# EFFECT OF FRICTION STIR WELDING PROCESS PARAMETERS ON POLYMER WELD

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***Abstract: High Density Polyethylene is one of the thermoplastic materials used in the lot of engineering applications such as manufacturing of pipes, bottles, doors, toys and etc. Friction Stir Welding (FSW) is a solid-state method of used for joining metals. FSW process was successfully extensive to join thermoplastic materials. In this paper an effort has been made to be aware of the method of friction stir welding joints of HDPE with filler minerals plates. The effects of important process parameters such as tool pin geometry, tool rotational speed, and work linear speed on tensile strength were investigated experimentally. Different tool pin geometries were used to find their effects on weld strength. Using the tool pin which produced the most excellent weld quality, the effects of other process parameters on weld quality were also investigated. The results indicated that tool pin geometry had a significant influence on weld strength.***
***Keywords: Friction stir welding, HDPE Sheets with filler minerals, tensile strength***

## I. INTRODUCTION

Friction stir welding which performance is very high for fatigue life and strength of the material joints. The welding of materials takes place during solid state with the help of a non-consumable tool. [1-2] It is a solid-state joining process which welds the materials whose characteristics must remain unchanged as far as possible. **Zoltán Kiss** et al. (2007)[3] studied applicability of friction stir welding in Polymeric materials. He analyzed joint strength in terms of rotation and translation speed. It has been verified that in addition to the careful selection of welding parameters the proper construction of the welding tool is also very important**. Zoltán Kiss**. et al. (2009)[4] worked on Friction Stir Welding of Fiber Reinforced Polymer Composites. Degree of fragmentation played an important role in the applicability of the FSW technology to glass fiber reinforced composites. In cases when the fiber length in the composite sheets to be welded is higher, it is expected that the average fiber length in the seam will also be higher, resulting in stronger joint. **Yahya Bozkurt** et al (2012)[5] studied the optimization of friction stir welding process parameters to achieve maximum tensile strength in polyethylene sheets.conslusion from study that the tool rotation speed plays an important role and contributes 73.85% to the overall welding parameters. The tilt angle was found to be the least contribution welding parameter. **Ehsan Azarsa** et al.(2014)[6] worked on flexural behavior of friction stir welded high density polyethylene sheets. It was found that welding at ahigh level of rotational speed and a lower level of tool travel speed increases weld flexural strength by reducing size of defects. Considering the research works done onpp composites, it is observed that a serious lack of published report regarding their weldability by FSW exists. Due to this, in the present research work, a study is carried out to assess FSW of HDPE with filler minerals. The effects of several FSW parameters such as tool pin geometry, tool rotational speed, work linear speed on tensile strength of this work material are also investigated.

## II. MATERIALS AND METHODS

### *A. Parent material*

HDPE plates with 4% filler minerals and 200 mm × 75 mm × 5 mm size with characteristics given in Table1 were used as a raw material.

| Polyethylene | Filler minerals(%) | Density($g/cm^3$) | Yield Strength(MPa) | Ultimate strength (Mpa) |
|---|---|---|---|---|
| High Density | 4 | 0.95 | 24-37 | 55 |

Table-1

### *B. FSW tools*

The rotating tools were made of En-8 steel. In order to study the tool geometry effect on strength, three different friction stir tools with different pins were used and experiments conducted. Details of these tools are shown in Figure 1 and Table 2. The shoulder diameter and pin length of the tools were 20 and 4.6 mm, respectively as dictated by thickness of plates


Fig. 1. Details of tools

| Tool # | Description of pin geometry | Diameter of pin (mm) |
|---|---|---|
| 1 | Cylindrical | 6 |
| 2 | Threaded cylindrical | 6 |
| 3 | Triangular | 6 |

Table-2

*C. Welding procedure*

The plates were welded on a vertical milling machine along their length after fixing them in a proper position using mechanical clamps. This research work was carried out in two stages. In the first stage, tools with different pin geometries and their effects on weld strength were studied to select the tool which produces better welds. For this phase of the work, a number of trial runs were conducted and the tool rotational and work linear speed were selected to be 1000, 40 mm/min. respectively. In the second stage, the selected tool was used to carry out extra trial runs to establish range of FSW parameters given in Table 3 to investigate the effects of other process parameters (tool rotational speed, work linear speed) on weld tensile strength.

| Plate thickness **t(mm)** | Rotation of tool (RPM) **N** | Welding speed (mm/min) **S** | Shoulder diameter*length **D*L(mm)** | Pin diameter **d(mm)** | Pin length **l(mm)** | Pin profile of tool |
|---|---|---|---|---|---|---|
| 5 | 1000 | 40 | 20×35 | 6 | 4.6 | Cylindrical |
| | 1000 | 40 | | | | Cylindrical threded |
| | 1000 | 40 | | | | Triangular |
| | 720 | 28 | | | | Cylindrical |
| | 1000 | 28 | | | | Cylindrical |
| | 1400 | 28 | | | | Cylindrical |
| | 720 | 14 | | | | Cylindrical |
| | 720 | 40 | | | | Cylindrical |
| | 720 | 56 | | | | Cylindrical |

Table-3

*D. Tensile test specimen preparation*

The tensile test specimens whose dimensions are given in Figure 2.

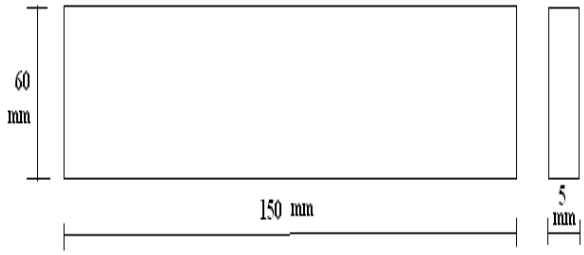


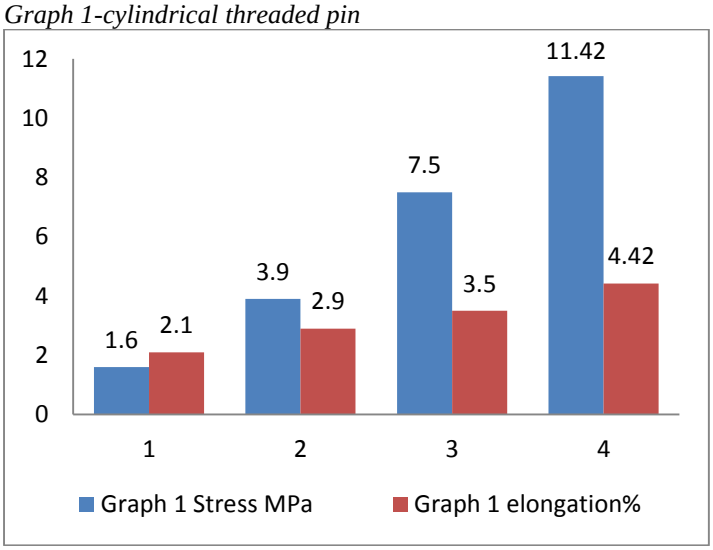

Fig. 2. Dimensions of tensile test specimen

## III. RESULTS AND DISCUSSION

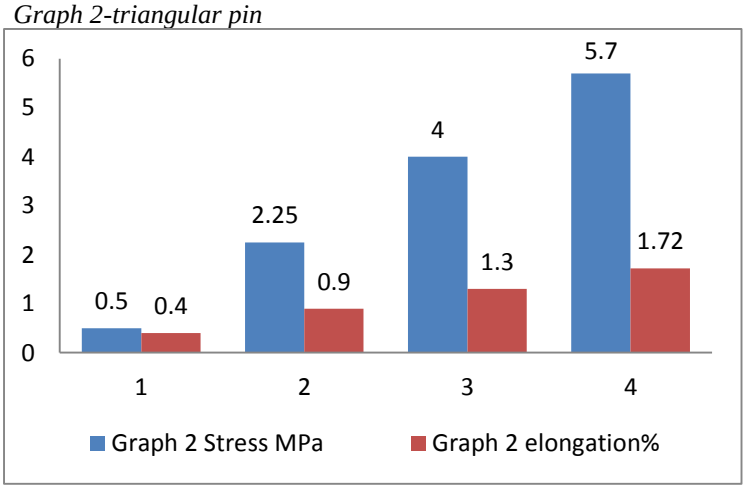
*A. Effect of tool geometry on tensile strength*

The effects of different tool pin geometries on tensile strength of friction stir welds are compared with the help of stress-elongation charts which are shown in Figures.

*Graph 1-cylindrical threaded pin*

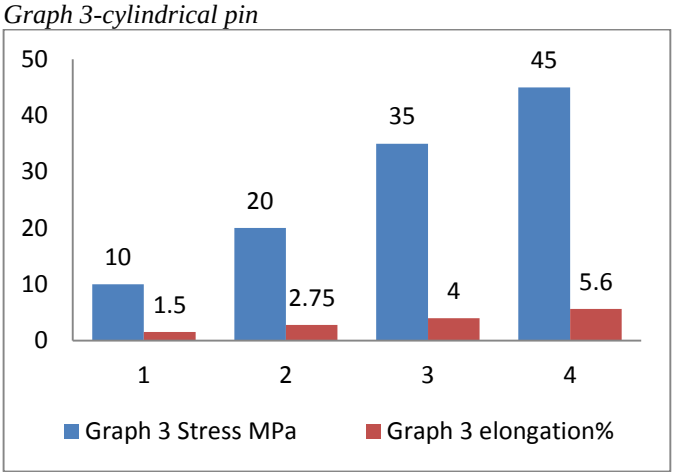



*Graph 2-triangular pin*



*Graph 3-cylindrical pin*




Graphs show that the UTS of the weld made by tool # 1 is about 45 MPa which is almost 80% of the UTS of the parent HDPE. Welds produced by other tools were much weaker in strength than the weld produced by tool #1. The same argument mentioned earlier for better weld surface appearance when welding with tool #1 could also be one of the reasons for higher tensile strength of welds with this tool.

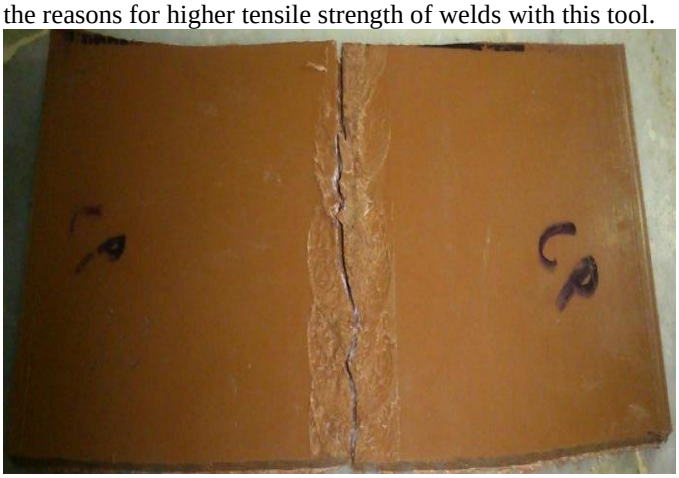


Fig. 3. The tensile test fractured specimen

*B. Effect of process parameters on tensile strength*

In order to study the welding process parameters effects on tensile strength of the joints, tool # 1 which produced better welds was used. With the rotational speed of 710 rev./min, the wormhole phenomenon at the retreating side of the weld due to insufficient frictional heat generation and insufficient matrix transportation which is reported by Lakshminarayanan and Balasubramanian (2008)[7], may be the reason for lower strength of the joint. The lower strength of the joint with the rotational speed of 1400 rev. /min., can be a result of the tunnel defect formed. The formation of this defect may be attributed to excessive turbulence of the weld caused by high tool rotational speed. Therefore, with the rotational speed of 1000 rev./min., a just sufficient amount of frictional heat is generated which with proper turbulence of the weld results in the highest tensile strength. When the linear speed is increased from 14 to 56 mm/min., the tensile strength decreases continuously. The excessive heat input per unit length of the weld at higher linear speeds and inadequate flow of the matrix which may cause tunnel defect could be the factors contributing to lower strength of the joints at higher linear speeds.

## IV. CONCLUSIONS

In this paper, HDPE plates with 4% filler minerals were welded using FSW process. The effect of tool pin geometry on tensile strength was first investigated experimentally to select a proper tool design to produce quality welds. The effects of tool rotational speed, work linear speed on tensile strength of the welds were also studied. The results indicated that:

- Although the tensile strength of the welded specimens was about 45MPa which is almost 80 % that of the base plate, the FSW process can be employed to weld HDPE plates with 4% filler minerals. Further research is recommended in this respect.
- The tool pin geometry had a significant effect on weld appearance and tensile strength.
- Increasing the tool rotational speed had an increasing and then a decreasing effect on weld tensile strength. The tool rotational speed of 1000 rev. /min. produced the strongest weld.
- Increasing the work linear speed from 14 to 56 mm/min.had a decreasing effect on tensile strength.

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