INFLUENCE OF TAPER TOOL PROFILE ON MECHANICAL AND MICROSTRUCTURAL CHARACTERIZATION OF FRICTION STIR WELDED 5083 ALUMINIUM ALLOY

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ABSTRACT:
A study was made of weldability of 4mm-thick aluminium alloy 5083 plates using friction stir welding. The plan of experiments was prepared based on abilities of universal milling machine and where different tool rotations speeds 900r/min, 1120r/min, 1400r/min and 1800r/min, the welding speed is at 40mm/min were taken. Analysis is made with the taper profile tool. Samples for microstructure analyses, Vickers micro-hardness measurements, tensile-testing, and SEM analysis were prepared. It was observed that the better mechanical properties were achieved at moderate tool rotational speed, and equi-axed grains obtained at threaded profile tool, grain size were obtained half of the base material.

Keywords: Friction-Stir Welding, AA 5083, Rotational Speed, Mechanical Properties, Microstructure characterization, SEM analysis, Taper Profile Tool.


1. INTRODUCTION
The 5083 aluminium alloy is exhibited good corrosion resistance to seawater, better mechanical properties. It has good formability, machinability and weldability. The 5083 aluminium alloy is used for providing of welded components for shipbuilding and railway vehicles. It has the highest strength of the non-heat treatable alloys. It is not
recommended for use in temperatures in excess of 650°C to a corrosive environment.\(^3\) Many studies were made on the weld ability of 5083 aluminium alloy.\(^4-6\) Aluminium alloys are friction-stir processed (FSP) then the properties of super plastic are obtained, as a consequence of grain refinement.\(^7\) Friction stir processing (FSP) is used to transform a heterogeneous microstructure to a more homogeneous, refined microstructure before not reaching its melting temperature. Welding is a process for joining different metals or materials. In order to join the pieces of metal through any welding process, the most vital requirement is heat. Pressure may also be employed but in many processes, is not essential.

![Figure 1 The Fsw process](image)

<table>
<thead>
<tr>
<th>Material</th>
<th>Density</th>
<th>UTS (MPa)</th>
<th>Yield strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA5083</td>
<td>2.66</td>
<td>240</td>
<td>135</td>
</tr>
</tbody>
</table>

2. LITERATURE REVIEW

M. K. Bilici, The impacts of hardware geometry and properties on grating mix spot welding properties of polypropylene sheets were considered. Four diverse apparatus stick geometries, with changing pin edges, stick lengths, bearing measurements and shoulder edges were utilized for rubbing mix spot welding. All the welding operations were done at the room temperature. Weld cross area external shell perceptions were likewise done. From the analyses the impact of hardware geometry on rubbing blend spot weld arrangement and weld quality were resolved. The ideal apparatus geometry for 4 mm thick polypropylene sheets were resolved. The decreased barrel shaped stick gave the greatest and the straight round and hollow stick gave the most minimal lap-shear crack load.\(^6\)

T. DebRoy et al., (2010) evaluated the mechanical properties of friction stir welds while varying process parameters in 5083-H111 aluminum alloy. Their tool had a shoulder diameter of 20 mm, and a pin with a length, diameter of 4.5, 5.0 mm respectively. The tool was made from SK tool steel, tilted at 2°. Welds were done at 500, 900, 1800 rpm and 40 to 120 mm/min. Tensile tests were performed on all welds. The welds performed at 500 rpm and 900 rpm showed a reduction in quality as the traverse feed increased. At 1800 rpm, the weld plate produced defects. In turn, these welds developed very low eminence mechanical properties. All fractures during tensile testing occurred in the stir zone. The optimum FSW parameters for this experiment were 900 rpm and 120 mm/min which had an ultimate tensile strength around 250 MPa.
3. EXPERIMENTAL PROCEDURE

Material
The plates of 4 mm thickness AA5083 aluminium alloy were cut into size 150 mm x 60 mm and machined with square butt joint configuration. The existing configuration was obtained by holding the plates in butt location using specially designed and fabricated fixture. Welding was carried out in a single pass using non-consumable tools made of High Speed steel. The chemical composition of the AA5083 material used in the present study is given in Table 2.

<table>
<thead>
<tr>
<th>Material</th>
<th>Mg</th>
<th>Mn</th>
<th>Si</th>
<th>Cr</th>
<th>Fe</th>
<th>Zn</th>
<th>Ti</th>
<th>Cu</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA5083</td>
<td>4.5</td>
<td>0.7</td>
<td>0.4</td>
<td>0.15</td>
<td>0.4</td>
<td>0.25</td>
<td>0.15</td>
<td>0.1</td>
<td>Rest</td>
</tr>
</tbody>
</table>

FSW
The welding was carried out in a universal milling machine with altering tool rotation speeds. The tool, viz tapered with cylindrical shoulder, was used to fabricate the joints. Based on the literature, with availability of speeds on the machine, three different rotational speeds were selected to carry out the experiment. The welding parameters and tool dimensions are as shown in Table 3.

<table>
<thead>
<tr>
<th>Process Parameter</th>
<th>Values/Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material used</td>
<td>AA5083</td>
</tr>
<tr>
<td>Type of Joint</td>
<td>Butt joint</td>
</tr>
<tr>
<td>Thickness of the material (mm)</td>
<td>4</td>
</tr>
<tr>
<td>Tool rotation speed (rpm)</td>
<td>900, 1120, 1400 and 1800</td>
</tr>
<tr>
<td>Traverse speed (mm/min)</td>
<td>40</td>
</tr>
<tr>
<td>Length of weld (mm)</td>
<td>75</td>
</tr>
<tr>
<td>Axial Load (KN)</td>
<td>5</td>
</tr>
</tbody>
</table>

The standard EN-AW 5083 aluminium alloy with chemical composition in mass fractions: 4.34%Mg, 0.51%Mn, 0.14%Si, 0.088%Cr, 0.28%Fe, 0.20%Zn, 0.013%Ti and the remaining Al, and temper O, was used for testing. The workpiece sizes were 150mmx60mmx4mm. The physical and mechanical properties as per standards were taken.
4. RESULTS AND DISCUSSIONS

4.1. Tensile Test

After FSW all the specimens were tested to observe out their ultimate tensile strength. Four specimens were tested for each reflected of parameter and their best joint values were considered. The results were plotted in the form of a bar chart ultimate tensile strength v/s Rotational speed as displayed. From the results of tensile test it can be studied that the ultimate tensile strength of the friction stir welded joint has been affected by the tool profile of the welding tool. The results of mechanical properties are mentioned in Table 4&5.

<table>
<thead>
<tr>
<th>Tool rotation speed(rpm)</th>
<th>Tensile stress(N/mm²)</th>
<th>Impact strength(Joules)</th>
<th>%Elongation</th>
<th>yield stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>900</td>
<td>184.049</td>
<td>16</td>
<td>10.94</td>
<td>93.176</td>
</tr>
<tr>
<td>1120</td>
<td>180.567</td>
<td>20</td>
<td>9.40</td>
<td>110.586</td>
</tr>
<tr>
<td>1400</td>
<td>211.886</td>
<td>28</td>
<td>17.8</td>
<td>101.208</td>
</tr>
<tr>
<td>1800</td>
<td>179.842</td>
<td>22</td>
<td>7.2</td>
<td>112.718</td>
</tr>
</tbody>
</table>

5083 plates after FSW

http://www.iaeme.com/IJMET/index.asp 330 editor@iaeme.com
Influence of Taper Tool Profile on Mechanical and Microstructural Characterization of Friction Stir Welded 5083 Aluminium Alloy

Figure 6 Bar graphs for different mechanical properties

From the above graphs it is to be clear that the ultimate tensile strength is more at a tool rotational speed of 14000rpm, because the heat input is sufficient at that condition and the grains were recrystallized and equi-axed. From the graph the % Elongation is more for 1400rpm and i.e., 29%, and less at 900rpm. The tensile strength obtained at moderate heat supply and by increasing the tool rotation speed the tensile strength decreases, due to the reason that the crystals are reallocated and there is a coarse grain structure obtained. The percentage change in the tensile strength is expected to be 15.62% by using Tapered unthreaded cylindrical shoulder tool as the welding speed rises from 900 to 1400rpm. The best joint of friction stir welding of aluminium 5083 among four plates is at 1400rpm and at a welding speed of 40mm/min.

4.2. Impact strength
Charpy Impact test is done to test the sudden load strength of the welded zone at different tool rotation speeds.

Figure 7 Charpy impact test specimens

4.3. Microstructure study
The tool rotation speed is important factor that influence the microstructure grain size. The following observations were studied:

Microstructure Results - Effect of Welding of AA5083 Assessment of structural properties at different zones of the weldments using optical microscope was carried out. Microstructure of base metal made out of fine hastens of alloying components spreaded in the matrix of aluminium solid solution. The (c) figure shows that the microstructure is having fine grains and the structure displays that the grains are equi-axed and equally spaced, grain size were obtained half of the base material. The small size grains are obtained in case of tool rotation speed of 1400rpm as compared to 900rpm in correlation with Tensile strength properties, %Elongation and Charpy impact strength. Small sized grains in the microstructure shows that, high friction input is in charge of warming the weld over the temperature of
recrystallization, in this way the grain improvement happens. Uniform grain growth can be seen at 1120 speed. The grain size is small at the top of the weld, which was in region of the tool shoulder. From the microstructure study the figure(c) shows a very high fine and smooth grain structure, i.e., the grain size approximately equal to the half the grain size of base metal.

![Microstructure photographs](image)

**Figure 8** (a), (b), (c) and (d) microstructure photographs by using conical taper tool at 900rpm, 1120rpm, 1400rpm and 1800rpm

### 4.4. Vickers Micro hardness

Vickers Micro hardness test is made to check the hardness of the weld samples. The small scale hardness of Vickers is accomplished awesome at 1800rpm and the esteem is 97.67Hv. What's more, it is closer to the estimation of 94.67Hv 1400rpm.

<table>
<thead>
<tr>
<th>Tool rotation speed(rpm)</th>
<th>Hardness value (Hv) for conical taper tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>900</td>
<td>96.47</td>
</tr>
<tr>
<td>1120</td>
<td>94.73</td>
</tr>
<tr>
<td>1400</td>
<td>94.67</td>
</tr>
<tr>
<td>1800</td>
<td>97.67</td>
</tr>
</tbody>
</table>

**Table 5** Vickers Micro hardness values for taper tool pin profile

### 4.4. SEM Analysis

![SEM photographs](image)

**Figure 9** SEM photographs at 900rpm & 1400rpm
Influence of Taper Tool Profile on Mechanical and Microstructural Characterization of Friction Stir Welded 5083 Aluminium Alloy

The fractured FSW tensile specimens showed obvious necking/plastic deformation but not the specimen at 1400rpm. The fractographs of the FSW examples uncover dimple break designs with teared edges brimming with micropores. The dimples were of various sizes and shapes. Contrasted with the example at 1400rpm, the dimples in the example at 900rpm (failure occurred in HAZ) were more profound and the teared edges were more slender. Therefore, the specimen at 900rpm exhibited worse mechanical properties than the specimen at 1400rpm. In addition, the specimen A had much deeper dimples and thinner teared edges than the specimen C and thus worse mechanical properties. And the specimen C exhibited much better mechanical properties, because there were no deeper dimples, micropores and teared edges present.\[9\]

Figure 9(a) is an enlarged SEM photograph showing a dimple pattern that indicates ductile fracture and the porosity in this matrix occurred. Figure 9(a) also contains the photograph of dimple patterns and some defects which caused fracture to initiate. Figures 9(a) exhibit the ductile fracture phenomena of FS welded specimens. From the SEM analysis fracture surfaces at 900rpm exhibited porosities than at 1400rpm by using friction stir welding process and that have caused the strength values to decrease.

5. CONCLUSIONS
From the investigation, the following conclusions have been found that:
For Aluminium 5083, at 1400 rpm, by using Tapered with cylindrical profile tool the mechanical properties obtained were optimum. It has been observed that the variation in tensile strength occurs for different tool rotational speeds. The tensile strength is found to be greater at 1400rpm and less at 1800rpm. \[8\] At 1800rpm the top of the weld was completely rough surface and the weld bead shows a defect which is shown in figure, because of lack of penetration of tool near the tip of it, wormhole defect (in which the more frictional heat generated) at 1800rpm and the grains were totally disturbed and finally the coarse microstructure was obtained at 1800rpm. Evaluation of basic properties at various zones of the weldments utilizing optical magnifying instrument was done. Microstructure of the joint is best at 1400rpm with fine grain structure. Hence the defect free joint was obtained at 1400rpm with better mechanical properties correlated with microstructure. Uniform grain growth can be at higher speed (1400rpm). The Scanning electron microscope exhibits micropores at 900rpm which is a weak joint and at 1400rpm the crystal structure is appears a strong joint.

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