Comparison of Mechanical Characteristics of Friction Stir Welded Joints of AA2195 Al-Li Alloy with AA2219

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Abstract— Friction stir welding is a solid state process of joining that utilises a non consumable tool for joining two work pieces. It utilises the heat produced by friction between the rotating tool and the work piece materials . Speed of the tool(rpm), feed(mm/min) and force(kgf) are taken as the input parameters while ultimate tensile strength(MPa) is taken as the output parameter. The tool material used is QRO90 (oil hardened steel) as it has high toughness and fatigue resistance. The workpiece material used is AA2195 Al-Li alloy because of its lower density and high strength compared to other aluminium alloys. Non destructive testing methods like Phased array ultrasonic testing, Die penetrant test and X-Ray radiography tests were done to identify various defects like porosity and hot cracks. Tensile test was performed to determine the strength of the specimen. A comparative study of friction stir welded joint of AA2195 Al-Li alloy is done with friction stir welded joint of AA 2219. It was found that AA2195 Al-Li alloy offered greater ultimate tensile strength, besides being less denser as compared to friction stir welded joint of AA2219.

Key words: Friction Stir Welding (FSW), AA2195 Al-Li Alloy AA2219

I. Introduction

FSW is a solid state process of joining that makes use of a non consumable tool for joining two work pieces without melting it. The heat generated by friction between the rotating tool and the work piece, creates a softened region, close to the tool. As the tool is moved along the joint line, it intermixes the two metal pieces and forges the hot and softened metal by the mechanical pressure applied by the shoulder of the tool.

The Welding Institute (1991) has successfully developed Friction Stir Welding technology to join different aluminium alloys like 2024-T3, 6082 AA-T651 and other materials which are difficult to be welded with conventional welding techniques[7].

Mishra (1996) designed and developed friction stir process to eliminate the defects associated with casting and refine microstructure for a monolithic work piece[4]. Aluminium or Silicon carbide surface composites with different volume fractions of particles were successfully fabricated. Thickness of the composite layer of the surface varied from 50 to 200 mm. The SiC particles were distributed uniformly in the aluminium matrix. The surface composites were found to have excellent bonding with the aluminium alloy substrate. Hence the results obtained were found desirable for high performance surface composites.

Kawasaki Heavy Industries (2003) designed and developed friction stir stir spot welding process to assemble the aluminium hood and rear doors of the RX-8 sports car[3]. The fundamental aim was to save electric power in joining aluminium sheets and to decline from precleaning of work pieces, fumes and spatter. This was accomplished by vertical plastic flow between top and bottom sheets around pin as opposed to resistance spot welding. The process was being performed by applying a rotating cylindrical tool to the sheets under pressure.

Squillac et al. (2016) investigated the effect of rotational and welding speed on tensile strength and fatigue strength of AA 6056 joints made by FSW[1]. The influence of process parameters on the weld quality was assessed by Analysis of Variance (ANOVA) methods using the experimental results.

Elangovan et al. (2017) developed a mathematical model using response surface method (RSM) to establish relationship between four process parameters and tensile strength for AA6061[5]. The process parameters included tool rotational speed, welding speed, axial force and the tool pin profile.

Elatharasan and Senthil Kumar (2017) studied the Ultimate tensile strength(UTS) and Yield strength(YS) of the friction welded AA6061-T6 alloy joints. UTS and YS are increased with the increase of tool rotational speed, welding speed and tool axial force up to a maximum value and then decreased[6].

II. Experiments

A. *Material preparation*

The rolled AA2195 Al-Li plates of thickness 5mm were cut into the required dimensions of length 500 mm and breadth 150 mm by power hacksaw cutting and milling[8]. Square butt joint configuration was set up to create the FSW joints.

B. *Experimental setup*

The experiment is conducted using a friction stir welding machine, namely ESAB-AB. A set of 9 experiments were performed using this machine. The input parameters considered were force, speed and feed. Force varied from 2800 kgf to 3200 kgf in the range of 200, Speed varied from 300 rpm to 500 rpm in the range of 100, Feed varied from 200 mm/min to 300 mm/min in the range of 50.

Fig 1: Friction stir welding machine

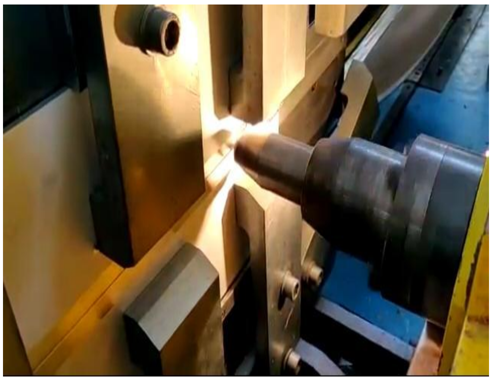

Fig 2: FSW operation

The FSW machine was custom built to perform linear seam welding up to 3000 mm length with finger clamps placed over the entire length on both sides and can be hydraulically actuated to provide rigid clamping on the job. Further, fixtures were designed with arms and rollers with clamps to support shell sheet panels in position while performing welding[9]. The advantages of this friction stir welding machine are that it offers very low distortion even in the case of long welds. No grinding or brushing operation is required even in the case of mass production. Moreover it is environment friendly as no fumes or harmful gases are produced.

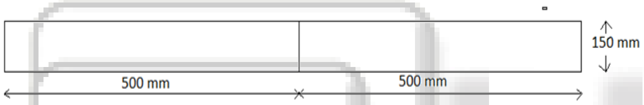

Fig 3: Work piece dimensions for FSW (Front view)

Fig 4: Work piece dimensions for FSW (Top view)

C. Experimental procedure and plans

The process parameters for making the FSW joints of AA2195 Al-Li alloy along with its values are shown in Table 1.

Welding parameters	Level 1	Level 2	Level 3
Force (kgf)	2800	3000	3200
Speed(rpm)	300	400	500
Feed(mm/min)	200	250	300

Table 1: Process parameters

III. RESULTS AND DISCUSSIONS

Testing welding defects

Non destructive testing (NDT) methods were done to analyse the welding defects, namely

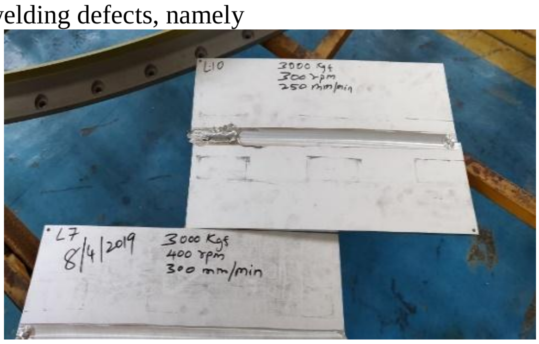

Fig 5: Welded specimen

porosity and hot cracks. The NDT techniques performed are X-Ray Radiography, Phased Array Ultrasonic testing and Die penetrant testing[2]. All the 9 specimens were observed to be defect free and qualified the NDT methods as mentioned above.

B. Tensile test results

The specimens were cut according to ASTM-E8 standard and were subjected to tensile test using a UTM[8].

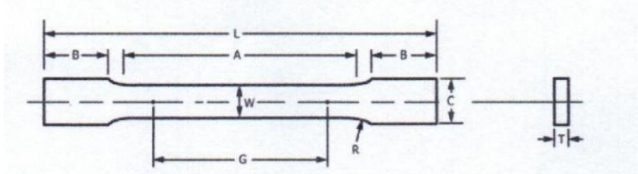

Fig 5: Tensile specimen after tensile test

Letters	Dimensions(mm)
G	200
W	40
T	1.5
R	25
L	450
A	225
B	75
C	50

Table 2: Standard dimensions for tensile test

The results of the ultimate tensile strength of the 9 specimens conducted using a UTM are obtained.

Fig 6: Universal Testing Machine

Fig 7: Specimens after tensile test

C. Influence of process parameters on ultimate tensile strength of FSW joints

The feed rate (mm/min) was observed to be the most influencing parameter, followed by tool rotational speed (rpm) and then the force(kgf). The optimised parameters are obtained by Taguchi technique using MiniTab software. The optimised parameters were found at Force=2800 kgf, Speed=400 rpm and Feed=300 mm/min. Now a confirmation test is done at the optimised parameters to obtain the ultimate tensile strength. It is found that an Ultimate tensile strength of 452 MPa is obtained at the optimised parameters. Mean effect graphs for ultimate tensile strengths are plotted.

Grey relational analysis was done using Microsoft Excel to verify the results obtained from Taguchi analysis methods.

Sl No.	Force (kgf)	Speed (rpm)	Feed (mm/min)	UTS (MPa)
1	2800	300	200	428.0
2	2800	400	250	398.0
3	2800	500	300	446.0
4	3000	300	250	357.5
5	3000	400	300	446.0
6	3000	500	200	406.5
7	3200	300	300	409.0
8	3200	400	200	421.5
9	3200	500	250	406.5

Table 3: Tensile test results

Level	Force	Speed	Feed
1	424.0	398.2	418.7
2	403.3	421.8	387.3
3	412.3	419.7	433.7
Delta	20.7	23.7	46.3
Rank	3	2	1

Table 4: Response table for means

Level	Force	Speed	Feed
1	52.54	51.98	52.44
2	52.08	52.49	51.75
3	52.30	52.45	52.74
Delta	0.46	0.52	0.99
Rank	3	2	1

Table 5: Response table for signal to noise ratios

Levels	Force (kgf)	Speed (rpm)	Feed (mm/min)
1	0.730173	0.529597	0.627613
2	0.620564	0.70777	0.447122
3	0.572203	0.685572	0.848205
Optimum	2800	400	300

Table 6: Grey relation analysis results

The mean effects plots for means are being shown in Fig 7.

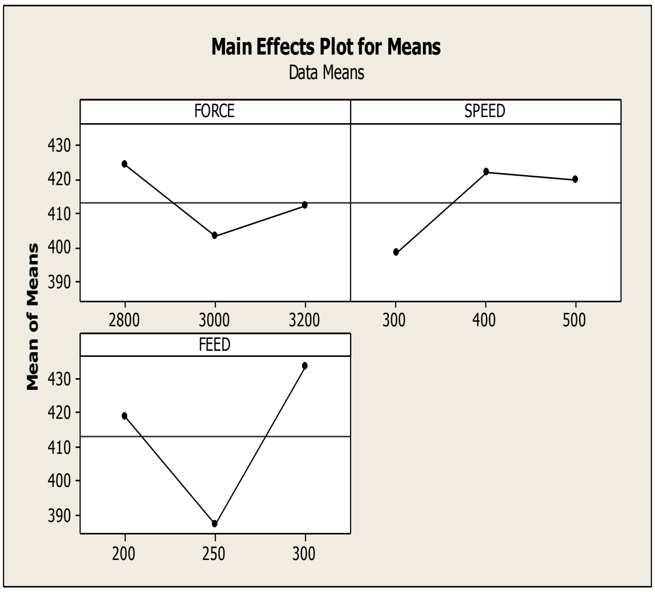

Fig 7: Mean effects plot for means

D. Comparison of results with FSW joint of AA2219

The ultimate tensile strength of FSW joint of AA2195 Al-Li alloy at the optimised parameters along with its weld efficiency are compared with that of FSW joint of AA2219 machined at the same process parameters.

Alloy	Density(g/cm^3)	UTS (MPa)	Weld efficiency
AA2219	2.78	333	75.7%
AA2195	2.71	452	81.7%

Table 6: Comparison of results

It is found that FSW joint of AA2195 Al-Li alloy offers more ultimate tensile strength and weld efficiency as compared to FSW joint of AA2219.

IV. CONCLUSIONS

Friction stir welding of AA2195 Al-Li alloy is being performed using the friction stir welding machine. The specimens are subjected to NDT techniques like X-Ray radiography, Phased array ultrasonic testing and die penetrant test. The process parameters are optimised by Taguchi technique using MiniTab software. The ultimate tensile strength value is obtained at the optimised parameter values. The strength results along with weld efficiency are compared of AA2195 Al-Li alloy are compared with that of AA2219. It is found that AA2195 offers greater ultimate tensile strength and weld efficiency as compared to AA2219, besides being less denser than AA2219[10].

The following points have been concluded from this project:

- The effect of friction stir welding parameters on the ultimate tensile strength of the friction stir welded joints of AA2195 Al-Li alloy are analysed. It can be inferred from those comparisons that the parameters selected directly influence the strength of the FSW joints.
- From the experimental analysis, the FSW weld with Force 2800 kgf, tool rotational speed 400 rpm and feed 300 mm/min was found to give optimised values
- A confirmation test was done on the optimised parameter values to obtain the ultimate tensile strength.

- The Feed rate(mm/min) was observed to be the most influencing parameter, followed by speed(rpm) and force(kgf) from the Taguchi analysis done.
- The ultimate tensile strength and weld efficiency of AA2195 Al-Li alloy was compared with that of AA2219.
- It was observed that AA2195 Al-Li alloy offered greater ultimate tensile strength and weld efficiency as compared to AA2219.

REFERENCES

[1] H.Y. Li, D.S. Huang, W. Kang, J.J. Liu, Y.X. Ou, D.W. Li, J. Mater. Sci. Technol. 32,2016.
[2] Y. Tao, D.R. Ni, B.L. Xiao, Z.Y. Ma, W. Wu, R.X. Zhang, Y.S. Zeng, Mater. Sci. Eng. A 693, 2017.
[3] Q. Chu, X.W. Yang, W.Y. Li, Y.B. Li, Sci. Technol. Weld. Join. 21,2016.
[4] R.S. Mishra, Z.Y. Ma, Mater. Sci. Eng. A 50 1–78,2005.
[5] Steuwer, M. Dumont, J. Altenkirch, S. Birosca, A. Deschamps, P.B. Prangnell, P.J. Withers, Acta Mater. 59,3002–3011,2011.
[6] A.K. Shukla, W.A. Baeslack, Sci. Tech. Weld. Join. 14,376–387,2009.
[7] J.A. Schneider, A.C. Nunes, P.S. Chen, G.J. Steele, J. Mater. Sci. 40,4341–4345,2005.
[8] BY RD, FU R, Sun R-C, Zhang F-C, LIU H-J., Welding Journal, 169–73, 2012.
[9] Sua JQ, Nelson TW, Sterling CJ. Materials Science Engineering (A), 405 277–86, 2005.
[10] Leal RM, Leit C, Loureiroa A, Rodriguesa DM, Vilac P. Materials Science Engineering (A), 384–391, 2008

