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Influence of Friction Stir Welding Parameters on Mechanical Properties of 6061- T6 Aluminum Alloy.

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Research Article

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ABSTRACT

In this investigation an attempt has been made to understand the three different tool rotational speeds, welding speed have been used to fabricate the joints .The formation of FSW zone has been analyzed tensile properties of the joints have been evaluated and correlated with the FSW zone formation. From this investigation it is found that the at 1120 rpm and welding speed 40 mm/min produces mechanically sound and metallurgically defect free welds compared to other joints.

INTRODUCTION

Friction stir welding (FSW) is a solid-state joining process using frictional and adiabatic heat generated by a rotating and traversing cylindrical tool with a profiled pin along a square butt weld joint. The advantages of the solid-state FSW process also encompass better mechanical properties, low residual stress and deformation, weight savings, and reduced occurrence of defects [1, 2]. The FSW was first developed in 1991 by The Welding Institute (TWI), and ever was investigated. The main focus was to examine the texture evolution, grain size change and grain boundary characteristics with respect to the welding parameters of advancing and rotating speed. In 6061 alloy of the mechanical properties are evaluated. recent years, demands for light-weight and/or high strength sheet metals such as aluminum alloys have steadily increased in aerospace, aircraft and automotive applications because of their excellent strength to weight ratio, good ductility, corrosion resistance and cracking resistance in adverse environments. During FSW process, the rotating tool induces a complex deformation in the surrounding material that varies as a function of welding condition [3,4,5]. Recrystallization of the microstructure takes place under severe plastic strain and elevated temperature due to FSW process, usually resulting in a very fine-grained structure in the weld zone. It is therefore expected that the complicated microstructure around the weld zone would govern the fatigue property of FSW joints.

However, the fatigue behavior of FSW joints is still unclear [6,7]. In this present investigation, effect of rotational speed (i.e. 900 rpm, 1120 rpm, and 1400 rpm) and welding speed on mechanical properties of friction stir welded of AA 6061 alloy. Since the FSW studies have been mainly focused on the joining of Al alloy systems [3,4], which has the greatest demand in various industries over conventional welding processes. In this study, the microstructure of Al 6061-T6 alloy welded by FSW method.

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In this investigation, an attempt has been made to understand the influence of various types of tool rotational speeds and welding speeds on mechanical properties of friction stir welded aluminum AA 6061 alloy.

EXPERIMENTAL WORK

Rolled plates of 5 mm thickness Al 6061-T6 alloy were cut to the required dimensions (240mm×60 mm×5mm) by wire cut Electric Discharge Machine. The schematic diagram of AZ31B Mg alloy plates used for FSW is shown in Fig.1. The chemical composition of base metal is presented in Table 1.

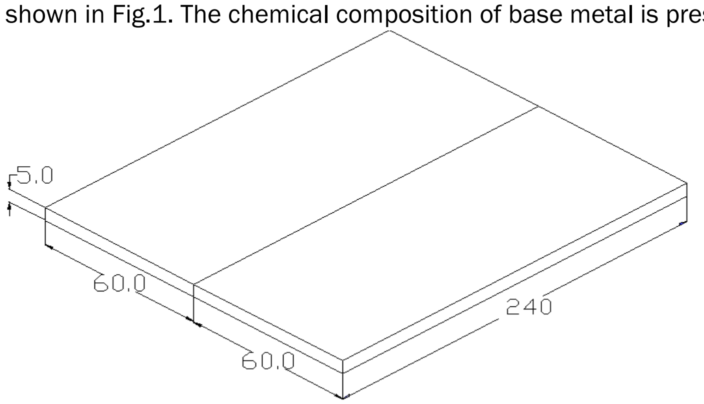

Figure 1: The schematic diagram of Al 6061-T6 alloy plates used for FSW

Table 1: Chemical composition (wt %) of base metal Al 6061-T6 alloy.

Element	Al	Mg	Si	Fe	Cu	Zn	Ti	Mn	Cr	Others
Amount (Wt %)	Bal	0.8-1.2	0.4-0.8	Max. 0.7	0.15-0.40	Max. 0.25	Max. 0.15	Max. 0.15	0.04-0.35	0.05

The initial joint configuration was obtained by securing the plates in position using mechanical clamps. The direction of welding is normal to the rolling direction and single pass FSW used to fabricate the joints. The diameter of the tool shoulder (D) is 18 mm and that of the insert pin diameter (d) and pin length (L) are 6 mm and 4.8 mm respectively. The schematic diagram of Tool geometry is shown in Fig.2. The FSW parameters such as tool rotational speeds and travelling speed were 900 rpm, 1120 rpm, 1400rpm, and 1800 rpm with 40mm/min respectively. The tool onward tilted an angle of 2.5^0 and a vertical load of 5KN is applied. The FSW process parameters and tool nomenclature are presented in Table 2.The process is carried out on a vertical milling machine (VMM) (Make HMT FM-2, 10hp, 3000rpm).

Table 2: FSW process parameters and tool nomenclature

Rotational speed(rpm)	900,1120,1400
Welding speed(mm/min)	25, 40, 80
Pin length(mm)	4.8
Tool shoulder diameter(mm)	18
Axial force(KN)	5
Tilt angle	2.5^0
Pin diameter(mm)	6
Shoulder diameter(mm)	18
D/d Ratio of tool	3.0
Tool materials	H13 tool steel
Tool Profile	Taper with Threaded

The specimens for metallographic examination were sectioned to the required size and then polished using different grades of emery papers. A standard reagent made of 4.2 g picric acid, 10 ml acetic acid, 10 ml diluted water, and 70 ml ethanol was used to reveal the microstructure of the welded joints. Micro structural analysis was carried out using a light optical microscope (Maker: Metzer-M, Binocular Microscope; model: METZ-57) incorporated with an image analysing at high magnification to estimate the weight percentage of elements. The smooth tensile specimens were prepared as per ASTM standard to evaluate yield strength, tensile strength, and elongation of the joints. Tensile test was carried out in a 100 KN electromechanical-controlled universal testing machine (maker: FIE-Bluestar, India; model: TUE-600C).

Tensile testes of as-received Al 6061-T6 alloy and the FSWed joint were determined at ambient temperature and three specimens were machined from each joint and the average was reported.

The charpy impact specimens were prepared according to the ASTM: E23-06 standard and evaluate the impact toughness of the weld metal and stir zone, and hence the notch was placed (machined) at the weld metal (weld centre) as well as in the SZ. The schematic sketch of charpy impact specimen is shown in Fig.5. Impact testing was conducted at room temperature using a pendulum type impact testing machine with maximum capacity of 300 J.

RESULTS AND DISCUSSIONS

Effect of tool rotational speed on Tensile Properties

Fig.3 reveals the effect of tool rotational speed on tensile strength of friction stir welded Al 6061-T6 alloy joints. At lower rotational speed (900 rpm), the tensile strength of FSW joints is lower. When the rotational speed is increased from 900 rpm, correspondingly the tensile strength also increases and reaches a maximum at 1120 rpm. If the rotational speed is increased above 1120 rpm, the tensile strength of the joint decreased. Higher tool rotational speed (1400 rpm) resulting in higher heat input per unit length and slower cooling rate in the FSW zone causes excessive grain growth, which subsequently leads to lower tensile properties of the joints. A Higher tool rotational speed also causes excessive release of stirred materials to the upper surface, which resultantly produces micro-voids in the stir zone and this may be one of the reasons for lower tensile properties of the joints. At lower rotational speed 900 rpm results in lack of stirring due to lower heat input per unit length, which results in not enough plasticization and this is also one of the reasons for lower tensile properties of the joints. The joint fabricated at a tool rotational speed of 1120 rpm exhibited maximum tensile strength and this may be due to optimum heat generation which is sufficient to cause free flow of plasticized material and adequate mechanical working.

Table 4: Effect of process parameters on Al 6061-T6 alloy joints

Sl.no	Tool material	Tool geometry	Rotational speed (rpm)	Weld speed (mm)	Ultimate tensile strength N/mm2	Yield stress N/mm2	Percentage of elongation (%)	Impact strength (joules)
Joint 1	H13	Taper threaded	900	25	138.97	89.004	4.32	6
Joint 2	H13	Taper threaded	1120	40	168.05	122.35	8.79	11
Joint 3	H13	Taper threaded	1400	80	143.73	111.06	5.11	7

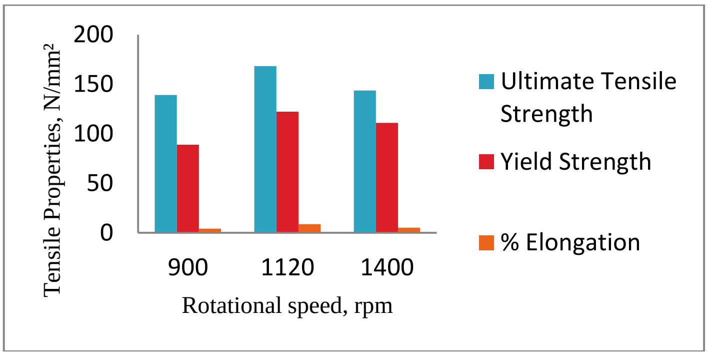

Figure 2:Effect of Rotational Speed on Tensile Properties

Effect of tool rotational speed on Impact Toughness

Charpy impact toughness of FSW joint was evaluated and presented in Table 4.The impact toughness of unwedded base metal is 13 J.However, the impact toughness of FSW joint with notch placed at the SZ region and reached maximum 11 J at 1120 rpm, compared to the other rotational speeds. It is observed that the joint fabricated at a tool rotational speed of 1120 rpm made of H13 tool steel material exhibited higher impact strength 11 joules and this may be due to optimum heat generation which is sufficient to cause free flow of plasticized material.

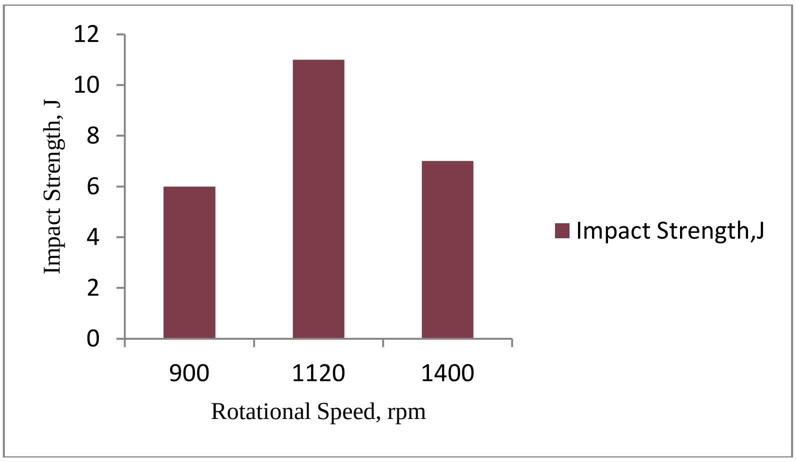

Figure 3: Effect of Rotational Speed on Impact tests

Effect of Welding Speed on Tensile Properties

The yield strength and tensile strength of all the joints are lower than that of the base material, irrespective of the welding speeds used to fabricate the joints. Of the three welding speeds used to fabricate AA 6061 alloy joints, the joint fabricated at a welding speed of 40 mm/min yielded good tensile properties. The above joints showed a maximum when compared to other joints. The joints fabricated using the welding speeds lower and higher than these values, exhibited comparatively inferior tensile properties and the reason are explained in the following paragraphs. When the welding speed is slower than a certain critical value, the FSW can produce defect-free joints. When the welding speed is faster than the critical value, welding defects can be produced in the joints. Lower welding speed (25 mm/min) results in higher temperature and slower cooling rate in the weld zone causes excessive grain growth, which subsequently may lead to lower tensile properties of the joints [8]. The joint fabricated at a welding speed of 40mm/min exhibited higher tensile strength and this may be due to adequate heat generation that is exactly sufficient to cause the material to flow plastically with appropriate mechanical working under this condition

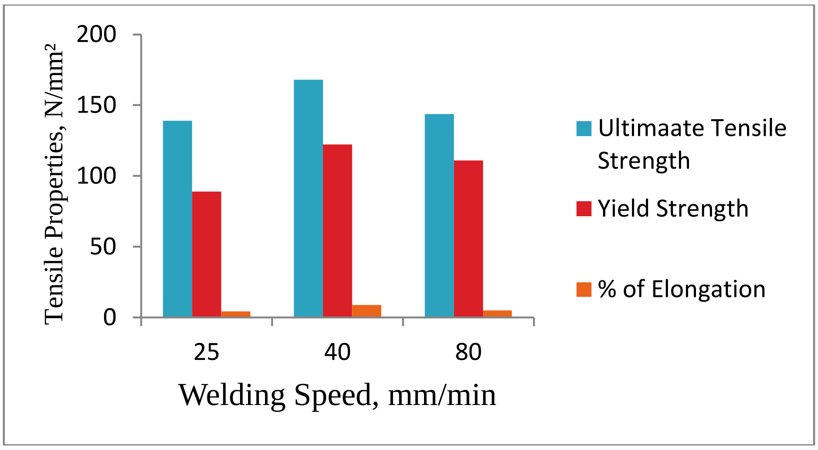

Figure 4: Effect of Welding Speed on Tensile Properties

Effect of welding speed on Impact Toughness

Fig.5. reveals the effect of welding speed on tensile strength of friction stir welded Al 6061-T6 alloy joints. At lower welding speed 25 mm/min, the tensile strength of FSW joints is lower. When the rotational speed is increased from 25 mm/min, correspondingly the tensile strength also increases and reaches a maximum at 40 mm/min. If the rotational speed is increased above 40 mm/min, the impact toughness of the joint decreased. The joint fabricated at a tool rotational speed of 1120 rpm exhibited

maximum tensile strength and this may be due to optimum heat generation which is sufficient to cause free flow of plasticized material and adequate mechanical properties.

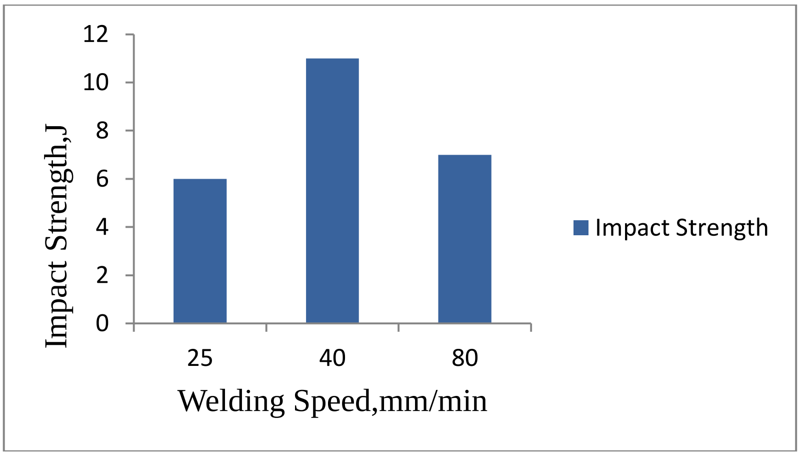

Figure 5: Effect of Welding Speed on Impact Toughness

CONCLUSION

The tool geometry and rotational speed have been identified as the important parameters that affect the stir zone microstructure and properties of Friction Stir Welding (FSW) process. The following conclusions can be obtained

- The joint fabricated at a rotational speed of 900rpm and 1400 rpm have also shown lower tensile strength properties compared to the joints fabricated at a rotational speed of 1120 rpm
- Of the three joints fabricated using three different welding speeds of 25 mm/min and 80 m shown lower mechanical properties as compared to the welding speed of 40 mm/min.

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