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# Investigating The Effect of Tool Pin Diameter Geometry on the Strength of Friction STIR Welds

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***Abstract:-*** **Friction stir welding(FSW) is a solid state welding technique offering lucrative alternative to join difficult to weld materials. Among the different process parameter, tool geometry is a crucial factor which affects the weld. In the current investigation the effect of different geometrical aspects of FSW tool pin diameters are studied to obtain weld with better mechanical properties. To check the quality of weld it was characterized for macrostructure, microstructure, tensile strength and hardness tests. It is observed that tool pin with 6.1/5 mm diameter exhibited improvement in properties of the welded specimen.**

## I. INTRODUCTION

The aluminum and its highly alloyed 2xxx and 8xxx series have high-strength, fatigue and fracture resistant weld is very difficult and has a wide use of welding for joining of aerospace components. Because of the solidification, microstructure and porosity in the fusion zone the aluminum alloys are termed to be non-weldable and surface oxide being major drawback. Previous researches indicate that thetool pin profile influences the weld quality.

## II. EXPERIMENTAL PROCEDURE

To weld the workpiece of AluminumAA 8011 of 3mm thickness the tool material choosedis High Carbon High Chromium (HCHC) material. The tool material must be much more harder than the base weld material so that the tool withstands the high friction and heat generation during the FSW process. The HCHC material is mainly used as Forge die in the forging industries, as it can sustain higher force, friction and heat generation. After the fabrication of the tool it is heat treated followed by tempering process to increase the base hardness of the HCHC material to 45-47 HRC. The two Aluminum plates of 200 mm×40 mm×3 mm (L×B×H) size is taken to carry out the Friction Stir Welding. The total weld length is précised to 160 mm. Over a thickness of 3 mm Al plate rotating tool pin is plunged completely of 2.5 mm and additional 0.2 mm of shoulder part is also plunged. For all first set of experiments, from the start to end of the weld the tool rotation speed (rpm) is set in five constraints for every 30 mm of weld length ranging from 400 rpm-800rpm. Only at the start and end of the weld it's taken as 35 mm because at the start of the weld rotating tool is dwelled for 10 sec to generate the sufficient heat and friction, and at the end of the weld the tool retract hole will be there so that part is not taken into account.After the weld the joint section of each segment of 30 mm carried out at different rpm are sliced into three parts for testing of tensile (T), hardness (H) and macrostructure, microstructure (M) respectively.

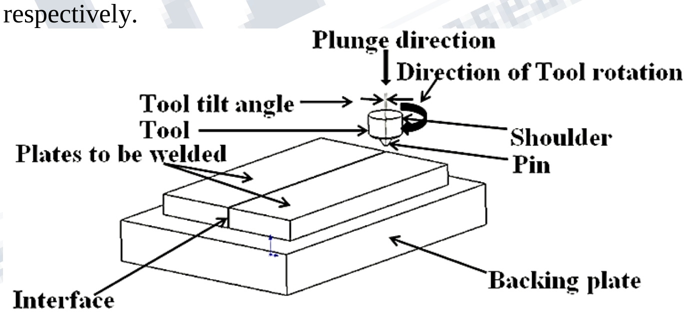



*Fig. 1 Schematic diagram of Friction Stir Welding process before welding starts*

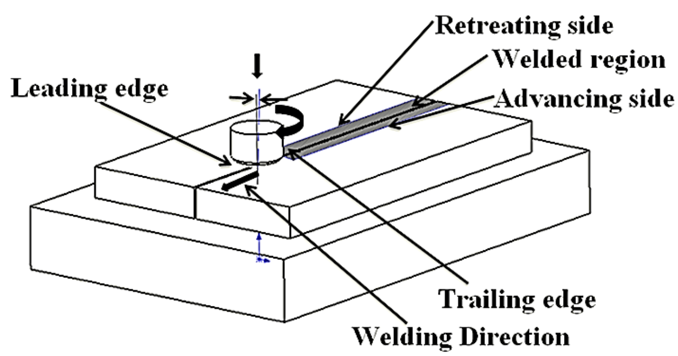



*Fig. 2 Schematic diagram of Friction Stir after Welding process*

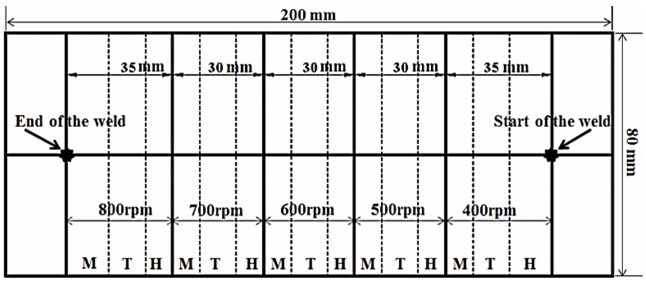



*Fig. 3 Schematic diagram of Welding specimen*

## III. TOOL DESIGN

In changing pin diameter three different Pins are designed and fabricated ranging from smaller, medium and larger pin diameters. The tool material is High Carbon High Chromium (HCHC) which is much harder than the Aluminum metal to withstand the friction and heat generated during the process.

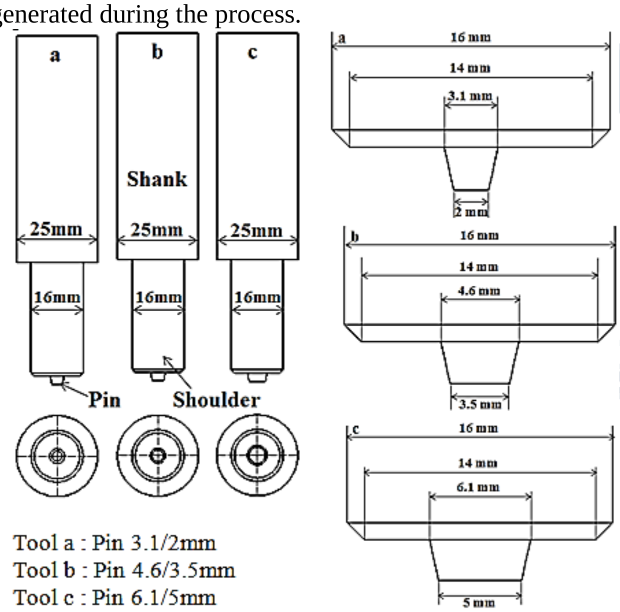



*Fig. 4 Tool designs (on left full tool view, on right enlarged view of Pin portions)*

## IV. SURFACE MORPHOLOGIES OF WELD

Friction Stir Welding is carried out for all the three tools of changing Pin diameter. The total weld length is of 160 mm with changing tool rotation speed (rpm) ranging from 400 rpm to 800 rpm.

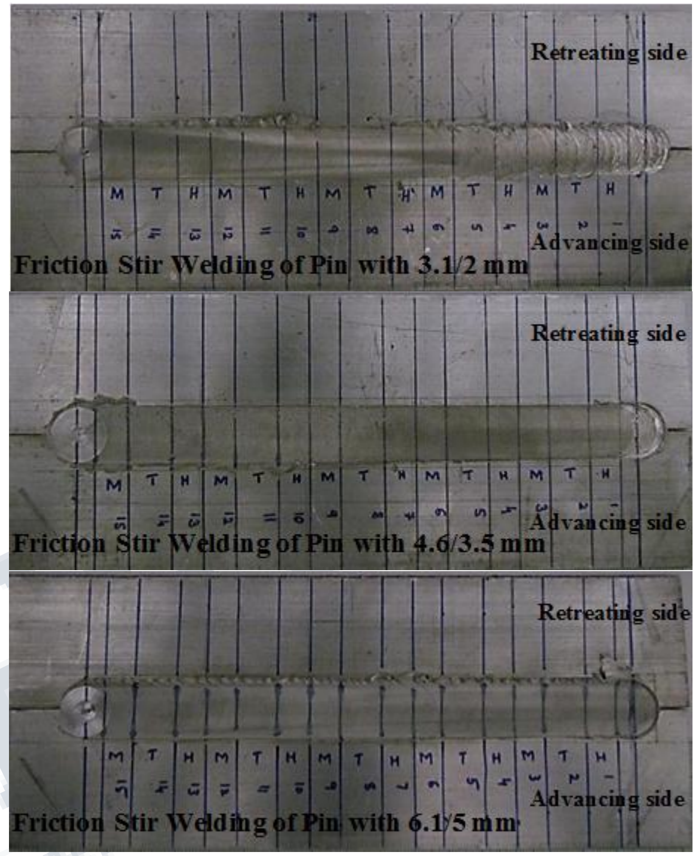



*Fig. 5 FSW corresponding to each tools*

## V. TENSILE TEST RESULTS

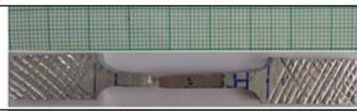
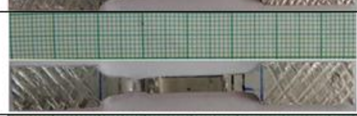
After the Friction Stir Welding, the specimens corresponding to 500 rpm and 700 rpm are sliced and designed according to the ASTM standards. For these three tools the results are compared at 500 rpm and 700 rpm.

*Table 1 Tensile Test Results for specimen at 500 rpm*

| Pin diameter (mm) | Tensile Strength (Mpa) | Specimens |
|---|---|---|
| 3.1/2 | 351.7956 |  |
| 4.6/3.5 | 471.3424 |  |
| 6.1/5 | 413.7685 |  |
| Base Material | 438.7484 |  |

The tensile strength is highest for the tool pin diameter 4.6/3.5 mm which has more strength than the base material, whereas the tool pin diameters 3.1/2 mm and 6.1/5 mm have less strength than pin 4.6/3.5 mm and less than the base material strength. The weld specimens of tool 3.1/2 mm and 4.6/3.5 mm have failed with in the weld region and the weld specimen of tool 6.1/5 mm has failed in the RS. The results showing the failure with in the weld region will conclude that the weld consolidation was not proper.

*Table 2 Tensile Test Results for specimen at 700 rpm*

| Pin diameter (mm) | Tensile Strength (Mpa) | Specimens |
|---|---|---|
| 3.1/2 | 591.3655 |  |
| 4.6/3.5 | 458.5288 |  |
| 6.1/5 | 505.6442 |  |
| Base Material | 438.7484 |  |

The tensile strength is observed more for the tool pin 3.1/2 mm and 6.1/5 mm is more when compared to 4.6/3.5 mm. However in all the cases weld strength is exhibited was more than the base material. Other thing noticed is weld specimens for tool pin 3.1/2 mm and 6.1/5 mm have failed on the RS and tool pin 4.6/3.5 mm has failed on the AS. In all the three cases specimen has failed away from the weld. Results indicate failure in heat affected zone.

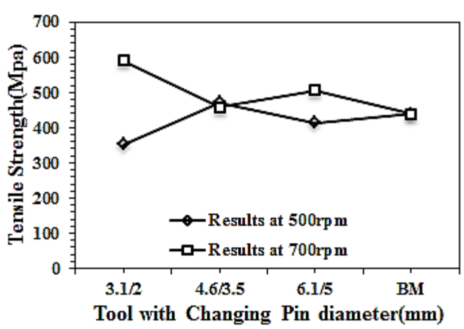



***Fig.6 Tensile Strength results of three different tool pins 3.1/2mm, 4.6/3.5mm and 6.1/5mm at 500rpm and 700rpm compared with base material(BS).***

## VI. ROCKWELL HARDNESS TEST RESULTS

***Table 3 Rockwell hardness Test Results for specimen at 500rpm and 700 rpm***

| Pin Diameter(mm) HRB Values | 3.1/2 | 4.6/3.5 | 6.1/5 | Base material |
|---|---|---|---|---|
| At 500rpm | 23 | 33 | 41 | 28 |
| At 700rpm | 33 | 46 | 54.5 | 28 |

At 500rpm Rockwell hardness results show a linear trend with respect to increasing tool pin diameter. Hardness of the weld joint increases with increase in tool pin diameter. Whereas the tool pins 4.6/3.5 mm and 6.1/5 mm have higher hardness than the base material and tool pin 3.1/2 mm has hardness less compared to base material.

At 700rpm Rockwell hardness values show a linear trend with respect to increasing tool pin diameter. Hardness of the weld increases with increase in pin diameter. Here too hardness of the weld in all the cases is higher than the base material hardness.

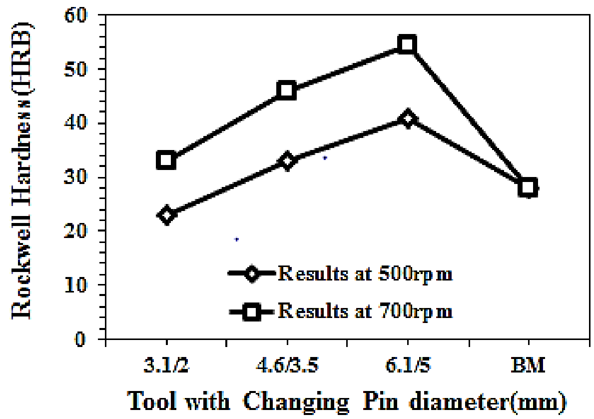



***Fig.7 Rockwell hardness results of three different tool pins 3.1/2mm, 4.6/3.5mm and 6.1/5mm at 500rpm and 700rpm compared with base material(BS).***

## VII. MACRO AND MICROSTRUCTURES

At 500rpm Macrostructure clearly evident that in weld specimen of tool pin 3.1/2 mm has a void defect so this is the reason corresponding pin showing less tensile strength and hardness, where in tool pins 4.6/3.5 mm and 6.1/5 mm have no defects. For all the three JLR in seen in microstructure.

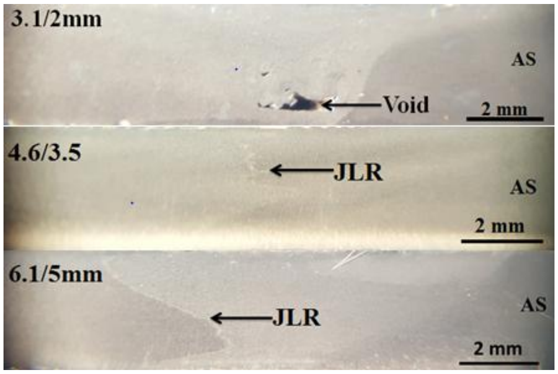



***Fig.8 Macrostructures of three different tool pins 3.1/2mm, 4.6/3.5mm and 6.1/5mm at 500rpm.***

At 700rpm no defects found in weld specimens with respect to all the tool pins in Macrostructure. Where in JLR is clearly visible for the microstructure of 3.1/2 mm tool pin, lightly diminished for the 6.1/5 mm and almost eliminated for the weld specimen corresponding to tool pin of 4.6/3.5 mm.

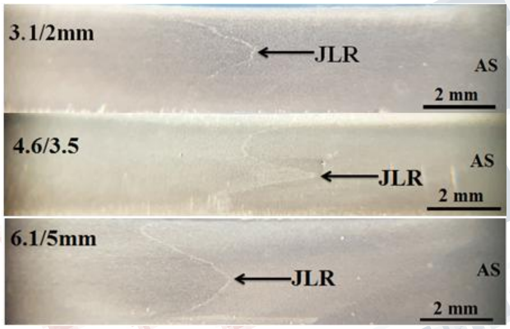



***Fig.9 Macrostructures of three different tool pins 3.1/2mm, 4.6/3.5mm and 6.1/5mm at 700rpm.***

At 700rpm the microstructure in weld specimens with respect to all the tool pins is evident that the grains distribution is found different. Where in the fine grained structure is found with 6.1/5mm and that leads to higher toughness.

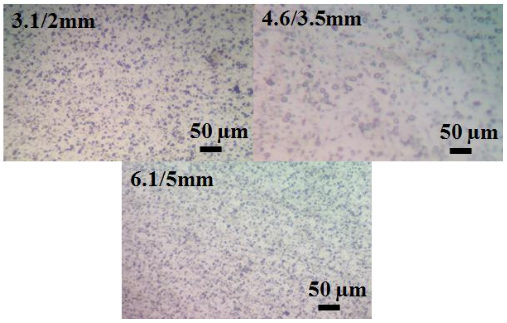



***Fig.10 Microstructures of three different tool pins 3.1/2mm, 4.6/3.5mm and 6.1/5mm at 700rpm.***

## VIII. CONCLUSION

The conclusion from the experiments is that, tool geometry plays a major role in accomplishment of better weld strength in FSW. For the experiments of changing tool pin diameter the tool pin with 6.1/5 mm exhibits a improvement in the strength of the weld. Therefore, among the tested diameters, the trend indicates at larger the diameter better the strength of the weld.

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