Applying design of experiments methods on studying the effect of preheat, the electrode diameter and sheet thickness on tensile strength for welded steel st37

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Abstract: In this paper, performing a practical project and using design of experiments method that is one of the most important tools in off line quality control, the effect of three factors, preheating, electrode diameter and thickness on tensile strength steel st37 has been investigated. Each of these factors has two levels that preheat in temperature 150°C and no applying preheat, electrode diameter 3.25 and 4 and sheet thickness 15 and 30 mm are considered. Accordingly, for data analysis, the statistical tools, analysis of variance (ANOVA) and different diagrams were used. [Ali Mohammad Jafarpour, Heidar Amjadi, Hossein Amirkhani. **Applying design of experiments methods on studying the effect of preheat, the electrode diameter and sheet thickness on tensile strength for welded steel st37**. *Life Sci J* 2013;10(3s):338-342] (ISSN:1097-8135). http://www.lifesciencesite.com.48

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1. Introduction

Welding as one of the production processes uses in the manufacture of components and maintenance, so that repair welding is one of important branches in welding processes. Control of welding section quality is one of important factors in the welding field and has been regarded by researchers. These studies generally performed as parametric. For example, Srivastava B. K et al studied the effect of arc welding parameters on mechanical behavior of ferrous alloys [1]. One of of the techniques that can be effective at control of weld section quality is design of experiments method that because of performing quality control of process that includes pre-production, prevents problems and defeats in weld section and thereby, increases productivity. Design of experiments includes a set of experiments that change input variables of process consciously to observe and identify deviation in output of process [2]. In fact, statistical quality control assume the concept of quality something beyond control of the final product and plan manufacturing process and set affective parameters of manufacturing process such that final product be without any defects or errors will be minimal. Despite the widespread application and many benefits design of experiments, due to many statistical data that there are in this method, some industrialists have little interest in using these methods. However, test designing is a powerful tool for evaluating new processes, adding knowledge about available processes and optimizing these processes[3]. that according to this condition, and recently the usage of test designing has been increased in various applications[2,4].

2-Research parameters

Effective parameters in research and related values are as follows:

1-Applying preheat in 150°C and not applying preheat

2-Selection of diameter as 3.25 and 4 millimeter for coated electrodes 7018.

3-Selection of thickness of 15 and 30 for sheet st37

4-Repetition of test for 3 times for each sample under same condition.

3-Selection of Ingredients and electrodes 3-1-selected steel

In work and sampling, sheet st37 has been used which its dimensions before wielding have been shown in Fig. 1. Table 1 show the chemical analyze for this steel.

3-2- Selected electrode

For wielding, coated electrode 7018 has been used, which is as per AWS standard.

4-Process of wielding and classification of parts

For wielding samples, Manual arc welding method (SMAW) has been used which the sample numbering for evaluating tension strength shown in table 2.

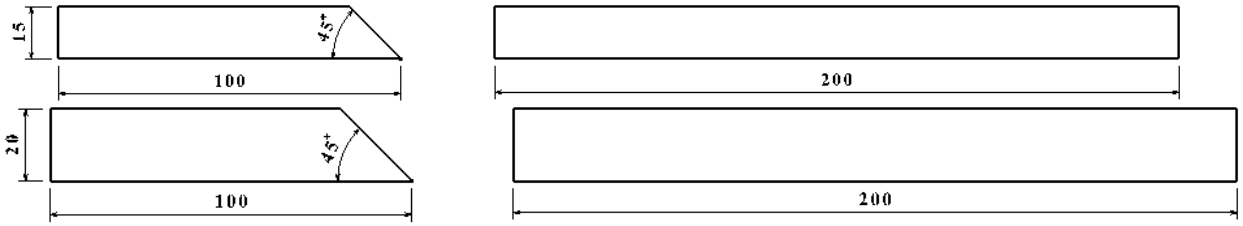


Fig 1 – Dimension of steel sheets before wielding

Table 1 – Chemical analyze of Non-alloyed steel (st37)

St 37	C	Si	Mn	P	S	Cr	Al	Cu	N	Pb
I	0.17	0.30	1.40	0.045	0.045	-	-	-	0.009	-
II	0.17	-	-	0.040	0.035	-	-	-	0.009	-

Table 2 – sample numbering according to the wielding conditions

No. of parts	150°c Preheat in	(mm) Distance of roots between adjacent parts	Dia. Of electrode (mm)	Thickness (mm)
1	✓	Core of electrode 4	4	30
2	✓	Core of electrode 4	4	15
3	✓	Core of electrode 3.25	3.25	30
4	✓	Core of electrode 3.25	3.25	15
5		Core of electrode 4	4	30
6		Core of electrode 4	4	15
7		Core of electrode 3.25	3.25	30
8		Core of electrode 3.25	3.25	15

4-Preparing samples and tensile test

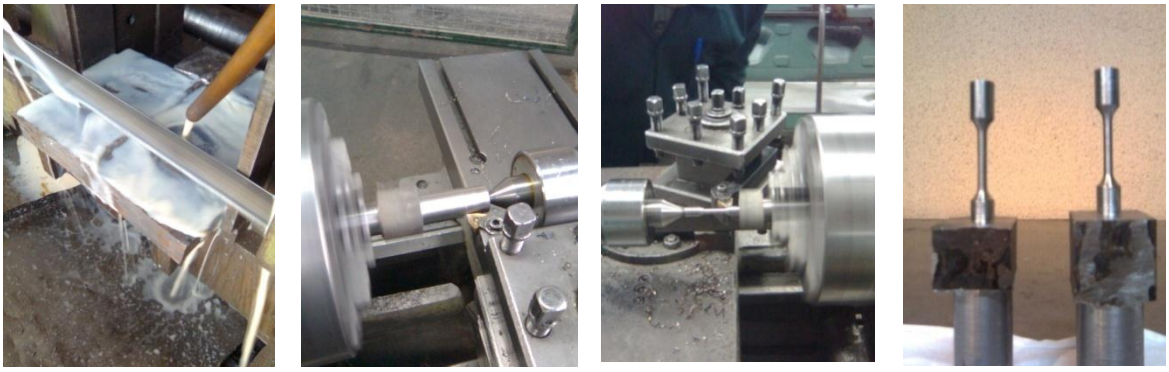
After wielding, sheets will be cut with band saw along their width and then turning has been done on samples to make them ready for tensile test. For decreasing test errors, for each sample 3 of them prepared and Fig 2 shows the preparation processes of samples.

For tensile test, a manual-hydraulic tensile machine used which Fig 3 shows the parts during the test and the samples after test also shown in Fig 4.

According to table 2 which shows the numbering of samples, the results of tensile test for all samples (3 samples from 8 wielded parts) shown in table 3.

Table 3- Tensile strength from repetition of tests

		Part Number							
Sample Number		1	2	3	4	5	6	7	8
	1	260.46	244.52	307.66	287.97	253.52	273.38	290.14	311.00
	2	260.28	242.14	306.15	287.29	251.53	275.28	292.08	312.84
	3	258.24	247.36	302.28	286.18	255.43	268.00	288.86	312.27



(a) (b) (c) (d)

Fig 2 – process of Machining samples for tensile test
Turning of parts to prepare samples.(b)&(c) turning of samples.(d) samples ready for tensile test.

Fig 3 – Tensile machine during test

Fig 4 – Samples after tensile test

5-Modeling and analyzing the test results

For processing data in Minitab software and designing tests, data given in table 3 has been used and the results of designing tests shown in table 4.

Analysis of variance (ANOVA) and their interaction effects for tensile strength have shown in table 5. According to P-values, preheat and electrode diameters and double interactions (preheat × electrode diameter) and (preheat × sheet thickness) are considered as Significant effects. (Factors with P-values less than 0.05, will be considered as significant effects).

Table 4 – test Outputs, Applying a random sequence

Std Order	Run Order	Preheat (ºC)	Electrode Dia. (mm)	Sheet thickness (mm)	Tensile Strenght (N/mm^2)
15	1	-	-	+	292.08
1	2	+	+	+	260.46
9	3	+	+	+	260.28
5	4	-	+	+	253.52
21	5	-	+	+	255.43
18	6	+	+	-	247.36
22	7	-	+	-	268.00
16	8	-	-	-	312.84
14	9	-	+	-	275.28
24	10	-	-	-	312.27
20	11	+	-	-	286.18
3	12	+	-	+	307.66

Std Order	Run Order	Preheat (ºC)	Electrode Dia. (mm)	Sheet thickness (mm)	Tensile Strenght (N/mm^2)
10	13	+	+	-	242.14
12	14	+	-	-	287.29
11	15	+	-	+	306.15
7	16	-	-	+	290.14
17	17	+	+	+	258.24
13	18	-	+	+	251.53
19	19	+	-	+	302.28
4	20	+	-	-	287.97
23	21	-	-	+	288.86
2	22	+	+	-	244.52
6	23	-	+	-	273.38
8	24	-	-	-	311.00

Table 5- Analysis of variance (ANOVA) related to interactions and their effects

Estimated Effects and Coefficients for Tensile Strength

Term	Effect	Coef	SE Coef	T	P
Constant		278.12	0.4475	621.54	0.000
Preheat	-7.82	-3.91	0.4475	-8.73	0.000
Electrode Dia.	-41.22	-20.61	0.4475	-46.05	0.000
sheet thickness	-1.80	-0.90	0.4475	-2.01	0.061
Preheat*Electrode Dia.	-2.87	-1.44	0.4475	-3.21	0.005
Preheat*sheet thickness	18.40	9.20	0.4475	20.56	0.000
Electrode Dia.*sheet thickness	-0.07	-0.03	0.4475	-0.08	0.939
Preheat*Electrode Dia.* sheet thickness	-1.54	-0.77	0.4475	-1.73	0.104

S = 2.19215 PRESS = 172.999
R-Sq = 99.40% R-Sq(pred) = 98.64% R-Sq(adj) = 99.13%

Fig 5 shows effects of each factors and Fig 6 shows the interaction effects on tensile strength.

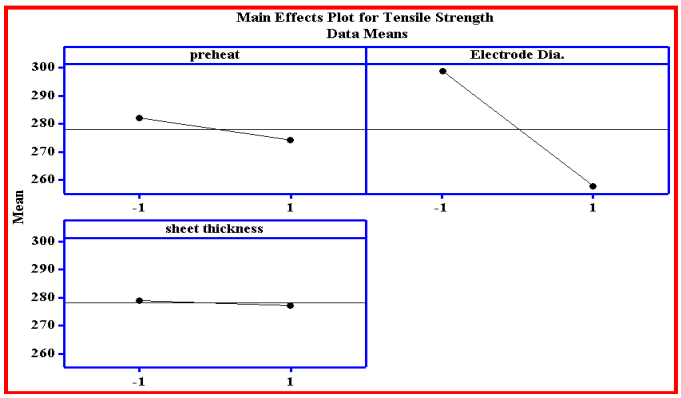


Fig 5 – Effect of each factor in tensile strength

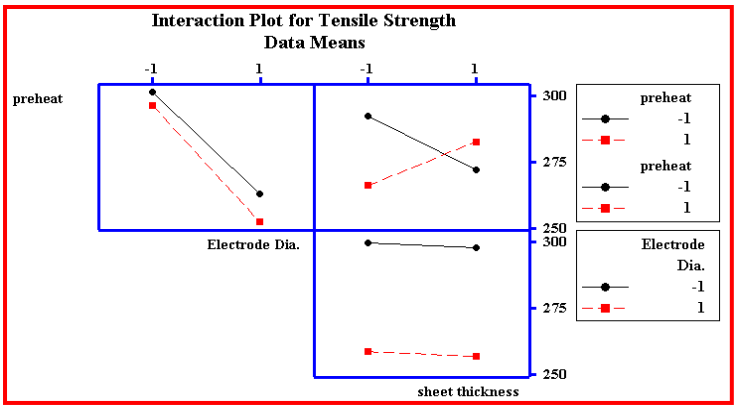


Fig 6- Interaction effect of factors in tensile strenght

6-Regression model

In selecting regression model, those types of factors will be used which are having significant effects on response variable. It means effect of factor or interaction of factors on test results is not due to errors but it is because of changes in values of study factors. Estimation for regression Coefficients shown in table 6 which according to them, regression formula related to tensile strength will be as formula 1.

The regression equation is:

Tensile Strength = 278 - 3.91 preheat - 20.6 Electrode Dia. - 1.44 preheat × Electrode dia. + 9.20 preheat × sheet thickness.

Table 6 – Estimation of regression coefficients for tensile strength

Estimated Regression Coefficients for Tensile Strength				
Term	Coef	SE Coef	T	P
Constant	278.119	0.4728	588.218	0.000
preheat	-3.908	0.4728	-8.266	0.000
Electrode Dia.	-20.608	0.4728	-43.585	0.000
sheet thickness	-0.900	0.4728	-1.903	0.074
preheat*Electrode Dia.	-1.437	0.4728	-3.039	0.007
preheat*sheet thickness	9.201	0.4728	19.460	0.000
Electrode Dia.*sheet thickness	-0.035	0.4728	-0.074	0.942

7-Conclusion

In present research, after site activities and preparing parts and related rests and finally obtaining experimental results, designing test method has been used for modeling and below results observed from tests.

1-By entering data in Minitab software and calculating effect of each factor for test, It is concluded that among these 3 factors, preheat and diameter factors have significant effects on response variable (tensile strength) and between these 2 factors, electrode diameter has more effect.

2-According to results from effects of each factor, for obtaining a reasonable wielding quality related to maximum tensile strength, it is better to focus first on electrode diameter and then on preheat.

3-Optimized value for maximum tensile strength will occur in low levels of effective parameters.

4-Evaluating interaction of each parameters on each other shows the interaction between these factors like (preheat × electrode diameter) and (preheat × sheet thickness), which means for every different levels of each parameter, different effects of other parameters will be observed.

1/15/2013

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