INVESTIGATION OF MECHANICAL PROPERTIES AND MICROSTRUCTURE ON FRICTION STIR WELDED DISSIMILAR ALUMINIUM ALLOY

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ABSTRACT

The aim of this experiment is to experimentally investigate and evaluate the potential of using the friction stir welding to join an Aluminium alloy plates in order to improve the weld strength. The difference in mechanical and micro structural characteristics of dissimilar joint by friction stir welding (FSW) has been investigated and compared. The present study is on the development of friction stir welding (FSW) of commercial grade Al-alloy to study the mechanical and micro structural properties. The proposed research will include experiments related to the weldability of Al alloy. This work has been subdivided in to two different sections namely Study of Mechanical properties and Study of micro-structural properties. This study describes the tensile strength of welded sample and distribution of micro hardness in different zones of friction stir weld specimen.

Key Words: Friction stir welding, Aluminium alloy, Mechanical properties, Dissimilar Weld.

1. INTRODUCTION

Friction Stir Welding (FSW) was developed at the Welding Institute (TWI), Cambridge, UK. This technique uses a non- consumable rotating tool to create frictional heat and distortion at the welding position, thereby upsetting the development of a joint, while the material is in the solid state. The main benefits of FSW, being a solid-state procedure, are low alteration, absenteeism of melt-related flaws and great joint strong point, even in those alloys that are considered non-joinable by conventional practices (e.g., 5xxx and 6xxx series aluminium alloys). In addition, friction stir welded joints are regarded as the absence of filler-induced glitches or defects, since the method necessitates no filler. Also the hydrogen damage that occurs during welding of steel and other iron alloys has been avoided by decreasing the hydrogen contents of the friction stir welded joints. FSW has been effectively castoff to weld alike and unlike cast and wrought aluminium (Al) alloys, steels, along with titanium (W), copper (Cu) and magnesium (Mg) alloys, different metal cluster alloys and metal matrix amalgams. The skill can be used to crop butt, corner, lap, T, spot, fillet and hem links also to weld deep objects, for example tanks and tube and parts with 3-D outlines. Many leading Industries involving in manufacturing aluminium parts are aerospace industries such as NASA, Boeing, Eclipse, Airbus, BEA, Lockheed Martin etc.

2. LITERATURE REVIEW

Bo Li et al [1] investigated the effects of welding parameters, especially the value of pin off-set, on weld formation, microstructures and mechanical tensile properties of the lap and butt joints of dissimilar aluminium. The parameter of pin off-set played a very important role and exerted stronger influence upon the joint quality. Three typical micro flow-patterns of plasticized materials were found in the weld-zones: circumfluence, laminar-flow and turbulent-flow. Some weld-defects and the morphologies of ‘onion rings’ were detected.

M. Simoncini et al [2] investigated the effect of welding parameters and tool configuration on the surface appearance, mechanical and micro structural properties of similar and dissimilar friction stir welded joints in AA5754 and AZ31 thin sheets. Two different tool configurations, with and without the pin, were used. As far as the similar friction stir welded joints in AZ31 and in AA5754 alloys were concerned, it was shown that the ‘‘pinless’’ tool leads to obtain the higher values of the tensile strength and ductility as compared to the ‘‘pin’’ one. On the contrary, by considering the dissimilar friction stir welding between AZ31 and AA5754 thin sheets, the welding process becomes very critical as the ‘‘pinless’’ tool was used. Sound dissimilar joints were obtained using the ‘‘pin’’ tool configuration, even though the effect of the material position with respect to the welding tool was a very important factor to be considered. A marked improvement in the surface appearance and mechanical properties was obtained by placing aluminium alloy in the advancing side and magnesium alloy in the retreating one. An investigation had been also carried out in order to evaluate the micro structural properties of similar and dissimilar welded joints.

R Palinivel , et al [3] Friction stir welding is a solid state joining technique developed to join high strength aluminum alloys and various ceramic reinforced metal matrix composites (MMCs). FSW produces sound welds in MMCs without any deleterious reaction between reinforcement and matrix. Their work focused on the effect of FSW parameters on the tensile strength of Al−B4C composite joints. The central composite design of four factors and five levels was used to control the number of experiments. A mathematical model was developed to analyze the influence of FSW parameters. The results indicated that the joint fabricated using rotational speed of 1000 rpm, welding speed of 1.3 mm/s, axial force of 10 kN and the reinforcement of 12% showed larger tensile strength compared with the other joints.

3. WORK METHODOLOGY

3.1 INTRODUCTION

In this investigation of friction stir welding, two dissimilar aluminum alloys Al6061 and Al7075 plates of size 100x50x6 mm was prepared from roll sheets. The chemical composition and mechanical properties of Al6061 and Al7075 are tabulated below. The dissimilar alloy plates was joined by friction stir welding by basic process parameter of spindle rotation speed, force applied on metal, movement of tool on metal.

3.2 TOOL DESIGN

Three various FSW tools are designed by varying the tool pin profile. The configurations of the designed FSW tools are:

- Tool pin profile of straight cylinder, square and tapered cylinder without draft.
- Tools having D/d ratio of 3.

Out of various tool materials like tool steel, high speed steel (HSS), high carbon high chromium (HCHCr), carbide and nitride, HSS is chosen as tool material because of its high strength, high melting point and low cost. The FSW tools will be manufactured by CNC lathe and CNC milling machine. The manufactured tools are shown in Figure.1.

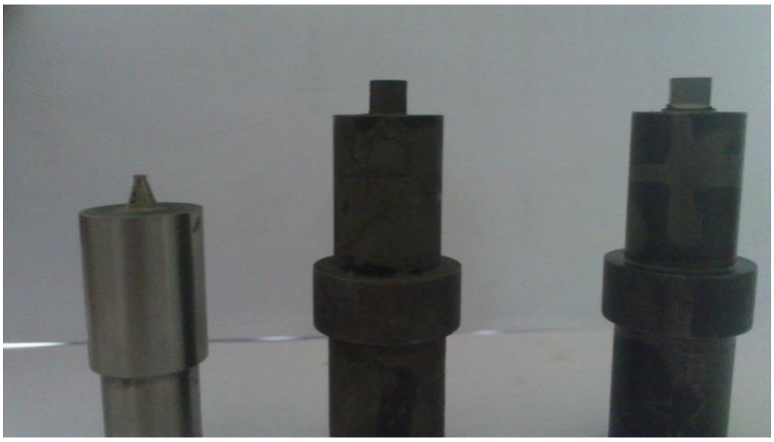

Figure.1. Three different tool pin design

The following figures show the dimensions for tool pin profile for straight tool and tapered tool.

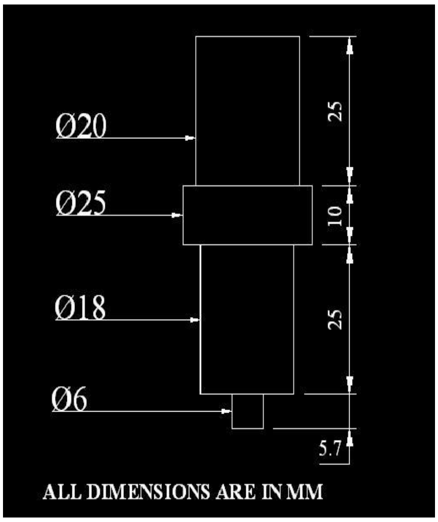

Figure. 1(a). Dimensions for straight tool pin profile

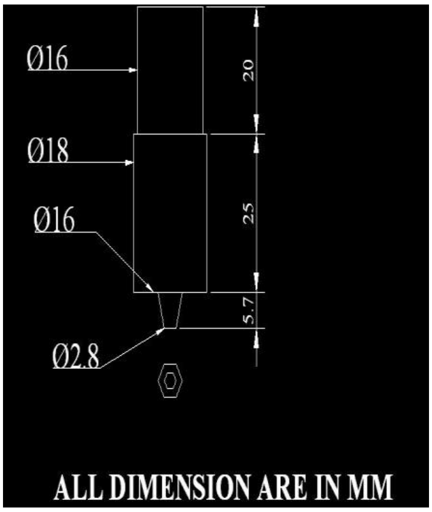

Figure. 1(b). Dimensions for tapered tool pin profile

3.3 FRICTION STIR WELDING OF AL6061 AND AL7075

The dissimilar joint is produced by FSW machine, keeping Al6061on retreating side and Al7075 on advancing side. Trail experiments are carried out for finding feasible limits of the parameter. Feasible limits of the parameters are chosen in such way that the joint should be free from visible defects. After finished with first set of trial experiments, second set of experiments are carried by keeping Al7075 on retreating side and Al6061 on advancing side for the same feasible limits. The Feasible limits of the parameters are given below

- Tool rotational speed 950 rpm
- Welding speed 1.05mm/s
- Axial force 1 tone

For this analyze six joints are fabricated using each tool. Then the joints are visually inspected for exterior weld defects and it is found that the joints are free from any external defects. The various samples of the FS welded plates is shown in figure below.

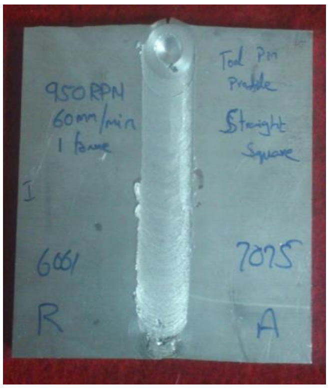

Figure.2. Tool: Square. Side: Al6061 on retreating side and Al7075 on advanced side

Figure.3. Tool: Square. Side: Al7075 on retreating side and Al6061 on advanced side

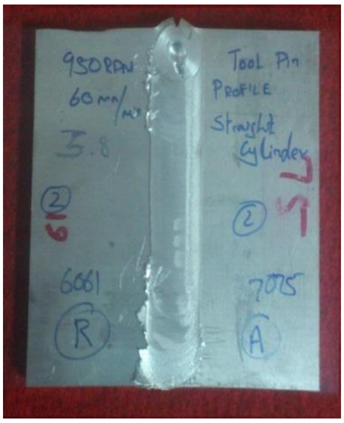

Figure.4. Tool: Cylinder. Side: Al6061 on retreating side and Al7075 on advanced side

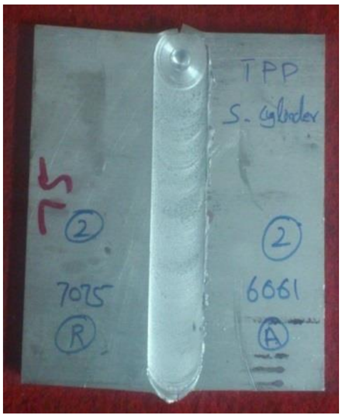

Figure.5. Tool: Cylinder. Side: Al7075 on retreating side and Al6061 on advanced side

Figure.6. Tool: Hexagon. Side: Al6061 on retreating side and Al7075 on advanced side

Figure.7. Tool: Hexagon. Side: Al7075 on retreating side and Al6061 on advanced side

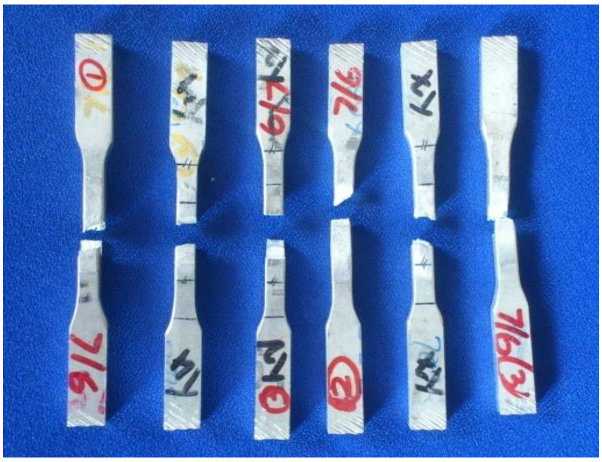

Figure.8. Specimen after finding tensile strength

Table 1. Mechanical properties of the friction stir welded Al6061 with Al7075

S. No	Tool pin profile	Material placement	Tensile Strength in MPa	Yield Stress in MPa	% of Elongation
1	Straight cylinder	Al6061 on retreating side and Al 7075 on advancing side	140.21	124.53	3.20
2		Al6061 on advancing side and Al 7075 on retreating side	196.96	174.13	8.80
3	Straight square	Al6061 on retreating side and Al 7075 on advancing side	168.03	151.65	4.40
4		Al6061 on advancing side and Al 7075 on retreating side	181.20	163.76	9.20
5	Tapered hexagon	Al6061 on retreating side and Al 7075 on advancing side	184.55	164.15	6.00
6		Al6061 on advancing side and Al 7075 on retreating side	171.41	152.11	6.40

The following graph shows the process flow for the tensile test for all six different plates.

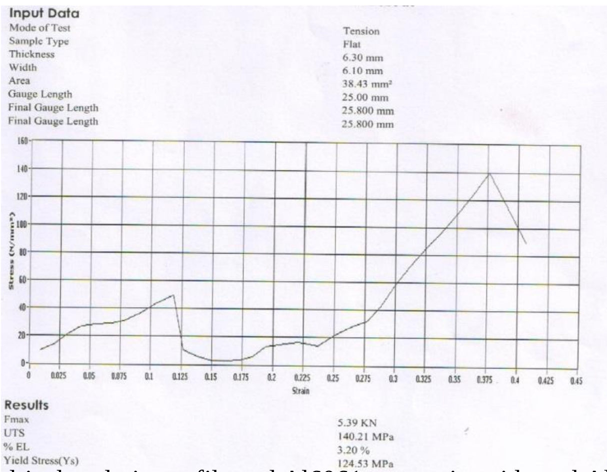

Figure. 9. Graph for cylindrical tool pin profile and Al6061 on treating side and Al7075 on advancing side.

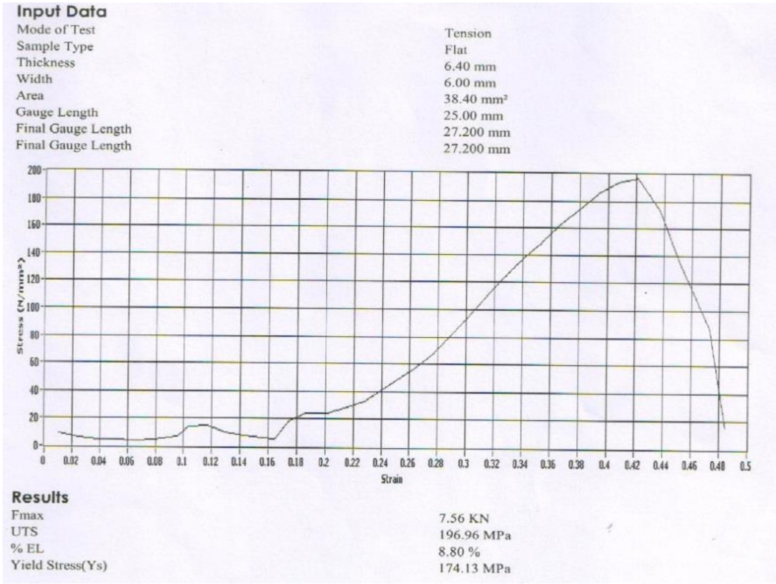

Figure. 10. Graph for cylindrical tool pin profile and Al7075 on treating side and Al6061 on advancing side.

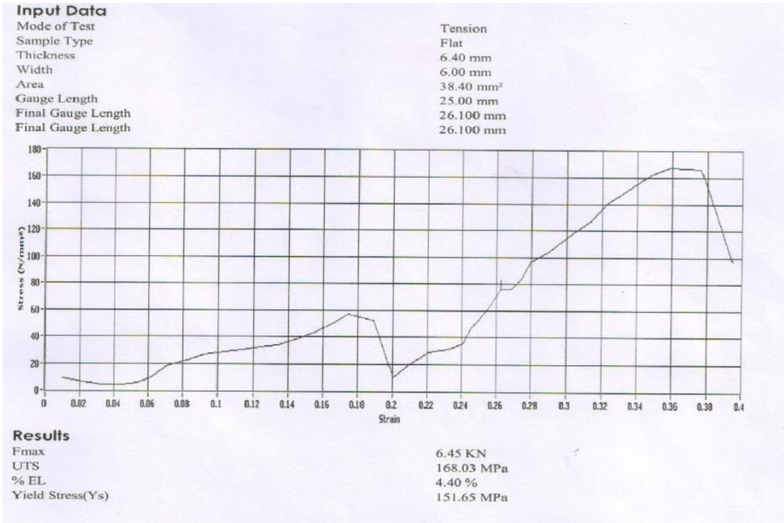

Figure. 11. Graph for square tool pin profile and Al6061 on retreating side and Al7075 on advancing side.

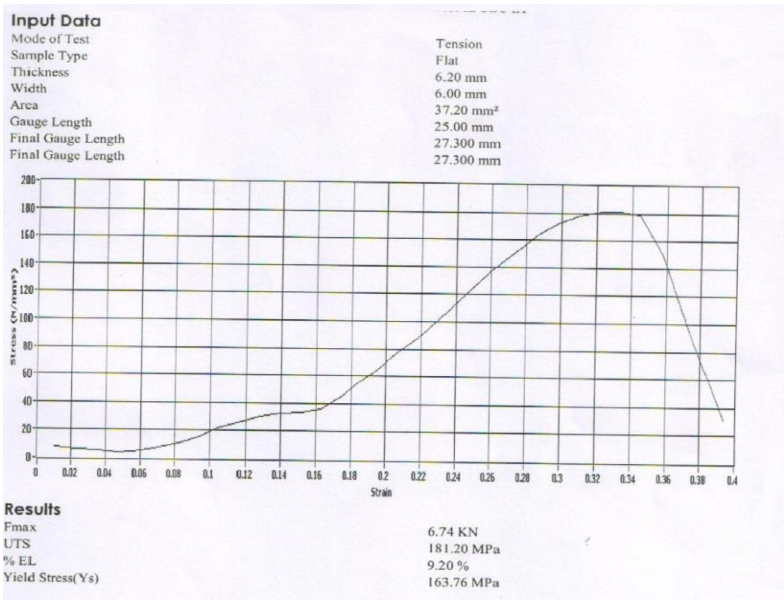

Figure. 12. Graph for square tool pin profile and Al7075 on retreating side and Al6061 on advancing side.

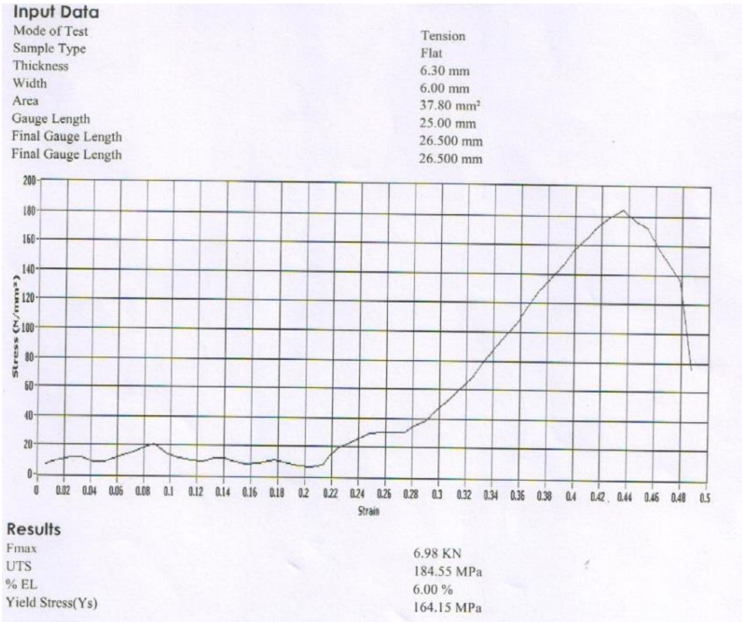

Figure. 13. Graph for hexagonal tool pin profile and Al6061 on retreating side and Al7075 on advancing side.

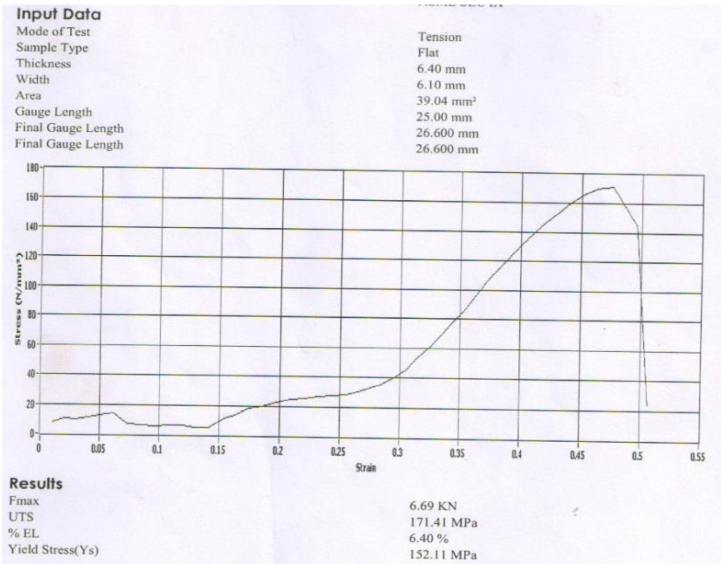

Figure. 14. Graph for hexagonal tool pin profile and Al7075 on retreating side and Al6061 on advancing side

Table 2. Hardness of six different plates

S. No	Area	Material placement					
		Square[1] 6/7	**Square[2] 7/6**	**Cylinder[3] 6/7**	**Cylinder[4] 7/6**	**Hexagon[5] 6/7**	**Hexagon[6] 7/6**
1	Weld	157.23	139.83	157.23	146.27	152.3	145.97
2	HAZ	132.93	121.57	132.93	128.3	131.2	132.57
3	Base metal	87.33	78.07	87.33	88.33	109.33	122.6

Note: [1] Al6061 on retreating side and Al 7075 on advancing side for square tool pin profile

[2] Al6061 on advancing side and Al 7075 on retreating side for square tool pin profile

[3] Al6061 on retreating side and Al 7075 on advancing side for cylinder tool pin profile

[4] Al6061 on advancing side and Al 7075 on retreating side for cylinder tool pin profile

[5] Al6061 on retreating side and Al 7075 on advancing side for hexagon tool pin profile

[6] Al6061 on advancing side and Al 7075 on retreating side for hexagon tool pin profile

4. RESULT AND DISCUSSION

The first step to characterize the obtained weld is a visual inspection of roots and crowns. A circle of material that is deformed by the tool shoulder always remains. The appearance of this material provides information about the weld quality. The weld quality is slightly varied by the different tool pin profile.

Figures 2 to 7 show the welded plates by three different tool pin profiles. All the pin profiles produced a complete circle around the hole. The weld quality from the straight square tool pin profile for Al7075 on retreating side and Al6061 on advancing side is weaker than compare with the other tool design and material placement. Al7075 is heavier than Al6061 by chemical composition due to this, the weld quality is not good for particular profile. But in other tool, they have smoother surfaces so it can give much good weld quality. Figure 8 shows the specimen after finding tensile strength. The values are tabulated in table 1. This table contains values of the mechanical properties like tensile strength, yield strength and % of elongation. Figure 9-14 shows the process flow graph for tensile test. From this flow process, we can get information about the way process was done.

The effect of tool pin profile on the tensile properties of the friction stir welding joints as described in table 1. In the table, information is about the three different tool pin profile and two different type material placement by changing retreating and advancing side. The welded joints by straight cylinder and Al7075 on retreating side and Al6061 on advancing side give better tensile properties than compared with tool pin profile and material placement.

The hardness properties for six different plates are listed in table 2 for three different zones. From the values displayed in table 2, Straight Square gives better hardness properties than compared with other welded plates.

The following graph represents the comparison values of the micro hardness for the various zone and material placement.

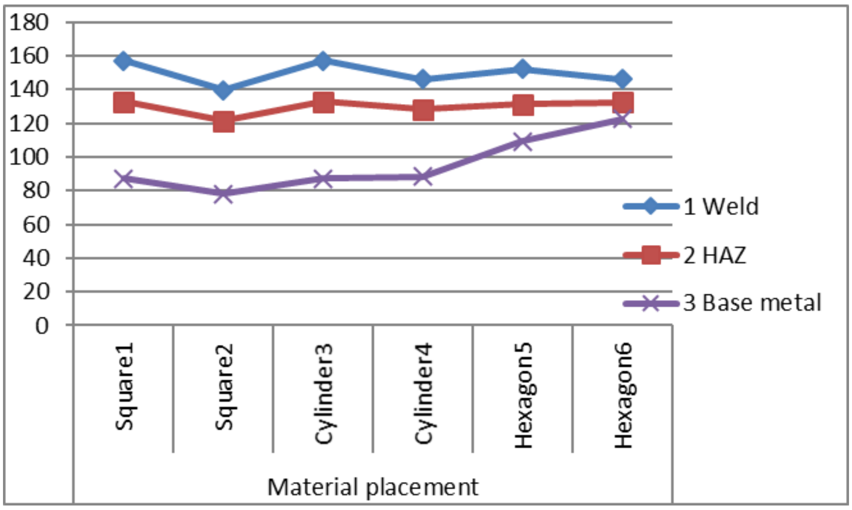

Figure 15. Graph for comparison values of the micro hardness between three different tool pin profiles on various zones.

Note: [1] Al6061 on retreating side and Al 7075 on advancing side for square tool pin profile

[2] Al6061 on advancing side and Al 7075 on retreating side for square tool pin profile

[3] Al6061 on retreating side and Al 7075 on advancing side for cylinder tool pin profile

[4] Al6061 on advancing side and Al 7075 on retreating side for cylinder tool pin profile

[5] Al6061 on retreating side and Al 7075 on advancing side for hexagon tool pin profile

[6] Al6061 on advancing side and Al 7075 on retreating side for hexagon tool pin profile

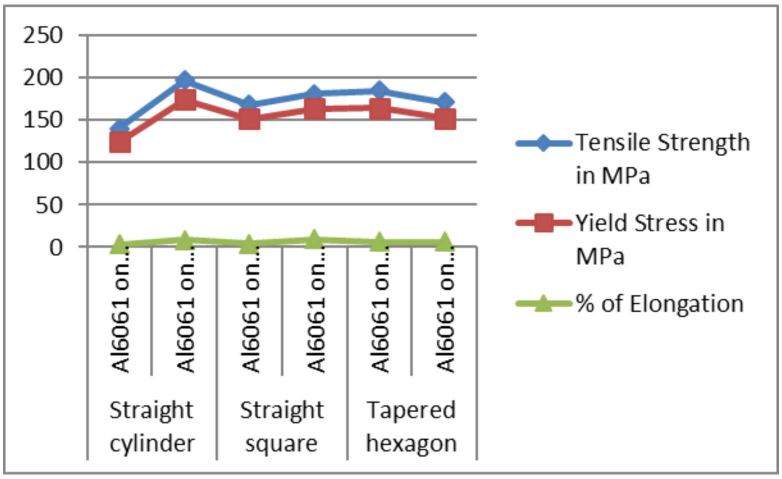

Figure 16. Graph for comparison values of the mechanical properties between three different tool pin profiles and material placement

5. CONCLUSION

The following conclusion has been made from the above investigation

- The dissimilar Al6061 and Al7075 aluminum alloy can be welded by Friction stir welding without any defect.
- The tensile strength of the friction stir welded is affected by the tool pin profile.
- Among the three different tool pin profile straight cylinder tool give more tensile strength by keeping Al6061 on advancing side and Al7075 on a retreating side then compared to other tools and other placement of the plates.
- For the purpose of hardness straight square tool can be more efficient and keeping Al6061 on advancing side and Al7075 on a retreating side gives better strength than compared with other tool pin profiles and placement of plates.

REFERENCES

1. Bo Li, Yifu Shen “A feasibility research on friction stir welding of a new-typed lap–butt joint of dissimilar Al alloys” on 14/05/2011.

2. M. Simoncini , A. Forcellese “Effect of the welding parameters and tool configuration on micro- and macro-mechanical properties of similar and dissimilar FSWed joints in AA5754 and AZ31 thin sheets” on 29/04/2012.

3. R. Palanivel , P. Koshy Mathews , N. Murugan , I. Dinaharan “Effect of tool rotational speed and pin profile on microstructure and tensile strength of dissimilar friction stir welded AA5083-H111 and AA6351-T6 aluminum alloys” Materials & Design volume 40, September 2012, Pages 7-16

4. Youbao Song, Xinqi Yang , Lei Cui, Xiaopeng Hou, Zhikang Shen, Yan Xu “Defect features and mechanical properties of friction stir lap welded dissimilar AA2024–AA7075 aluminum alloy sheets” on 28/09/2013.

5. Pooya pourahmad, Mehrdad abbasi “Materials flow and phase transformation in friction stir welding of Al 6013/Mg” on 20/ 09/ 2012.

6. Abderrahmane Djili, Boudjema Bezzazi, Nadjet Zioui , Mohamed Haboussi “Effect of natural aging on the tensile properties and the toughness of friction stir welds of 2024-T3 aluminum alloy”, Journal of Advanced Joining Processes Volume 8, November 2023, 100153

7. S. Malarvizhi , V. Balasubramanian “Influences of tool shoulder diameter to plate thickness ratio (D/T) on stir zone formation and tensile properties of friction stir welded dissimilar joints of AA6061 aluminum–AZ31B magnesium alloys” on 02/04/2012.

8. M. Dehghani , A.Amadeh,S.A.A.Akbari Mousavi "Investigations on the effects offriction stir welding parameters onintermetallic and defect formation in joining aluminum alloy tomild steel" on 05/01/ 2013.

9. C.W. Tan, Z.G. Jiang, L.Q. Li , Y.B. Chen a, X.Y. Chen "Microstructural evolution and mechanical properties of dissimilar Al–Cu joints produced by friction stir welding" on 14/04/2013

10. Dejia Liu a, RenlongXin a,b,n, XuanZheng a, ZhengZhou a, QingLiu a,b, "Microstructure and mechanical properties of friction stir welded dissimilar Mg alloys of ZK60–AZ31" on 15/10/2012.

11. Tao Liu , Song Gao , Weicheng Ye, Lei Shi , Sachin Kumar , Junnan Qiao , "Achievement of high-quality joints and regulation of intermetallic compounds in ultrasonic vibration enhanced friction stir lap welding of aluminum/steel" Journal of Materials Research and Technology, Volume 25, July–August 2023, Pages 5096-5109

12. M. Dehghani, S. A. A. Akbari Mousavi, A. Amadeh "Effects of welding parameters and tool geometry on properties of 3003-H18 aluminum alloy to mild steel friction stir weld" Transactions of Nonferrous Metals Society of China Volume 23, Issue 7, July 2013, Pages 1957-1965.

13. A. Saravana Sundar , Amlan Kar , Krishna Kishore Mugada, Adepu Kumar "Enhancement of microstructure, micro-texture, and mechanical properties of Al6061 friction stir welds using the developed static shoulder welding tool" , Materials Characterization Volume 203, September 2023.