AN ANALYSIS OF FRICTION STIR WELDING OF MARINE GRADE 5083 ALUMINIUM ALLOY USING WELD PARAMETERS

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ABSTRACT

The most popular alloys to weld with friction stir welding, a relatively new joining technique, are aluminium alloys. This study looked at weld characteristics and friction stir welding of marine grade 5083 aluminium alloy. Numerous studies looked into how tool traversing and rotational speed affected the microstructure and mechanical properties of the welded connection. It was demonstrated that the tool traverse speed significantly affected the final characteristics of the welded connection. In TMAZ, grain refinement was observed, which improved the mechanical properties of the welded connection. However, keeping the rotation speed constant while raising the welding speed led to a loss of mechanical properties. According to the research, using the right process parameters may make it possible to produce a marine grade 5083 aluminium alloy welding joint of very high quality.

1. INTRODUCTION

The Welding Institute in Cambridge invented the friction stir welding method, which includes bonding metals without the use of fusion or filler materials. Construction of structural components for significant applications uses aluminium and its alloys. Two materials are linked together using a non-consumable spinning tool to plasticize and then stir the connecting zone into a solid piece of material. This plasticizing is carried out by heating a portion of the substance by friction between the substance and the rotating instrument. The process works best with flat, long components (plates and sheets), while it may also be used with hollow sections, pipes, and positional welding. The combined effects of frictional heating and mechanical deformation brought on by a revolving tool produce the welds. The highest temperature achieved is around 0.8 degrees below the melting point of the plates being welded. The instrument features a probe at the end of a circular portion. The shoulder is the point where the probe and cylindrical part meet. While the shoulder rubs against the top surface, the probe penetrates the work piece. The primary source of the heat is friction between rotating tools whose shoulders scrape against the work piece. The Welding Institute (TWI) obtained a patent for friction stir welding (FSW), a newly developed solid-state joining process, in 1991 [1]. Due to lower welding temperatures than fusion welding techniques [1], FSW welds are stronger and more formable [14]. FSW may be used in place of resistance spot welding and riveting of aluminium and steel sheets in the aerospace and automotive industries, respectively [15]. Both Tang et al. [3] and McClure et al. [2] monitored the temperature of the workpiece in FSW. Colegrove et al. [4] simulated the FSW for thermal and material flow, including the pin. A heat input was suggested by Russel and Shercliff [5] based on the material's shear strength. Shercliffe and co. [6] and his team developed a simple process model in the UK to forecast microstructural alterations brought on by the temperature cycle enforced in FSW. They created a softening model for heat-treatable 6000 series aluminium alloys that is used with aerospace alloys in peak-aged state from 2014.

FSW can provide high-quality, flawless welds of aluminium alloys since it is a solid state joining method. Due to the lower welding temperatures used by FSW techniques vs fusion welding processes 3 [7], the welded joints are stronger and more formable. It is feasible to automate the FSW procedure. Numerous additional benefits of FSW include: Non-consumable tool, no need for filler wire, ability to weld complex curves, no need for gas shielding when welding aluminium, no need for welder certification, no need for surface preparation, Low distortion even in lengthy welds, no harmful fumes, no porosity, no spatter, and solid state process rather than molten metal are all advantages of this process. The process parameters of RPM, translational weld speed, and downward plunge force must be carefully adjusted in order to produce a weld that is defect-free.

The processes of this method, particularly the metal flow direction, are still up for dispute since it was copyrighted at the Welding Institute in 1991 [1] [9–11]. At the moment, the tensile strength of the welded connection is used to establish the processing parameters for an FSW in a trial-and-error method to get a satisfactory weld. However, this strategy is expensive and slows down the process of developing FSW and integrating it into the production schedule. There are several pin tool varieties that each claim to provide a superior weld [12]. Steel, ceramics, and composites are just a few of the materials that may be used to make pin tools. The sole prerequisite is that, at high temperatures, the tool material must be much tougher than the workpiece material. In order to study the shearing around the tool pin, Seidel et al. [13] used a marker insertion approach in which thin sheets of Al 5454 were inserted into slots machined into the workpiece's face of Al 2195. Serial sectioning was used to rebuild the flow route and create three-dimensional maps of the deformed marker.

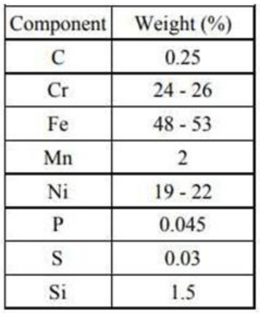
Based on this information, it can be concluded that an FSW's flow path is complex and may possibly have many pathways [13]. The goal of the current experiment is to weld sound joints on 5083 marine grade aluminium alloy while also examining how different process factors affect the welded joint's mechanical and microstructural qualities.

2. EXPERIMENTAL SETUP

For the FSW of the 5083 aluminium alloy, an appropriate experimental setup was created. Using 310 stainless steel, an FSW tool with a certain taper pin shape was created, as illustrated in Fig. 1. The investigations on FSW were conducted using a milling machine with a 7.5 hp engine. A appropriate collate was used to install the tool in the milling machine's vertical arbour. The test samples were fixed on the horizontal bed. The FSW experimental setup is shown in Fig.2.

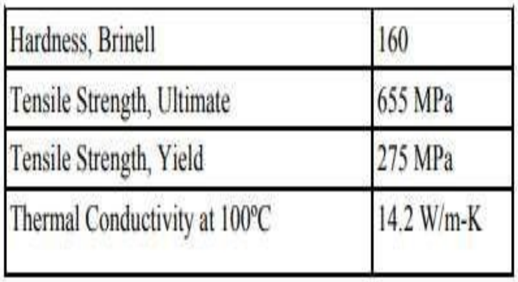
Fig.1 FSW tool

Tables 1 and 2, respectively, display the material composition and pertinent physical characteristics of the material utilised to make the tool. Figure 3 depicts a sample of friction stir welding.



Component	Weight (%)
C	0.25
Cr	24 - 26
Fe	48 - 53
Mn	2
Ni	19 - 22
P	0.045
S	0.03
Si	1.5

Table 1: FSW Tool Material Composition



Hardness, Brinell	160
Tensile Strength, Ultimate	655 MPa
Tensile Strength, Yield	275 MPa
Thermal Conductivity at 100ºC	14.2 W/m-K

Table 2: FSW Tool Material PhysicalProperties

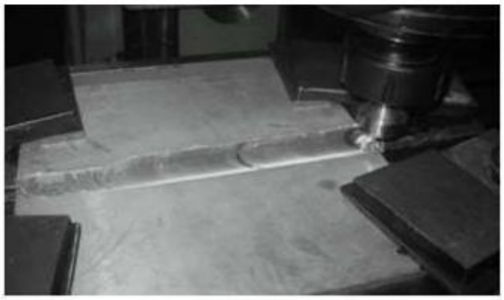


Fig.2 Experimental setup of FSW process

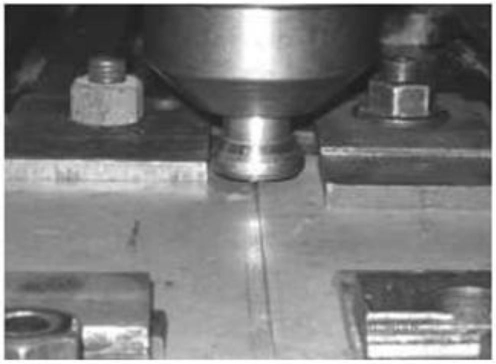


Fig. 3 A friction stir welded sample

MECHANICAL PROPERTIES

The effect of the tool rotational speed andthe tool traverse speed on the hardness, tensile strength and elongation of frictionstir welded samples were investigated.

VICKERS MICRO HARDNESS

By inserting an indenter into the material under test with a certain weight and dwell duration, the hardness was determined. The created impression was measured and the "hardness number" was computed when the indenter was removed. The alterations the indenter generates are mostly determined by the material's elasto-plastic characteristics. The Vickers indenter is a square-base, four-sided pyramid with an apex angle of = 136o (15') between opposing sides.

By dividing the load (indentation force) by the imprint's surface, the hardness number (HV) was determined. A metallographic finish is necessary for the surface being examined; the greater the surface polish needed, the smaller the load employed. On the cross sections that were parallel to the welding direction, hardness measurements 9 were made. In the current experiment, two diagonal indentation diameters ranged from 30 to 45 metres while the indentation load was maintained at 25 gf. The setup of Vickers Micro hardness tester is shown in Fig.4

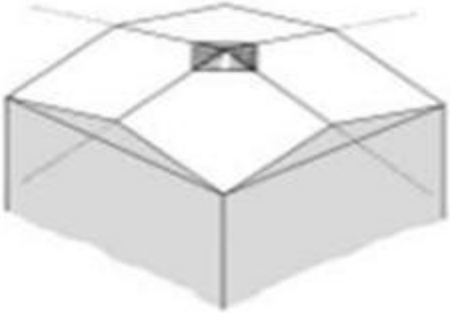


Fig.4 Vickers indenter

Fig.5 Vickers Microhardness tester

The results of this study's analysis of the hardness in the various zones of welded samples show that the hardness steadily decreases from the source metal towards the weld line's centre. The HAZ's hardness increases with faster traverse speed while maintaining constant tool rotating speed.

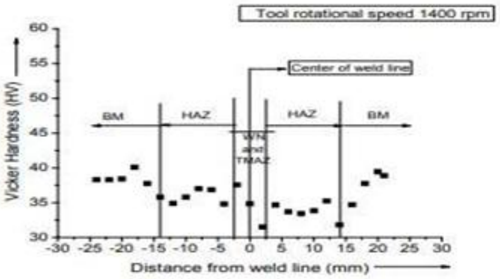


Fig.6 Variations of the hardness at variousregions of welded plate for a traverse speedof 160 mm/min

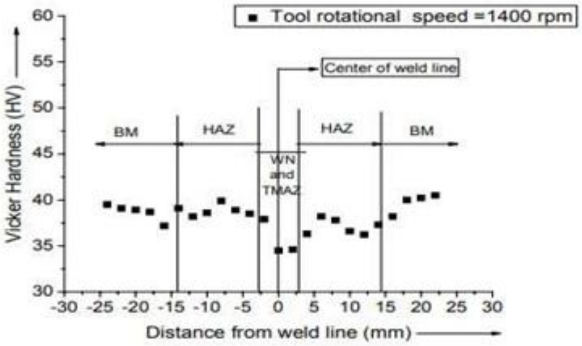


Fig.7 Variations of the hardness at variousregions of welded plate for a traverse speedof 224 mm/min

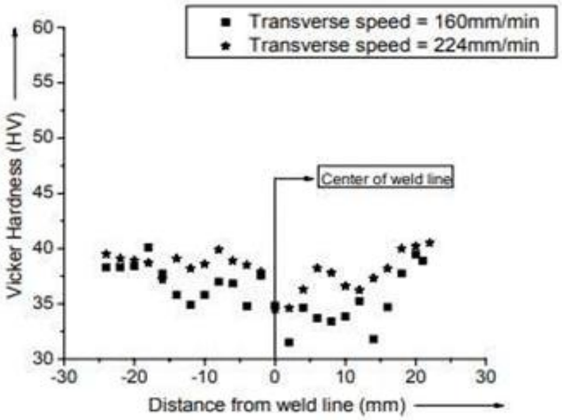


Fig.8 Comparison of hardness at various regions of welded plate for variation in traverse speed and keeping rotational speedconstant at 1400 rpm

TENSILE STRENGTH

The tensile test specimens were cut from test samples of the friction stir-welded 5083 aluminium alloy in the longitudinal and transverse directions (along and perpendicular to the welding direction, respectively). All tensile tests were carried out on a Tinius Olsen tensile testing apparatus at a fixed crosshead displacement rate of 10 mm/min.

Fig. 9 Tensile testing setup

In order to investigate the impact of traverse speed while maintaining the FSW tool's rotating speed constant, tensile tests were performed on a number of test samples made of FSW 5083 aluminium alloy. Figures 15 and 16 display the results of the tensile test. The stress-strain properties of the tensile test specimens along the welding line at various traversal speeds. Here, a change in traverse speed has a very clear and noticeable impact on the tensile strength and maximum elongation. Tensile strength and maximum elongation both significantly decreased as weld speed, or tool traverse speed, increased.

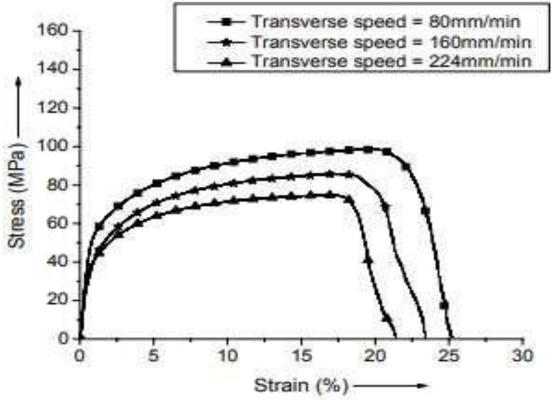


Fig.10 Stress strain characteristics of testspecimens along weld line with varying traverse speed keeping rotational speed constant at 1000 rpm

Fig.10 shows the stress strain characteristics of tensile test specimens of base metal, perpendicular to weld line and along weld line with same welding parameters (i.e. rotational speed = 1000rpm and transverse speed =80mm/min). From the Fig.16, one can observe that there is a distinct increasein the ductility of the welded metal compared to that of the original base metal.

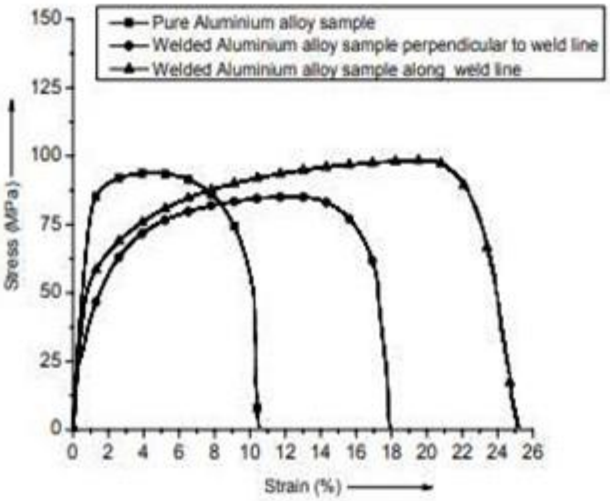


Fig.11 Stress strain characteristics at variouszones of a FSW sample

CONCLUSIONS

The investigations mentioned above led to the following findings.

To investigate the impact of weld settings on the microstructural features and mechanical characteristics of the welded joints, an experimental investigation of FSW of marine grade 5083 aluminium alloy was conducted.

In the HAZ and TMAZ, there was a clear instance of grain refining caused by FSW. It was discovered that the parent metal, HAZ, and TMAZ had average grain sizes of 5.5 m, 4.7 m, and 3 m, respectively.

Grain structure became coarser as traverse speed increased. The typical diameters at TMAZ were 3 mm and 3.94 mm for traverse speeds of 112 mm/min and 160 mm/min, respectively. As a result, the test samples for friction stir welding saw a dramatic decrease in tensile strength as well as elongation.

A steady reduction in the material hardness in the HAZ and TMAZ was seen along with grain refining. With increasing traverse speed, an increase in hardness was also seen in the FSW of the 5083 aluminium alloy.

The TMAZ showed the highest levels of grain refinement, which also supports the increased ductility seen there. The study strongly suggests that with the right choice of process parameters, it is possible to achieve a very good welded joint in marine grade 5083 aluminium alloy.

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