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# OPTIMIZATION OF THE PARAMETERS IN WELDING OF PLASTICS USING FRICTION WELDING

**Shubham Jain[1], Shashank Singh[2], Saransh Tiwari[3], Anoop Pandey[4]**

*[1,2,3] Student B.Tech,[4] Sr. Assistant Professor, Department of Mechanical Engineering,*
*ABES Engineering College, (India)*

## ABSTRACT

*This paper is the part of study that aims at optimization of process parameters of tensile strength for PE-100 plasticswhich is widely used foe potable water transportation system using Taguchi approach. Nine cylindrical bars of PE-100 plastics of outer diameter 30mm are welded through friction in each experiment for different spindle speeds. Revolutions per minute of rotor, weld time, axial force are taken as the process parameters. A Taguchi orthogonal array is designed with three levels of parameters and analysis of S/N ratios, response table and regression equations were made with the help of Minitab 17 software. Analysis showed that weld time plays a pivotal role in the strength of the weldment.*

***Keywords: DOE, PE-100,S/N Ratio, Taguchi Method etc.***

## I. INTRODUCTION

Friction welding (FW) is a fairly recent technique that utilizes a non-consumable welding tool to generate frictional heat and plastic deformation at the welding location, there by affecting the formation of a joint while the material is in solid state. Friction welding is used with metals and thermoplastics in a wide variety specifically in aviation and automotive applications[1]. This is particularly useful in water and gas pipeline for a leak proof joint of high density polyethylene pipes as per PE 100+ association.

Attaining optimum tensile strength in the presence of constraints like blow off length and economics of joining of plastics is one of the challenging tasks encountered by many growing industries these days. Taguchi method can help in optimizing these parameters taking into consideration of economy[2].

For tensile strength, the solution is "larger is better" and S/N ratio (signal to noise ratio) is determined by the following equation:

$$S/N = -10 *\log(\Sigma(1/Y2)/n) \qquad (1)$$

Where n = No. of Measurements, y = Measured Value which is in MPa.

In this experiment, 3 parameters are chosen having 3 levels. Without using Taguchi method total number of experiments should be $3^3$=27 numbers. But using Taguchi L9 array as shown in table 1, 9 experiments are proposed providing nearly same accuracy. These nine experiments will give 98% accurate result. By using this method number of experiments are reduced to 9 instead of 27 with almost same accuracy.

**Table 1: Design of Experiment**

| S.NO. | TIME (SEC) | F (N) | RPM |
|---|---|---|---|
| 1 | 50 | 28.72 | 1490 |
| 2 | 50 | 25.80 | 1440 |
| 3 | 50 | 9.81 | 1410 |
| 4 | 40 | 25.80 | 1490 |
| 5 | 40 | 9.81 | 1440 |
| 6 | 40 | 28.72 | 1410 |
| 7 | 30 | 9.81 | 1490 |
| 8 | 30 | 28.72 | 1440 |
| 9 | 30 | 25.80 | 1410 |

## II. EXPERIMENTAL SET UP DETAILS

Animage of setup used for producing required welds is shown in figure 1.

**Fig. 1: Welding Setup**

### 2.1 Work Material

PE-100 is a High Density Polyethylene plastics having Hydrostatic strength of 10MPa. Table2 shows the mechanical and thermal properties of PE-100.

**Table 2: Mechanical and Thermal properties of PE-100**

| S.No | Parameters | Standard |
|---|---|---|
| 1 | Density, kg/cm$^3$<br>at 23 °C<br>at 20 °C | 954-960<br>956-962 |

| | | |
|---|---|---|
| 2 | Melt Flow Index at 190 °C, g/10 min.:<br>a) at 212 N (21.6 kgf )<br>b) at 49 N (5 kgf ) | 5-7<br>0,1 |
| 3 | MFI21,6/MFI2.16 ratio | 100-170 |
| 4 | MFI spread within one batch, %, maximum | 10 |
| 5 | Tensile yield strength, MPa, minimum | 21 |
| 6 | Elongation at break, %, minimum | 500 |
| 7 | Carbon black weight content, % | 2,0-2,5 |
| 8 | Volatile weight content, mg/kg, maximum | 350 |
| 9 | Melting Point | 95-100 °C |

As seen from the table because of the lower melting point it cannot be welded by conventional fusion welding methods so, there is a need of friction welding. Proper set of parameters are to be chosen to obtain optimum tensile strength without degrading the properties of the material [3].It can be well understood that tensile strength of welded pieces would be less than the continuous piece. Through this optimization process, it is attempted to obtain optimum tensile strength of the joint closest to the minimum strength mentioned in the table 2.

### 2.2 Motor and Coupling

A 0.5 HP single phase AC induction motor coupled with stainless steel rigid coupling is deployed to hold the rotating part of the work piece.

### 2.3 Spring

Spring with modulus of rigidity 84GPa is used to transfer uniform axial force to the stationary part of the work piece.

## III. EXPERIMENTAL PROCEDURE

The procedure for welding PE-100 having outer diameter = 30 mm and inner diameter = 21mm can be described best in the three steps as follows:

STEP 1: Component in the spindle is brought up to pre-determined rotational speed and then a pre-determined axial force is applied.

STEP 2: These conditions are maintained for a pre-determined amount of time until desired temperatures and material conditions arrives.

STEP 3: Motor is then stopped and axial force is applied until desired upset is obtained. Then the components are unloaded and the cycle is repeated [4].

After performing experiments 3 values of each parameter i.e. at 3 levels are obtainedso that the efficient weld can be produced [5].Table 3 shows the values of parameters at different levels.

**Table 3: Welding parameters and levels**

| | Time (Seconds) | Axial force (N) | RPM |
|---|---|---|---|
| **Level 1** | 50 | 28.72 | 1490 |
| **Level 2** | 40 | 25.8 | 1440 |
| **Level 3** | 30 | 9.81 | 1410 |

Using Taguchi L9 array and DOE, the experiments are designed as shown in the Table 1 above. Using Ultimate Testing Machine (UTM) the tensile strength of various welded samples are obtained which are shown in Table 4.

**Table 4: Experimental Values of Tensile Strength**

| S.NO. | TIME (SEC) | F (N) | RPM | Tensile Strength. (MPa) |
|---|---|---|---|---|
| 1 | 50 | 28.72 | 1490 | 12.3 |
| 2 | 50 | 25.80 | 1440 | 11.7 |
| 3 | 50 | 9.81 | 1410 | 11.7 |
| 4 | 40 | 25.80 | 1490 | 11.8 |
| 5 | 40 | 9.81 | 1440 | 11.1 |
| 6 | 40 | 28.72 | 1410 | 11.6 |
| 7 | 30 | 9.81 | 1490 | 8.3 |
| 8 | 30 | 28.72 | 1440 | 9.4 |
| 9 | 30 | 25.80 | 1410 | 6.7 |

## IV. DATA ANALYSIS

After performing experiments, parameters are optimized by using Minitab 17 software. The calculation, results and graphs of S/N ratio, response table and regression equation are obtained from Minitab 17 software and are shown in Fig. 2.

**S/N plots:**

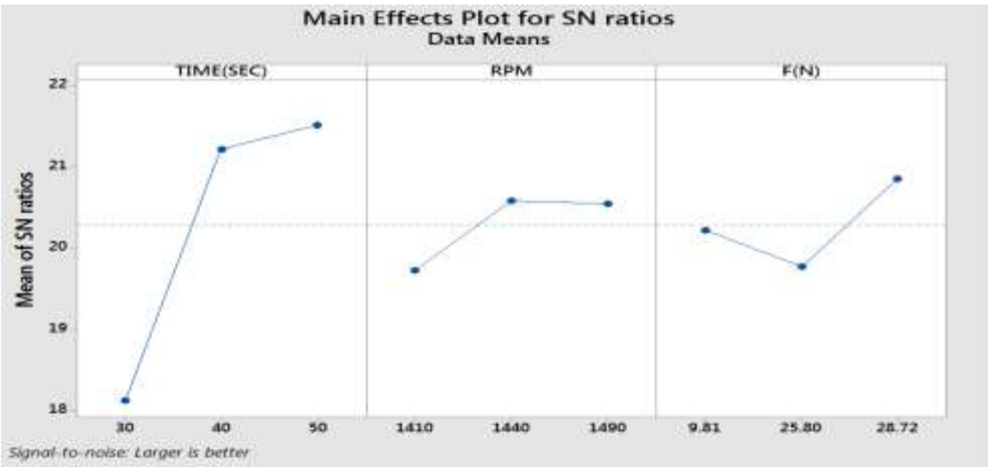


**Fig 2: S/N PLOT @ MINITAB 1**

## V. RESULT

Following points are observed from fig. 2:

a) S/N ratios increases as weld time increases and reaches maximum at 50 seconds value of weld time.

b) S/N ratio increases as the RPM increases and after 1440 RPM almost becomes constant.

c) S/N ratio decreases as the axial force increases, achieves minimum value at an axial force of 25.80 N and then increases.

### 5.1 Response table

**Table 5: Response Table for Signal toNoise Ratios obtained @ Minitab 17**

| LEVEL | Time (sec) | RPM | Axial force |
|---|---|---|---|
| 1 | 18.12 | 19.72 | 20.22 |
| 2 | 21.21 | 20.58 | 19.77 |
| 3 | 21.51 | 20.54 | 20.85 |
| Delta | 3.39 | 0.85 | 1.08 |
| Rank | 1 | 3 | 2 |

**Table 6: Response Table for Means obtained @ Minitab 17**

| LEVEL | Time (sec) | RPM | Axial force |
|---|---|---|---|
| 1 | 8.133 | 10.00 | 10.367 |
| 2 | 11.500 | 10.733 | 10.067 |
| 3 | 11.900 | 10.800 | 11.100 |
| Delta | 3.767 | 0.800 | 1.033 |
| Rank | 1 | 3 | 2 |

As observed form the response table, weld time is ranked 1, axial force ranked 2 and RPM is ranked 3 in optimization of tensile strength.

### 5.2 Regression Equation

Regression equation was implemented to obtain the correlation between the welding parameters and tensile strength of welded samples.

The regression equation is:

**T.S (MPa) = -10.6 + 0.1883 TIME (SEC) + 0.0091 RPM + 0.0194 F (N)** (2)

From the Plots & SN Ratio table it is clear that optimum conditions for optimum Ultimate Tensile Strength (UTS) are:

**Time = 50 sec**

**Speed = 1440 RPM**

**Force = 28.72 N**

Using These Optimised Conditions the Optimum **Tensile Strength** Comes Out To Be **12.3 Mpa**.

From the **response table**it can be concluded that TIME, which gets least attention in most of the literatures turns out to be the most influential factor in our analysis followed by AXIAL FORCE and SPEED.

## VI. CONCLUSION

Weld time as one of the parameters in friction welding has not drawn attention of many researchers [6], while as witnessed in the study, it has come out to be the most influential parameter. In this piece of study other parameters such as burn off length, coefficient of friction etc. have not been considered for optimizing tensile strength, these parameters if taken into account [7] will cause number of experiments to increase accordingly butprecise results can be obtained. Besides this the process can also be used for welding different grades of materials with suitably optimized parameters [4].

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