Development of Mathematical Modelling for Cross Breaking Load of Hot Air Welded Poly Vinyl Chloride Sample

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Abstract

This work has been carried out to study the effect of some welding parameters on the desired response in the Poly Vinyl Chloride work piece welding by hot air technique. There are three input variables i.e. hot air temperature, welding speed and air flow rate which has been evaluated on the Cross Breaking Load of the welded joints. The mathematical Modelling is developed using the analysis of variance (ANOVA) and experimental Modelling. Plots of significant factors and experimental Modelling have been used to validate the experimental values to the predicted values with the help of developed mathematical relation. This equation is further use to find the input variable values for desired output variable.

Keywords- P.V.C., Welding of PVC, Plastic, Temperature, Joining, Hot air welding, ANOVA technique, Experimental Modeling

I. INTRODUCTION

Efforts in material science became focused on developing a material which could offer the mechanical features of metals and ceramics but itself being of low density and easy workability in the early 20th century. Therefore in 1910 first synthetic polymer and polymeric composites was developed. Polymers have been developed nowadays which are as strong as metals and in some cases stronger than metals. Polymers have been developed with improved mechanical properties and also having chemical and corrosion resistance. [2,17,18]

Plastics application in industries have increased with improvement in its mechanical as well as other properties. The joining of polymers is done by mechanical fastening, adhesive joining and welding. Plastics have the ability to take good surface finish, good corrosion resistance and excellent strength to weight ratio. Plastics can be categorized as thermosets and thermoplastics. Only thermoplastic is weld able. Thermoset plastic can be joined by mechanical fastening and adhesive joining only, as it cannot be softened. [3,16]

II. DESIGN OF EXPERIMENT

The experiment has been designed using 2n factorial method. Here n is the number of variables taken during the experiment [8]. In the present case, n= 3. A full factorial design contains all possible combinations of a set of factors. The 23 factorial design has two levels of each of the three variables requiring 2×2×2= 8 runs [9]. The 23 design matrix is shown in Table 1.

Table 1: Matrix prepared for input variables and corresponding response

Exp. Run	*Temperature (°C) T*	*Air flow Rate cm3/s AF*	*Welding Speed mm/s WS*
1	*225*	*5.893*	*0.25*
2	*225*	*5.893*	*0.35*
3	*225*	*17.679*	*0.25*

4	*225*	*17.679*	*0.35*
5	*275*	*17.679*	*0.25*
6	*275*	*17.679*	*0.35*
7	*275*	*5.893*	*0.25*
8	*275*	*5.893*	*0.35*

A total of 8 experiments have been conducted using 3 different parameters. The combination of input parameter is taken on the basis of full factorial technique. Three parameters have been taken as hot air temperature, welding speed and air flow rate Detail description of input parameters are given below:

III. INPUT PARAMETERS

A. Welding Temperature (T)

Maximum Temperature (Tmax) = 275 °C
Minimum Temperature (Tmin) = 225 °C

B. Air flow rate (AF)

Maximum Air flow rate (AFmax) = 17.679 cm3/sec
Minimum Air flow rate (AFmin) = 5.893 cm3/sec

C. Welding Speed (WS)

Maximum welding speed= $(WS_{max}) = \dfrac{\text{Distance travel}}{\text{Minimum time taken to cover the distance}} = \dfrac{50}{143} = 0.35 mm/s$

And minimum welding speed $=(WS_{min}) = \dfrac{\text{Distance travel}}{\text{Maximum time taken to cover the distance}} = \dfrac{50}{200} = 0.25 mm/s$

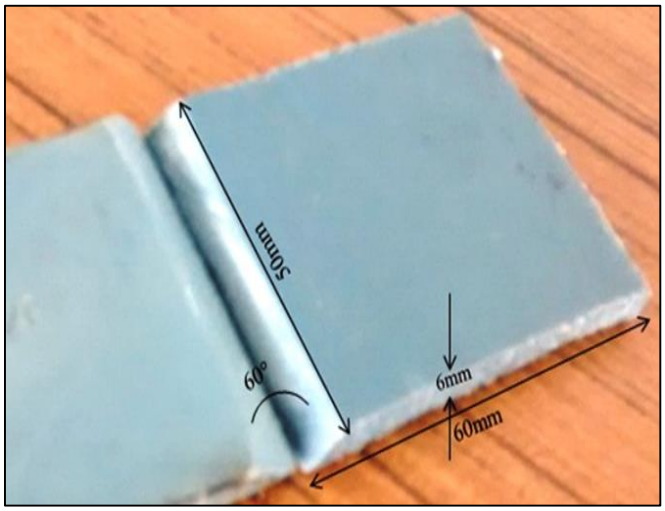
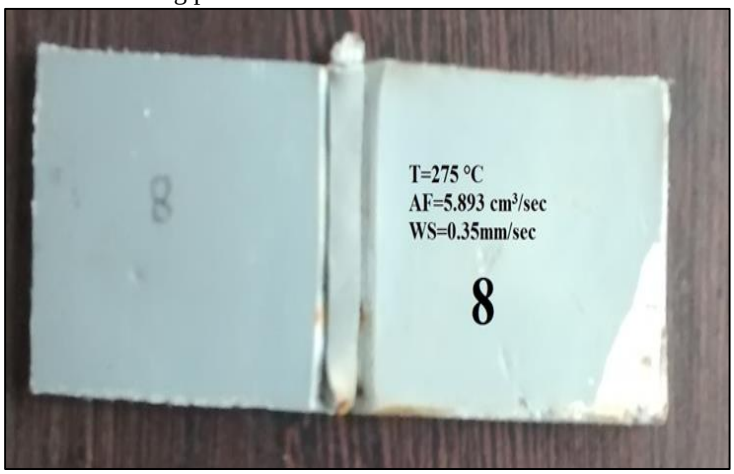


Fig. 1: Sample Details

Fig. 2: Hot air welding operation performing in Lab

Weld beads at different combination of welding parameter obtained are shown below:



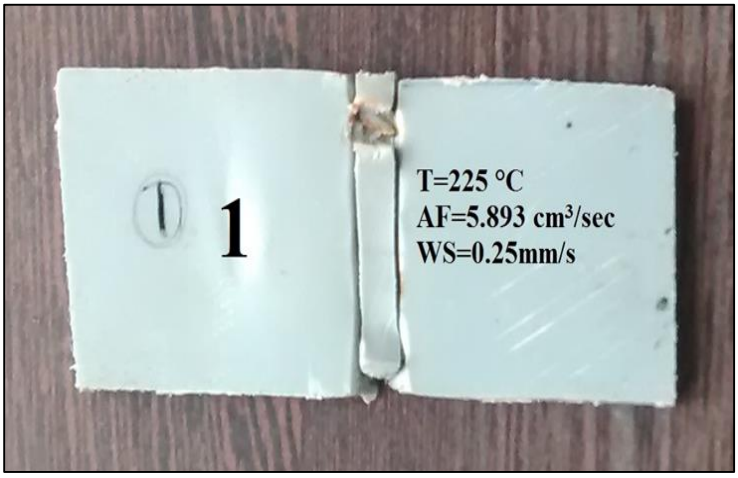


Fig. 3: Weld bead obtained using different combination of input parameter

IV. TESTING OF WELDED WORK PIECE

Bending tests for Cross Breaking Load have been being conducted on EUTM Unitek-9450. The bending span is taken as 100mm. And the force speed is 5N/Sec. The figure 4 shows the bending test performing in the Lab.

Fig. 4: Bending Test performed on EUTM Unitek-9450

Cross breaking load responses were obtained in the tests and reported in the following table 2 for each experiment runs.

Table 2: Cross Breaking Load at different values of input parameters

Exp.	*Temperature (°C)*	*Air flow Rate cm3/s*	*Welding Speed mm/s*	*Cross Breaking Load(N)*
Run	*T*	*AF*	*WS*	*CBL*
1	*225*	*5.893*	*0.25*	*73*
2	*225*	*5.893*	*0.35*	*72*
3	*225*	*17.679*	*0.25*	*77*
4	*225*	*17.679*	*0.35*	*72*
5	*275*	*17.679*	*0.25*	*80*
6	*275*	*17.679*	*0.35*	*79*
7	*275*	*5.893*	*0.25*	*78*
8	*275*	*5.893*	*0.35*	*77*

V. DEVELOPMENT OF MATHEMATICAL RELATION

The correlation between the factors such as temperature (T), air flow (AF) and welding speed (WS) with the mechanical property of welded joint i.e. Cross breaking load (CBL) for hot air welding of poly vinyl chloride are obtained by multiple linear regressions. The empirical relations obtained by regression analysis give fairly good results within the range of temperature (T) within 225 to 275°C, air flow (AF) within 5.893 to 17.679 cm3/s and welding speed (WS) 0.25 to 0.35 mm/s. The equation or regression model obtained is as follows:

$$CBL = 55.00 + 0.1000\,T + 0.1697\,AF - 20.00\,WS \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

A. Validation of Regression model

In order to validate the regression model, the values obtained by regression model and experiments are compared as shown in table 3, it is observed that the experimental result shows the variation from -1.5 to 1.49 as shown in figure 5.

Table: 3 Variation in Cross Breaking Load

Exp.	*Cross Breaking Load (PREDICTED) N*	*Cross Breaking Load (EXPERIMENTAL) N*	*Variation*
Run	*CBL'*	*CBL*	
1	*73.50*	*73*	*-0.5000*
2	*71.50*	*72*	*0.5000*
3	*75.50*	*77*	*1.4999*
4	*73.50*	*72*	*-1.5001*
5	*80.50*	*80*	*-0.5001*
6	*78.50*	*79*	*0.4999*
7	*78.50*	*78*	*-0.5000*
8	*76.50*	*77*	*0.5000*

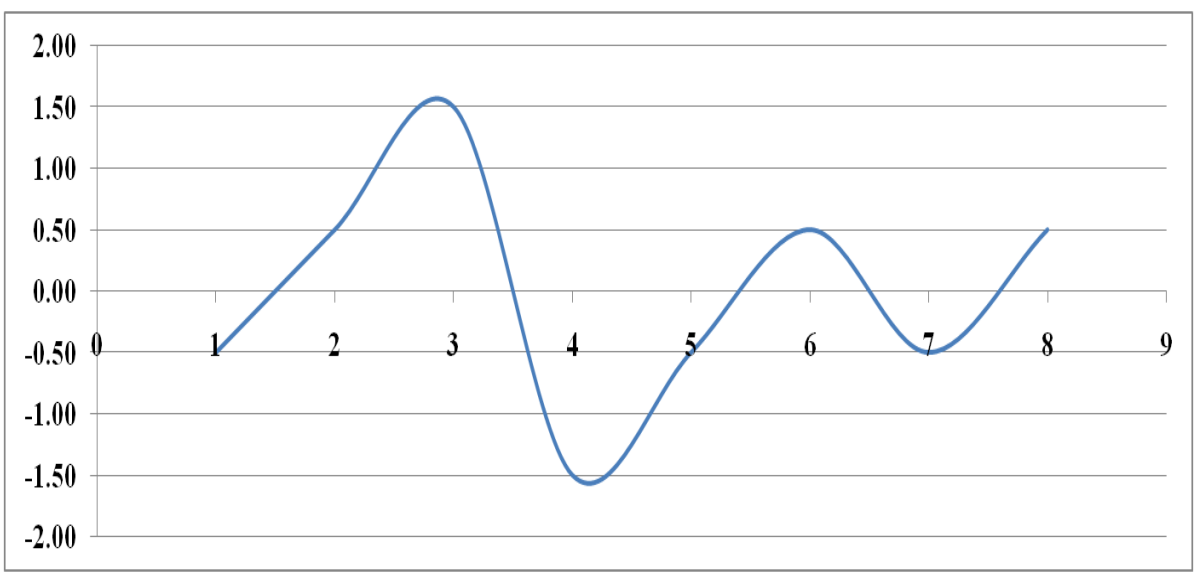


Fig. 5: Graphical representation of variation of cross breaking load

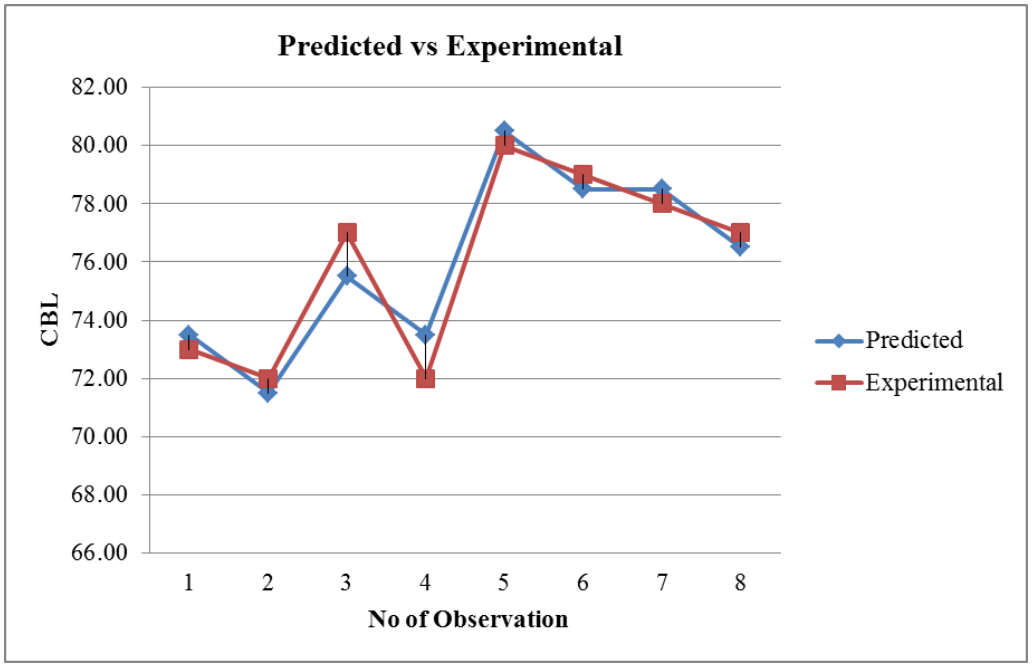


Fig. 6: Prediction vs Experimental Variation of Cross breaking load

As the graph (figure 6) shows very less variations are obtained between predicted values and experimental values of hardness of the weld joint of poly vinyl chloride.

VI. CONCLUSION

Regression model developed in this investigation could be used for real time prediction of cross breaking load for selected range of process parameters. There is huge scope for research in order to investigate the aspects responsible for high quality welding of plastics. 2n Design of Experiment method is used for this analysis. For more close results use another method of DOE. This mathematical relation is used for analysis of the cross breaking load of welded poly vinyl chloride. Use of nitrogen and other inert gases can be done in order to prevent oxidation. Use of proper jigs and fixtures as well as roller can be done to increase the welding pressure applied on welding rod for proper fusion.

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