THERMAL STRESS ANALYSIS OF FSW PROCESS ON UHMWPE BY USING TRIANGULAR TOOL PROFILE

Manoj M[1], Dr.Subburam V[2], Sathees T[3]

[1]*PG Student, Department of Mechanical Engineering, Paavai Engineering College, Namakkal, India*
[2]*Assistant professor, Department of Mechanical Engineering, Paavai Engineering College, Namakkal, India*
[3]*Assistant professor, Department of Mechanical Engineering, Paavai Engineering College, Namakkal, India*

---***---

Abstract - *In the age of rapid industrialization, a light-weighted product having high performance characteristics is the major concern for any manufacturer, and in the current scenario, thermoplastics are serving as one of the light-weight materials in various manufacturing sectors. The aim of this study is to predict the tool stress during the FSW process on* ***UHMWPE.*** *Ultra-High Molecular Weight Polyethylene is an extremely tough, abrasion-resistant, low-cost plastic, used for a wide range of wear applications. According to the 3D-DEFORM the result shows during the slow speed process affecting temperate is higher than the high-speed operation. During the medium speed operation strain rate and percentage of tool damage is highly compared than other speed. Based on the 3D –Deformation analysis found minimum temperature, strain rate and tool damage occurred on 9th sample. 3D –Deformation analysis satisfied result obtained during maximum speed (1500RPM), maximum Tool Traverse (25mm/min) and medium level of Axial Force (9KN).*

Key Words: *FSW,UHMWPE, HDPE, Tool Steel, Speed, Axial Force*

1.INTRODUCTION

Friction stir welding (FSW) is an innovative solid-state joining process invented in the 1990s by The Welding Institute in the United Kingdom (UK). It is considered as one of the most significant welding process inventions in the last two decades. Compared to other solid-state joining processes such as rotary friction welding and inertial welding, the FSW process is unique in that it enables the advantages of solid-state joining for fabrication of continuous linear welds, the most common form of weld joint configurations that are predominately made by the arc welding processes in today's i.

The basic principles of FSW process are illustrated in Figure 2. The specially designed tool has two essential parts. The first part is the profiled pin extending along the rotating axis. The second part is the shoulder. Rotating at high angular speeds, the pin plunges into the work piece until the shoulder makes full contact with work piece surfaces. The rotating tool then moves along the joint line with the shoulder fully in contact with the work piece surface under a relatively high axial forging force. Owning to largely the frictional heating between the rotating tool and the work piece, the temperature in a column of work piece material under the tool is increased substantially, but remains below the melting point of the material. The increase in temperature softens the material, and allows the rotating tool to mechanically stir the softened material flowing to the backside of the pin where it is consolidated to form a metallurgical bond. FSW creates a weld joint without bulk melting. Compared to the widely used fusion welding processes (e.g. arc welding, laser welding), an inherent advantage of FSW is that it is immune to the defects and property deteriorations associated with solidification. Solidification cracking, porosity, and melting and coarsening of strengthening phases are eliminated in FSW. FSW is a "green" technology due to its energy efficiency, environment friendliness, and versatility. As compared to the conventional welding methods, FSW consumes considerably less energy. Also, because it is solid state, no harmful emissions are created, thereby making the process environmentally friendly.

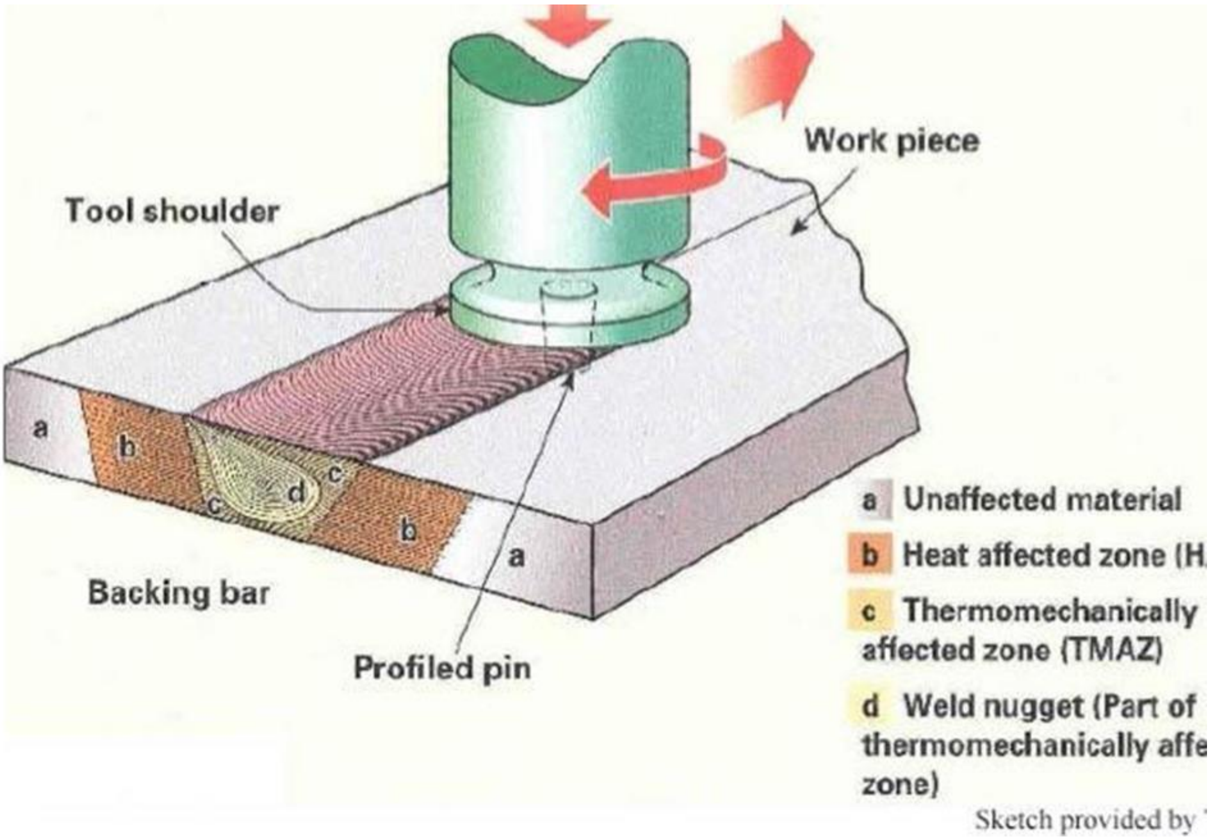


Fig: 1.1 Principles of FSW Process

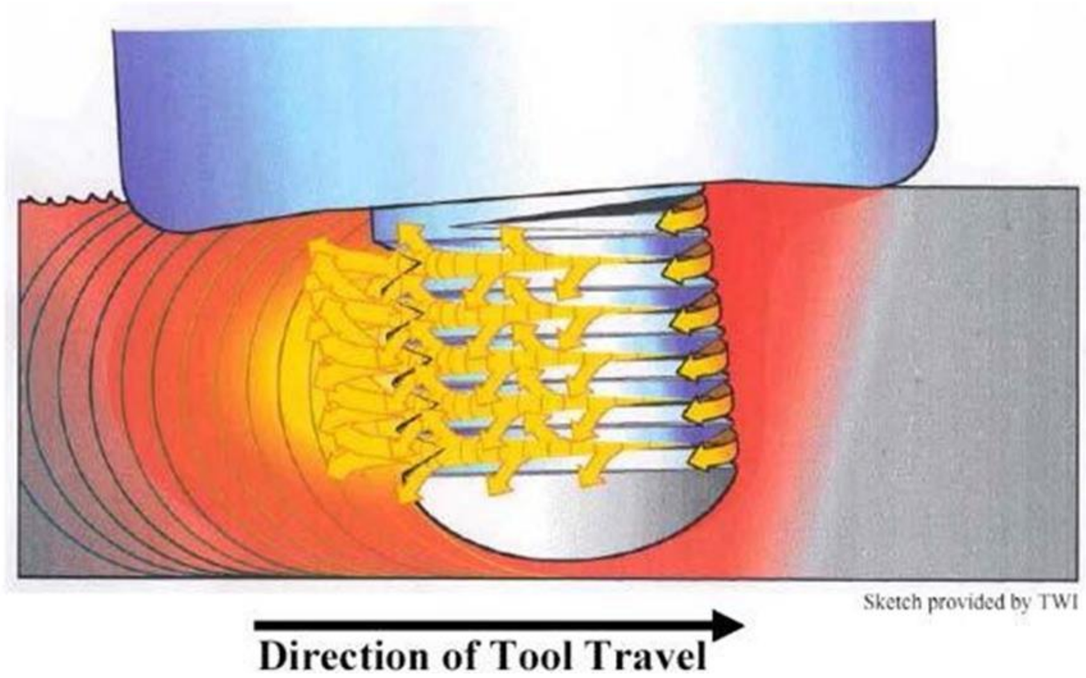


Figure: 1.2. Friction Stir Welding Process

2 . OBJECTIVES

For this research, the objectives that are tried to achieve by the researcher are:

1. To get optimum parameters for the materials under considerations i.e.,UHMWPE.

2. To investigate the Various Mechanical behaviors

3. Defects occurring during the welding process

SCOP OF STUDY

The focus of the research work will be concentrated in the mechanical performance and the stir zone microstructure by FSW butt welded part having 100mm × 100mm × 8 mm thick sheet UHMWPE using constant pin diameters. All the testing of welded part will be tested by ASTM standard. Triangular pin tool will used to conduct experiments.

In this research, Universal Testing Machine (UTM), Hardness testing machine (Bead Geometry Analysis) will also be used to measure the. Friction stir processing is a method of changing the properties of a metal through intense, localized plastic deformation.

3 . FRICTION STIR WELDING

Friction Stir Welding (FSW) is considered to be the most significant development in metal joining in a decade and is a "green" technology due to its energy efficiency, environment friendliness and versatility (Mishra and Ma, 2005).

As compared to the conventional welding methods, FSW consumes considerably less energy. No cover gas or flux is used, thereby making the process environmentally friendly.

The joining, does not involve any use of filler metal and therefore any aluminum alloy can be joined without concern for the compatibility of composition, which is an issue in fusion welding. When desirable, dissimilar aluminum alloys and composites can be joined with equal ease.

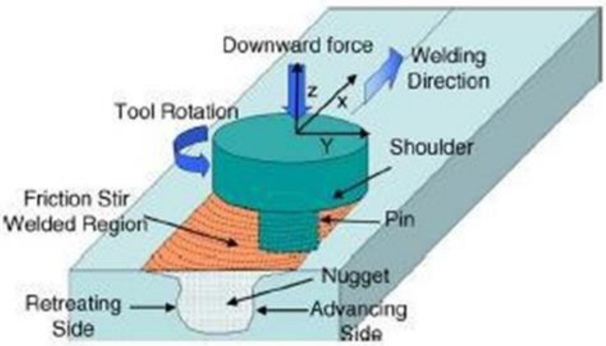


Figure 3.1: Schematic diagram of friction stir welding

COMPARISON OF FIRCTION STIR WELDING TO OTHER WELDING PROCESSES

Comparison of FSW to other welding processes is typically done within the context of justifying the use of the process over other, more conventional techniques. Successful application of FSW depends upon a clear misunderstanding of the characteristics of the process, so favorable technical and economic justification can be developed. The unique, favorable characteristics of FSW compared to traditional arc welding methods provide several sources for technical justification for use of the process.

The main points for technical justification of FSW compared to arc welding processes are:

1. Improved weld ability
2. Reduced distortion
3. Reduced residual stress, improved fatigue, corrosion, and stress corrosioncracking performance
4. Improved cosmetic performance
5. Elimination of under matched filler metal improved static strength andductility & mechanized process.

WELDING TOOLS AND PARAMETERS

WELDING TOOL

Many of the advanced made in friction stir welding have been enabled by the development of new welding tools. The welding tool design, including both its geometry and the material from which it is made, is critical to the successful use of the process. The uniformity of microstructure and properties as well as process loads is governed by the tool design. Generally, a concave shoulder and triangular cylindrical pins are used.

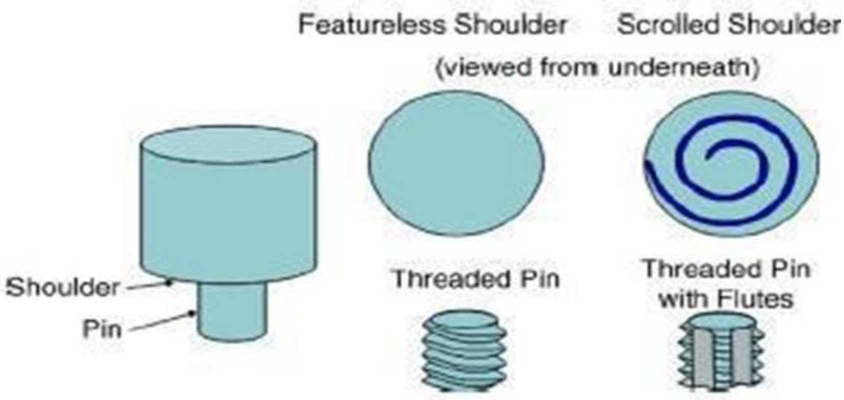


Figure 3.2: Schematic drawing of the FSW tool

WELDING PARAMETERS

With the general principles of the effect of process variables on the friction stir welding process have much in common with other welding processes, the details are completely different, as one might expect.

4 .LITERATURE REVIEW

N. Mendes [1] et.al were studied the tool rotational speed which varied between 1000 and 1500 (rpm); the traverse speed which varied between 50 and 200 (mm/min), and the axial force ranging from 0.75 to 4 (kN). The major novelty is to study the influence of the parameter axial force on FSW of polymers. Produced welds have always a tensile strength below the base material, reachingthe maximum efficiencies of above 60 (%) for welds made with higher rotational speed and axial force. Good quality welds are achieved without using external heating, when the tool rotational speed and axial force are above a certain threshold. Above that threshold the formation of cavities and porosity in the retreating side of the stir zone is avoided and the weld region is very uniform and smooth. For low rotational speed and axial force welds have poor material mixing at the retreating side and voids at the nugget. For this reason thestrain at break of these welded plates is low when compared with that of base material.

Armag An Arici [2] et.al were research work focused on the need to produce larger, more complex parts from polymers has created an increased need for joining, particularly thermoplastics. Injection moulding has led to increased use for disposable products because the plastic parts can be made inexpensively and in high volume. However, injection moulding is not capable of producing all type of structures and the most cost effective way to make them will often involve moulding two or more parts and joining them together. Mechanical fasteners, adhesives, and welding processes can all be employed to form joints between engineering plastics Adhesives can provide good properties and fully sound joints, but they are difficult to handle and slow to cure.

Also joint preparation and surface cleanliness need to be given importance in adhesive bonding. Mechanical fasteners can join two components quickly, but they do not provide a leak tight joint, and the localized stresses may cause them to pull free of the polymeric material.

SACHIN GHALME [3] et.al was five samples of Si3N4–hBN are evaluated against alumina for its wear performance. The results of the experiments along with S/N ratios are presented and Taguchi method is a suitable technique in the field of process parameter optimization and experimental analysis. They found that 15 N load and 8 % HBN in Si3N4 is suitable to minimize its wear loss against alumina counter face.

Yahya Bozkurt [4] et.al was presented the weld strength of thermoplastics, such as high density polyethylene and polypropylene sheets are influenced by friction stir welding parameters. The determination of the welding parameters plays an important role for the weld strength. For the influential use of the thermoplastics joints, the weld should have adequate strength. The quality of thejoint was evaluated by examining the characteristics of the joint efficiency as a result of ultimate tensile strength. In this study, the Taguchi approach of parameter design was used as a statistical design of experiment technique to set the optimal welding parameters. The experiments were arranged by using Taguchi’s L9 orthogonal array.

5 . TOOL DETAILS

TOOLS IN FSW

The photographic view of the important parts of FSW tools. Frictional & deformation heat is created due to the contact of the pin with the work piece and this heat softens the work piece material. The contact of shoulder with the work pieces increases the heating action, and leads to the expansion of softened material zone and thereby constraining the deformed material. The tool design influences the heat generation, plastic flow, the power required and the uniformity of the welded joint. The pin profile has a greater input on the material flow during FSW and it regulates the FSW speed. The shoulder performs the function of generating most of the heat and also prevents the plasticized material from escaping the work piece surface. So, the two important fields of tool design include selection of appropriate tool material, tool geometry and tool type.

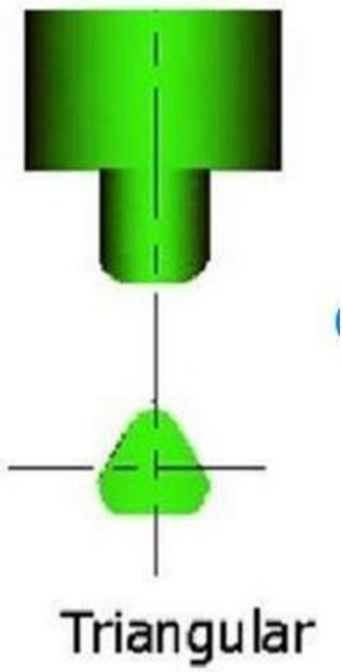


Fig 5.1 Diagrammatic view of parts of FSW tool

OBJECTIVE OF THE PRESENT WORK

In this study, the effect of the presence of various parameters with Triangular profile tool welded with friction stir processing UHMWPE plates is documented.

Friction stir welded UHMWPE plates have to be evaluated by using through macro test. The tests were conducted as per the statistical procedure andthe results were correlated of the tested weld samples with triangular tool.

FLOWCHART

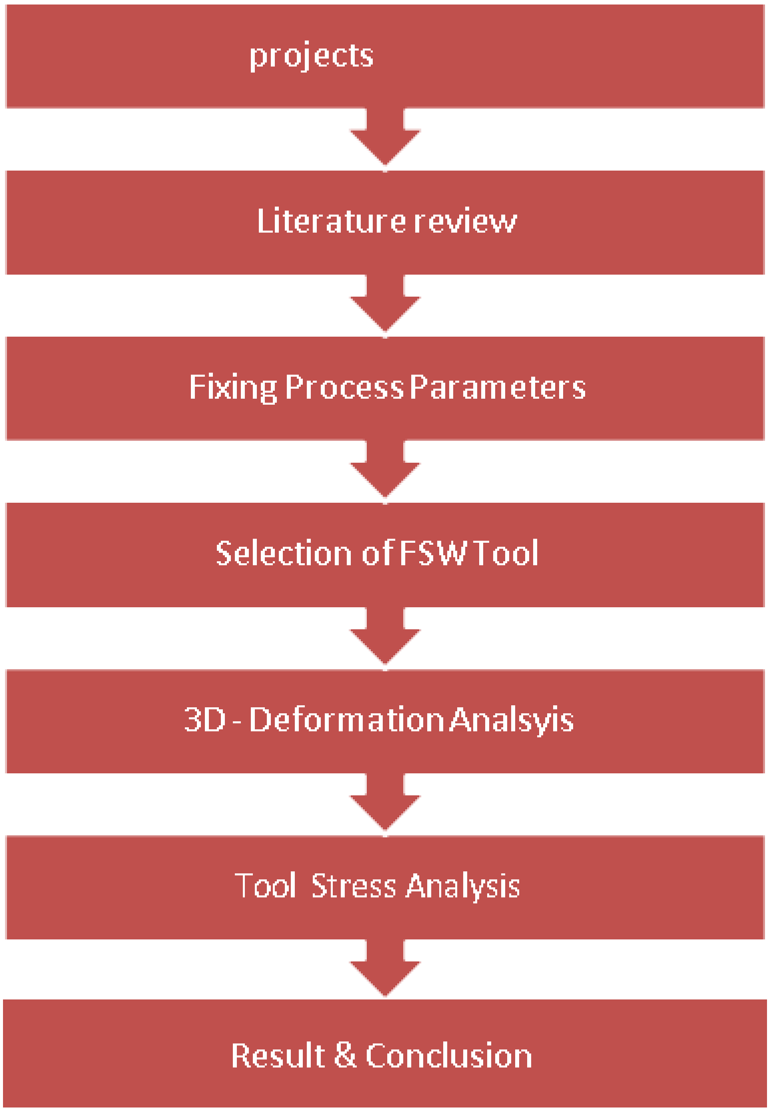


Fig.5.2 Flowchart

SELECTION OF TOOL SHOULDER DIAMETER-UHMWPE was used as base metal to perform friction stir welding in this study. The prepared samples to be welded using triangular profile tools with 6mm with shoulder diameters 18mm.

Fig. 5.3 Triangular tool pin profile

6 . FEA ANALYSIS

1 Levels and ranges of FSW process parameters Taguchi method L_9Factor

S.NO	SPEED RPM	TOOL-TR Mm/min	AXFC KN
1	1300	15	8
2	1400	20	9
3	1500	25	10

FEA INTRODUCTION

Finite element method (FEM) was applied in machining more than thirty years ago. The DEFORM system is engineering software that enables designers to analyze metal forming, heat treatment, machining and mechanical joining processes on the computer rather than the shop floor using trial and error. Process simulation using DEFORM has been instrumental in cost, quality and delivery improvements at leading companies for two decades. Today's competitive pressures require companies to take advantage of every tool at their disposal. DEFORM has proven itself to be extremely effective in a wide range of research and industrial applications.

7 . CAD GEOMETRY

The gear geometry generated from Auto Cad is imported in to DEFORMWorkbench through Design Model.

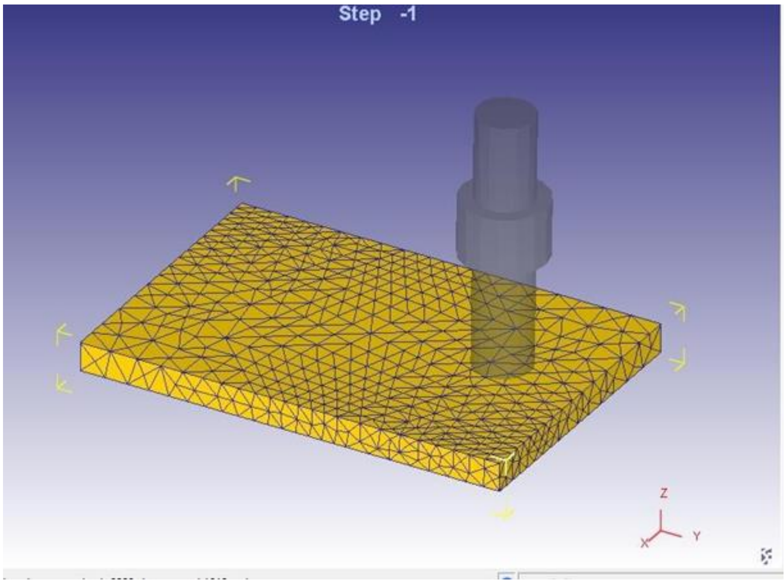


Fig: 7.1 FSW Tool & Plate Mesh of Triangular Pin

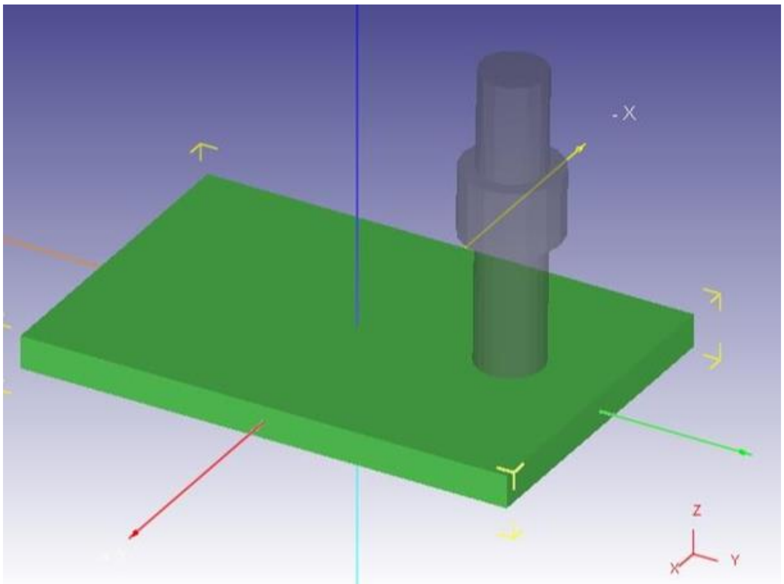
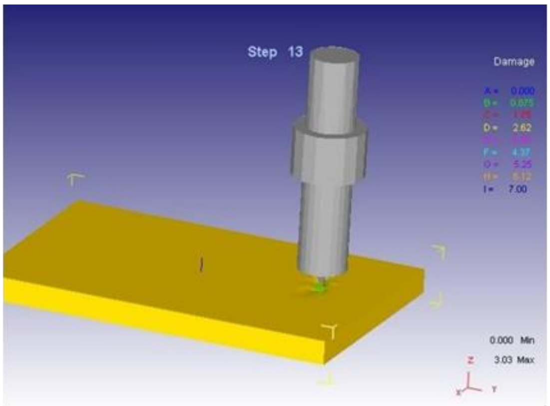
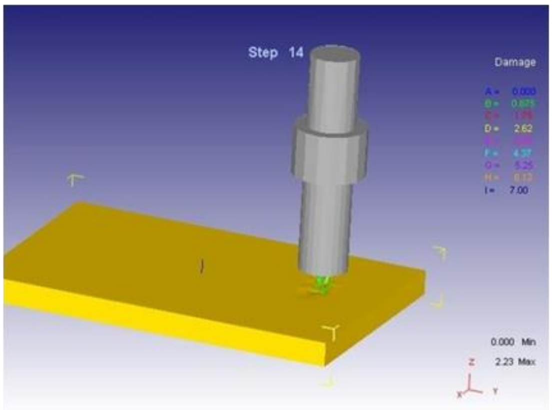
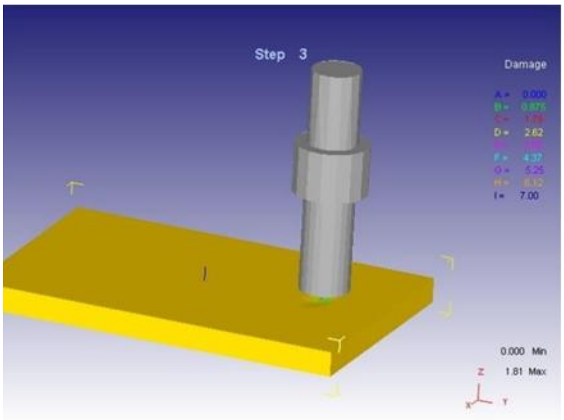


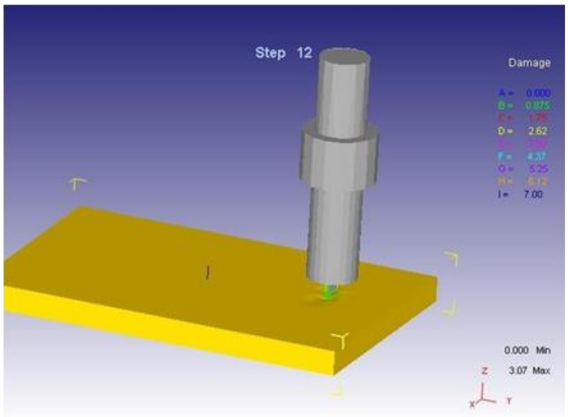
Fig: 7.2 FSW Tool & Plate Model of Triangular Pin

DAMAGE ANALYSIS









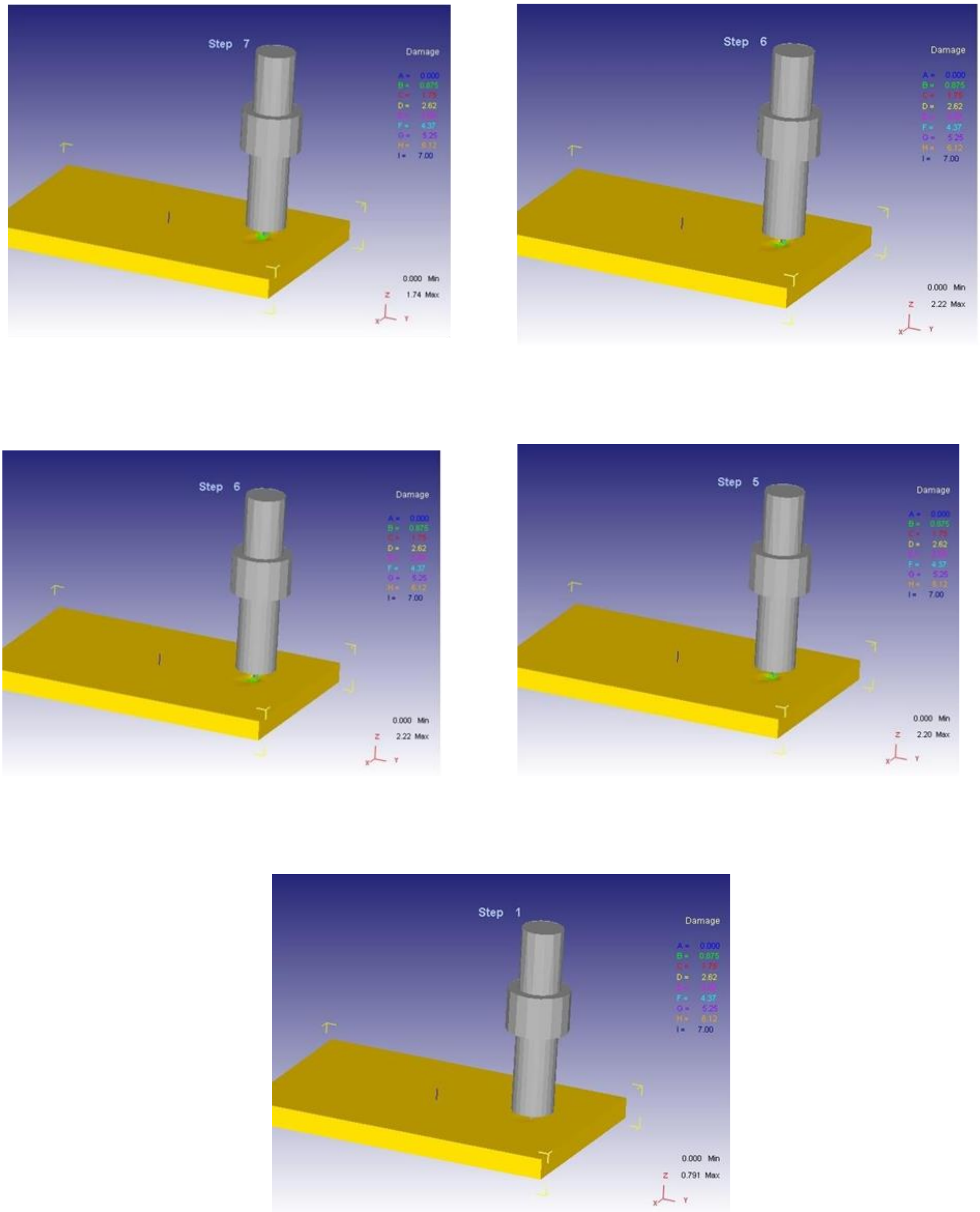
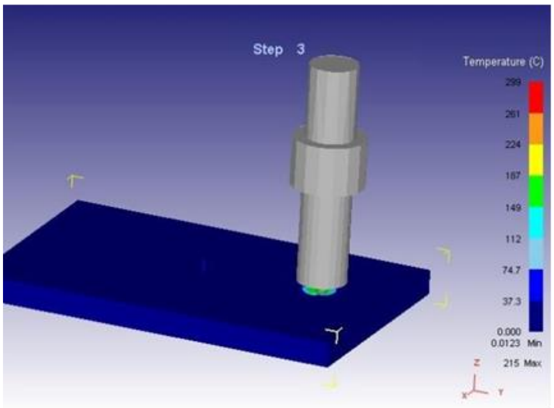
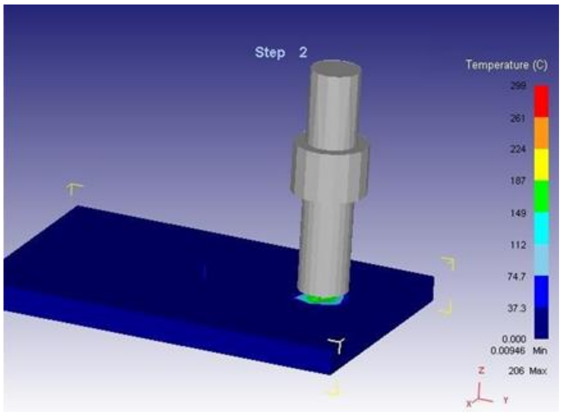
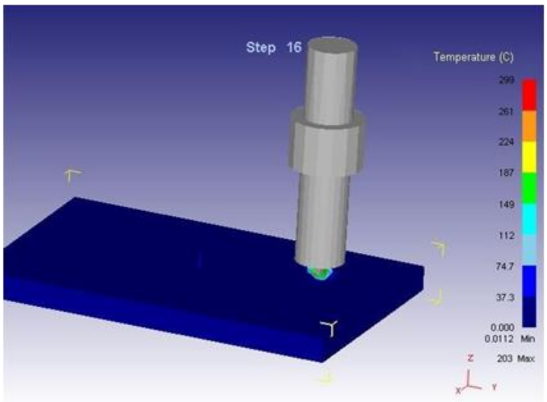


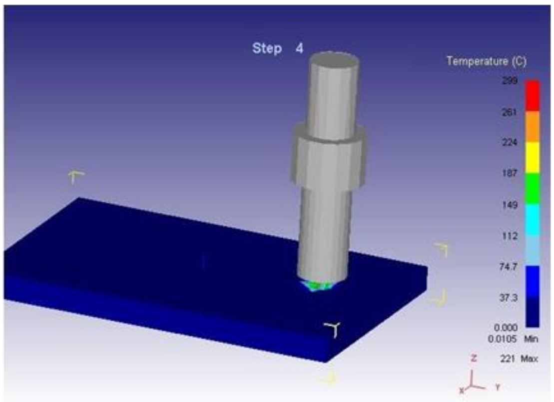
Fig: 7.3 % of Damage Analysis of Triangular Pin

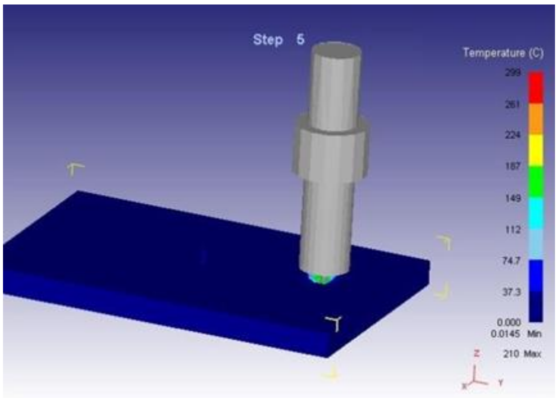
8. TEMPERATURE ANALYSIS

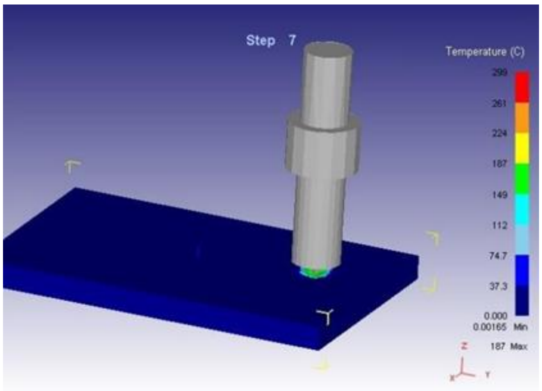


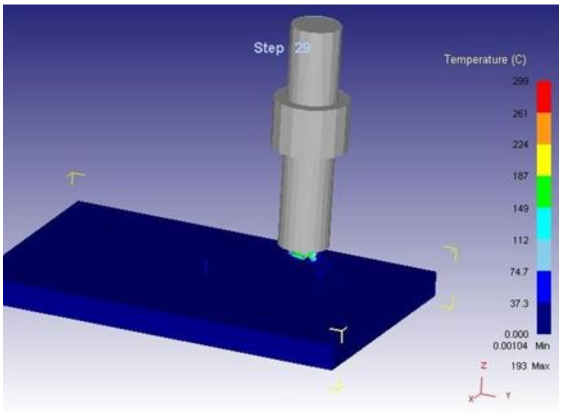


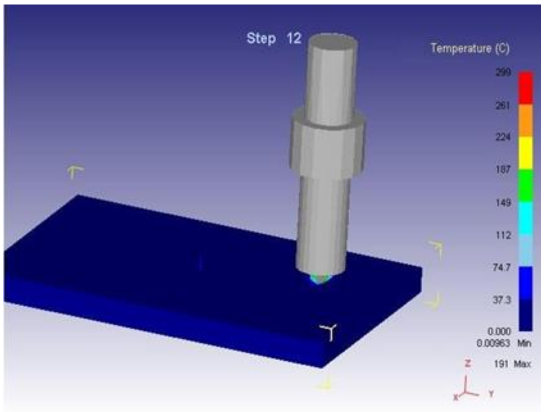












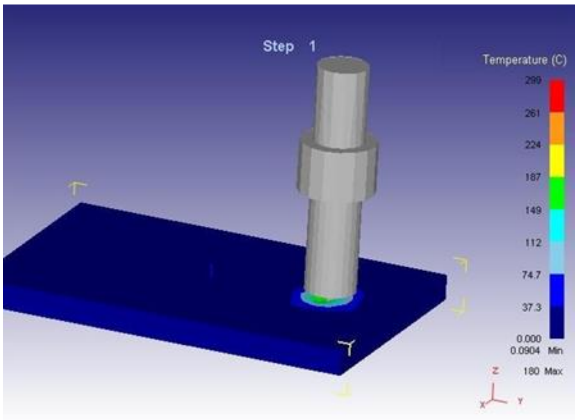


Fig: 8.1 Temperature Analysis of Triangular Pin

Table 8.2 Experimental input and DEFORM Results output of FSW process

S.NO	PEEDRPM	TOOL-TR mm/min	XFCKN	TEMP (^{0}C)	STRAIN	DAMAGE %
1	1300	15	8	215	2.36	3.03
2	1300	20	9	206	1.27	2.23
3	1300	25	10	203	1.54	1.81
4	1400	15	9	221	2.36	3.07
5	1400	20	10	210	2.07	2.62
6	1400	25	8	187	1.03	1.74
7	1500	15	10	193	1.83	2.22
8	1500	20	8	191	1.80	2.20
9	1500	25	9	180	0.848	0.791

9. RESULT AND CONCLUSION

The UHMWPE were analyzed through 3D –Deformation analysis with various parameters like speed, tool traverse and axial force. Friction sir weld of UHMWPE plates were executed with Triangular profile tool. The parameter hasdesigned through Taguchi design L_9 array. Tool interaction temperature strain rate and percentage of damage evaluated through 3D –Deformation analysis. Increase of rotational speed leads to decrease of interaction Temperature between the tool and the specimen while FSW process. Similarity, the effect of feed rate reduction influencing on welding Temperature. According to the 3D- DEFORM the result shows during the slow speed process affecting temperate is higher than the high-speed operation. During the medium speed operation strain rate and percentage of tool damage is high compared than other speed. Based on the 3D –Deformation analysis found minimum temperature, strain rate and tool damage occurred on 9th sample. 3D –Deformation analysis satisfied result obtained during maximum speed (1500RPM), maximum Tool Traverse (25mm/min) and medium level of Axial Force (9KN).

10. REFERENCES

1. **N. Mendes** Effect of friction stir welding parameters on morphology and strength of acrylonitrile butadiene styrene plate welds Materials and Design 58 (2014) 457–464
2. **ARMAGˇ ARICI Effects** of double passes of the tool on friction stir welding of polyethylene JOURNAL OF MATERIALS SCIENCE 40 (2005) 3313 – 3316
3. **M. K. Bilici** Effect of tool geometry on friction stir spot welding of polypropylene sheets Express Polymer Letters Vol.6, No.10 (2012) 805–813
4. **Yahya Bozkurt** The optimization of friction stir welding process parameters to achieve maximum tensile strength in polyethylene sheets Materials and Design 35 (2012) 440–445
5. **Imad M. Husain,** Mechanical properties of friction-stir-welded polyamide sheets International Journal of Mechanical and Materials Engineering (2015) 10:18 DOI 10.1186/s40712-015-0047-6
6. **Arvin Bagheri,** An experimental study on mechanical properties of friction stir welded ABS sheets Materials and Design 43 (2013) 402–409
7. **K. Panneerselvam** Effects and Defects of the Polypropylene Plate for Different Parameters in Friction Stir Welding Process International Journal of Engineering Research & Technology (IJERT) ISSN: 2319 - 1163
8. **K. Lenin** Joining of Nylon 6 plate by friction stir welding process using triangular pin profile materials and Design 53 (2014) 302–307
9. **K. Panneerselvam** Investigation on Effect of Tool Forces and Joint Defects during FSW of Polypropylene Plate Procedia Engineering 38 (2012) 3927-3940
10. **A. Zafar** Investigating Friction Stir Welding on Thick Nylon 6 Plates 210-sWelding Journal / June 2016, Vol. 95