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Effect of Welding Parameters on Mechanical Properties of Friction Stir Welded Aluminium 5086 Alloy

Girish.G[1] Deepandurai.K[2]

[1 2]Assistant professor, Department of Mechanical Engineering,

Kongu Engineering College,

Perundurai, Erode- 638052,

Tamil nadu, India

ABSTRACT

Friction stir welding is widely employed for joining of non-ferrous materials. The process uses a non-consumable electrode that plastically deforms the material over the joint region and completes the weld. In this study, mechanical properties of friction stir welded Al 5086 was investigated. The process parameters used in this study are tool force, tool rotation speed, tool traverse speed. Single pass welds were made by varying the tool rotation speed keeping the traverse speed and the force applied on the tool constant. Three welds were made at tool rotation speeds of 600, 750 and 850 rpm and the corresponding tensile strength, yield strength and ductility were measured. It was observed that the tensile strength decreases with increase in tool rotation speed. Specimen welded at 600 rpm recorded the highest tensile strength of 0.199 KN /mm^2 and the specimen welded at 850 rpm experienced the lowest tensile strength of 0.078 KN/mm^2. The yield strength of the material had also decreased considerably with increase in tool rotation speed. The specimen welded at 600 rpm obtained the highest percentage of elongation as compared to other two specimens. There was no variation in micro hardness values at the stir zone of the specimens.

Key Words: *Aluminium alloy, Friction stir welding, Percentage of elongation, Stir zone, Tensile strength, Traverse speed*

1. INTRODUCTION

Aluminium alloys are widely preferred in various heavy duty engineering applications. Light weight, less cost, superior mechanical properties, and corrosion resistance attracts engineers and designers to utilize the material in varieties of applications. High-strength alloyed materials are difficult to join by conventional fusion welding due to the occurrence of hot cracking during welding, low weld ability, improper solidification and occurrence of internal residual stresses. Moreover, materials of different thickness are impossible to weld by conventional methods. To overcome all these defects friction stir welding was developed. Friction stir welding (FSW) is a solid-state welding technique which uses a rotating tool to develop intense heat at the interface region between the tool and the work piece and joins the two ends of the material by plastic deformation. The tools for FSW are available in various profiles and configurations. Lightweight materials joined by FSW are well known for its high strength which makes them suitable for various engineering applications. Cao et al. [1] investigated the effect of welding speed on the quality of friction stir welded butt joints of AZ31B-H24 magnesium alloy. Equiaxed grains were observed in the stir zone and TMAZ zones. The grain size in the stir zone decreases with increasing welding speed due to lower heat input. Higher welding speeds resulted in increase in hardness in the stir zone. The tensile strength increases first with increase in welding speed but remained constant from 15 to 30 mm/s. Elangovan et al. [2] made an attempt to understand the effect of tool pin profile and tool shoulder diameter on FSP zone formation in AA6061 aluminium alloy. Five different tool pin with three different shoulder diameters have been used to fabricate the joints. It was found that the square pin profiled tool with 18 mm shoulder diameter produced mechanically sound and defect free welds compared to other tool pin profiles. Lakshminarayanan et al. [3] analysed the microstructure and mechanical characteristics of friction stir welded 409M ferritic stainless steel. Single pass welds free of volumetric defects were produced at a welding speed of 50 mm/min and rotational speed of 1000 rpm. Optical microscopy, micro hardness testing, transverse tensile, impact and bend tests were performed. The coarse ferrite grains in the base material changed to very fine grains consisting duplex structure of ferrite and martensite due to the rapid cooling rate and high strain induced by severe plastic deformation caused by frictional stirring. Moreira et al. [4] made a comparative study between fatigue crack growth behaviour of friction stir welded 6082-T6 and 6061-T6 aluminium alloys. Fatigue crack growth behaviour was determined at different zones of the specimen. The material exhibited lower strength and ductility than the base material. An enhanced crack propagation resistance is observed in the welded material. Min-su han et al [5] investigated the mechanical characteristics of friction stir welded (FSW) 5083 Al alloy. A slight weld defect and rough stir zone are seen both at the start and end points of the specimen welded at 342 mm/min. Weld fractures relative to rotational and travel speeds are observed at the stir zone. The optimum weld was obtained at a welding speed of 124 mm/min and a rotational speed of 800 Rpm.

2. EXPERIMENTAL PROCEDURE

Aluminium 5086 alloy which has magnesium as its major alloying element is mainly used in marine applications. It becomes stronger due to stress hardening or cold mechanical working of the material. Since heat treatment doesn’t strongly affect strength it can be readily welded and retain most of its mechanical strength. The good results with welding and good corrosion resistant properties in sea water make 5086 extremely popular for vessel gang ways, building boats and yachts. The mechanical strength of 5086 varies significantly with hardening and temperature and has the tendency to undergo stress corrosion cracking. The mechanical properties of 5086 aluminium alloy are indicated in Table 1. In this study, mechanical properties of friction stir welded aluminium 5086 alloy are investigated. The schematic view of FSW process is shown in figure 1.

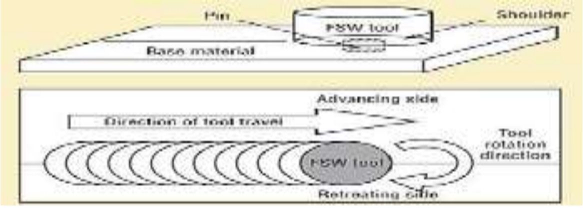


Figure 1.Schematic view of FSW process

The specimens are cut to required sizes (100mm x 50mm x 6mm) by using power hacksaw. A friction stir welding machine with specially designed fixtures was used to fabricate the joints. The typical chemical composition of the material is presented in Table 2. The tool shown in figure 2 is a non- consumable straight cylindrical profiled tool made of high speed steel. The key parameters used in this study are tool force, tool rotational speed and tool traverse speed.

Table 1. Mechanical properties of Al 5086 alloy

Ultimate Tensile Strength KN/mm^2	Tensile Yield Strength KN/mm^2	Elongation at Break %	Hardness, Vickers (HV)
0.290	0.207	12	88

Table 2. Chemical composition of Al 5086 alloy

Chemical composition	Silicon	Iron	Copper	Manganese & Magnesium	Zinc	Others	Aluminium
Limits (wt. %)	0.4	0.5	0.1	Mn-max. 0.75 Mg-Max. 4.5	0.25	0.25	90-93

Figure 2.Straight cylindrical FSW tool

Welding was made on Al 5086 aluminium plates by varying the spindle speed, keeping the transverse speed and load constant. The process parameters used in this study are given in Table 3.

Table 3. Process parameters used in this study

Specimen No.	Tool rotation speed (Rpm)	Force (KN)	Welding speed (mm/min)
C1	600	8	45
C2	750	8	45
C3	850	8	45

3. RESULTS AND DISCUSSIONS

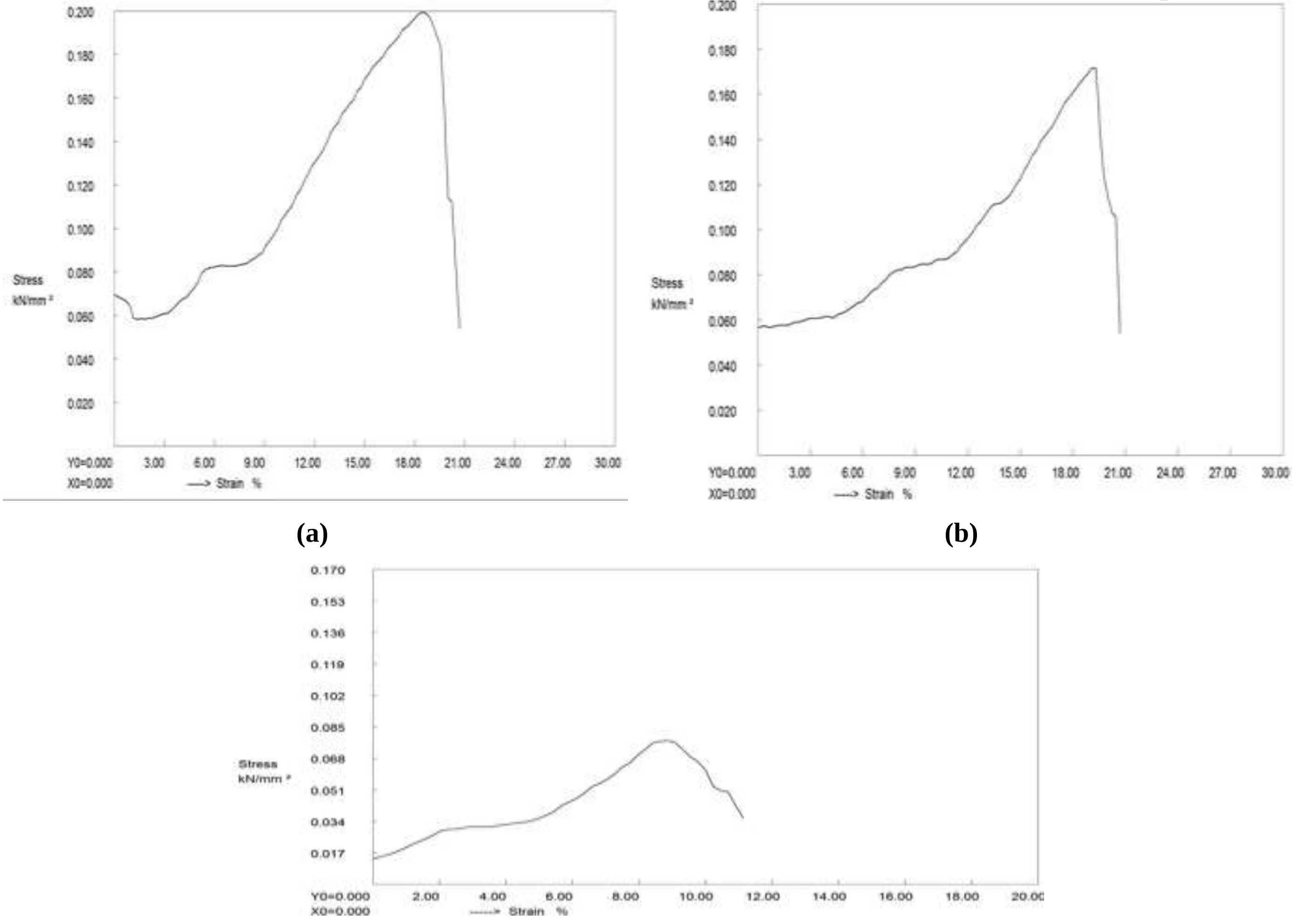
Butt joints were made on Al 5086 plates by varying the tool rotation speed. The other two factors force and welding speed were kept constant. The samples were properly aligned by using special fixtures in order to avoid distortion during the process. The as welded specimens were then cut to required dimension as per ASTM standard for tensile testing.

3.1 Tensile Test

Computerized Universal Tensile Tester is designed for determining tensile, elongation, compression, fold resisting, adhesive, bending, flaking, extension and shearing strength of various objects. The control panel in the machine displays all the information in relation to actual load capacity and elongation. The Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area. In all the three specimens the fracture took place exactly at the stir zone. The mechanical properties obtained from tensile testing are given in Table 4. The value of the tensile strength was higher for specimen C1 and the value decreases when the weld was carried out at a higher rotational speed. The ductility of the material has also decreased with increase in welding speed. The yield strength of specimens C2 and C3 were also lower than the yield strength of specimen C1. The typical stress strain curves obtained at various speeds are given in figure 3.

Table4. Mechanical properties of the welded specimens

Specimen No	Tool rotation speed (Rpm)	Force	Welding speed (mm/sec)	Yield strength (KN/mm^2)	Tensile strength (KN/mm^2)	% of Elongation	Maximum force (KN)
C1	600	8	45	0.067	0.199	4.545	14.96
C2	750	8	45	0.051	0.172	4.545	12.92
C3	850	8	45	0.017	0.078	3.409	5.82



(a) (b)

(c)

Figure 3.stress strain curve of specimens welded at (a) 600 Rpm, (b) 750 Rpm, (c) 850 rpm

The impact of weld properties on tensile strength of the material is depicted in figure 4 and the corresponding loads are presented in figure 5. The tensile strength and yield strength was higher at the tool rotational speed of 600 Rpm and it drastically declines at higher tool rotation speeds. The impact of tool rotation speed on the ductility of the material is shown in figure 6.

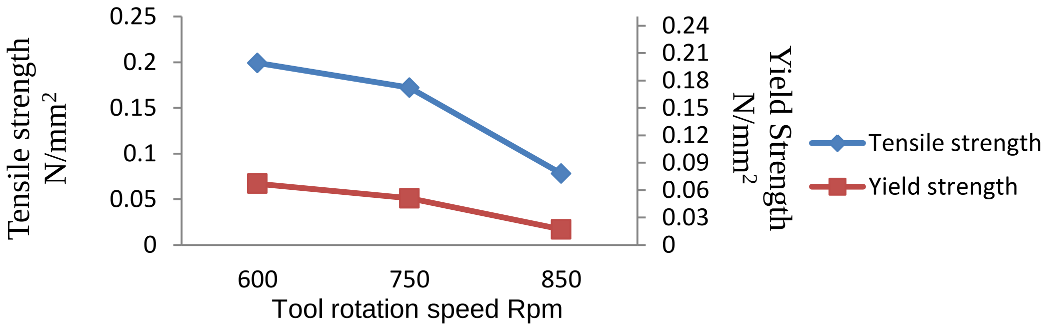


Figure 4.Effect of process parameters on tensile strength

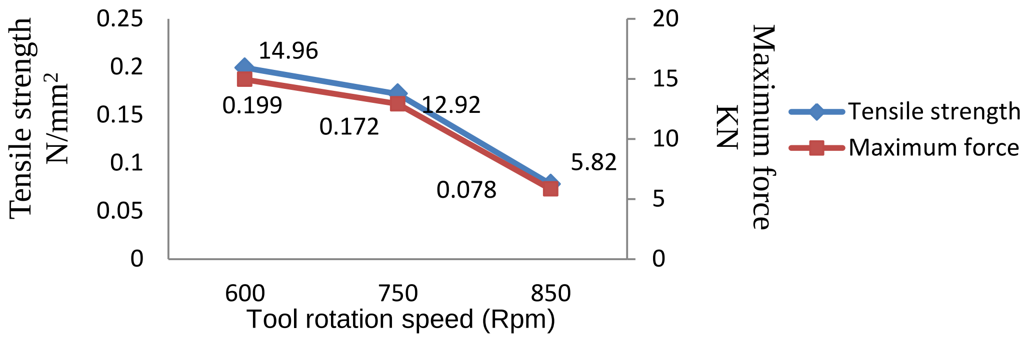


Figure 5.Load experienced by the specimen at its corresponding tensile strength.

3.2 MICRO HARDNESS

Micro hardness values that have been obtained at the stir zones of all the three specimens are shown in figure6. Vickers hardness tester uses a diamond indenter at an apical angle of 136 degree. The test surface of the specimen is made flat and polished with grits of various sizes and finally etched to obtain a clear surface and placed in the fixture and the variation in hardness values were determined.

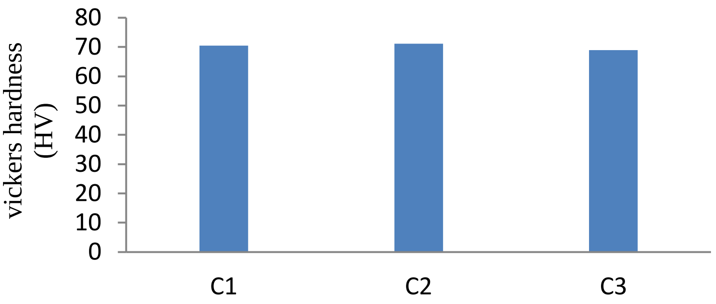


Figure 6.Microhardnes values at stir zones of three specimens

4. CONCLUSION

From the above observations the following conclusions were made,

i) Higher tensile strength can be attained at lower tool rotational speeds by keeping the other parameters constant. However, variation in other process parameters could bring up a significant change in the properties of the material.

ii) The tensile strength, yield strength and percentage of elongation attained by the welded specimens were considerably lower to that of base material.

iii) There is no significant variation in hardness in the stir zone of the specimen and localised heating of the tool would have induced strain hardening in the stir zone.

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