RESEARCH ARTICLE OPEN ACCESS

A Parametric Investigation of Butt Fusion Welding (Plastic welding novel approaches) Process Parameter on HDPE Pipe

Abhishek Nandi*, Rupendra kumar Marre**

*(Research Scholar, Department of Mechanical Engineering, RSR Rungta college of Engineering and Technology, Bhilai, CG, India
Email: abhishek.an1420@gmail.com)

** (Assistant Professor, Department of Mechanical Engineering, RSR Rungta college of Engineering and Technology, Bhilai, CG, India

--************************----------------------------------

Abstract:

Recently, pipe welding has been widely applied in the pipe fitting operations. There are many types of pipe welding facilities available. High Density Polyethylene Pipes (HDPE) is the most versatile and widely used plastic, available in a wider range of products and forms than any other types of plastic. It is widely used in pipe line industry, municipal corporation work so it is chosen for this proposed research work. In this research work, experimental investigations will be perform related to Butt fusion welding of HDPE pipe and optimization of different welding process parameters will be performed. In butt-fusion welding for joining of two pipes, the welded joint is produced with the help of heated plate. After performing the welding, the joints are tested for tensile strength using universal testing machine. Two performance parameters viz. temperature and tensile strength and three process parameters viz. drag pressure, Welding pressure for Butt fusion welding of HDPE pipes with specified dimension will optimized using Grey relational analysis optimization technique. The optimum process parameter temperature, Extension and tensile stress as output parameters are A1B3C3, i.e- heating plate temperature, drag pressure, welding pressure are 110 0C, 14 bar, 30 bar respectively.

Keywords **—**Pipe welding, HDPE, Butt fusion welding, optimization

--************************----------------------------------

I. INTRODUCTION

Butt-fusion jointing may be a thermo-fusion method that involves the synchronic heating of the ends of two elements that square measure to be joined till a soften state is reached on every contact surface. Figure 1 shows the butt fusion welding machine [1].

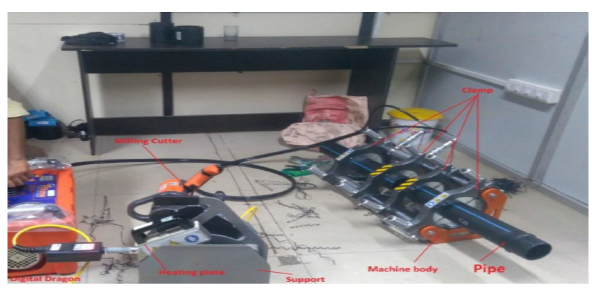

Figure 1. Butt-fusion welding set up [1]

The two surfaces square measure then brought along beneath controlled pressure for a particular cooling time and undiversified fusion is created upon cooling. Butt fusion may be a thermo-fusion method that involves the synchronic heating of the ends of two pipe/fitting elements that square measure to be joined, till a liquefied state is earned on every contact surface. The two surfaces square measure then brought along beneath controlled pressure for a particular cooling time and an undiversified fusion joint is created. Based on the concluding remarks made following problem can be formulated for this research work. The insufficient study about plastic welding process parameter. Need to optimize the process parameter of butt fusion welding to get stronger weld strength.

.

II. EXPERIMENTAL STUDY

The raw material selected for this experiment is high density polyethylene pipe (HDPE) with grade of PE 63 and PN 2.5. Table 1 depicts the dimension of the selected pipe Table 1. Dimension of the selected pipe

Table 1. Dimension of the selected pipe

Outer diameter(mm)	80
Inner diameter (mm)	72
Wall Thickness(mm)	7
Length of pipe (mm)	200
Number of pipes	18

A. Selection of input and output variable

In this thesis L9 orthogonal array and robust design with Grey based Taguchi method is used for conduct of experiments, to find out contributions of each factor and to optimize the parameters. Based on the literature reviewed, three process parameters for Butt-fusion welding are heating plate temperature, drag pressure and welding pressure as shown in Table 2.

Table 2: Process parameter and their levels for Butt-fusion welding

Factors	**Welding process parameters**	**Level**		
		Level 1	Level 2	Level 3
A	Heating plate temp. (^{0}C)	110	115	120
B	Drag pressure (bar)	10	12	14
C	Welding pressure(bar)	20	25	30

Nine set of specimens of welding of HDPE pipe with different combination of data are used for doing experiment for Butt-fusion welding. The combinations are shown in table 3.

Table 3:L9 Orthogonal array for experimental input parameter of Butt-fusion welding

Experiment number	L9 orthogonal array		
	Input Process Parameters		
	Heating plate temperature(^{0}C)	Drag pressure (Bar)	Welding pressure(Bar)
1	110	10	20
2	110	12	25
3	110	14	30
4	115	10	25
5	115	12	30
6	115	14	20
7	120	10	30
8	120	12	20
9	120	14	25

B. Experimental set-up

For this research work Butt-fusion welding machine set up available at Government polytechnic Betul, India is used to perform all the experiments.
Butt-Fusion welding setup consists of following components as shown in Figure 1

- Machine body
- Gear case
- Support
- Heating plate
- Milling cutter
- Digital dragon
- Clamps

C. Steps Used For Experimentation (Butt-Fusion Welding)

a. Cutting of the pipe into 18 numbers of pieces with length 250 mm each using hacksaw-cutter same as done for Electro-Fusion welding as shown in figure 2(a).
b. Setting up of the clamps according to diameter of pipes in clamping unit. The clamps are the no. of semi-circular blades

which are available according to diameter of Pipe. Here we have 90 mm diameter pipes so set 90 mm diameter shown in figure 2(b)

c. Fitting of both the pipe samples in clamping unit. One pipe sample is to be fit in movable clamp jaw which is connected with hydraulic cylinders and other then is in fixed clamp jaws shown in figure 2(c).
d. Setting the drag pressure for movable jaw. The drag pressure is set by the drag pressure control gear inside the hydraulic gear case. The drag pressure is set according to the orthogonal array for every sample.
e. Facing the pipe ends with the help of a milling cutter as shown in figure 4.16 and cleaning of pipes ends with tissue paper or napkin.
f. Setting the temperature of heating by digital dragon connected in heater plate for heating of pipe end surfaces as per the 9 welding set of orthogonal array.
g. Heating the ends which will result into formation of weld bead.
h. Setting the welding pressure according to the orthogonal array for particular pipe samples and applies welding pressure by gear controls using gear case.
i. Opening the clamps by clamping screws and taking out the welded pipes from clamping jaws of machine body.
j. Taking the temperature reading at weld joint or where weld bead is form, with the help of temperature measurement device. In this welding process temperature readings take by infrared thermometer.
k. Waiting for cooling of joint till room for better weld strength and take the temperature reading in every 5 minute intervals till temperature of joint reaches up to room temperature shown in figure 2 (d).
l. Perform tensile test of welded pipe structure in UNIVERSAL TESTING MACHINE to estimate the tensile strength and elongation.

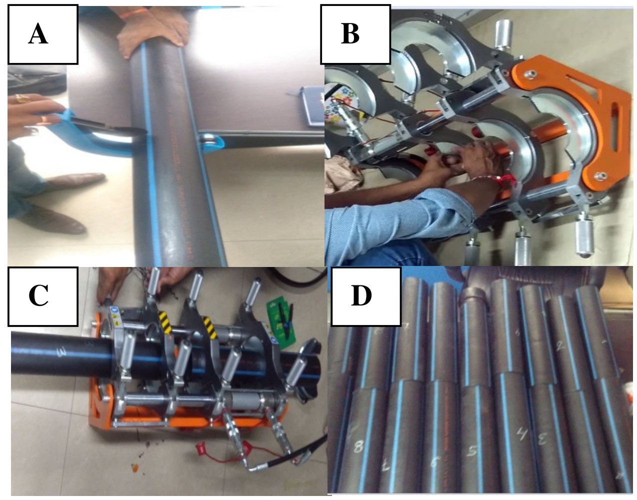

Figure 2. Shows (a) cutting of sample pipes (b) butt fusion machine (c) fitting of pipes in machine (d) joined pipes

III. OPTIMIZATION RESULT AND DISCUSSION

A. Experimental result

The input parameters viz. heating plate temperature, Drag pressure, Welding pressure are set on the selected welding machine according to the design of experiment table. Each welding pipe is set in Butt-fusion machine setup for heating and welding. The BASIC160 power source is set in manual mode and welding is performed. Same process is repeated for all 9 samples. The measured temperatures after completion of welding are tabulated in table 4.

Table 4. Measured Temperature values as per L-9 orthogonal array

Exp No.	Input parameter			Output parameter			
	Heating plate temperature (^{0}C)	Drag pressure (bar)	Welding pressure (bar)	Temperature distribution (^{0}C)	Load (N)	Extension (mm)	Tensile stress at max tensile strength (MPa

							)
1	110	10	20	90.3	1378.92	3.99	3.4473
2	110	12	25	79.4	1816.97	7.33	4.542425
3	110	14	30	80.2	498.60	2.12	1.2465
4	115	10	25	99.8	2223.55	25.56	5.558875
5	115	12	30	73.3	2038.83	8.77	5.097075
6	115	14	20	78	1978.87	10.78	4.947175
7	120	10	30	89	1979.65	8.32	4.949125
8	120	12	20	78.1	2004.22	40.85	5.01055
9	120	14	25	87.3	2018.64	34.94	5.0466

B. Optimization of Experimental Result of Butt-fusion welding process

Butt-fusion welding experimental values are optimize using Grey regression analysis, ANOVA and the effects of individual welding process parameters on the selected quality characteristics are calculated separately and presented in following section. The average value and S/N ratio of the response characteristics for each variable from different level are calculated from the experimental data.

S/N Ratio of temperature

To describe the effect of various input parameters (Heating plate temp., Drag pressure, welding pressure) on temperature, Extension, and tensile strength the S/N ratio values are estimated and presented in table 5.

Table 5. S/N Ratio of temperature and tensile stress

Ex. No.	Temperature (K)	S/N Ratio	Tensile Stress (MPa)	S/N Ratio	Extension (mm)	S/N Ratio
1	90.3	39.19	3.4473	10.74	3.99	12.01
2	79.4	37.99	4.542425	13.10	7.33	17.30
3	80.2	38.08	1.2465	1.86	2.12	6.52
4	99.8	39.98	5.558875	14.88	25.56	28.15
5	73.3	37.30	5.097075	14.13	8.77	18.85
6	78	37.84	4.947175	13.87	10.78	20.65
7	89	38.987	4.949125	13.88	8.32	18.40
8	78.1	37.85	5.01055	13.99	40.85	32.22
9	87.3	38.82	5.0466	14.04	34.94	30.86

Determination of optimal welding parameter

The experimentally obtained values of temperature are also presented in table 6. In this section, the use of OA with the GRA for determining the optimal welding parameters is reported step by step. The optimal machining parameter with consideration of the multiple performance characteristics are obtained and verified.

Table 6 Experimental layout using an L9 OA and performance result

Exp. NO.	Levels of parameters			Temperature	Tensile stress	Extension
	Heating plate temp.	Drag pressure	Welding pressure			
1	1	1	1	39.4994	21.95	12.01
2	1	2	2	38.3079	26.066	17.30
3	1	3	3	38.5165	14.370	6.52
4	2	1	2	38.9192	27.633	28.15

5	2	2	3	38.4337	26.977	18.85
6	2	3	1	38.1697	26.844	20.65
7	3	1	3	38.1808	26.816	18.40
8	3	2	1	38.7107	27.658	32.22
9	3	3	2	38.0943	27.769	30.86

Data pre-processing

Temperature and tensile stress are the dominant response in Butt-fusion attachment that decides the strength of joint. For the "Higher-the-better" characteristic, the initial sequence may be normalized as follows:

$$x_i^* = \frac{x_i(k) - x_{i\,min}(K)}{x_{i\,max}(k) - x_{i\,min}(k)}$$

Where, x_i (k)* and x (k) are the sequence after the data preprocessing and comparability sequence respectively, k=1 for temperature; i=1, 2, 3…, 9 for experiment numbers 1 to 9.

Table 7: Normalized S/N Ratio

Exp. No.	Temperature	Tensile stress	Extension
1	1	0.434286	0.786381
2	0.152018	0.127099	0.580545
3	0.300477	1	1
4	0.587076	0.01015	0.158366
5	0.241549	0.059109	0.520233
6	0.053662	0.069035	0.450195
7	0.061561	0.071125	0.537743
8	0.438688	0.008284	0
9	0	0	0.052918

Now, $\Delta_{0i}(k)$ is the deviation sequence of the reference sequence x^0_i (k) and the comparability sequence x_i^* (k), i.e.

$$\Delta_{0i}(k) = \left| x^*_0(k) - x_i^*(k) \right|$$

Table 8 shows all the deviation sequence of temperature

Table 8: Deviation sequence

Exp. No.	Δ_{0i} (k) Temperature	Δ_{0i} (k) Tensile stress	Δ_{0i} (k) Extension
1	0	0.565714	0.213619
2	0.847982	0.872901	0.419455
3	0.699523	0	0
4	0.412924	0.98985	0.841634
5	0.758451	0.940891	0.479767
6	0.946338	0.930965	0.549805
7	0.938439	0.928875	0.462257
8	0.561312	0.991716	1
9	1	1	0.947082

Computing the Grey Relation Coefficient and the Grey Relation Grade

Grey relational coefficient is calculated with the pre-processed sequence.

$$\xi_i(k) = \frac{\Delta_{min} + \zeta\Delta_{max}}{\Delta_{oi} + \zeta\Delta_{max}}$$

Where Δ_{0i} (k) is the deviation sequence of the reference sequence x_0^* (k) and the comparability sequence is x_i^* (k),ζ distinguishing or identification coefficient. If all the parameters are given equal preference, is taken as 0.5. The grey relational coefficient for each experiment of the L9 OA can be calculated.

Table 8: The calculated grey relational coefficient and grey relational grade

Exp. No.	Grey relational coefficient			Grey relational grade	rank
	Temperature	Tensile stress	Extension		
1	1	0.469169	0.700654	0.361637	**2**
2	0.370925	0.364192	0.5438	0.213153	**3**
3	0.416832	1	1	0.402805	**1**
4	0.547691	0.335604	0.37268	0.209329	**4**
5	0.397314	0.347007	0.510326	0.209108	**5**
6	0.345701	0.349415	0.476279	0.195232	**7**
7	0.347599	0.349926	0.519612	0.202856	**6**
8	0.471115	0.335184	0.333333	0.189939	**8**

9	0.333333	0.33333 3	0.345523	0.168698	**9**

In this study have two performance parameter temperature and tensile stress so the grey relation grade is the average of grey relational coefficient of temperature and tensile stress for all 9 experiments. Since the experimental design is orthogonal, it is then possible to separate out the effect of each machining parameter on the grey relational grade at different levels. For example, the mean of the grey relational grade for the voltage at levels 1, 2 and 3 can be calculated by averaging the grey relational grade for the experiments 1 to 3, 4 to 6 and 7 to 9 respectively as shown in Table 9.

Table 9: Response table for grey relational grade

Parameter	**Grey Relational Grade**			**Main effect**	**Rank**
	Level 1	**Level 2**	**Level 3**		
Plate temperature (A)	**0.595919**	0.430235	0.384016	0.211903	3
Drag pressure (B)	0.3849	0.348794	**0.560916**	0.212122	2
Welding pressure(C)	0.503422	0.420668	**0.676646**	0.255978	1

The total mean value of grey relational grade Υ_m= **0.6393**

From this we can find out the best combination. For grade best performance the parameters performed is shown in table 9 i,e **A1B3C3.**

IV. CONCLUSION

Experimental and Optimization studies of Butt-fusion welding on HDPE pipe material have been conducted in previous chapter. Tensile Testing has been done using UTM. Current chapter contains comparative evaluations, future Scope and conclusion of the current work. In Butt-fusion welding the temperature is the output temperature at the time of welding. The value of obtained temperature. The optimization done with the help of Grey based taguchi analysis for temperature, Extension and tensile stress as output parameters are **A1B3C3** which isshown in table 6.3.

Table 10: Optimum result

Plate temperature	Level 2	A1
Drag pressure	Level 1	B3
Welding pressure	Level 1	C3

From the response table of the grey relational grade, it is found that the largest value of grey relational grade for heating plate temperature, drag pressure, welding pressure are 110 ^{0}C, 14 bar, 30 bar respectively.

V. FUTURE SCOPE

The future scope for the current study is:

- The optimum result can also be validated from simulation study.
- The experiment can also be performing other types of pipe materials like MDPE etc.
- The experimental study also be performing with different diameters of pipes

REFERENCES

[1]. MarjanDoaei, M. SadeghTavallali [2018] "Intelligent screening of electro-fusion-polyethylene joints based on a thermal NDT method" Infrared Physics & Technology 90 (2018) 1–7

[2]. Jianfeng Shi ,JinyangZheng [2016] "A Model for Predicting Temperature of Electro-fusion Joints for Polyethylene Pipes"Journal of Pressure Vessel Technology 08 April 2016.

[3]. VipinVijayan, PashupatiPokharel, Miu Kwan Kang, Sunwoong Choi [2016] "Thermal and mechanical properties of e-beam irradiated butt-fusion joint in high-density polyethylene pipes"Radiation Physics and Chemistry 4 January 2016.

[4]. Jerome LeBono, Lewis Barton, Martin Birkett[2016] "Low temperature tensile lap-shear testing of adhesively bonded polyethylene pipe" International Journal of Adhesion and Adhesives 26 November 2016.

[5]. Tarek M.A.A. EL-Bagory , Hossam E.M. Sallam, Maher Y.A. Younan [2014] "Effect of strain rate, thickness, welding on the J–R curve for polyethylene pipe materials”Theoretical and Applied Fracture Mechanics,2014.

[6]. JinyangZheng,Jianfeng Shi,WeicanGuo [2012] “Development of Nondestructive Test and Safety Assessment of Electro-fusion Joints for Connecting Polyethylene Pipes” Journal of Pressure Vessel Technology, april 2012.

[7]. MinghaoGu, Jun Zhanga, Xiaolin Wang, Haijun Tao, LitianGe[2006] “Formation of poly(vinylidene fluoride) (PVDF) membranes via thermally induced phase separation”. Desalination 192 (2006)

[8]. K. Leskovics, M. Koll´ar, P. B´arczy,[2006] “A study of structure and mechanical properties of welded joints in polyethylene pipes” Materials Science and Engineering A 419 (2006).

[9]. M. Fujikakef, M. Fukumurat and K. Kitao [1997] “Analysis f the electro fusion joining process of polyethylene gas piping system” computer and Structures Vol. 64, No. 5/6.pp. 939-948. 1997.

[10]. Jeremy bowman [1997] “A review of the electro fusion joining process for polyethylene pipe systems” polymer engineering and science, April 1997 Vol. 37, No. 4.

[11]. Hiroyuki Nishimura, Fumioinoue and Akionakashiba [1994] “Design of Electrofusion Joints and Evaluationof Fusion Strength UsingFusion Simulation Technology” polymer engineering and scienceOctober 1994 vol. 34 no.20.

[12]. Vijay K. stokes [1989] “Joining Methods for Plastics and Plastic Composites:
An Overview” polymer engineering and scienceOctober 1989 vol. 29 no. 19

[13]. R.P. Wool, B L Yuan, O J Mcgarel [1989] “Welding of Polymer Interfaces” polymer engineering and science October 1989

[14]. L M Moore, G P Marshal, N S Allen [1989] “Thermal Analysis of MDPE Pipe: A Critical View” Polymer Degradation and Stability 25 (1989) 161-180.

[15]. Saurabhpathak, S K Pradhan [2020] “Experimentation and optimization of HDPE pipe electro fusion and butt fusion welding processes” Materials Today: Proceedings 27 (2020) 2925–2929.

[16]. Mohammad Mehdi Rasti, Thermal analysis of Electro fusionally welded Polyethylene joints, and Introducing an NDT screening method based on Thermal Stimulation, Chemical Engineering Department, 2017, Islamic Azad University, Shiraz-Iran.

[17]. Carosena Meola, Simone Boccardi, Giovanni maria Carlomagno, Nondestructive Testing With Infrared Thermograph, in Infrared Thermograph in the Evaluation of Aerospace Composite Materials, 2017, Wood head Publishing, p. 85–125 (Chapter 4).

[18]. Lee B, Kim YK, Hwnag W, Kim J, Lee S. Studies on the improvement of butt welding characteristics of double wall polyethylene pipes. Met Mater Int, in press.

[19]. Balkan O, Demirer H, Ezde A, Yıldırım H. Effects of welding procedures on mechanical and morphological properties of hot gas butt welded PE, PP, and PVC sheets. Polym Eng Sci 2008; 48:732–46.

[20]. Bo-Young Lee, Jae-Seong Kim, Sang-Yul Lee, Yeong K. Kim, Butt-welding technology for double walled Polyethylene pipe, Materials and Design.