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Comparative Analysis and Weld Behaviour of Mg-AZ31 and AL2024 with Various Profile Pin by Using FSW Process

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A B S T R A C T

Al, Mg, Cu, Ti, and their alloys are usually joined in similar ways using friction stir welding (FSW), a solid-state joining process. In the current investigation, several tool combinations with constant rotation speeds, feed, and axial force must be used to perform friction stir welding of dissimilar aluminum joins. In this experiment, controlling weld distortion and therefore raising process productivity need careful selection of input friction welding parameters. Controlling the input welding parameters is therefore essential to produce a high-quality weld and minimize weld distortion.. This research project demands carrying out experiments on 6 mm thick AZ31 and Al2024 using a friction welding procedure with square and triangle pins as tools. Additionally, during the FSW process, the square tool profile had the lowest hardness and the highest penetration, while the triangle tool profile pin had the maximum tensile strength. The triangle pin's bead appearance further demonstrates how superior it is over the square pin. During the analysis, the angle distortion only displays a value that is almost equal. In the end, a triangle profile with AA2024 & AZ31-6mm thickness was completed with the best possible weld properties throughout the FSW process.

Keywords: FSW, Tool profile, Tensile strength, Axial force, Mechanical properties

1. Introduction of various grinding process

Solid state joining is the combination of various welding techniques carried out with solid state components. In solid state joining, numerous factors including as temperature, duration, and stress are typically taken into account. Cold pressure welding, diffusion bonding, explosive welding, forge welding, friction welding, hot pressure welding, roll bonding, and ultrasonic welding are examples of solid state joining processes. The base metals are not melted in the process of creating the joints. Comparing solid state joining to fusion welding procedures reveals various advantages. This method keeps the original qualities because it does not involve melting.

When different metals are integrated together, their thermal expansion and the conductivity are of very least importance with solid state welding than with conventional fusion welding. The integration of immiscible or partially miscible alloy systems is also possible with the help of solid state joining. In solid state joining, the quality of a joint is entirely based on the process parameters like time, temperature and stress which are maintained during the process. In some processes, the time of welding is extremely short, up to a few seconds like in friction welding. When integrating various metals, solid state welding is less important than conventional fusion welding in terms of the metals' thermal expansion and conductivity. Solid state joining can also be used to integrate immiscible or partially miscible alloy systems. The quality of a solid state joint is solely dependent on the process parameters—such as time, temperature, and stress—that are kept constant throughout the process. In certain procedures, such as friction welding, the welding duration could vary by just as a few seconds.

Magnesium (Mg) and aluminum (Al) have been investigated in numerous different fields because of their exceptional mechanical qualities, low density, and other outstanding qualities. These magnesium and aluminum alloys' thermodynamic properties should be flexible at lower temperatures in order to determine their varied mechanical, metallurgical, and physical qualities. Magnesium has a melting point of 650 degrees Celsius, and at roughly 450 degrees Celsius, its solubility in the aluminum melt increases to a maximum of 18.9%.. The maximal solubility of aluminum in magnesium, however, is still 11.8 at the eutectic temperature. The aluminum magnesium phase diagram is displayed in Because of this decreased solubility at lower temperatures, fabrication feasibility becomes more flexible, allowing the automotive and aerospace sectors to use it for lightweight applications.

1.1 Applications

Mg alloys are widely used in structural and Non-structural applications. The structural applications including

1. Automotive components & Aerospace equipment's.

2. Material handling, Industrial & other Commercial purposes

Automotive application includes

1. Clutch & Brake pedal support bracket
2. Steering column lock housing
    1) Fabrication of honey comb, rocket engines, helicopter rotor hub, turbine components in aerospace missiles and rocket industries.
    2) Fabrication of reactor components in atomic energy industries.
    3) To controversial aerospace vehicles have brought diffusion bonding in to the light B-1 bomber and space shuttle.
    4) Fabrication of composite materials.

1.2 Objectives

- ✓ For this research, the objectives that are tried to achieve by the researcher are:
- ✓ In this study, the effect of the presence of various process parameters with various tools are Square and Triangular tool pin profile welded with friction stir processing Al2024 & AZ31 alloy plates is documented.
- ✓ Friction stir welded Al2024 & AZ31 alloy plates have to be evaluated by using through macro test. The tests were conducted as per the comparative procedure and the results were correlated of the tested weld samples with Square and Triangular profile tool pin.

2. Reasons For Choosing of AA & Mg FSW Process

Two of the biggest issues facing the transportation sector are fuel usage and greenhouse gas emissions, both of which call for quick fixes. Magnesium alloys are difficult to join using conventional welding techniques due to their high energy requirements, great sensitivity to cracking, and rapid corrosion rate from magnesium to copper electrode .The formation of brittle intermetallic, higher distortion & oxidation, partial melting, formation of defects like hot cracks, porosity, etc. are some of the reasons why welding of magnesium alloys by fusion welding techniques, such as laser beam welding, electron beam welding, etc., has not produced high quality joints. Because of their strong affinity for oxygen and their chemical reactivity, magnesium alloys easily oxidize at high temperatures. To prevent contamination in weldments, pure shielding gases should be used. Furthermore, because the processes of solidification and melting are crucial in establishing the microstructural features, issues like as residual stresses arise during these welding operations. Thus, the development of a dependable, appropriate, and affordable welding technique is necessary for the application of magnesium alloys in the transportation sector.

2.1 Scope

1. When compared to other metals like copper, steel, and aluminum, which have cubic lattice structures, magnesium alloys are reported to have additional issues regarding plastic deformation because of their hexagonal lattice structure.

2. Therefore, the majority of magnesium alloys are cast, although wrought magnesium alloys, such as AZ31, are widely utilized in the production of contemporary automotive components, and engine blocks made of these alloys are chosen for some high-performance automobiles. It is possible to achieve enhancements in the mechanical properties of FSW-ed joints by the management of the FSW process parameters, such as tool shape, feed rate, axial force, and tool rotation speed. Therefore, it is necessary to conduct a thorough experimental study concentrating on the combined impact of these disparate FSW process parameters on the mechanical properties of AZ31 & AA2024.

3. Tool Types And Functions

The friction stirring tool consists of a pin (probe) and a shoulder. The pin plunges into the mating place of the work piece creates frictional and deformational heating and softens the work piece material; contacting the shoulder to the work piece increases the work piece heating, expands the zone of softened material, and constrains the deformed material.

Naturally, there are important effects to the tool during welding: high temperature, abrasive wear and dynamic effects.

Therefore, the good tool materials must satisfy some properties such as

1. Good wear resistance
2. High temperature strength, temper resistance
3. Good toughness

3.1 Aluminium-2024

AA2024 aluminum is heat-treatable aluminum alloy with copper as the primary alloying element. It is malleable when in the fully soft, annealed temper and can be heat-treated to high strength levels after forming. Due to its high strength to weight ratio, it is widely used in aerospace applications.

3 2 Magnesium AZ31B Alloy

Magnesium alloys are light weight and have high machinability. They are often anodized to improve their corrosion resistance. They are designated using the ASTM and SAE system in which the first part indicates the two main alloying elements in the alloy and the second part represents their percentages.

Magnesium AZ31B alloy is available in different forms such as plate, sheet, and bar. It is an alternative to aluminum alloys as it has high strength to weight ratio. It is widely available when compared to other magnesium grades. The following datasheet gives an overview of magnesium AZ31B alloy.

4. Machine Details

Friction stir welding operation is done using the Czechoslovakian vertical milling machine. The quality of the welded joint is ascertained by visual inspection of weld bead and defect free joints along the weld region

4.1 Tool Profile Used

Aluminum alloy was used as base metal to perform friction stir welding in this study. The prepared samples were welded using Square and Triangular tool pin profile tool pin.

Square tool pin profile & Triangular tool pin profile

5. Various Tool And Parameter

Levels and ranges of FSW process parameters

SPEED RPM	TOOL-TR Mm/min	AXFC KN	TOOL PROFILE
900	13	8	
1000	14	9	Square
1100	15	10	

900	13	8	Triangular
1000	14	9	
1100	15	10	

5.1 Various Tool and Parameter FSW Plates

AZ31 Mg & AA2014 FSW Various Tool Plates

6. Hardness Test

Before Weld Both Materials HRB Value

2024 – 32 HRB, AZ31 - 28 HRB

SPEED RPM	TOOL-TR Mm/min	AXFC KN	Avg HARDNESS AA2024 HRB	Avg HARDNESS AZ31-Mg HRB	TOOL PROFILE
900	13	8	41	38	Square
1000	14	9	34	41	
1100	15	10	37	42	
900	13	8	54	40	Triangular
1000	14	9	46	44	
1100	15	10	50	42	

The Rockwell Hardness values were measured at Welded area of the FSW plates. Avg values were calculated. Low hardness value was obtained during the process through welded with square tool pin.

6.1 Tensile Test & Elongation

Friction processed joints are evaluated for their mechanical characteristics through tensile testing. A tensile test helps determining tensile properties such as tensile strength, yield strength, percentage of elongation, and percentage of reduction in area and modulus of elasticity.

SL.NO	SPEED RPM	TOOL-TR mm/min	AXFC KN	TENSILE LOAD KN	TENSILE STRENGTH N/mm^2	TOOL PROFILE
T_1	900	13	8	1.02	19.57	Square
T_2	1000	14	9	1.42	25.1	
T_3	1100	15	10	2.16	45.2	

T_4	900	13	8	2.04	44.56	Triangular
T_5	1000	14	9	1.09	21.81	
T_6	1100	15	10	2.77	57.71	

Very High tensile strength obtained with Triangular tool profile pin compared than others.

6.2 Angle Distortion

TOOL PROFILE	**SQUARE**			**TRIANGULAR**		
NO OF PLATES	1st	2nd	3th	4th	5th	6th
ANGLE DISTORTION	**1 º**	**0 º**	**0 º**	**1 º**	**1 º**	**0 º**

Angle Distortion plate or Bead Straightness were analyzed through auto cad and found above mentioned deviations almost both profiles were weld executed same amount of distortion of welded with both profile tool pin.

6.3 Various Sizes of Bead Width, Depth of Penetration and Heat Affected Zone-AL2024 & AZ31FSW

SL.NO	**AREA**	**MEAN**	**MIN**	**MAX**	**ANGLE**	**DEPTH**	**WIDTH**
1	0.081	62.662	37.667	92	90	4mm plate	14.745
	0.061	60.338	46.667	105.333	90	3.03	
2	0.113	63.889	40.333	87.333	90	4	18.264
	0.083	76.906	53.333	101.333	90	2.87	
3	0.105	71.065	58	100.333	90	4	20.961
	0.092	85.993	58.667	200.667	90	3.529	
4	0.113	60.379	41	131	90	4	15.923
	0.115	71.544	53.333	96.333	90	3.721	
5	0.113	85.358	55.444	252.667	90	4	17.277
	0.121	80.045	56	123	90	3.629	
6	0.105	74.646	55	148.667	90	4	17.642
	0.109	66.123	50	104	90	3.417	

Through Image J software found maximum depth of penetration obtained at square tool profile pin compared than triangular pin.

6.4 Appearance

After friction stir welding process the weld beads were observed. And following conclusion were informed below mentioned table.

TOOL PROFILE	**SPEED RPM**	**TOOL-TR mm/min**	**AXFC KN**	**RESULT**
Square	900	13	8	Rough texture at weld region,
	1000	14	9	Rough texture at weld region, mild cracks found on top portion of advancing side
	1100	15	10	Very fine texture but Flash effects formed at the Retreating side.
Triangular	900	13	8	Mild coarse texture but it has no any surface defects.
	1000	14	9	Very fine texture but excessive flash formed at the Advancing side

	1100	15	10	Very fine texture but it has no any surface defects. But mild flash effect found

In our experimental we found Smooth bead appearance & mild porosity obtained at cylindrical tool with parameter speed of -1000 RPM, tool traverse-14mm/min and axial force-9 KN. Coarse bead appearance & Mild transverse crack shows at square tool profile.

7. Result & Conclusion

A variety of tool profiles were examined and assessed in relation to the FSW constant process parameter. In general, the weld quality has also been impacted by the tool pin profile. According to this research, the square tool profile had the lowest hardness and the highest penetration during the FSW process, while the triangle tool profile pin had the largest tensile strength.. The triangle pin's bead appearance further demonstrates how superior it is over the square pin. During the analysis, the angle distortion only displays a value that is almost equal. In the end, a triangle profile with AA2024 & AZ31-6mm thickness was completed with the best possible weld properties throughout the FSW process.

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