Design and Analysis of Molybdenum Super Alloy FSW Tools

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Abstract

Friction stir welding is an exciting process for welding two pieces of material together as it doesn’t require weld preparation, operates at low temperatures with absences of fumes, is environmentally friendly, energy efficient and can be used by only semi-skilled personnel to produce a satisfactory weld. This project emphasizes on some current uses, variations in tool design, improved welding techniques and new tool materials being developed for the welding of more difficult aluminium alloys to give increased tool life. The tool (made of molybdenum super alloy), its pin profile, shape and dimensions plays a vital role in making the weld joint. In FSW, the stress distribution of tool pin is affected by the thermo mechanical characteristics of the work piece. In this present work, three tools with different pin shapes (Conical, Cylindrical and Frustum) were designed with and without threads in their profiles. Initially the tools dimensions are based on the base material plate thickness taken in to consideration, the induced structural stresses were checked with in the permissible stress limits. The tools were modeled in CATIA and analysis is performed in ANSYS software for exploring stress distributions and displacement vector sum in the pin, at different speeds and temperatures. The frictional force between the tool shoulder and work piece is considered for simulating the stress and displacement vector in the pin profiles. The vonmises stress distributions in pin profiles, displacement vector sum of the pin profiles, are obtained from ANSYS software and the pin with optimum strength is determined.

Keywords: CATIA, Molybdenum, ANSYS Software.

1. Introduction

Friction stir welding (FSW) is a Solid-state joining technique invented in 1991, and it is initially applied to aluminium alloys. The concept of FSW is simple. A non-consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of sheets or plates to be joined and traversed along the line of joint. The tool serves as heating of work piece, and movement of material to produce the joint. The heating is accomplished by friction between the tool and the work piece and plastic deformation of work piece. The localized heating softens the material around the pin and combination of tool rotation and translation leads to movement of material from the front of the pin to the back of the pin. As a result of this process a joint is produced in ‘solid state’. Because of various geometrical features of the tool, the material movement around the pin can be quite complex.

FSW is considered to be the most significant development in metal joining in a decade and is a “green” technology due to its energy efficiency, environment friendliness, and versatility.

2. Tool Geometry

![Fig.1 Principle of Operation of FSW](image)

![Fig.2 Basic pin profiles of FSW tool](image)

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flow of material and in turn governs the traverse rate at which FSW can be conducted.

3. Parameters considered in this project

Molybdenum super alloy material is used for pin profile. Material to be welded is aluminium alloys. Analysis is carried out for 600°C, 700°C, 800°C temperatures. Analysis is carried out for following speeds 1200 rpm, 1400 rpm, 1600 rpm. 50, 70, 90 m/min are the following welding speeds considered for the project.

4. Analysis of various profiles of FSW tools

4.1 Analysis of FSW tool with cylindrical pin

![Fig. 3 meshed tool with loads and boundary conditions](image1.png)

![Fig. 4 stress distribution and displacement vector sum at 1200 rpm](image2.png)

![Fig. 5 stress distribution and displacement vector sum at 1300 rpm](image3.png)

4.2 Analysis of FSW tool with frustum pin

![Fig. 6 stress distribution and displacement vector sum at 1600 rpm](image4.png)

![Fig. 7 stress distribution and displacement vector sum at 700°C](image5.png)

![Fig. 8 Schematic view of stress distribution and displacement vector sum at 800°C.](image6.png)

![Fig. 9 Schematic view of stress distribution and displacement vector sum](image7.png)
4.3. Analysis of FSW tool with conical pin

Fig. 10 Schematic view of stress distribution and displacement vector sum at 1300 rpm

Fig. 11 Schematic view of stress distribution and displacement vector sum at 1600 rpm

Fig. 12 Schematic view of stress distribution and displacement vector sum at 700°C

Fig. 13 Schematic view of stress distribution and displacement vector sum at 800°C

Fig. 14 Schematic view of meshed tool with applied loads & boundary conditions

Fig. 15 Schematic view of stress distribution and displacement vector sum at 1200 rpm

Fig. 16 Schematic view of stress distribution and displacement vector sum at 1300 rpm

Fig. 17 Schematic view of stress distribution and displacement vector sum at 1600 rpm
Fig. 18 Schematic view of stress distribution and displacement vector sum at 700°C

Fig. 19 Schematic view of stress distribution and displacement vector sum at 800°C

4.4. Analysis of FSW tool with threaded frustum pin

Fig. 20 Schematic view of stress distribution and displacement vector sum at 1200 rpm

Fig. 21 Schematic view of stress distribution and displacement vector sum at 1300 rpm

Fig. 22 Schematic view of stress distribution and displacement vector sum at 1600 rpm

Fig. 23 Schematic view of stress distribution and displacement vector sum at 700°C.

Fig. 24 Schematic view of stress distribution and displacement vector sum at 800°C.

4.6. Analysis of FSW tool with threaded conical pin

Fig. 25 Schematic view of stress distribution and displacement vector sum at 1200 rpm
Table 1 Stress distribution and Displacement vector sum of various tool profiles for without and with thread

<table>
<thead>
<tr>
<th>Speed (rpm)</th>
<th>Cylindrical pin</th>
<th>Frustum pin</th>
<th>Conical Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stress Distribution (N/mm²)</td>
<td>Displacement Vector Sum (mm)</td>
<td>Stress Distribution (N/mm²)</td>
</tr>
<tr>
<td>1200</td>
<td>704.847</td>
<td>0.0414</td>
<td>726.465</td>
</tr>
<tr>
<td>1300</td>
<td>704.86</td>
<td>0.0415</td>
<td>726.475</td>
</tr>
<tr>
<td>1600</td>
<td>704.922</td>
<td>0.0421</td>
<td>726.513</td>
</tr>
<tr>
<td>Temp(°C)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>700</td>
<td>704.922</td>
<td>0.0421</td>
<td>726.513</td>
</tr>
<tr>
<td>800</td>
<td>820.541</td>
<td>0.047</td>
<td>845.517</td>
</tr>
<tr>
<td>900</td>
<td>936.08</td>
<td>0.0554</td>
<td>964.55</td>
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</table>

Table 1 continued...

<table>
<thead>
<tr>
<th>Speed (rpm)</th>
<th>Threaded Cylindrical pin</th>
<th>Threaded Frustum pin</th>
<th>Threaded Conical Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stress Distribution (N/mm²)</td>
<td>Displacement Vector Sum (mm)</td>
<td>Stress Distribution (N/mm²)</td>
</tr>
<tr>
<td>1200</td>
<td>544.8</td>
<td>0.0413</td>
<td>640.557</td>
</tr>
<tr>
<td>1300</td>
<td>544.9</td>
<td>0.0415</td>
<td>640.576</td>
</tr>
<tr>
<td>1600</td>
<td>545.15</td>
<td>0.042</td>
<td>640.64</td>
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<tr>
<td>Temp(°C)</td>
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</tr>
<tr>
<td>700</td>
<td>545.15</td>
<td>0.042</td>
<td>640.64</td>
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<tr>
<td>800</td>
<td>634.35</td>
<td>0.0486</td>
<td>745.45</td>
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<tr>
<td>900</td>
<td>723.56</td>
<td>0.0552</td>
<td>801.29</td>
</tr>
</tbody>
</table>

Fig. 26 Schematic view of stress distribution and displacement vector sum at 1300 rpm

Fig. 27 Schematic view of stress distribution and displacement vector sum at 1600 rpm

Fig. 28 Schematic view of stress distribution and displacement vector sum

Fig. 29 Schematic view of stress distribution and displacement vector sum
Conclusions

From the above results it can be concluded that, among all profiles in the tool with cylindrical profile with threads is preferable because the maximum stress distribution and displacement vector sum are very less.

As the temperature in the welding zone increases in the profiles for with and without threads, the stress distribution and displacement vector sum are observed to be increased and it is maximum in the tool with conical profile.

If the results of profiles with and without threads are compared, the stress distribution and displacement vector sum are observed to be maximum in the tool profiles without threads.

Among all the profiles, the maximum stress distribution and displacement vector sum are maximum in the FSW tool with conical profile and is observed that by increasing the rotational speed there is not much change in the maximum stress distribution and displacement vector sum.

References


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