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MECHANICAL AND THERMAL CHARACTERIZATION OF FRICTION STIR WELD JOINTS OF AL – MG ALLOY

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Abstract

The present paper incorporates the Mechanical and Thermal characteristics of friction stir weld plates of aluminium and magnesium; Friction stir welding is carried out for different set of welding and position parameters and the weld joints are majorly investigated for the mechanical and thermal characteristics. The thorough assortment of learning that has developed with regard to friction stir welding (FSW) of aluminum and magnesium alloys since the friction stir welding was invented in 1991 is validated in this paper. The fundamental standards of Friction stir welding are portrayed, including "metal flow and process characteristics. Before examining how process parameters influence the weld microstructure and the probability of imperfections. The scope of mechanical properties that can be accomplished is verified through a number of experimental tests as per ASTM standards. It is evident that FSW of aluminum magnesium alloys is turning into a progressive innovative technique with various engineering applications. The mechanical properties such as Tensile Strength, Hardness and Bending Strength are evaluated along with the temperature distribution over the duration of welding process. The properties are evaluated for different set of process parameters thus designed as per Taguchi Techniques and the results are optimized for definite set of values.

Key words: Aluminium, Magnesium, Friction, Stir, Welding, Mechanical, Thermal, Characteristics.

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1. INTRODUCTION

Friction stir welding of advanced engineering materials like aluminum, magnesium alloys, titanium and nickel super alloys have pulled in significant consideration because of their engaging mechanical properties and an unmistakable potential for aviation applications. They are in this manner seen as a perfect hope for automobile and aerospace applications [1– 3]. The process of friction stir welding is not only confined for automobile and aerospace domains but also used for other engineering applications, however there exists some degree of difficulty as a result of the troubles that are identified with the joining of these metals by plastic deformation [2,4].

Productive joints as far as quality of Aluminium alloys can't be accomplished by combination based welding strategies because of the response amongst grain structure prompting the need for optimizing the process [4,5]. Regarding welding forms, it has been demonstrated by a few examinations that more proficient joints with much diminished defects can be accomplished when friction stir welding (FSW) is embraced.

As of late, a few research papers have been identified for FSW. Thomas et al. [6], Rai et al. [7], and Zhang et al. [8] have carried out effective research on FSW devices and advancement. Threadgill et al. [9] gave a basic diagram of FSW of aluminum alloys. Mishra and Ma [10] gave an efficient audit on FSW and Friction stir processing (FSP).
Santhosh N et al. [11] have carried out extensive work on thermo-mechanical modeling and experimental validation of friction stir welding of aluminium alloys. They have used numerical investigations to validate the experiments and correlate the results.
Tutum and Hattel [12] carried out research on the numerical improvement of FSW and its difficulties and Çam [13] gave an exhaustive review of Friction stir welding process for various metals and alloys.

In any case, there is little data identified with FSW of Aluminium - Magnesium alloys. The present paper has an aim of investigating the mechanical and thermal properties of the Aluminium - Magnesium alloys.

2. EXPERIMENTAL DETAILS

“Magnesium AZ31B and Aluminium AA 6061 – T6 alloy plates are procured and specimens of dimension 300 mm*75 mm * 6 mm are machined from the plates”.
Magnesium AZ31B alloy has better machinability characteristics and is known for its use in aerospace and other engineering applications. The chemical composition of the Magnesium alloy is as mentioned in Table 1.

Table 1 Chemical Composition of AZ31B Magnesium alloy

Element	Magnesium	Aluminium	Zinc	Manganese	Silicon	Copper	Calcium	Iron	Remainder
Content (%)	96	2.5	0.7	0.2	0.1	0.05	0.01	0.05	0.3

Aluminium AA 6061 – T6 is “a high strength precipitation hardened T6 tempered alloy” with silicon and magnesium as the major alloying constituents. The chemical composition of the Aluminium AA 6061 – T6 alloy is as given in the **Table 2.**

Table 2 Chemical Composition of Aluminium AA 6061 - T6 alloy

Element	Copper	Magnesium	Silicon	Manganese	Iron	Zinc	Chromium	Titanium	Remainder (Al)
Content (%)	0.2	1.2	0.8	0.15	0.5	0.25	0.3	0.2	96.4

Friction stir welding is carried out by utilizing a FSW tool made of H13 tool steel comprising of a shoulder and pin, the shoulder is having a diameter of 15 mm and is a tapered pin with 2.5 mm length. Friction stir welding is carried out utilizing a mechanized all inclusive processing machine of ETA make. The work pieces are settled on the work table of the processing machine and the rotational FSW tool is plunged into the joint. "Penetration depth" is given such that the tool shoulder totally touches the surface of the work pieces; the tool is then traversed all along the length of the joint. Joining is performed at various process parameters ("3 unique speeds and feeds") and optimized parameters are acquired where the joint is observed to be without deformity. "After effective joining, samples are cut at various regions utilizing a wire cut electric discharge machine (EDM). The specimens are then metallographically polished utilizing different grade of emery sheets followed by polishing utilizing diamond paste and cleaned with ethanol. Chemical etching of the polished specimens is carried out utilizing suitable reagents (contained 5 g of picric acid, 5 ml acetic acid, 5 ml distilled water and 100 ml ethanol), and dried in hot air. Micro-hardness estimations is done by Vickers Micro-hardness tester over the weld joint by applying 100 g load for 10 s. Estimations are completed on three parallel specimens (n = 3) got over the joint. The weld joint tensile strength is evaluated by utilizing Instron make Universal Testing Machine at a strain rate of 1×10^{-3} s^{-1}. The tensile test is carried out for the specimens as per the ASTM E8 – M11 standards on a specimen as shown in Figure – 1. Bending test is carried out using specimens of 150 x 10 x 5 mm dimensions on an UTM by making use of three point bending test setup.

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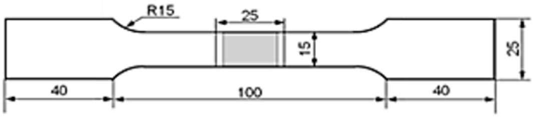

Figure – 1 Tensile Test Specimen as per ASTM standards

The results of the tests are tabulated and the statistical validation is carried out to determine the effect of process parameters on the specimen. Microstructural observations of the fractured surfaces (Fracto-graphs) are carried out using a Hitachi Make SU9000 FE Scanning Electron Microscope to analyse and critically comprehend the image obtained.

3. RESULTS AND DISCUSSION

a) Mechanical Properties

The experiments are carried out in accordance with the taguchi techniques, i.e. L9 orthogonal array is used for designing the experiments and carrying out the trials.

Table – 3 Test results of Experiments as per Taguchi Techniques

Run Order	Spindle Speed rpm	Spindle Feed mm/min	Plunger Speed mm/min	Tensile Strength MPa	Yield Strength MPa	Percentage of Elongation (%)	Vickers Hardness (VHN)	Bending Strength MPa
1	500	30	10	212.32	188.61	6.87	86.88	19.55
2	500	60	20	209.87	183.27	7.02	85.37	18.32
3	500	90	30	205.43	180.75	7.15	84.88	17.85
4	1000	30	20	216.59	195.35	6.29	91.22	21.47
5	1000	60	30	218.77	198.84	5.87	92.55	22.63
6	1000	90	10	220.68	201.55	5.59	93.47	22.79
7	1500	30	30	224.58	203.22	5.47	95.66	23.11
8	1500	60	10	227.39	204.25	5.39	96.73	23.54
9	1500	90	20	228.87	205.60	5.26	97.85	23.97

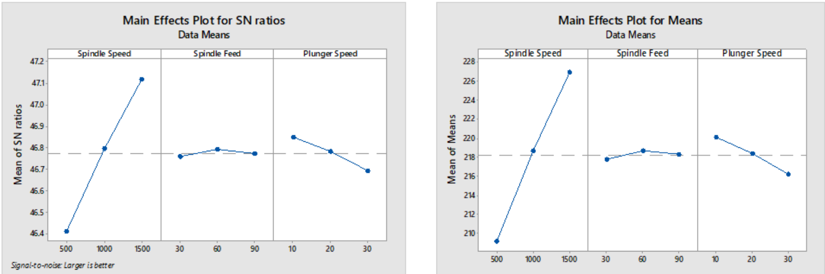

Figure – 2 Main Effects plot for SN ratios and Mean for Tensile Strength in MPa

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Table – 4 Response Table for Signal to Noise Ratios for Tensile Strength in MPa

Level	Spindle Speed	Spindle Feed	Plunger Speed
1	46.41	46.76	46.85
2	46.80	46.79	46.78
3	47.12	46.77	46.69
Delta	0.71	0.03	0.16
Rank	1	3	2

Larger is better

Table – 5 Response Table for Means for Tensile strength in MPa

Table – 5 Response Table for Means for Tensile strength in MPa

Level	Spindle Speed	Spindle Feed	Plunger Speed
1	209.2	217.8	220.1
2	218.7	218.7	218.4
3	226.9	218.3	216.3
Delta	17.7	0.8	3.9
Rank	1	3	2

Larger is better

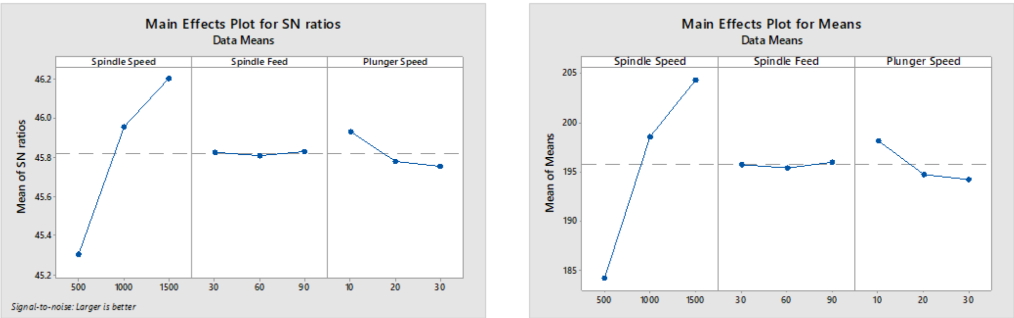

Figure – 3 Main Effects plot for SN ratios and Mean for Yield Strength in MPa

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Table – 6 Response Table for Signal to Noise Ratios for Yield Strength in MPa

Level	Spindle Speed	Spindle Feed	Plunger Speed
1	45.30	45.83	45.93
2	45.96	45.81	45.78
3	46.21	45.83	45.76
Delta	0.90	0.02	0.18
Rank	1	3	2

Larger is better

Table – 7 Response Table for Means for Yield Strength in MPa

Level	Spindle Speed	Spindle Feed	Plunger Speed
1	184.2	195.7	198.1
2	198.6	195.5	194.7
3	204.4	196.0	194.3
Delta	20.1	0.5	3.9
Rank	1	3	2

Large is better

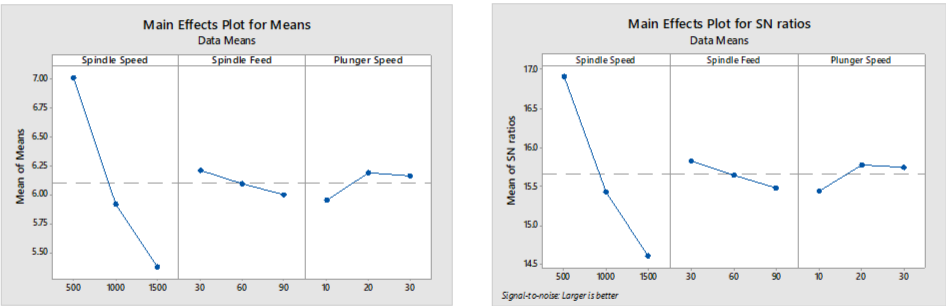

Figure – 4 Main Effects plot for Means and S N ratios for % Elongation

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Table – 8 Response Table for Signal to Noise Ratios for % Elongation

Level	Spindle Speed	Spindle Feed	Plunger Speed
1	16.92	15.82	15.44
2	15.43	15.64	15.77
3	14.60	15.48	15.74
Delta	2.31	0.34	0.33
Rank	1	2	3

Larger is better

Table – 9 Response Table for Means for % Elongation

Level	Spindle Speed	Spindle Feed	Plunger Speed
1	7.013	6.210	5.950
2	5.917	6.093	6.190
3	5.373	6.000	6.163
Delta	1.640	0.210	0.240
Rank	1	3	2

Larger is better

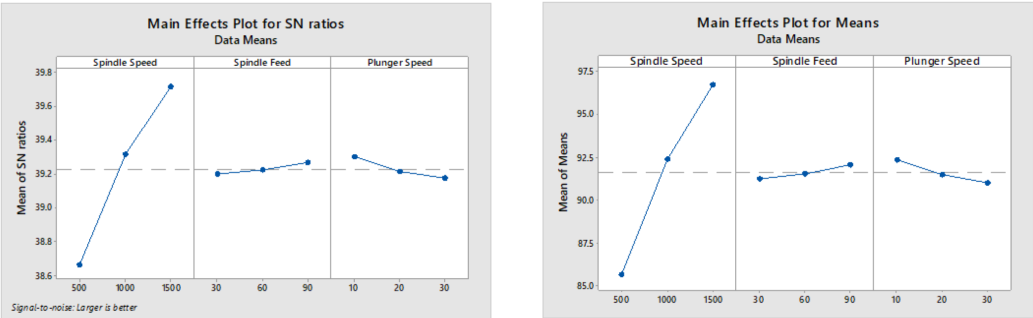

Figure – 5 Main Effects plot for Means and S N ratios for Hardness in VHN

Table – 10 Response Table for Signal to Noise Ratios for Hardness in VHN

Level	Spindle Speed	Spindle Feed	Plunger Speed
1	38.66	39.20	39.30
2	39.31	39.22	39.21
3	39.71	39.27	39.17
Delta	1.05	0.07	0.13
Rank	1	3	2

Larger is better

Table – 11 Response Table for Means for Hardness in VHN

Level	Spindle Speed	Spindle Feed	Plunger Speed
1	85.71	91.25	92.36
2	92.41	91.55	91.48
3	96.75	92.07	91.03
Delta	11.04	0.81	1.33
Rank	1	3	2

Larger is better

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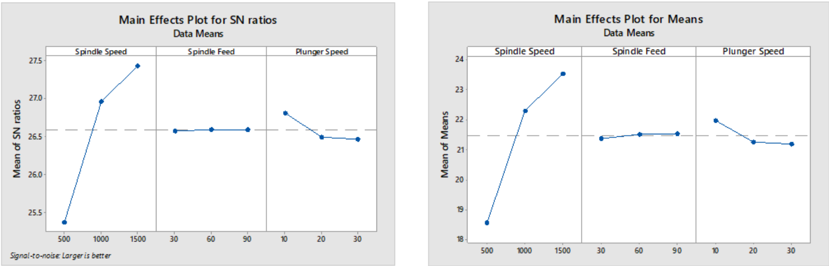

Figure – 6 Main Effects plot for Means and S N ratios for Bending Strength in MPa

Table – 12 Response Table for Signal to Noise Ratios for Bending Strength

Level	Spindle Speed	Spindle Feed	Plunger Speed
1	25.37	26.58	26.80
2	26.96	26.60	26.50
3	27.44	26.59	26.47
Delta	2.06	0.02	0.34
Rank	1	3	2

Larger is better

Table – 13 Response Table for Means for Bending Strength

Level	Spindle Speed	Spindle Feed	Plunger Speed
1	18.57	21.38	21.96
2	22.30	21.50	21.25
3	23.54	21.54	21.20
Delta	4.97	0.16	0.76
Rank	1	3	2

Larger is better

b) S.E.M. Images of Fractured Surfaces

The S.E.M. Images of the fractured surfaces is as given in Figure 7. It gives a distinct purview of the fractured faces of the specimens after tensile test. “The fractured surface reveals the crack nuclei structures with impeded precipitates all around the grain boundaries interfaced with strain hardened bands. The crack is generally divided into terraced steps crossing the grain boundaries. The newly developed crack planes interface with a characteristic river like pattern all around the peripheries of each of the atoms at the juncture of weld bead”.

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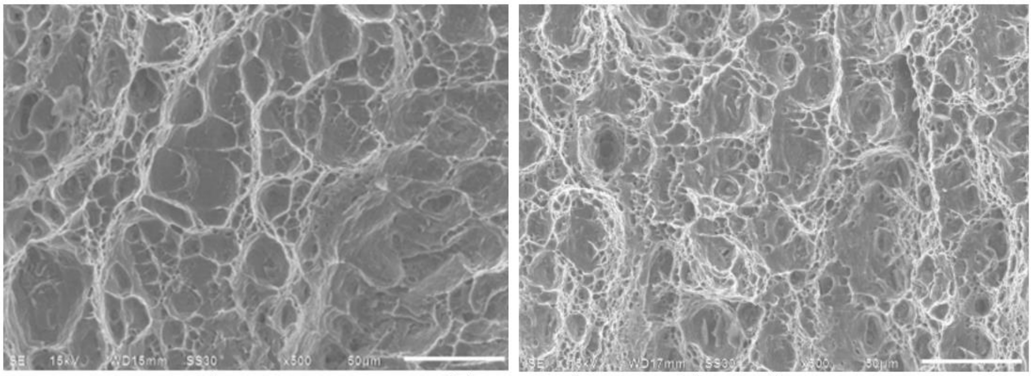

Figure - 7 S.E.M. Images of the Fractured surfaces of the Tensile Test

4. CONCLUSION

The critical inferences of the results clearly give a description of the following aspects pertaining to the mechanical and microstructural aspects of the specimens welded using Friction stir welding.

i. Tensile Strength and Yield strength are found to be maximum for the specimens welded at a maximum spindle speed of 1500 rpm, Spindle feed of 90 mm/min and plunger speed of 20 mm/min.
ii. Percentage Elongation are found to be maximum for the specimens welded at a spindle speed of 500 rpm, spindle feed of 90 mm/min and plunger speed of 30 mm/min.
iii. Hardness and Bending strength are found to be maximum for the specimens welded at a maximum spindle speed of 1500 rpm, spindle feed of 90 mm/min and plunger speed of 20 mm/min.
iv. The microstructure of the fractured surface clearly reveals that a ribbon band like structure is formed due to plastic deformation of the welded joints and is an indication of the deformation by slipping phenomenon during tensile test thus giving a proof for justifying the friction stir welding process as the best option for joining dissimilar metals.

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REFERENCES

[1] G. Çam, M. KoçakProgress in joining of advanced materials, Int. Mater. Rev., 43 (1) (1998), pp. 1-44

[2] A.M. Hassan, M. Almomani, T. Qasim, A. Ghaithan Effect of processing parameters on friction stir welded aluminum matrix composites wear behavior, Mater. Manuf. Process., 27 (12) (2012), pp. 1419-1423

[3] K. Suryanarayanan, R. Praveen, S. Raghuraman Silicon carbide reinforced aluminium metal matrix composites for aerospace applications: a literature review, Int. J. Innov. Res. Sci. Eng. Technol., 2 (11) (2013)

[4] M.B.D. Ellis, Joining of aluminium based metal matrix composites, Int. Mater. Rev., 41 (2) (1996), pp. 41-58

[5] R.Y. Huang, S.C. Chen, J.C. Huang Electron and laser beam welding of high strain rate superplastic Al 6061/SiC composites, Metall. Mater. Trans. A Phys. Metall. Mater. Sci., 32 (10) (2001), pp. 2575-2584

[6] W.M. Thomas, D.G. Staines, I.M. Norris, R. de Frias Friction stir welding tools and developments Weld. World, 47 (2003), pp. 10-17

[7] R. Rai, A. De, H.K.D.H. Bhadeshia, T. DebRoy Review: friction stir welding tools Sci. Technol. Weld. Join., 16 (4) (2011), pp. 325-342

[8] Y.N. Zhang, X. Cao, S. Larose, P. Wanjara Review of tools for friction stir welding and processing Can. Metall. Q., 51 (3) (2012), pp. 250-261

[9] P.L. Threadgill, A.J. Leonard, H.R. Shercliff, P.J. Withers Friction stir welding of aluminium alloys Int. Mater. Rev., 54 (2) (2009), pp. 49-93

[10] R.S. Mishra, Z.Y. Ma Friction stir welding and processing Mater. Sci. Eng. R Rep., 50 (1–2) (2005), pp. 1-78.

[11] Santhosh. N, Mahamad Mudabir, Thermo-mechanical Modeling and Experimental Evaluation of Friction Stir Welds of Aluminium AA 6061 Alloy, International Journal of Engineering Research and Technology (IJERT), ISSN: 2278-0181, Vol. 2, Issue 8, (2013), pp. 1494-1499.

[12] C.C. Tutum, J.H. Hattel Numerical optimisation of friction stir welding: review of future challenges Sci. Technol. Weld. Join., 16 (4) (2011), pp. 318-324.

[13] G. Cam Friction stir welded structural materials: beyond Al-alloys Int. Mater. Rev., 56 (1) (2011), pp. 1-47