Friction welding study of marine-grade aluminum alloys

Dr. T. SURYA SEKHARA REDDY, KALLA PARTHASARATHI REDDY, TAHLARI VIJAYARAJ
PROFESSOR[1] ASSISTANT PROFESSOR[2] ASSISTANT PROFESSOR[3]
tssreddy2010@gmail.com, kpsreddy999@gmail.com, vijayaraj12@gmail.com
Department of Mechanical Engineering, Sri Venkateswara Institute of Technology,
N.H 44, Hampapuram, Rapthadu, Anantapuramu, Andhra Pradesh 515722

ABSTRACT

A more modern joining technique, friction stir welding is mostly used to connect aluminium alloys. To that end, this study looked at how different weld parameters affected friction stir welding of marine grade 5083 aluminium alloy. The microstructure and mechanical properties of the welded connection were examined by a battery of experiments that examined the impact of tool traversal speed and tool rotation speed. The end characteristics of the welded joint were found to be significantly affected by the tool traverse speed. The TMAZ improved the mechanical properties of the welded junction by refining the grain. Unfortunately, mechanical properties were lost when the welding speed was increased while the rotation speed was maintained. Based on the results, it seems that a very excellent welded joint in marine grade 5083 aluminium alloy is within the realm of possibility with the right process parameter selection.

1. INTRODUCTION

The Welding Institute in Cambridge developed the friction stir welding technique, which allows metals to be joined without the need of filler or fusion ingredients. For crucial uses, such as attaching structural parts composed of aluminium and its alloys, it is indispensable. A non-consumable, spinning tool is used to connect two materials together. The tool plasticizes and stirs the joining zone until it becomes a solid. A section of the material is heated by friction between the substance and the revolving tool, allowing it to undergo plasticizing. Although it may be modified for pipes, hollow sections, and positional welding, the procedure works best with long, flat components like sheets and plates. The process of frictional heating and coupled with
physical distortion caused by a tool that is in motion. Welding temperatures may go up to around 0.8 times the melting point of the metal plates. A circular portion with a probe attached to the end makes up the tool. At its shoulder, the cylindrical part meets the probe. While the shoulder brushes against the upper surface, the probe goes into the work piece. The shoulder of a rotating-translating tool grinds against the work piece, creating friction and, in turn, heat. The Welding Institute (TWI) patented friction stir welding (FSW) in 1991 [1], which is a newly developed method of solid-state joining. As a result of using lower welding temperatures than fusion welding methods, FSW produces welds that are more strong and shapeable [14]. Both the aerospace and automobile sectors have the ability to use FSW as a substitute for riveting and resistance spot welding, respectively, on steel and aluminium sheets [15]. The workpiece's temperature was measured in FSW by Tang et al. [3] and McClure et al. [2]. To simulate the pin's impact on thermal and material flows, Colegrove et al. [4] used FSW. Theoretically, the shear strength of a material determines the heat input proposed by Russel and Shercliff [5]. Within the realm of British soil, Shercliff. [6] and his crew created a simple process models to predict microstructural changes due to thermal cycle imposed in FSW.They developeda softening modelfor heattreatable aluminum alloys of the 6000

seriesisappliedtotheaerospacealloys2014 in the peak-aged condition.

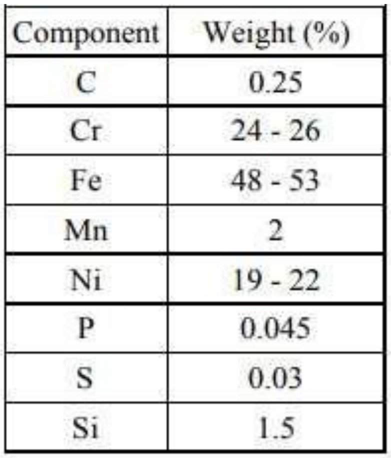
Since FSW is a solid-state joining method, it may produce defect-free welds of aluminium alloys of excellent quality. The low welding temperatures used in FSW result in welds that are more strong and easier to shape than those made using fusion welding [7]. Automating the FSW procedure would be a good fit. Additional benefits of FSW are many [8]: Features: • It is a non-consumable tool. • It eliminates the need for filler wire. • It can weld complex curves. • It doesn't require gas shielding for welding aluminum. • It doesn't necessitate welder certification. • It doesn't require surface preparation. • It has low distortion, even in long welds. • It doesn't emit toxic fumes. • It doesn't have porosity. • It uses a solid state process, so there is no molten metal. A flawless weld is the result of precisely calibrated process parameters, including rotational speed, translational weld speed, and downward plunge force. Discussions over the metal flow channel and other aspects of this technology have persisted since its 1991 patenting at the Welding Institute [1]. Currently, in order to get a good weld, the processing parameters for an FSW are determined by trying out various values until the welded connection reaches a sufficient tensile strength. Adding FSW to the production schedule adds additional expenses and lengthens the development duration, which are drawbacks of this approach. A wide range of pin tools are available, each claiming to provide an improved weld compared to its predecessor [12]. A variety of materials, including steel, ceramics, and composites, may be used to fabricate the pin tool. Only that the tool material be much harder than the workpiece material is sufficient to withstand high temperatures. Seidel et al. [13] used a marker insertion method to analyse the shearing around the tool pin. Part of the process included cutting holes into the faying surface of Al 2195 workpieces and inserting thin sheets of Al 5454 into those slots. The deformed marker was plotted in three dimensions by recreating the flow path using a serial sectioning method.
In light of these results, the flow path within an FSW is likely multi-channeled and intricate [13]. The main goal of this effort is to achieve strong welded connections on 5083 marine grade steel. material, and to examine how different process settings impact the microstructural features and mechanical qualities of the resulting welded junction.

Fig.1FSWtool

2. EXPERIMENTALSETUP

A suitable experimental setup wasdeveloped to carry out FSW of 5083 aluminum alloy. FSW tool with a particular taper pin geometry was designed and developedusing310stainlesssteelasshown in Fig.1. A milling machine having a 7.5 hp motor was used to carry out the experiments on FSW. The tool was mounted in the vertical arbor of the milling machine by a suitablecollate.Thehorizontalbedwasused for fixing the test samples. The FSW experimental setup is shown in Fig.2.

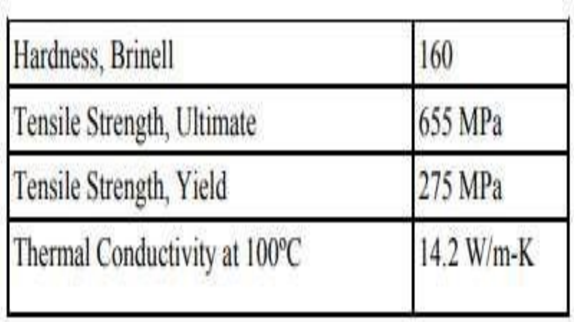
The material composition and the relevant physical properties of the material used for manufacturing the tool are shown in Tables1 and 2 respectively. A friction stir welded sample is shown in Fig.3



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

Table1:FSWToolMaterialComposition

Table2:FSWToolMaterialPhysical Properties



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

Fig.2ExperimentalsetupofFSW process

Fig.3Africtionstirweldedsample

3. MECHANICALPROPERTIES

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

3.1 VICKERSMICROHARDNESS

The hardness was determination by meansof an indenter entering the material to be tested with a specific load and dwell time. After removing the indenter, the produced imprint was measured and the "hardness number" calculated. The changes produced by the indenter entering the material mainly depend on the elasto-plastic characteristics of the material. The Vickers indenter is a four sided pyramid with square base as shown in Fig.9 with an apex angle between opposite sides of α = 136o (± 15').

The hardness number (HV) was calculated by dividing the load (indentation force) by the surface of the imprint. The surface being tested requires a metallographic finish; the smaller the load used, the higher the surface finish required. Hardness measurements 9 were taken on the cross sections perpendicular to the welding direction. Inthepresentinvestigationtheindentationload waskeptat25gf andtwo diagonaldiameters of indentation were varied from 30µm to 45µm. The setup of Vickers Microhardness tester is shown in Fig.10

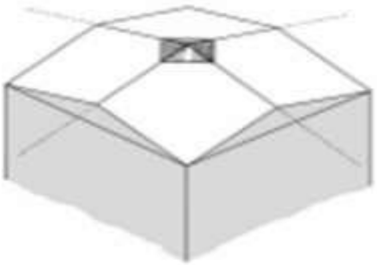


Fig.9Vickersindenter

Fig.10VickersMicrohardnesstester

The hardness in the different zones of weldedsamples obtained from this study are shown in Figs.11 to 13. Figs.11 and 12 indicate that the hardness gradually decreases from parent metal towards center of weld line. At the same time keeping the tool rotational speed same the hardness in the HAZ increased with increasing traverse speed as shown in Fig.13

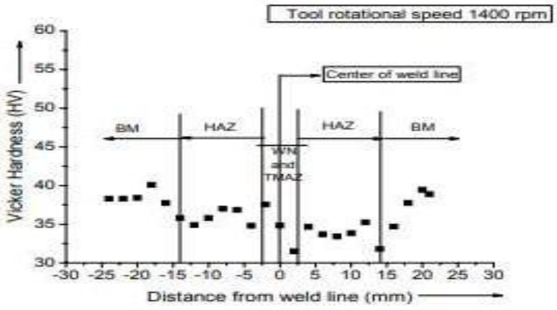


Fig.11Variationsofthehardnessatvarious regionsofweldedplateforatraversespeed of 160 mm/min

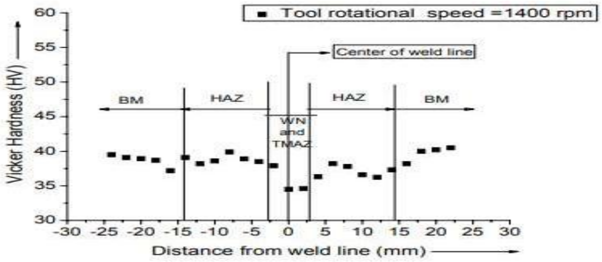


Fig.12Variationsofthehardnessatvarious regionsofweldedplateforatraversespeed of 224 mm/min

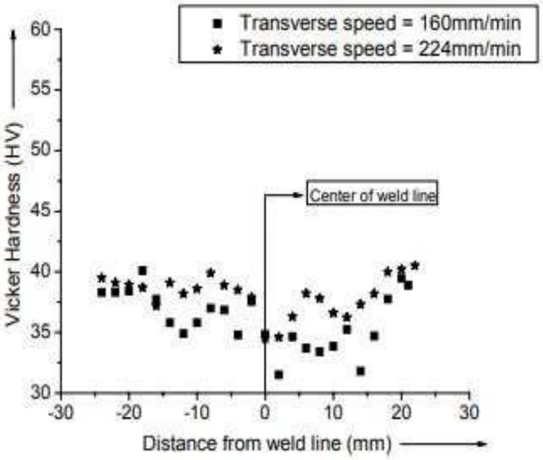


Fig.13 Comparison of hardness at various regions of welded plate for variation in traversespeedandkeepingrotationalspeed constant at 1400 rpm

3.2 TENSILESTRENGTH

The tensile test specimens were sectioned in the longitudinal direction i.e. (along weld line) and transverse direction i.e. perpendicular to the welding direction from friction stir welded 5083 aluminum alloytest samples. All tensile tests wereperformed at a constant crosshead displacement rate of 10 mm/min using a Tinius Olsen tensile testing machine.

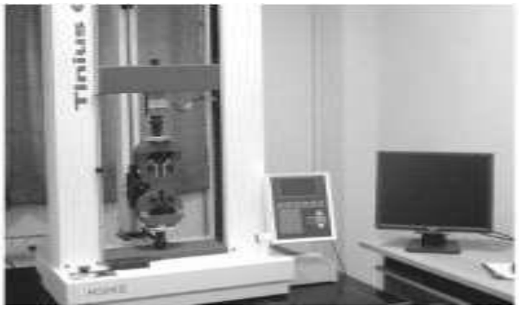


Fig.14Tensiletesting setup

Tensile tests were carried out on several FSW 5083 aluminum alloy test samples to study the effect of traverse speed keeping rotational speed of the FSW tool constant. The tensile test results are shown in Figs.15 and 16. The stress strain characteristics of the tensile test specimens along weld line with varying traverse speed are shown in Fig.15. Here one can observe a very distinct and conspicuous effect on the tensile strength and maximum elongation with variation of traverse speed. With increasing weld speed i.e. increasing tool traverse speed, a sharp drop in tensile strength aswell as drop in maximum elongation took place.

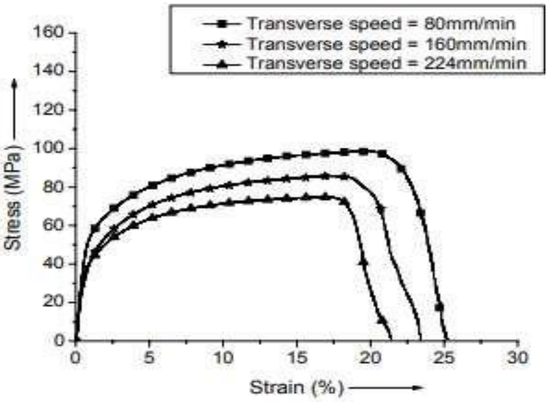


Fig.15Stressstraincharacteristicsoftest specimens along weld line with varying traverse speed keeping rotational speed constant at 1000 rpm

Fig.16 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.

4. CONCLUSIONS

The following conclusions are drawn from the above investigations. 1. An experimental study of FSW of marine grade 5083 aluminum alloy was carried out to study the effect of weld parameters on microstructural features and the mechanical properties of the welded joints. 2. A distinct case of grain refinement was observed in the HAZ and TMAZ due to FSW. The average grain sizes in parent metal, HAZ and TMAZ were found to be 5.5 µm, 4.7 µm and 3 µm respectively. 3. Increasing traverse speed led to coarsening of grain structure. The average sizes at TMAZ for traverse speed of 112 mm/min and 160 mm/min were 3 µm and 3.94 µm respectively. This caused a sharp drop in tensile strength as well as elongation in friction stir welded test samples. 4. Along with grain refinement, a gradual decrease in the material hardness in the HAZ and TMAZ was observed. Increase in hardness was also observed in FSW of 5083 aluminum alloy with increasing traverse speed. 5. Maximum grain refinement was observed in the TMAZ which also corroborates the higher ductility observed in TMAZ. 6. The study strongly indicates a possibility of achieving a very superior welded joint in marine grade 5083 aluminum alloy with adequate selection of process parameters

REFERENCES

1. W.M. Thomas, E.D. Nicholas, J.C. Need ham, M.G. Murch, P. Templesmith, C.J. Dawes, “Friction stir butt welding” International patent application no. PCT/GB92/02203 and GB patent application no. 9125978.8, 6 December 1991. 14 2. McClure, J. C., Tang, T., Murr, L. E., Guo, X., and Feng, Z., ‘‘A Thermal Model of Friction Stir Welding,’’ Trends in Welding Research, J. M. Vitek,et al., eds., Proceedings of the 5th International Conference, Pine Mountain, GA, June 1–5, pp. 590–595, 1998. 3. Tang, W., Guo, X., McClure, J. C., Murr, L. E., Nunes, A.,‘‘Heat Input and Temperature Distribution in Friction Stir Welding,’’ Journal of Materials Processing and Manufacturing Science, Vol. 7(2), pp. 163–172, 1988.Colegrove, P., Painter, M., Graham, D., and Miller, T., ‘‘3 Dimensional Flow and Thermal Modeling of the Friction Stir Welding Process”, Proceedings of the Second International Symposium on Friction Stir Welding, June 26–28, Gothenburg, Sweden, 2000. 4. Russel, M. J., and Shercliff, H. R.,‘‘Analytical Modeling of Microstructure Development in Friction Stir Welding’’, Proceedings of the First International Symposium on Friction Stir Welding, June 14–16, Rockwell Science Center, Thousand Oaks, California, 1999. 5. Shercliff, H.R., Russell, M.J., Taylor, A., Dickerson, T.L, “ Microstructural Modelling in Friction Stir Welding of 2000 Series Aluminium Alloys”, Mecanique & Industries, 2005, 6, pp.25-35. 6. R. S. Mishra, Z. Y. Ma, Mater. Sci. Eng. R 50 (2005) Iii-78. 7. Okamura, H. Welding and joining methods - 6. Friction Stir Welding (FSW): Equipment and Tools. Keikinzoku Yosets/Journal of Light Metal Welding and Construction. Vol.40. No.10. pp.500-505. Oct. 2002. 8. Arbegast, William J. Using Process Forces As A Statistical Process Control Tool for Friction Stir Welds. Proceedings of 2005 TMS Annual Meeting, San Francisco, CA, Feb. 13-17, 2005, p. 193-205. 9. Nunes, A.C., Guerra, M., Schmidt, C., McClure, J.C., and

Murr, L.E. Flow Patterns During Friction Stir Welding. Materials Characterization. Vol. 49. No. 2. pp. 95-101. September, 2002. 10. Nunes, Jr., Wiping Metal Transfer in friction stir welding," Aluminum 2001: Automotive Alloys and Joining Aluminum Symp., eds. G. Kaufmann, J. Green, S. Das (2001) 235-248. 15 11. Lederich, R.J., Baumann, J.A., and Oelgoetz, P.A. Friction Stir Welding of D357 Castings and Wrought Products. Friction Stir Welding and Processing edited by K.V. Jata, M.W. Mahoney. pp. 71-81. Nov. 2001Seidel, T.U. and Reynolds, A.P. Visualization of the Material Flow in AA 2195 Friction Stir Welds Using Marker Insertion Technique. Met. & Mat. Trans. A, Vol.32A. pp. 2879-2884. 2001. 12. Su, J. Q., Nelson, T. W., Mishra, R. and Mahoney, M., Acta Mater. 51 (2003) 713- 729. 16. Sinke, M. M. Stofregen, E. Estraatsma, Tailor made blanks for the aircraft industry: a pilot study, technical