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Edwin AInfluence of Tool Rotational Speed, Feed Rate and Tool Material on Mechanical Properties of Friction Stir Welded Aa6061 and Aa6082 Aluminium Alloy

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Abstract: **The major objective of this work is to investigate the effect of tool rotational speed, feed rate and tool material on the tensile properties of the friction stir welded AA6061 and AA6082 aluminum alloys plates of thickness 4mm. The tensile test was done for the joints prepared at different trials, fracture analysis was done with the help of a scanning electron microscope(SEM). From the analysis, it was found that there is no effect of tool material on the strength of the welded joint. Joint prepared at the tool rotational speed 1400rpm and feed rate 31.5mm/min shows the highest joint efficiency. SEM image of the fractured surface clearly shows that fracture occurred was of the type ductile.**

Keywords: Friction stir welding (FSW), Tensile strength, SEM, AA6061, AA6082, EN39B, HSS.

I. INTRODUCTION

Friction stir welding is a solid state welding process which uses a non-consumable tool to weld workpieces. The process of welding is accomplished by the help of heat generated by the action of rubbing between tool and workpiece. The quality of the weld joint is majorly depends on the different process parameters like tool rotational speed, feed rate, tilt angle and tool profile. [1] In the recent advancements of technology joining of different alloys, materials is playing a major role in order to reduce weight and to increase the strength of the final product. This can be achieved by the help of friction stir welding and it easily joins the materials which are soft than the tool used in the process of welding. [2]

The joints obtained by this type of welding were found to be very good mechanical properties, corrosion behaviour, and error free. FSW process is very useful to join the aluminium alloy series such as 6xxx and 7xxx which were very difficult to join by normal fusion welding processes. [3] Yoshihika Uumatsu et al. [4] examined the FSW joint of aluminium alloy 6061-T6 under fatigue load. Madhusudhan reddy et al. [5] examined the mechanical properties, microstructure of friction stir welded AA6061 alloy and about residual stress development in the weld region. Elatharasan et al. [6] investigated the tensile behaviour of friction stir welded AA6061-T6 alloy and stated that ultimate tensile test and yield stress increases as the increase in tool rotational speed, welding speed and tool axial force upto certain maximum level and later dectreases. Squillac et al. [7] examined the strength of friction stir welded AA6056 under tensile and fatigue load and also investigated the effect of tool rotational speed and feed on the quality of weld. The analysis of the results was carried out with the help of analysis of variance (ANOVA) method. MC willians et al. [8] examined the FSW AA2139-T8 25.4mm thick aluminium alloy by the numerical simulation and experimental methods and stated that tensile strength at upper weld nugget is more when compared to lower weld nugget zone . Jawdat A. Al-Jarrah et al. [9] study the effect of tool rotational speed, feed and shoulder diameter to increase the quality of FSW. Satish kumar et al. [10] investigated the effect of tool rotational speed, feed and tool pin diameter on various mechanical properties like hardness and tensile strength of friction stir welded AA6061 alloy. S.Rajendra Prasad et al. [11] examined the effect of tool shoulder geometry and feed with a constant tool rotational speed on microstructure and mechanical properties of friction stir welded AA2014-T6 alloy. By analysing the literature survey it is elucidate that the friction stir welded joint quality mainly depends on the process parameters of welding. Hence in this work, major attempt was carried out to optimise the parameters like tool rotational speed, feed and material of tool on friction stir welding of AA6061 and AA6082 alloy.

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II. EXPERIMENTAL PROCEDURE

2.1 Materials and Methods

Aluminium alloy AA6061 and AA6082 plates of thickness 4mm having size of 100X50mm was taken as workpiece materials. The chemical composition of the selected workpiece materials are listed in table 1 and table2. To weld the aluminium alloy HSS and EN39B were selected as a tool material, chemical composition of the tool materials are listed in table 3 and table 4.

Mechanical Properties of AA6061 are:

- Ultimate Tensile Strength 328 Mpa
- % of Elongation 12-26

Table 1 Chemical composition of AA6061

Mg	Mn	Fe	Si	Cu	Cr	Zn	Ti	Al
0.8 -1.2	≤0.15	≤0.70	0.4-0.8	0.15-0.40	0.04-0.35	≤0.25	≤0.10	Balance

Table 2 Chemical composition of AA6082

Mg	Mn	Fe	Si	Cu	Cr	Zn	Ti	Al
0.6-1.2	0.4-1.0	≤0.5	0.7-1.3	≤0.10	≤0.25	≤0.20	≤0.15	Balance

Mechanical Properties of AA6082 are:

- Ultimate Tensile Strength 340-346 Mpa
- % of Elongation 12-22

Table 3 Chemical compositions of HSS

Sl No	Material	Percentage (%)
1.	Tungsten	18
2.	Chromium	4
3.	Vanadium	1
4.	Carbon	0.7
5.	Iron	Remaining

Table 4 Chemical composition of EN39B

Sl. No	Material	Percentage (%)
1.	Carbon	0.15
2.	Silicon	0.25
3.	Manganese	0.4
4.	Nickel	4.2
5.	Chromium	1.2
6.	Molybdenum	0.25
7.	Sulphur	0.025
8.	Phosphorous	0.025
9.	Iron	Remaining

2.2 Process parameters

The major process parameters which affect the quality of friction stir welding are tool rotational speed, feed and geometry of tool. In this work process parameters selected were tool rotational speed, feed and tool materials for experimentation. Based on the previous literature survey, the different tool rotational speed, feed and tool geometry selected are listed in the table 5.

Table 5 Process parameter and Dimensions of Tool.

Process Parameters	Values
Tool Rotational Speed (RPM)	1400,900 and 560
Traverse Speed (mm/min)	31.5,45,63 and 90
Length of Pin (mm)	3.8
Tool shoulder diameter (mm)	20
Major diameter of pin (mm)	7
Minor diameter of pin (mm)	3.8

2.3 Experimentations

Welding of samples was carried out at Department of Mechanical Engineering, Siddaganga institute of Technology, Tumakuru, Karnataka, India with the help of vertical milling machine. Workpiece materials of size 100X50mm were joined by clamping firmly on the table of vertical milling machine as shown in fig 1. Before

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starting the actual welding process edge preparation of workpiece was done in order to avoid the improper joining and many other welding defects. Once the edge preparation is done the actual welding process will start by making the required arrangements. Different specimens are prepared by varying the
selected process parameters listed in table 5. Strength analysis of the prepared samples was made by conducting the tensile test, samples for the test was taken perpendicular to the weld joint. Fractured tensile specimen were analysed with the help of scanning electron microscope (SEM) in order to know the type of fracture and reason of variation of weld strength.

III. RESULTS AND DISCUSSION

3. 1 Tensile Test

Tensile properties like ultimate tensile strength and % of elongation of welded joints prepared at different speed, feed and with different tool materials were tabulated in table 6. At high speed and low feed the value of tensile strength is more and at low speed and high feed value of the tensile strength and % of elongation is less. The maximum ultimate tensile strength value obtained is 220Mpa which is 62.66% of base material. At high speed and low feed the tool rotates very fast and the timings of welding is more and at high speed lot of heat is generated at the place of welding and due to low feed the tool spends more timings at each spot is more this leads to the generation of high amount of friction that in turn leads to the melting of material and proper mixing of the material at the weld zone, that increases the strength of the welded joint. But in case of low speed and high feed the tool rotates very slowly and table moves faster so less frictional forces and time spent at each spot of welding is very less that leads to improper melting and mixing of the material, hence the strength of the welded joint will be less.

3.2 Fracture Analysis

Fig 1 a, b, c and d shows the SEM images of the fractured tensile specimen. Formation of the dimples can be observed in the SEM images that shows the fracture occurred is of the type ductile. More dimple formations can be observed in the fig 3a and b because of proper mixing of material and less defects in the weld joint. In fig 3c and d less dimples are formed that indicates joint formed is of very less strength.

Trial Number	Tool Material	Speed (RPM)	Feed (mm/min)	Ultimate tensile strength (Mpa)	Elongation (%)	Weld Strengt (%)
1	EN39B	1400	31.5	220.820	17.084	62.66
2	EN39B	1400	45	169.398	15.09	48.07
3	EN39B	1400	63	157.826	13.06	44.78
4	EN39B	1400	90	130.666	7.198	37.08
5	EN39B	900	31.5	148.961	12.379	42.27
6	EN39B	900	45	123.84	9.655	35.13
7	EN39B	900	63	122.936	8.417	34.488
8	EN39B	900	90	113.437	5.661	32.9
9	EN39B	560	31.5	124.88	9.55	35.185
10	EN39B	560	45	105.596	6.559	29.96
11	EN39B	560	63	92.879	6.554	26.35
12	EN39B	560	90	90.080	5.77	25.56
13	HSS	1400	31.5	177.719	15.58	50.42
14	HSS	1400	45	160.680	11.587	45.59
15	HSS	1400	63	150.934	11.512	42.83
16	HSS	1400	90	137.941	10.069	39.14
17	HSS	900	31.5	155.346	11.429	41.24
18	HSS	900	45	148.961	12.379	42.27
19	HSS	900	63	137.94	9.987	39.14
20	HSS	900	90	123.84	9.655	35.13
21	HSS	560	31.5	123.894	10.111	35.16
22	HSS	560	45	120.843	9.646	34.29
23	HSS	560	63	112.801	9.045	32.01
24	HSS	560	90	102.026	7.622	28.95

Table 6 Tabulated results of strength analysis of welded joint

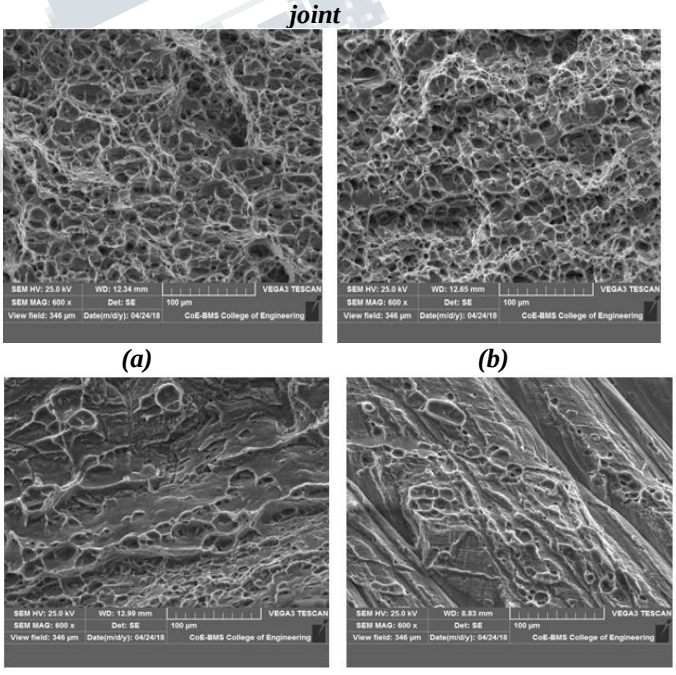

Fig 1 a,b,c and d indicates the SEM images of fractured surfaces

IV. CONCLUSIONS

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Welding of AA6061 and AA6082 Aluminium alloy in FSW process successfully obtained for different tool rotational speeds, feed rate and tool materials. Based on the analysis results, following conclusions can be made.

• It is found that at tool rotational speed 1400 rpm, 31.5mm/min feed rate very good joint strength can be obtained.
• Strength of the welded joint is more at high speed and low feed rate.
• By SEM images it was found that fracture occurred is of the type ductile.
• There is no influence of tool material on the weld strength. Only criteria that tool material should pass are, it must be harder than the workpiece material.

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