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Experimental Investigation on Aluminum Alloy 6061 Friction Stir Welding With Varying Tool Pin Profiles

CH. Yadagiri[1], S. Uday Bhaskar[1,a)], K. Phani Raja Kumar[2], Subramanyam Pavuluri[1,b)], CH. Ashok Kumar[1]

[1]Department of Mechanical Engineering, Malla Reddy Engineering College, Secunderabad, Telangana State, India
[2]Tech Mahindra, 4965 PRESTON PARK BLVD, Plano, Texas, United States.

[a)] *Corresponding author: udayashok@gmail.com*
[b)] *subramanyampavuluri@gmail.com*

Abstract. For lightweight, high-strength-to-weight ratio constructions, Al alloy 6061 is a popular choice in manufacturing. It is a new method of combining materials that doesn't need melting or casting, but instead uses friction stir welding. Frictional heat is created whenever two surfaces come into contact. The quality of the weld is influenced by the welding tool's pin profile. In this study, the effect of welding speed and tool pin shape on FSP zones in 6061 and 6082 Al is examined. This is an experimental study. The profiles of the tool pins are utilized to examine welding joints. Triangular and square profiles are also included in the list of possible shapes. Cutting tools were compared to welding plates in this investigation. A milling machine with a fixture, cutting tools, and plates was used for all practical experiments. This technique makes use of spindle revolutions per minute (rpm) and cutting feed.

Keywords: Friction Stir Welding, Pin Tool profile, Al Alloy 6061, Analysis.

INTRODUCTION

This instrument creates heat by spinning and travelling cylindrically with a profiled pin. It warms the workpiece and moves plasticized material to make the junction. The tool-to-workpiece friction warms the workpiece. The plasticized substance softens the material surrounding the pin as it flows from front to rear. This method leaves a joint "Solid". Fine and equiaxed recrystallized grains result from high temperature plastic deformation. Since its inception in 1991, friction stir welding (FSW) has fascinated the scientific and industrial worlds. (TWI) In high-tech fields including aerospace, automotive, and micro welding for over 22 years.

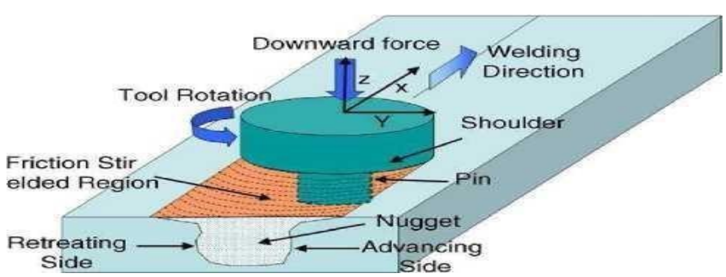

FIG. 1. Schematic Drawing of Friction Stir Welding

Compare the work material's non-melting to the connecting materials' melting points. Metal fusion welding demands a lot of heat. This kind of weld is less costly. These metals can be friction stir welded. Their obvious advantages have expanded their use in structural applications. FSW can now weld the 5000 and 7000 class aluminum alloys. No

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sparks or flames from FSW. The situation is safe and lawful. FSW does not use filler metal, resulting in better weldability and lower costs. Aerospace, automotive, and shipbuilding sectors have all used FSW. In many applications, better understanding and optimizing FSW is crucial. Research on the interaction of matter and its environment has included mathematical modelling. A system or technique to quantitatively quantify welding parameters like force and torque in the FSW process has yet to be documented in the literature.

LITERATURE SURVEY

Metals that are often used include 6061-T6aluminium and 6061-T5aluminium. Aerospace and automobile industries both often use this metal [1–4]. For example, microporosity and thermic instability (hardening precipitates) may be found in the components linked to MIG and TIG fusion welds. Aside from a reduction in FZ and HAZ but an increase in porosity, laser welding of 6061-T6 alloy enhanced mechanical characteristics and finishing [7, 8]. Friction stir welding, the first solid state welding technology developed by the Welding Institute of Great Britain, was first used in 1991 [9]. Both metal alloys get energy from a rotating inert tool. Deformation and mixing of high-shear plastic shear pressures are easier because heat is diffused across the two opposing surfaces. Axial tool force and tool tilt angle (relative to the welding surface) impact the bonding strength and microstructure of the welding surface [13, 14]. The mechanical characteristics of aluminum alloy 6061-T6 have been examined in relation to a unique pin shape [15–19]. Pin profile influences material mixing, grain size, and welding flaws [20–22]. The mechanical characteristics of welded materials have been studied using a variety of pin profiles [23–25]. Pin profiles have also been the subject of recent study, including a model for a cylindrical pin [22].

PARAMETER OF FRICTION STIR WELDING

During the friction stir welding process, a ring of plastic deformation surrounds the pin on the stir zone. Using rotating tools and the pin shapes and joint configurations that go along with them is a key part of creating a material flow pattern, distributing heat throughout the weld line, and creating strong weld joints. There are three basic parameters in FSW: welding speed (F, mm/min), axial force (A), and tool rotating speed (N, rpm) (P, kN). With its high silicon content, Al-Si is the most important aluminum casting system (4.0 percent to 13 percent). Engineers often use lightweight, corrosion-resistant materials in their designs. Aluminum and magnesium alloys have played a major role in the production of aeronautical components. Because of the magnesium content, alloys with aluminum-magnesium are both lighter and less combustible than those with just a little amount of magnesium. Aluminum oxide forms a transparent, protective coating on aluminum alloy surfaces in a dry atmosphere, allowing them to retain their brilliance. Aluminum alloys may corrode when they come into contact with metals with lower corrosion potentials, such as copper, in a damp environment. The Aluminum Association maintains an alloy register. Many organizations, like the Society of Automotive Engineers and ASTM International, offer more precise standards for aluminum alloy production. The pin tool manufactured of HSS material with dimensions of 100x50x3mm, a 20mm radius, and a height of 3mm is angle 2mm for welding dissimilar aluminum metals. A 3 Axis Machine Centre model BFW45 is used in the friction stir welding process, which uses a spin type 3 Axis Machine Centre with a spin type 3 Axis Machine Center's servo motor with a maximum speed of 6000rpm to rotate an HSS tool with a total tool movement of 610x450mm and bed dimensions of 800x500mm.

Table 1. Mechanical Properties of Al6061&6082 alloy

Hardness, Brinell	Tensile Strength, Ultimate	Elongation at Break	Shear Modulus	Shear Strength
30	124 MPa	25%	26.0 GPa	82.7
75	130MPa	27%	27.00 GPa	85

Table 2. Chemical Properties of Al 6061 and 6082 alloy

Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al
0.7-1.3	0.0-0.5	0.0-0.1	0.4-1.0	0.6-1.2	0.0-0.2	0.0-0.1	0.0-0.25	Balance
-	≤0.70	0.15–0.40	0.80–1.20	≤0.15	-	-	0.040–0.35	Balance

TABLE 3. Thermal Properties of Al6061alloy

Specific heat capacity	Thermal conductivity	Melting point	Solidus	Liquidus
0.896 J/g-°C	180 W/m-K	582 – 651.7 °C	582 °C	651.7 °C
0.875 J/g-°C	180 W/m.K	555°C	592 °C	649.8 °C

EXPERIMENTAL PROCEDURE

Aluminum alloys 6061 and 6082 are described in detail in Tables 3 to 8, together with their relative weight-based chemical compositions and key mechanical and thermal characteristics. Plates with dimensions of 200 mm x 150 mm x 9.5 mm were utilized for the FSW experimentation. The tool tilt angle is set to 0 degrees for the categorization of the FSW tests based on the welding parameters for this task. A vertical machining center was used to conduct the FSW procedure.

FIGURE 2. After Welding Workpiece

FIGURE 3. Tools of Friction Stir Welding (TV)

FIGURE 4. Tools of Friction Stir Welding (TV)

EXPERIMENTAL MODELS

In addition to industry-leading productivity tools, Pro/ENGINEER Wildfire promotes best practices in design by Pro/robust, ENGINEER's easy-to-use, inexpensive solution.

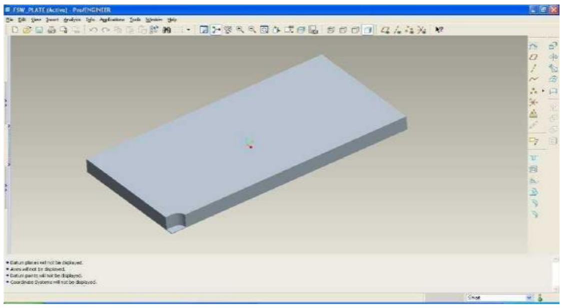

Fig. 5. Pro-E model of component 1

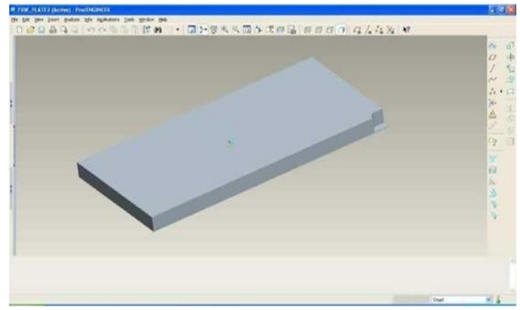

Fig. 6. Pro-E model of component 2

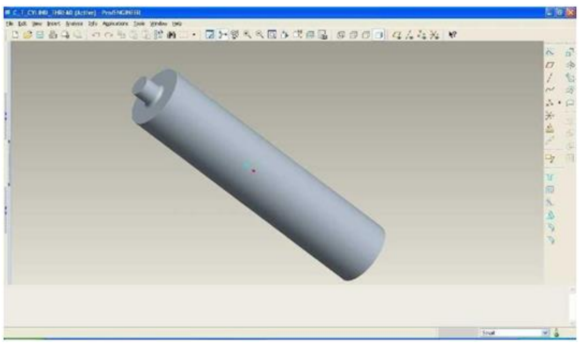

Fig. 7. Pro-E round tool model

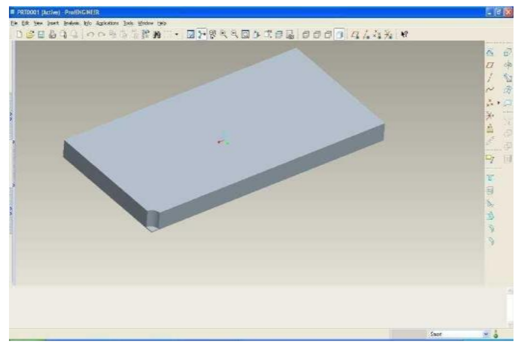

Fig. 8. Pro-Ecomponent1

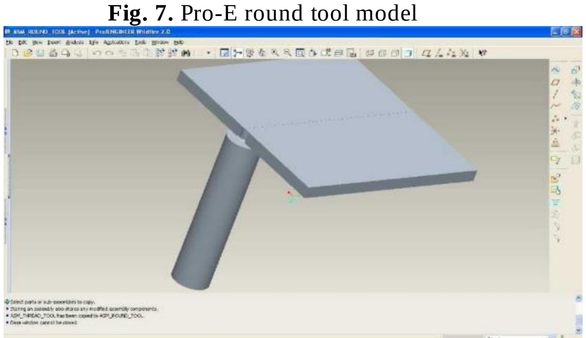

Fig. 9. Pro-E round taper tool

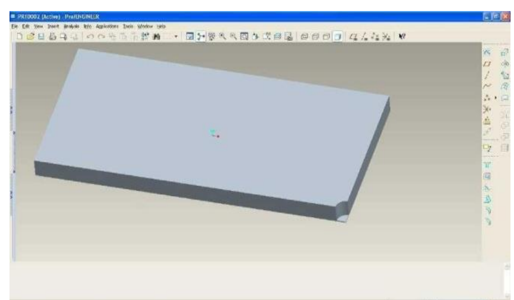

Fig10. Pro-Eroundtool

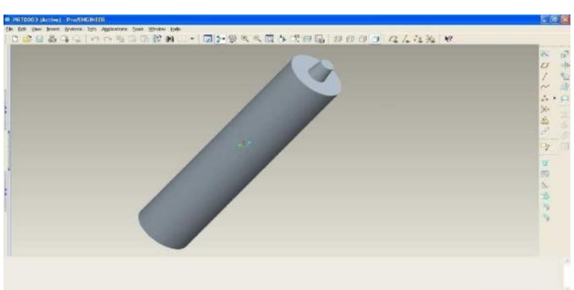

Fig11.Pro-Emodelofround taper tool

Fig12. Pro-E round taper tool

ANALYSIS REPORTS

For complicated systems, Finite Element Analysis (FEA) is a sophisticated approach. Structure and continuous analysis are numerical. When the issue is too complicated for more typical analytical techniques. The Finite Element technique is used to build and solve several simultaneous algebraic problems. The Finite Element Method began with stress analysis. Aside from heat transfer and fluid movement, finite element techniques are used to study lubrication, electric and magnetic fields.

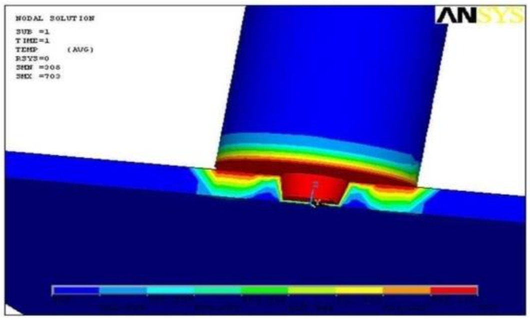

Fig. 13. Temperature Distribution Model at Temperature 703℃ in Closer look

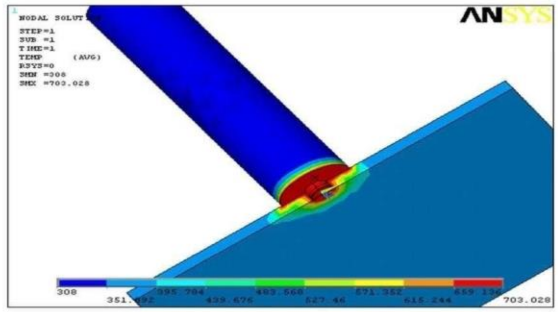

Fig. 14. Temperature Distribution Model at Temperature 703°c

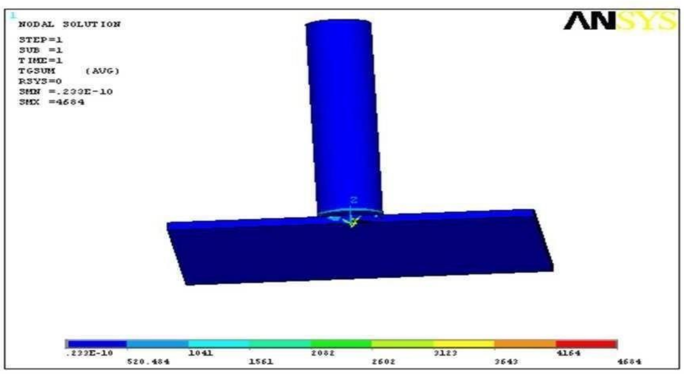

Fig. 15. Thermal Gradient Model at Temperature 703°c

RESULTS AND DISCUSSION

Table 4. Thermal result (T.G-Temperature gradient TF- Thermal flux) AA-6061 and 6082

Type of Tool	Revolution per Minute	AA-6061			AA-6082		
		Temp.	Temperature gradient	Thermal flux	Temperature	Temperature gradient	Thermal flux
Round Tool	1000	673^0C	5398	971	673^0C	5432	934
	1200	703^0C	6232	1122	703^0C	5879	1011
Round Taper Tool	1000	673^0C	5460	982	673^0C	5498	945
	1200	703^0C	5909	1064	703^0C	5950	1023
Square Tool	1000	673^0C	5919	1065	673^0C	6041	1039
	1200	703^0C	6406	1153	703^0C	6449	1109
Thread Tool	1000	673^0C	5082	914	673^0C	1910	314
	1200	703^0C	1327	86	703^0C	9505	1635
Triangular Tool	1000	673^0C	4916	884	673^0C	4329	744
	1200	703^0C	5457	982	703^0C	4684	805

Table 5. Structural Analysis Results AA-6061 AND 6082

	Revolution per Minute	Displacement	Stress	Displacement	Stress
Round Tool	1000	0.001017	298.821	0.001017	298.212
	1200	0.001158	340.81	0.001261	339.896
Round Taper Tool	1000	0.881e-^{03}	359.675	0.870 e^{-03}	359.422
	1200	0.001281	316.49	0.001256	315.811
Square Tool	1000	0.997 e^{-03}	215.966	0.0997 e^{-03}	215.651
	1200	0.001269	246.555	0.001254	246.421
Thread Tool	1000	0.00113	1710	0.00113	1692
	1200	0.001287	1937	0.001271	1930
Triangular Tool	1000	0.885 e^{-03}	153.276	0.001123 e^{-03}	153.288
	1200	0.001275	190.233	0.976 e^{-03}	152.686

Table 6. Comparative Tensile Strength at Maximum Load of 6061

Tool geometry	MaximumLoad(N)	TensileStrength(Mpa)
Cylindricaltool(CY)	11000	298.7
Taperedcylindrical(TCY)	10900	294.1
Triangular (TRI)	10950	293.6
Square(SQA)	10750	295.1
Threaded(THRED)	1070	293.7

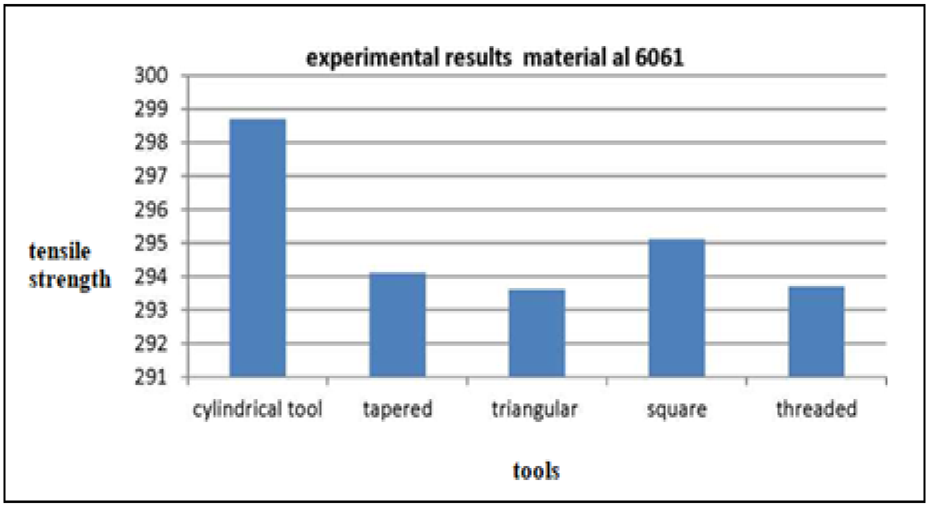

Figure 15. Tensile Strength of 6061 Vs Tools

Table 7. Comparative Tensile Strength at Maximum Load of 6082

Tool geometry	Maximum Load(N)	Tensile Strength (MPa)
Cylindrical tool (CY)	10900	291.9
Tapered cylindrical(TCY)	10350	285.0
Triangular (TRI)	10200	283.5
Square (SQA)	10650	286.4
Threaded (THRED)	10700	285.8

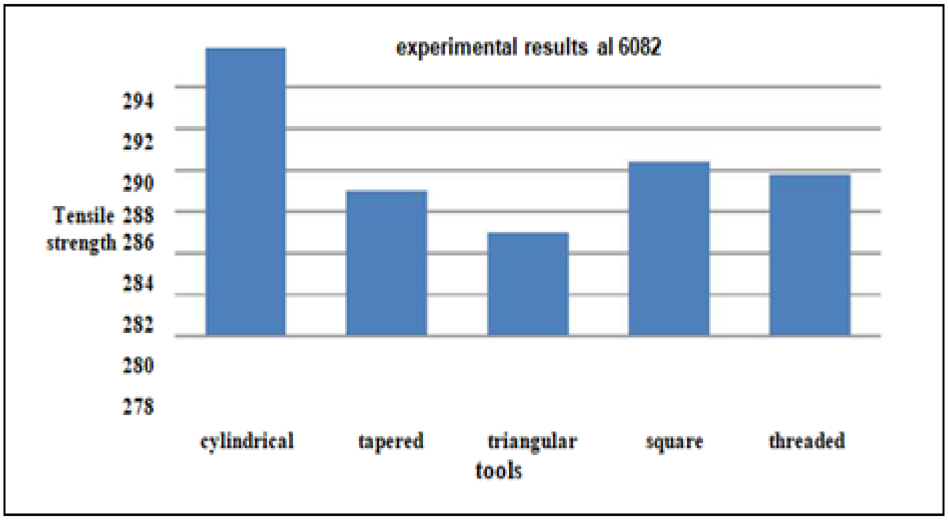

Figure 16. Tensile Strength of 6082 Vs Tools

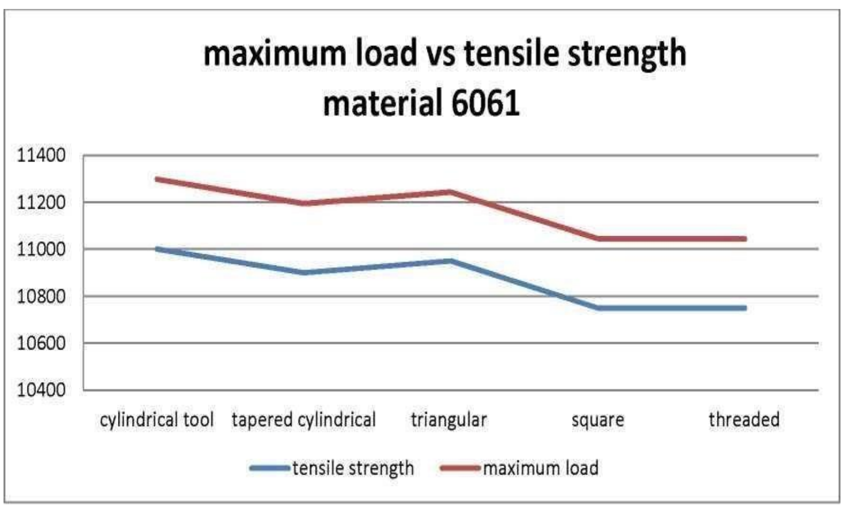

Figure 17. Maximum Load for Al6061 Vs Tools

CONCLUSION

FSW is ideal for combining light-weight materials such as Al alloys, which are difficult to join using traditional methods. Just as in any other welding operation, the quality of the weld joint and the efficiency of the welding process depend on the efficient creation and transport of heat. A great deal of research has been done on the process mechanism and how it affects welding, but gaining a comprehensive grasp of the process mechanism is essential if you want to choose the best process parameter and get the best results in practice. Friction Stir Welding uses cylindrical, round-circular and square-triangle cutting tools. An improved weld property may be found by looking at the data presented above, as well as the actual weld results themselves. The tensile strength of 6061 is superior than that of 6082. Displacement and yield stress may both be reduced with the Triangle tool. Similarly, the remaining resources are restricted. FSW requires the use of a cylindrical tool.

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