

# Weld Strength Evaluation and Optimization of Industrial Polymer on Few Process

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**Abstract**—The use of polymeric materials has grown widely in various sectors such as packaging, building, electronic, automotive, and aerospace industries. Particularly, Ultra-High Molecular Weight Polyethylene (UHMWPE) has wide engineering applications and is used in large quantities in automotive oil pans, gears, slides, cams, bearings, fluid reservoirs, and the sports industry. Friction Stir Welding (FSW) is a solid-state process in joining thermoplastic materials. In this investigation, FSW process is applied to join a UHMWPE plate of 10 mm thickness with specially designed hexagonal tool pin profile. After welding, the UHMWPE tensile specimen was tested using the FIE-600KN equipment. In this tensile test, the seventh sample exhibited a greater tensile strength of 6.72 N/mm<sup>2</sup>. Based on the Taguchi design optimized parameter was UHMWPE for 10mm with executed hexagonal profile with higher speed medium tool traverse and low tool tilting Angle exhibits maximum tensile strength. The hardness, angle distortion, bead geometry and radiography test were evaluated.

**Index Terms**—FSW, Tool Profile, Taguchi, HRM, Polyethylene, Tensile strength, Angle distortion.

## I INTRODUCTION

Fractional stir welds and hot-worked aluminum extrusions and forgings are quite comparable in terms of microstructure and metal flow. Forging, extrusion, preheating, deformation, cooling, and post-heating are the five zones that make up conventional metalworking's FSW. A preheat zone is formed in front of the pin by adiabatic and frictional heating from the revolving tool. This zone's size and heating rate are determined by its thermal properties and the speed at which the tool traverses it. It's also acknowledged as one of the most advanced welding techniques of the

current era. Furthermore, spatter, embrittlement, solidification, shrinkage, cracking, and porosity are among the flaws that FSW helps to avoid. Since FSW eliminates the need for an arc, dangerous gases produced during other fusion welding techniques, and shielding protective gas, it is also referred to as "green technology." It lowers the cost of this process and uses less energy.

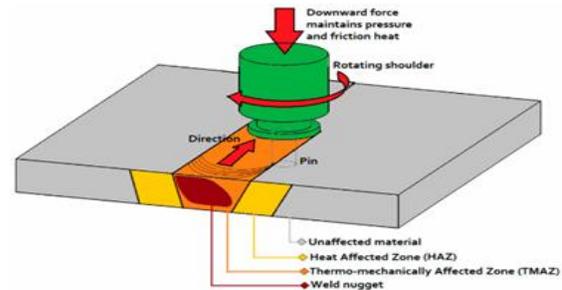


Figure. 1 FSW Process

FSW includes complex material deformation. Welding parameters, the temperature distribution and material flow are impacted by joint design and tool geometry, determining microstructural evolution. The amount of heat created, and the flow of material significantly affect the quality of FSW processes. Temperature distribution in the nugget zone, rate of cooling, and torque applied chemical, and automotive industries, where high weld quality and reliability are paramount.

## Introduction of Polymers

Polymers are extremely large molecular mass compounds created by joining several simple molecules together. Monomers are the basic molecules that combine to form polymers. Polymerization is the

process by which monomers and other simple molecules are changed into polymers.

Homopolymer is a polymer made of a single kind of monomer. As an illustration, polyethylene is a homopolymer of ethylene. Copolymer, also known as mixed polymer, is a polymer composed of two or more distinct monomers. For example, terylene is a polymer made of terephthalic acid and ethylene glycol. The polymers are also called as macromolecules because of the large size of their molecules. They are used frequently without any distinction. But a polymer will always consist of thousands of repeating monomer units. Such as chlorophyll is macromolecule but not a polymer because it does not contain monomers. Polyethylene can be called as polymer as well as macromolecule. Consequently, not all macromolecules are polymers, but all polymers are macromolecules.

#### Friction Stir Weldability of Polymers

The physical and rheological variations seen in each polymer make the FSW of polymers crucial. When it comes to weld polymers with low melt viscosity, like nylon-6A, achieving the ideal process conditions becomes more difficult. The primary process variable in the FSW process is rotational speed, which changes based on the physical characteristics of each type of material. The polymer degrades at greater rotational speeds, whereas poor mixing and cavities are created in the stir zone at lower rotational rates. Consequently, it is essential to look into the ideal settings for every polymer.

## II FSW PROCESS PARAMETERS

### (a) Tool Rotation Speed

During the FSW process, the tool rotation speed (TRS) has a big impact on the quantity and rate of heat generation and, consequently, the material flow. Because of the advancing material's inadequate thermal softening, the tool will generate less heat as it advances, resulting in defect formation. As a result of poor tool rubbing, low rotational speeds of the tool result in inadequate production of heat and heat generation rate. As a result, there are defects in the fabricated joint. Higher tool rotation speeds result in nugget zone defects in FSW joints. As a result of the high rubbing force, excess heat is generated, causing turbulence in the flow of materials. Additionally,

excessive plasticization makes the material soft, resulting in poor friction over the tool. Therefore, the content will slip, and defects will occur.

### (b) Tool Transverse Speed (TTS)

The rotational speed of the FSW tool as it moves down the welding line is known as the welding or tool transverse speed (TTS). Using high tool transverse speed (TTS) to fabricate FSW joints, defects occurred in the stir zone due to insufficient heat and material flow. The brief period of time when stirring limited the extent of thermal softening and plasticization, resulting in defective stir zones. Long stirring times at low transverse speeds result in high heat input, which produces more significant thermal softening around the tool. Excess plasticization of material results in a reduction of the material's and tool's friction. The stir zone's defect formation was aided by the slipping state.

### (c) Axial Force

Under axial force, the rotating tool generates heat, the primary welding heat source. By applying axial force, reduction in friction at this temperature between the shoulder of the nugget indicated that frictional heat was the primary heat source. Because the upper surface of the plates to be connected and the tool shoulder are in close contact, the nugget zone is widened near the top of the surface because of the high temperature caused by higher axial forces. When sufficient axial force is required to form a good weld, the plunge depth of the tool is directly affected by the axial force. FSW is characterized by temperature, and the axial force greatly influences temperature during friction stir welding.

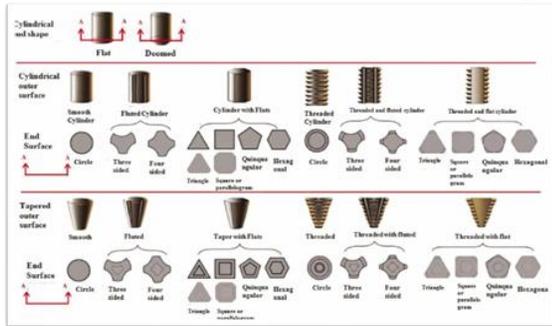
### (d) Tool Tilt Angle

The material deformed by FSW is forged into the hollow cavity that develops behind the tool as it retreats to advance at the tilt angle of increased, the area between the tool and the workpiece widens. Raising the tilt angle prevents plasticized material from the tool's shoulder bottom. Due to the discontinuity in the weld, some voids appear at the surface of the weld. Increasing the tilt angle can remove more material from the tool's bottom. If the tilt angle is reduced, there will be no weld since the material will not be forged.

### (e) Tool Pin Profile

The flow of material around the tool is controlled by the FSW tool pin. To enhance the stirring and material

flow during FSW, researchers have created a number of tool pin designs. The length, pin thickness and diameter, cross-sectional form, tapering angle, and surface characteristics are a tool pin's key geometrical characteristics. Because the thickness of the plate to be welded determines the length of an FSW tool pin, 90–95% of the plate



thickness is considered for near complete penetration.  
Figure: 1.2 Different Tool Pin Shapes and Profiles

### III EXPERIMENTAL DETAILS

#### BASE MATERIAL OF WELD

For this research purpose UHMWPE were purchased from LONG LAST POLYMERS – COIMBATORE the size is 100X100X10 mm. Before and after weld plate images .



(a)



(b)

Figure:1.3 UHMWPE weld plates Before and after image

#### TAGUCHI METHOD

##### DESIGN OF EXPERIMENT

Basically, experimental design methods were developed original fisher. However experimental

design methods are too complex and not easy to use. Furthermore, a large number of experiments have to be carried out when the number of the process parameters increases, to solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only.

Table:1 Levels and ranges of FSW process parameters Taguchi method L<sub>9</sub> Factor

S.NO	SPEED rpm	TOOL-TR mm/min	TOOL TILT ANGLE °
1	900	10	0.5
2	1000	15	1.0
3	1100	20	1.5

#### DESIGN OF ORTHOGONAL ARRAY

First Taguchi Orthogonal array is designed in minitab-16 to calculate S/N ratio.

Table: 1.1 L<sub>9</sub> Array formation

SL.NO	SPEED rpm	TOOL-TR mm/min	TOOL TILT ANGLE °
1	900	10	0.5
2	900	15	1.0
3	900	20	1.5
4	1000	10	1.0
5	1000	15	1.5
6	1000	20	0.5
7	1100	10	1.5
8	1100	15	0.5
9	1100	20	1.0

IV RESULTS AND DISCUSSION

ROCKWELL HARDNESS TEST

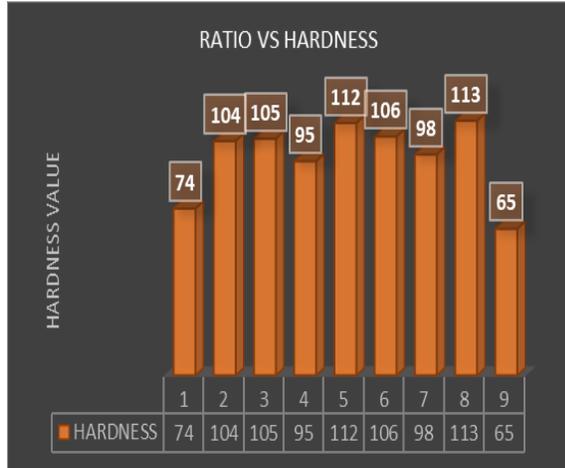


Figure: 1.4 Hardness strength graph

The ninth sample exhibited a minimum value of -65 HRM during this hardness inspection. The maximum speed and tool traverse and medium tool tilt angle induces minimum hardness of UHMWPE during FSW process.

TENSILE TEST & ELONGATION

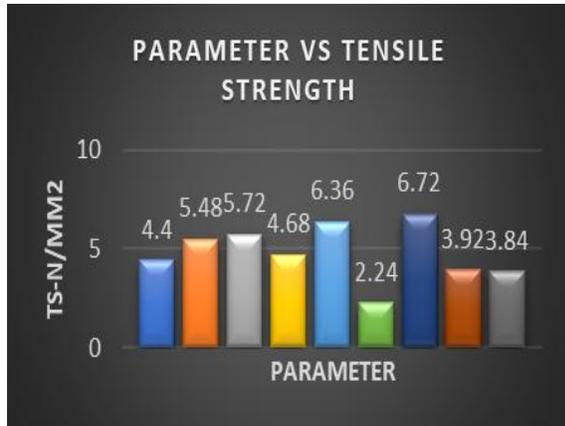


Figure: 1.5 Tensile strength graph

The FIE-600KN equipment was used to test the UHMWPE tensile specimen after welding. The seventh sample in this tensile test had a higher tensile strength of 6.72 N/mm<sup>2</sup>.

ANGLE DISTORTION

Angle distortion is common problem in welding, including friction stir welding (FSW) that can cause the welded parts to change angle. With the help of AUTOCAD software measured angle distortion.

Table:1.3 Angle Distortion

NO OF PLATES	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	6 <sup>th</sup>	7 <sup>th</sup>	8 <sup>th</sup>	9 <sup>th</sup>
ANGLE DISTORTION	0.611°	0.932°	0.817°	0.970°	0.873°	0.870°	1.055°	0.688°	1.154°

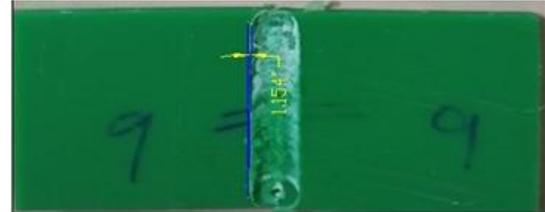


Figure: 1.6 Angle Distortion plate

According to the angle distortion analysis, test plate 9 exhibited the highest angle deviation. High angle distortion of the bead is caused by the maximum speed and tool traverse. Straight weld bead achieved minimum level of all parameters during the FSW process.

DEPTH OF PENETRATION

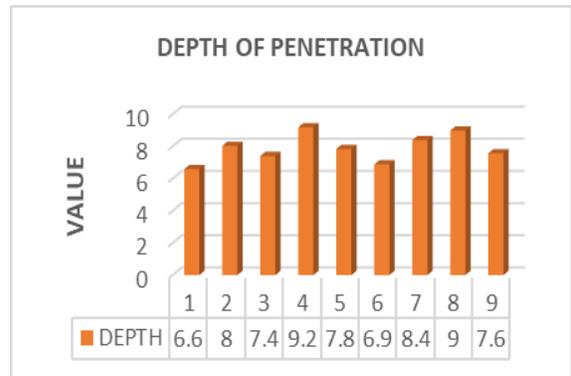


Figure:1.7 Depth of penetration

Through IMAGE-J software depth of penetration and bead width were evaluated found during this investigation nominal bead width and maximum depth obtained sample no 4. (Width -17.944 mm / depth-9.177 mm).

RADIOGRAPHY TEST

When test plate 7th was inspected, the radiographic analysis confirmed that there were no cracks, voids, or discontinuities on the internal weld area. On UHMWPE materials, higher speed, a lesser tool

traverse, and a tilt angle accomplished a weld free of defects.

## V CONCLUSION

1. During this hardness test, the ninth sample showed a minimum value of -65 HRM. The minimum hardness of UHMWPE is induced during the FSW process by the maximum speed, tool traverse, and medium tool tilt angle.
2. After welding, the UHMWPE tensile specimen was tested using the FIE-600KN equipment. In this tensile test, the seventh sample exhibited a greater tensile strength of 6.72 N/mm<sup>2</sup>.
3. Test plate 9 had the most angle deviation, according to the angle distortion investigation. The maximum speed and tool traverse cause the bead to be distorted at high angles. During the FSW process, the straight weld bead achieved the minimum level of all parameters.
4. During this experiment, the nominal bead width and maximum depth obtained from sample number four were assessed using the IMAGE-J software. (Depth: 9.177 mm; width: -17.944 mm).
5. Based on the final bead appearance, the seventh test plate looks to have a very fine texture, no porosity, and no cracks.
6. While inspecting test plate no 7, the radiography examination verified that the internal weld area was free of fractures, voids, and discontinuities. Higher speed, less tool travel, and a tilt angle produced a defect-free weld on UHMWPE materials.

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