An investigation on Microstructures and Mechanical Properties of AA1050 in friction Stir Processing Technique

R. Bharathikanna and G. Elatharasan

Assistant Professor, Department of Automobile Engineering, Nehru Institute of Technology, Coimbatore. 
Assistant Professor, Department of Mechanical Engineering, University College of Engineering, Pattukkottai.

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Address For Correspondence:
R. Bharathikanna, Assistant Professor, Department of Automobile Engineering, Nehru Institute of Technology, Coimbatore.
E-mail: bharathikanna89@gmail.com

ABSTRACT
The friction stir welding process plays a vital role in deciding the weld characteristics. The main aims of this project to establish a fundamental understanding of microstructural and property development during friction stir processing (FSP), with a special focus on commercial Al AA1050 Aluminium. In the present study, experimentally investigate the influence of tool pin profile with different tool rotational speeds on microstructure of AA1050 commercial Al by FSP technique. Tool of various pin profiles such as cylindrical, conical, cylindrical threaded, conical threaded and shoulder with probe will be inserted into a single piece of material, for micro structural modification. Effect of tool rotational speed and welding speed of base metals (AA1050) on macrostructures, microstructures and impact strength of the welded joints were investigated.

KEYWORDS: Friction Stir Processing; AA1050; Microstructure; Hardness

INTRODUCTION

In 1991, the welding institute invented the friction stir welding process in United Kingdom. Friction stir processing (FSP) is a technique for changing the properties of a metal through intense, localized plastic deformation resulting in dynamically recrystallized grain structure. In this process tool plays a vital role in deciding the weld characteristics. When compared to the traditional welding process, the friction stir welding process is mostly used in automotive and aerospace industry for excellent performance structural demanding applications. A great deal more perception has been concentrated on AA1050 aluminum combination in a view in reality that expansive variety of extraordinary properties, especially low properties of density. Aluminum alloy 1050 is a most popular grade of aluminum for general sheet metal work where moderate strength is essential.Alloy 1050 is known for its high corrosion resistance, good ductility and better reflective finish. It is mostly used in Chemical process plant equipment, Food industry containers, Pyrotechnic powder, Architectural flashings, Lamp reflectors and Cable sheathing. Fig 1 shows the schematic representation of friction stir welding process.
Different literatures were contemplated for strengthening the mechanical properties of Aluminum alloy. G.Elatharasan et al.[1] performed experimental study in friction stir welding of AA7075 Aluminium alloy to improve the mechanical properties of base metal. He achieved a good microstructure and mechanical property for the joint produced at rotational speed of 800 rpm and traverse speed of 20mm/sec. By applying the annealing process, M.Habibnia et al. [2] found that the tool offset is increased up to 1.5mm and 9% in elongation were accomplished in friction stir welded of 5050 Al alloy and 304 stainless steel plates. A.Yazidpour et al. [3] found the FeAl$_3$ intermetallic compounds form in the dispersed steel fragments and Al interface during FSW of dissimilar Al 5083-H321 and 316L stainless steel alloy joints. A.Thangarasu et al. [4] increased the hardness value of Aluminum matrix composites by 45% in AA1050/TiC surface composite fabricated using friction stir processing. Mohammad Narimani et al. [5] increased the tensile strength 70% higher than that of the parent metal in Al-TiB$_2$ composite fabricated by FSP. Farzad Heirani et al. [6] increased the hardness value up to 25% in the weld nugget zone by using of underwater friction stir welding of Al5083 alloy. Vivek.V.Patel et al. [7] found that uniform super plastic elongation of 227% was obtained in the gage region of the square probe sample in friction stir processed of AA7075 alloy by using polygonal pin profile. V.Balasubramanian et al. [8] found that the square probe profiled tool with shoulder diameter 80mm produced good mechanical properties when compared to other tool pin profiles in formation of friction stir processing zone in AA6061 aluminium alloy.

In the present work, the influence of both the rotational speed and various pin profiles on the microstructure and mechanical properties of the SZ in AA 1050 were systematically investigated in Friction stir processing technique.

II. Experimental procedure:

A Base Material:

Aluminium alloy AA1050 plates thickness of 7 mm is used as a base material in this experimental investigation. It's belonging to commercially pure wrought family. Because of having high electrical conductivity, corrosion resistance, and workability, it may be used in chemical and electrical industries. It is also utilized for the manufacture of heat sinks. The chemical properties of AA1050 are shown in Table 1.

<table>
<thead>
<tr>
<th>Element</th>
<th>Cu</th>
<th>Mg</th>
<th>Si</th>
<th>Fe</th>
<th>Mn</th>
<th>Zn</th>
<th>Ti</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent</td>
<td>0.05</td>
<td>0.05</td>
<td>0.25</td>
<td>0.40</td>
<td>0.13</td>
<td>0.05</td>
<td>0.03</td>
<td>Bal</td>
</tr>
</tbody>
</table>

B Tool design:

Friction stir processing tool was made by high carbon high chromium steel. Generally by high carbon high chromium steel has particularly suitable for aluminium alloys. When compared to other tool materials, the strength of HCHCr is high, excellent hardness, procurement of the tool material is ease and its cost also less. A tool has been designed by AutoCAD and it was manufactured by using conventional lathe machining. Then the tool is quenched and tempered condition with 18 mm shoulder diameter, pin diameter of 6 mm and 6.5 mm pin length. 60 HRC is the hardness value of tool material. Four different pin profiles used in this experimental investigation are cylindrical, cylindrical threaded, cone and cone threaded pin profile. Fig 2 shows the schematic diagram of friction stir processing tool.
Cylindrical pin profile tool

Cylindrical threaded pin profile tool

Cone pin profile tool

Cone threaded pin profile tool

C Friction stir processing parameters:

The FSW machine is used for processing of aluminium alloy as shown in Fig. 3. Bead on plate welding operation is carried out on the base metal. The dimension of the plate is 100x50x7 mm is prepared. In this experimental work only the rotational speed of the tool is varied, the other parameters remains constant. The optimized process parameters are used in this friction stir processing technique such as different rotational speed of 600, 800 and 1000 rpm. The Welding speed and axial load is given as 1mm/sec and 5 KN respectively is kept constant for all the rotational speeds. In this experimental investigation, each tool pin profile is taken three FSP at three different rotational speeds and the welding speed and axial load is constant and hence 12 friction stir processed samples have been fabricated and analyzed in this investigation.

Fig. 3: Friction stir processed plate of AA1050 alloy

RESULTS AND DISCUSSIONS

A. Microstructural Results:

By using optical microscopy, macrostructures of the friction stir processed samples were analyzed. For reveal the macrostructures of the sample is suitably etched. The etching reagent (Keller’s reagent) is used for aluminium alloy to get the macrostructural studies are mixed with the following in correct proportion. 1 volume part of hydrofluoric acid, 1.5 volume part of hydrochloric acid, 2.5 volume parts of nitric acid and 95 volume parts water. Macrostructure studies is useful for identify the presence of macro level defects in all zones.

Table 2: Macrostructure and observations of the friction stir processed samples fabricated by cylindrical pin profile

<table>
<thead>
<tr>
<th>Tool rotational speed</th>
<th>Macro structure</th>
<th>Name of the defect</th>
<th>Probable reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td></td>
<td>Pin hole</td>
<td>Insufficient heat input due to plastic flow of material is incomplete</td>
</tr>
<tr>
<td>800</td>
<td>Crack in the bottom portion of the processed sample at retreating side</td>
<td>Insufficient heat generation</td>
<td></td>
</tr>
</tbody>
</table>
Table 3: Macrostructure and observations of the friction stir processed samples fabricated by cone pin profile

<table>
<thead>
<tr>
<th>Tool rotational speed</th>
<th>Macro structure</th>
<th>Name of the defect</th>
<th>Probable reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td></td>
<td>Tunnel defect occurs at the retreating side of the processed sample</td>
<td>Plastic flow of material is incomplete</td>
</tr>
<tr>
<td>800</td>
<td></td>
<td>Crack in the bottom portion of the processed sample at retreating side</td>
<td>Insufficient heat generation</td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td>Defect free</td>
<td>Sufficient generation of heat and the flow of metal</td>
</tr>
</tbody>
</table>

Table 4: Macrostructure and observations of the friction stir processed samples fabricated by cylindrical threaded pin profile

<table>
<thead>
<tr>
<th>Tool rotational speed</th>
<th>Macro structure</th>
<th>Name of the defect</th>
<th>Probable reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td></td>
<td>Pinhole</td>
<td>Improper plastic flow</td>
</tr>
<tr>
<td>800</td>
<td></td>
<td>Crack occurs in the bottom portion of the processed sample at the retreating side</td>
<td>Insufficient heat generation</td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td>Defect free</td>
<td>Sufficient generation of heat and the flow of metal</td>
</tr>
</tbody>
</table>

Table 4: Macrostructure and observations of the friction stir processed samples fabricated by cone threaded pin profile

<table>
<thead>
<tr>
<th>Tool rotational speed</th>
<th>Macro structure</th>
<th>Name of the defect</th>
<th>Probable reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td></td>
<td>Light crack occurs in the bottom portion of the processed sample at the retreating side</td>
<td>Insufficient heat input</td>
</tr>
<tr>
<td>800</td>
<td></td>
<td>Defect free</td>
<td>Sufficient generation of heat and the flow of metal</td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td>Defect free</td>
<td>Sufficient generation of heat and the flow of metal</td>
</tr>
</tbody>
</table>
B. Microstructure results:

The friction stir processed specimen used for metallographic examinations were sectioned to the required sizes from the processed region consisting stir zone (SZ), thermo mechanically affected zone (TMAZ), heat affected zone (HAZ) and parent metal. Then it has polished using various grades of emery sheets. Further final polishing was done using the alumina powder (400 microns particle size) in the disc polishing machine. Then the polished samples were etched by using Keller’s reagent. The microstructures of the friction stir processed samples were analyzed by using a light optical microscopy incorporated with an image analyzing software. Fig 4 shows the micro structural studies photographs of friction stir processed samples in the stir zone region.

From the micrographs, it is understood that there is an excellent difference in the average grain size because coarse grains of parent metal are changed into fine grains in the stir zone region. This may be due to sufficient generation of heat and extensive plastic deformation of metal. And also it is noted that there is an appreciable variation in grain size in the stir zone region and TMAZ. Because of the mechanical action from the processed tool, the size of the grains in TMAZ is coarser than the stir zone region. The HAZ is unaffected due to there is no mechanical effects from the processing tool. The grain structure in HAZ region resembles the base material grain structure due to no mechanical action from the processing tool.

![Microstructure photographs of friction stir processed samples](image)

C. Impact test results:

Generally impact test is used to study the behaviour of metals under suddenly applied load. It indicates the amount of energy absorbed by the metals during plastic deformation. Impact studies is carried out on the friction stir processed samples. Charpy test is used to determine the impact strength of the friction stir processed specimen.

![Impact test results](image)
Fig. 5: shows the impact test results of the FSP samples.

**Conclusion:**

In the present study, the bead on plate friction stir welding was carried out on AA1050 commercial aluminium was successfully carried out. The macrostructure, microstructure observations and impact test were carried out and evaluated. The following results were obtained:

1. It has been exhibited that FSP was a suitable technique to change the microstructure and mechanical properties of commercial Aluminum. The technique was energy efficient, environmentally friendly and versatile, for localized microstructural modification and specific property enhancement. The FSP brought about extraordinary plastic deformation, material blending, and thermal exposure, bringing about huge microstructural refinement, densification, and homogeneity of processed zone.

2. The depth of the surface layer can be tailored by welding parameters or pin design.

3. FSP technique enhance the formability of plain examples; henceforth they could be utilized for super plastic applications

4. From the microstructural observations with different rotational speeds and with various pin profiles, it was found the grain refinement was better in the case of threaded tools due to effective stirring action. It was also concluded that with increase in rotational speed of the tool grain refinement was better.

5. The grain refinement and impact strength was best for the threaded conical pin profile with rotational speed of 1000 rpm and least for cylindrical pin profile with rotational speed of 600 rpm.

**REFERENCES**


