utilized in sporting goods and aeronautical applications, including bicycle frames and aircraft parts. In conclusion, the choice of an aluminium alloy is influenced by the particular application, considering elements like strength, corrosion resistance, formability, and cost. Aluminium has some qualities that make it suitable for some uses, yet it is not always stronger than all other metals. Several factors make aluminium a popular alternative to other metals, including the following. Lightweight: Compared to many other metals, aluminium is lightweight due to its low density. As a result, it is beneficial in applications where weight is an issue, like in the aircraft sector. Resistant to corrosion: Aluminium is resistant to corrosion because of the thin oxide layer that accumulates on its surface. Because of this, it is a suitable option for outdoor applications and places where it might be exposed to chemicals or dampness. Ductile: Aluminium can readily be stretched or bent without breaking because of its high degree of ductility. Because of this, it may be molded into intricate shapes for use in certain applications. Thermal and electrical conductivity: Excellent thermal and electrical conductivity: Aluminium is a great material for heat sinks and electrical wiring because of its outstanding thermal and electrical conductivity. High strength-to-weight ratio: Aluminium has a high strength-to-weight ratio despite not being the strongest metal. As a result, it is useful for applications where weight is an issue but strength is still crucial. It is relatively strong for its weight. PANYA BUAHOMBURA. et al [1] investigated in comparison to base materials (BM) was the fatigue crack growth (FCG) behavior at weld nugget zones (WNZ) and heat affected zones (HAZ) in friction stir welded (FSWed) joints made of the aluminium alloys 5052, 6N01, and 7N01. With a stress ratio of 0.1, tests on the growth of fatigue cracks under constant stress amplitude were performed. In parallel with the fatigue test, the crack closure behavior was examined using the unloading elastic compliance method. According to the study's findings, the WNZ of the FSWed 5052 and 6N01 joints had lower FCG resistance in the region close to the threshold than did the BM and the HAZ. However, compared to the BM and the HAZ, the WNZ of the FSWed 7N01 joint had stronger FCG resistance. W.Y. L et al.[2] On the microstructure and mechanical characteristics of bobbin tool friction stir welded (BT-FSW) Mg AZ31, the influence of rotational and welding rates were examined. The findings showed that equiaxed grains made up the thermo mechanical affected zone (TMAZ), which was in contrast to the distorted, rotated, and elongated grains present in the TMAZs of Al alloys that were friction stir welded using a bobbin tool and Al and Mg alloys that were friction stir welded. As the ratio of rotational speed to welding speed grew, so did the average grain size.

Huijie Zhang et al [3] At varied welding speeds, 2A14-T6 aluminium alloy was bobbin tool friction stir welded (BT-FSW). According to the microstructural investigation, the upper layer's grains in the weld nugget are smaller than due to the greater degree of heat dissipation through the top shoulder, those of the bottom layer should be attributed to this. The middle layer of the weld nugget of BT-FSW joints contains an ellipse-shaped region and a triangle-shaped region with substantial elongated grain structures. The two zones are thought to have formed as a result of inadequate material plastic deformation brought on by the tool pin's flat shape. The fracture characteristics of joints during a tensile test can be greatly impacted by the insufficiently agitated sections.D. Alléhaux et al[5]. The current study examines the qualities of a brand-new aluminum-copper alloy that was created by ALCAN and designed 2139 and welded using the FSW bobbin tool technique process. Both the T4 and T8 tempers before welding are evaluated in light of the age formable alloy's greatest results after T8 ageing. Therefore, the behavior of the FSW bobbin tool welds on 2139 after T8 post-aging and on the T8 as welded condition is studied under static and fatigue load circumstances as well as in damage tolerance, including both fracture toughness and fatigue crack propagation. The impact of artificial ageing on the properties obtained by the T8 as welded condition is also discussed. The corrosion resistance of the welds is explored by an accelerated corrosion test with the objective of evaluating the weld's intergranular corrosion sensitivity.

M. Esmailya, et al [6] Bobbin friction stir welding (BFSW) extruded AA6005-T6 weldments produced using fast and slow process conditions have had their atmospheric corrosion examined. As a point of comparison, the same material's typical FSW-fabricated weldments were also exposed. rich in copper phase .At the grain boundaries in the stir zone of both specimens, particles were found. It is clear that BFSW specimens have better corrosion behavior than those made using slow process parameters. The increased corrosion resistance of the fast BFSW specimens was carefully attributed to the different microstructure of the weldments.JannikGoebelaet al [8] The aluminium lithium alloy AA2198-T851 has been bobbin tool friction stir welded using a tool concept with one stationary and one rotating shoulder. Defect free welds in 3mm thick sheet have been produced with a high quality surface finish on the stationary side. The macrostructure forms an asymmetrical shape with microstructural characteristics known from standard friction stir welding. Because there is only one rotating side a material flow direction towards the station.

L. Zhouaet al [9] utilized the specifically created bobbin tool with different rotation speeds, the 5-mm-thick AZ61 magnesium alloy was friction stir welded. With rotational speeds ranging from 550 to 600 rev min1, defect-free welds were effectively produced. Depending on the rotation speed, different areas of the joints had variable grain sizes. The joint's hardness value is constant. While the defect-free joints' fracture position switched to the heat-affected zone, the defective joint fractured in the weld nugget zone with the lowest tensile strength. Weld nugget zone impact energy is larger than heat impacted zone impact energy, and both impact energies in a defect-free joint reduced with increasing rotation speed. YunqiangZhaoet al [10] This work led to the development of the water-cooling bobbin-tool friction stir welding (WBT-FSW) innovative welding technique. WBT-FSW was used to successfully attach sheets of 6063-T6 aluminium alloy that were 4 mm thick. Studies comparing the mechanical qualities and macro/microstructural traits of joints created by conventional bobbin-tool friction stir welding (BT-FSW) and WBT-FSW were conducted. According to the findings, water mist cooling can drastically lower the welding temperature and enhance the joint's mechanical qualities as well as weld formation. The WBT-FSW joint's tensile strength was 11.4% higher than the BT-FSW joint's.

Yupeng Li et al [10] 6082-T6 at various rotational speeds. The specimens' heat cycles, microstructure, microhardness, and tensile characteristics were examined. The findings demonstrate that as rotational speed is increased, the maximum temperature at the joint increases initially before decreasing. The highest temperature is 509 C at 1000 r/min. An "S" line, a gray-white texture, and a rectangular micromorphology may be seen in the joint's cross-section. Equiaxed recrystallized grains were considerably smaller in the agitated zone. The average grain size in the stirred zone region decreases as welding speed increases. Fuse K, Badheka Vet al [15]The present report successfully examined the viability of fabricating composites simultaneously on the top and bottom sides of the workpiece utilising B4C reinforcing particles in Al 6061 alloy. Exceptional B4C dispersion particles produced using this method on the workpiece's bottom side. Optical and scanning electron microscopy were used to conduct the metallurgical analysis of Al 6061/B4C double side composites. The manufactured composites' mechanical characteristics, which include sliding wear behavior and microhardness, were carefully examined. With three passes, the data showed a more even distribution of B4C particles. In comparison to Al as received, the produced composites' microhardness and wear characteristics were greatly improved by the B4C's refined grains and homogenous distribution.

Table 1. Material composition of tool steel.

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WNr 1,6582/DIN 34CrNiMo$_6$—∅16 mm							
C	**Mn**	**Si**	**P**	**S**	**Cr**	**Mo**	**Ni**
0.30–0.38	0.5–0.8	0.40 max	0.025 max	0.035 max	1.3–1.7	0.15–0.30	1.3–1.7

Table 2. Composition of 7075 aluminum alloy

Al Alloy	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Ga	V	Al
7075	0.12	0.2	1.4	0.063	2.53	0.2	0.004	5.62	0.03	0.008	0.016	bal.

FIG 1 Bobbin Tool

II DESIGN OF FIXTURE

A welding fixture can be custom-designed for a particular job or it can be a standardized fixture that is used for multiple jobs. It typically consists of a frame or structure that holds the workpieces securely, along with clamps, jigs, and other components that are used to position the workpiece precisely. Welding fixtures can be used in a variety of welding processes, including MIG, TIG, and stick welding, and they are commonly used in industries such as automotive, aerospace, and construction. They can improve welding efficiency, reduce labour costs, and improve the quality of the finished product by ensuring consistent weld quality and reducing the risk of errors. A welding fixture is a specialized type of fixture that is designed to hold and position two or more workpieces together during a welding operation. Welding fixtures are used to ensure accurate and consistent placement of the workpieces, which is critical to achieving a high-quality weld. The design of a welding fixture depends on the specific requirements of the welding operation. The 2D design of fixture as shown in the Figure 2

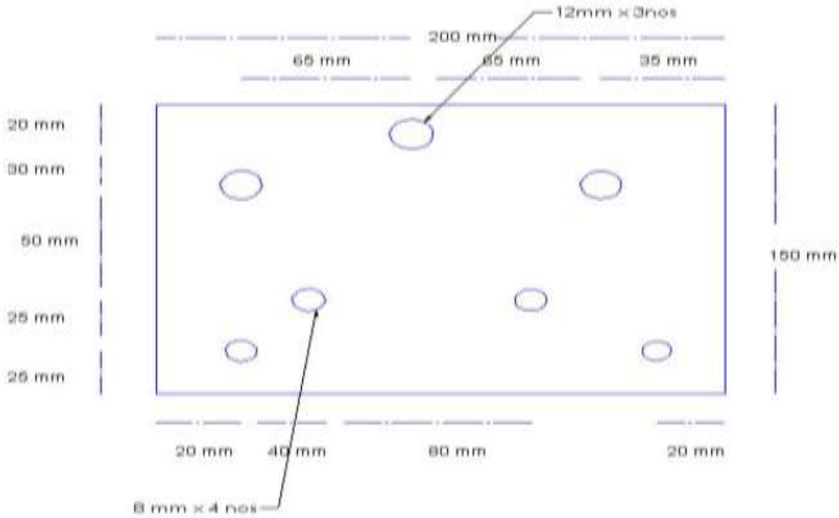

FIG 2:2D drawing of fixture

FIG 3:3D Model

III DESCRIPTION OF THE MACHINE

3.1VerticalMillingMachine

Experiments were performed on a variable speed bed type milling machine with a robust solid cast bed, power feed on the x, y and z-axes and equipped with a 7.5 HP motor. The spindle speed on the milling machine can be varied from 900 to 1400 rpm. However, we conducted the experiment at three different spindle speed and traverse speed namely 900, 1150, 1400 rpm and 90, 120, 150 mm/min respectively. Schematic image of HMT vertical milling machine is shown in Fig 4. A fixture was prepared in house for performing the welding. The fixture was clamped in the bench vice of the machine, which acts as the backing plate during welding. Aluminium sheets were bolted at the ends before welding

FIG:4 HMT Vertical Milling Machine

IV PROCESS PARAMETER

Table 3 Process Parameter

Parameter	Effects
Tool rotation speed	"stirring", oxide layer breaking and mixing of material
Tilt angle	The appearance of the weld, thinning, good material flow
Welding speed	Appearance, heatcontrol.
Down force	Frictionalheat, maintainingcontact conditions.

V PARAMETERS OF BBTFSW

In BTFSW process have only two parameters. These are

1) **Spindle speed**–produce frictional heat
2) **Welding speed**–control heat production

Table 4 PARAMETERS OF FSW

TOOL ROTATIONSPEED (rpm)	TOOL TRAVERSE SPEED (mm/min)
A	B

450	80
500	90
550	100

VI EXPERIMENTAL WORK FIXTURE SETUP

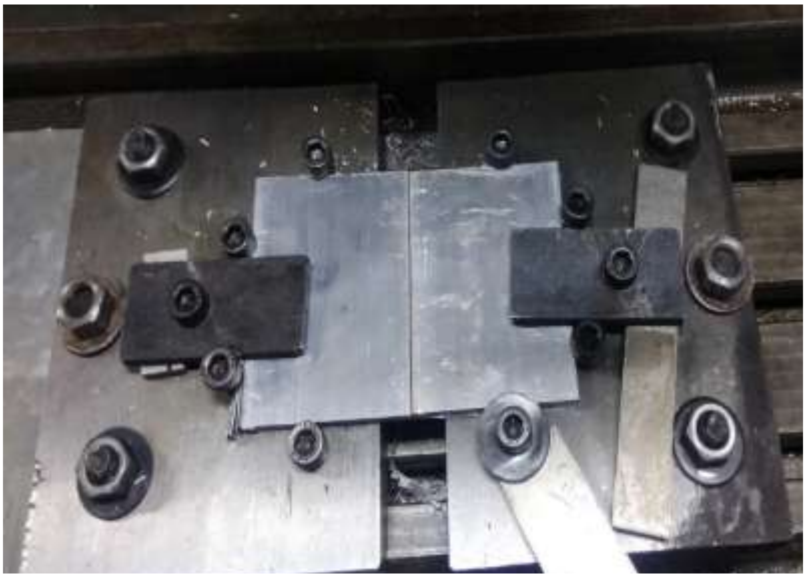

Fig: 5 Fixture Setup

The figure 5 shows the fixture setup Fixtures must correctly locate a work piece in a given orientation with respect to a cutting tool or a measuring device, or with respect to another component, as for instance in assembly or welding. Such location must be invariant in the sense that the devices must clamp and secure the work piece in that location for the particular processing operation.

VII RESULT & DISCUSSION

Bobbin tool Friction Stir Welding was carried out on AA7075 plates having dimensions 150 mm (l) × 75mm (w) × 6mm (h) in butt joint configuration using hexagon profile high speed tool. For welding purpose vertical milling machine was used. Trial runs were conducted prior to conducting actual experiments During welding process tool pin profile was kept constant. BTFSW carried out for different tool rotation speed, tool traverse speed and using Taguchi orthogonal array design of experiments technique. Welding operation of BTFSW is shown in Fig 6

Fig:6 BTFSW Welding Operation

Fig:7 BTFSW WeldedSpecimen

BTFSW with nine different parameter conditions through Taguchi design of experiments was carried out in vertical milling machine. The above Fig 7 shows welded specimens

TENSILETEST

Tensile testing is also known as tension testing, is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react other types of forces. The universal testing machine used for testing is shown in figure 8

Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation can also be determined: Young's modulus, Poisson's ratio, yield strength and strain-hardening characteristics. Uniaxial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic materials. Tensile test specimen dimensions are shown in Fig 9

$\sigma = P/A0$

$\in = l - l0/l0 = \Delta l/l0$

Where,

P is the load on the sample,
A0 the original cross-sectional area of the sample,
L is the gauge length at a certain load and
L0 is the original length.

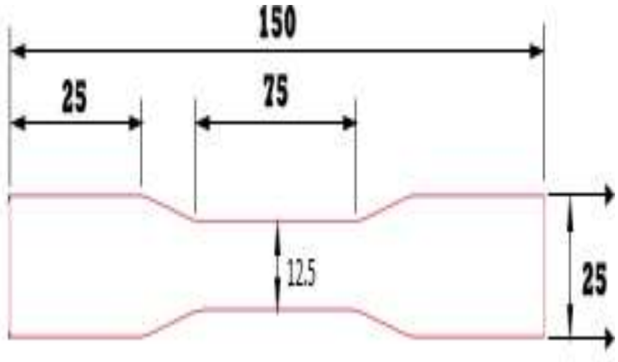

Fig 8 Tensile Test Specimen

Fig: 9 Computerized UTM Machine

VIII MACROSTRUCTURE ANALYSIS

Macro examination is generally done by viewing in naked eye or under a digital scanner machine. In our process we have view edit by taking a scanning of the specimen and the macro structure is seen in naked eye. In FSW there are three regions that are taken into consideration for the macro structural analysis and they are base metal, HAZ, Stir zone or nugget zone. The macrostructures for the different weld joints are shown below,

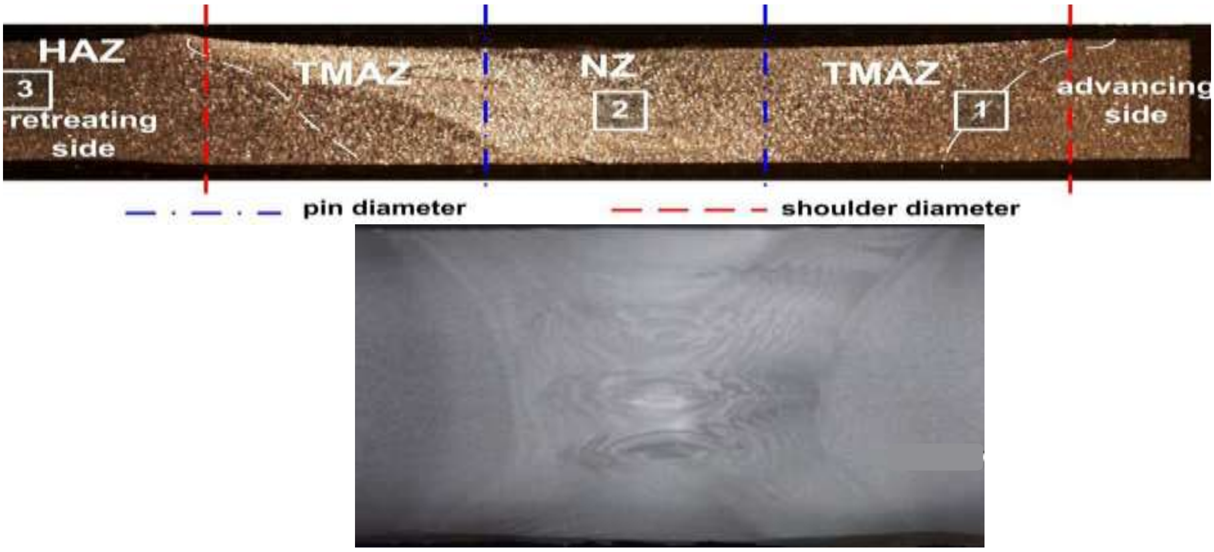

Fig: 10 Macrostructure from Bobbin Tool Welds at 550 rpm and 90mm/min

Typical macro sections are shown in Figure 11, and are interesting in that the single onion ring pattern observed in the nugget in conventional welds is replaced by series of three onion rings stacked vertically through the thickness in the probe dominated mid-section of the weld. This implies that the motion of the flowing material around the tool is more complex than in a simple tool.

We observed that the grain distribution is much better in stir zone of the joint welded under optimum working conditions (900 rpm & 120 mm/min) than the other weld joints. This is due to right combination of spindle rotation speed and weld speed rate.

IXCONCLUSION

An attempt is made to weld harder alloy 7075 using bobbin tool friction sir welding. A dedicated fixture is design and fabricated. The specimens are prepared for solid state welding. With the optimal tool rotational speed and travel speed of 550 rpm and 90 mm/min the coupons are welded. After welding, the specimens are tested for ultimate tensile strength and microhardness. The tensile strength is increased to ~25% and microhardness to ~20%.The macro structure shows minimum defects and homogenous mixture. This work shows future scope for research to weld harder alloys for applications.

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