Statistical Comparative Analyses of the Effects of Welding Processes on Break Point and Modulus of Elasticity Properties of Welded Mild Steel Plates

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ABSTRACT

As test samples, mild steel plates with thicknesses of 0.5 mm, 0.6 mm, 0.7 mm, 0.8 mm, 0.9 mm, and 1.0 mm were made. The samples were subjected to break point and modulus of elasticity analyzes after being welded with the Integrated Welding Robot and Electric Arc Welding Machine. All data obtained including break points and modulus of elasticity were analyzed and the data produced from Electric Arc welding operations, the Robot welding operations and un-welded plates (control) were compared with one another.

The descriptive statistics, ANOVA analysis, test of homogeneity of Variances and Post Hoc test (Least Significant Differences) were the statistical tools deployed using Statistical Package of Social Sciences (SPSS version 2016). The results of the statistical analyses as revealed by the descriptive statistics of the break point showed that the developed robot welding samples collectively have the lowest mean value of 2.16, standard deviation value of 0.79 and variance value of 0.62. The homogeneity of variance test among break points of the samples revealed that there was variation in the break points among the test samples since p-value is 0.019. The ANOVA test result showed that there is significant difference in the break point of the samples in which developed robot welding operation gave the lowest break point compared with electric arc welding and un-welded (CONTROL) since p-value is 0.001. Also, there were mean differences of -7.80 between the developed robot welding and un-welded (CONTROL) samples and -1.94 between the developed robot welding and electric arc welding samples.

Furthermore, the descriptive statistics of the modulus of elasticity revealed that the un-welded (CONTROL) samples have the highest mean value of 19629.35 while the developed robot welding samples have the highest standard deviation value of 8810.67 and variance value of 77627905.85. The homogeneity of variance test among modulus of elasticity of the samples reveals that there is no variation in the modulus of elasticity among the tests of the samples since p-value is 0.984. Finally, the ANOVA test result shows that there is no significant difference in the modulus of elasticity of the samples since p-value is 0.57.

It is evident that the welding processes have significant impact on the break point of the welded mild steel plates while on modulus of elasticity, the impact was not significant. The developed welding robot is therefore recommended for better performance where premium is placed on break point property of the welded mild steel plates.

(Keywords: welding processes, break point, modulus of elasticity, mild steel, statistical analysis)

INTRODUCTION

Steel is an important material in the engineering sector. Across many fields, it has found applications, such as vehicle parts, truck bed floors, automotive doors, domestic appliances etc. It is able to offer a very large variety of mechanical and other properties economically.

Traditionally mechanical elements have been joined by fasteners, rivet joints and so on. In addition, welding method is typically introduced to minimize time for production, weight reduction and enhancement of mechanical properties. Today there are a number of different welding processes available, and welding is commonly used as a manufacturing method for joining materials in a broad range of compositions, component shapes and sizes.

Welding is an important joining process, due to high joint efficiency, simple installation, flexibility and low manufacturing costs [1]. Welding is a simple, cost-effective and dependable operation and welded joints find applications in critical components where faults are a disaster. Consequently, inspection methods are growing and adherence to appropriate standards. These acceptance criteria reflect the minimum weld quality based on welded specimen testing involving such discontinuities [2, 3, 4].

Welding requires a broad range of variables, such as time, temperature, electrode, pulse frequency, input power and welding speed, affecting the eventual properties of welding metal [5, 6, 7, 8, 9]. Steel-welding is not always easy. There is a need to pick the welding parameters properly to provide a good weld quality for a given job.

The use of the control system in arc welding will also remove much of the "guess job" that is often used by welders to determine welding parameters for a given task [10]. Experimental work is therefore required to generate data for the design of a welding control system which can offer optimized properties.

Talabi, et al., [11] investigated the impact of welding variables on the mechanical properties of arc welded joints with low carbon steel. The experiment was performed with the intention of understanding how these individual variables influence the mechanical properties of the welded steel sample. In addition, welding method is typically introduced to minimize time for production, weight reduction and enhancement of mechanical properties.

Consequently, inspection methods are growing and adherence to appropriate standards. These acceptance criteria reflect the minimum weld quality that is focused on checking certain discontinuities of welded specimen. An attempt was made to research the effect of welding variables on low carbon steel welded joint mechanical properties by Talabi et al, [11].

There was, however, very little attempt to determine the impact of each parameter separately. Hence, this work aims to determine the effect of various welding processes on the break point and modulus of the elasticity properties of mild steel weld joints. Statistical methodology plays a vital role in the design of research experiments, empirical data analysis, findings interpretation and the drawing of definitive claims. Appropriate statistical method was therefore adopted for performing various analyzes in this research work.

Instruments Deployed for the Experiments

The following instrument was deployed for carrying out experiments of mechanical properties on the welded and un-welded mild steel plates of different thickness as shown in Plate 1 [12].

Plate 1: Universal Instron Machine, Model 3369, Maker (Instron).

Tensile Test on Different Thicknesses of Mild Steel Plate Specimens with Manual, Developed Robot Welding Operations and Without Welding Operation (Control)

Table 1 shows the performance and interpretation of the tensile strength test of welded and un-welded mild steel plates for various thicknesses. The test concentrated on evaluating the break point and elasticity modulus for welded and un-welded samples of mild steel.

Table 1: Tensile Test on Different Thicknesses of Mild Steel Plate Specimens with Manual Arc Welding, developed Robot Welding Operations and without Welding Operation (Control).

Specimen/Gauge (mm)	Modulus of Elasticity (MPa)	Break Point (mm)	Modulus of Elasticity (MPa)	Break Point (mm)	Modulus of Elasticity (MPa)	Break Point (mm)
	Control		Robot welded		Manually welded	
0.5	13735.00061	5.82750	10020.62	1.622184	6254.27803	3.225364
0.6	12758.95157	8.30000	9911.093	1.89826	9702.272	3.766748
0.7	14891.91437	8.43331	12809.34	1.398412	11388.9	2.540086
0.8	20461.91559	12.70019	13190.57	2.638286	16363.54	6.791548
0.9	24727.86560	10.60012	33077.47612	1.881898	21761.03	4.57345
1.0	31200.43335	13.90012	13164.88	3.519948	26593.8535	4.076774

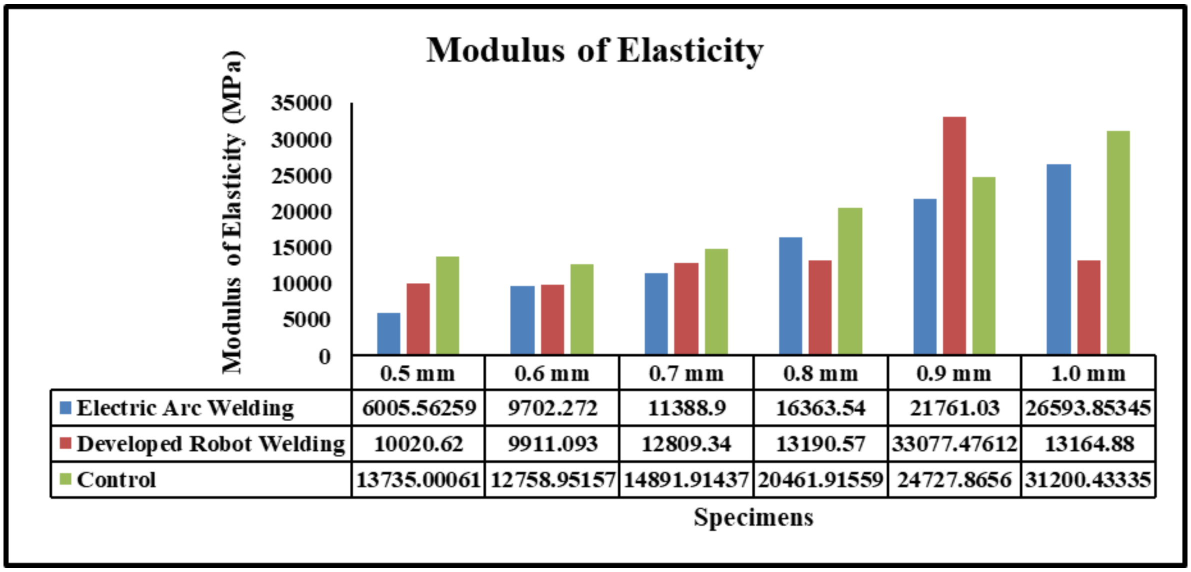

Figure 1: Modulus of Elasticity of Welded and Un-welded Mild Steel Plate Specimen for the Tensile Strength Test.

Figure 1 shows that the un-welded mild steel (CONTROL) samples gave a very good trend of high values of modulus of elasticity. The developed robot welding samples gave a trend of comparatively lower values of modulus of elasticity than both the un-welded and electric arc welding samples. This trend was expected given the higher values of hardness, lower values of extension, tensile stress and tensile strain of the developed robot welding samples over those of the electric arc welding and un-welded (CONTROL) samples.

Figure 2 shows variation in break point on welded and un-welded mild steel plates (specimens) of different sizes in which the un-welded (CONTROL) samples gave the highest while developed robot welding samples gave the lowest, This result was in trend and agreement with the earlier results of high values of hardness, low values of extension, tensile stress, tensile strain and modulus of elasticity exhibited by the developed robot welding samples in comparison with those of the electric arc welding and un-welded (CONTROL) samples.

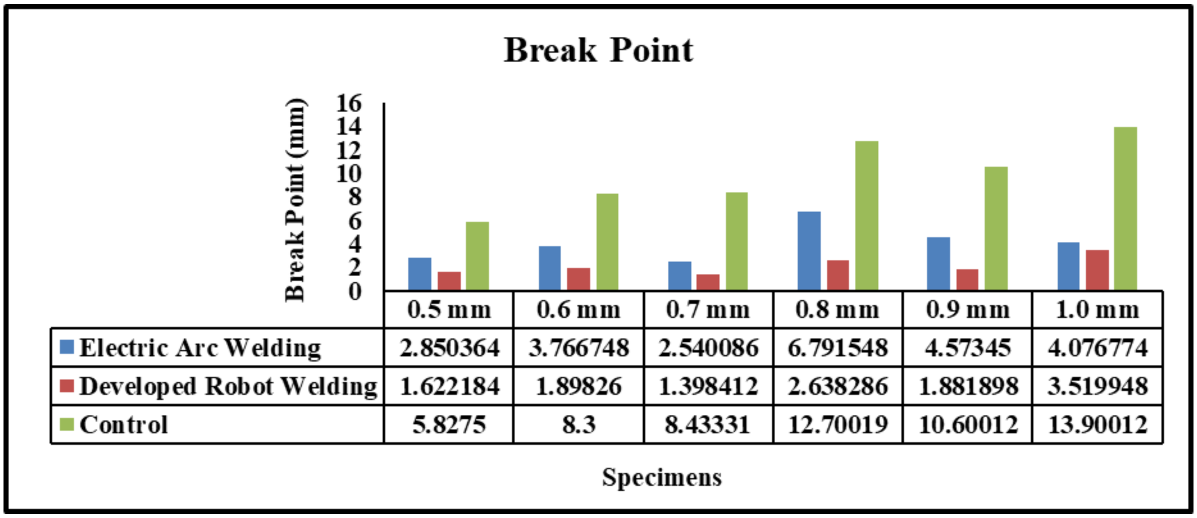

Figure 2: Break Point of Welded and Un-welded Mild Steel Plate Specimen for the Tensile Strength Test.

STATISTICAL ANALYSES RESULTS AND DISCUSSION

The statistical tools adopted in this research include; descriptive statistics, ANOVA analysis, test of homogeneity of Variances and Post Hoc test (Least Significant Differences) while the software deployed for the analysis is Statistical Package of Social Sciences (SPSS version 2016).

Statistical Analysis of the Break Point of Welded and Un-Welded Mild Steel Plate Specimens

Table 2 shows the statistical analysis of the break point of welded and un-welded mild steel plate specimens. Table 2a reveals the descriptive statistics of the break point in which the developed robot welding samples collectively have the lowest mean value of 2.16, standard deviation value of 0.79 and variance value of 0.62.

Table 2b shows homogeneity of variance among break points of the samples in which the result reveals that there is variation in the break points among the tests of the samples since p-value is 0.019.

Table 2c shows in the ANOVA test result that there is significant difference in the break point of the samples in which developed robot welding operation gave the lowest break point compared with electric arc welding and un-welded (CONTROL) since p-value is 0.001.

Table 2d shows the mean difference of -7.80 between developed robot welding and un-welded (CONTROL) samples and -1.94 between developed robot welding and electric arc welding samples.

Statistical Analysis of the Modulus of Elasticity of Welded and Un-Welded Mild Steel Plate Specimens

Table 3 shows the statistical analysis of the modulus of elasticity on welded and un-welded mild steel plate specimens. Table 3a reveals the descriptive statistics of the modulus of elasticity in which the un-welded (CONTROL) samples have the highest mean value of 19629.35 while developed robot welding samples have the highest standard deviation value of 8810.67 and variance value of 77627905.85.

Table 3b shows homogeneity of variance among modulus of elasticity of the samples in which the result reveals that there is no variation in the modulus of elasticity among the tests of the samples since p-value is 0.984.

Table 3c shows in the ANOVA test result that there is no significant difference in the modulus of elasticity of the samples since p-value is 0.57.

Table 2a: Descriptive Statistics of the Break Point of the Samples.

Group	N	Mean	Std. Deviation	Variance	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Control	6	9.96	3.02	9.12	1.23	6.79	13.13	5.83	13.90
Electric Arc Welding	6	4.10	1.52	2.31	0.62	2.50	5.70	2.54	6.79
Developed Robot Welding	6	2.16	0.79	0.62	0.32	1.33	2.99	1.40	3.52
Total	18	5.41	3.90	15.21	0.92	3.47	7.34	1.40	13.90

Table 2b: Test of Homogeneity of Variances among Break Point of the Samples.

Levene Statistic	df1	df2	Sig. (p-value)
5.238	2	15	0.019

Table 2c: ANOVA Test of the Break Point of the Samples.

Test	Sum of Squares	df	Mean Square	F calc.	Sig. (p-value)	F critical
Between Groups	197.89	2	98.94	24.63	0.001	3.68
Within Groups	60.25	15	4.02			
Total	258.14	17				

Table 2d: Post Hoc test: Least Significant Differences (LSD) for Break Point Multiple Comparisons between the Samples.

(I) Samples	(J) Samples	Mean Difference (I-J)	Std. Error	Sig. (p-value)	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Control	Electric Arc Welding	5.86*	1.16	0.001	3.39	8.33
	Developed Robot Welding	7.80*	1.16	0.001	5.33	10.27
Electric Arc Welding	Control	-5.86*	1.16	0.001	-8.33	-3.39
	Developed Robot Welding	1.94	1.16	0.114	-0.53	4.41
Developed Robot Welding	Control	-7.80*	1.16	0.001	-10.27	-5.33
	Electric Arc Welding	-1.94	1.16	0.114	-4.41	0.53

Table 3a: Descriptive Statistics of the Modulus of Elasticity of the Samples.

Group	N	Mean	Std. Deviation	Variance	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Control	6	19629.35	7279.66	52993449.72	2971.91	11989.81	27268.88	12758.95	31200.43
Electric Arc Welding	6	15302.53	7790.31	60688929.90	3180.38	7127.09	23477.96	6005.56	26593.85
Developed Robot Welding	6	15362.33	8810.67	77627905.85	3596.94	6116.10	24608.56	9911.09	33077.48
Total	18	16764.73	7785.42	60612764.58	1835.04	12893.14	20636.33	6005.56	33077.48

Table 3b: Test of Homogeneity of Variances among Modulus of Elasticity of the Samples.

Levene Statistic	df1	df2	Sig. (p-value)
0.016	2	15	0.984

Table 3c: ANOVA Test of the Modulus of Elasticity of the Samples.

Test	Sum of Squares	df	Mean Square	F calc.	Sig. (p-value)	F critical
Between Groups	73864772.40	2	36932386.20	0.58	0.57	3.68
Within Groups	956551303.17	15	63770086.88			
Total	1030416075.57	17				

CONCLUSION

The results of the statistical analyses as revealed by the descriptive statistics of the break point showed that the developed robot welding samples collectively have the lowest mean value of 2.16, standard deviation value of 0.79 and variance value of 0.62. The homogeneity of variance test among break points of the samples revealed that there was variation in the break points among the test samples since p-value is 0.019. The ANOVA test result showed that there is significant difference in the break point of the samples in which developed robot welding operation gave the lowest break point compared with electric arc welding and un-welded (CONTROL) since p-value is 0.001. Also, there were mean differences of -7.80 between the developed robot welding and un-welded (CONTROL) samples and -1.94 between the developed robot welding and electric arc welding samples.

Furthermore, the descriptive statistics of the modulus of elasticity revealed that the un-welded (CONTROL) samples have the highest mean value of 19629.35 while the developed robot welding samples have the highest standard deviation value of 8810.67 and variance value of 77627905.85. The homogeneity of variance test among modulus of elasticity of the samples reveals that there is no variation in the modulus of elasticity among the tests of the samples since p-value is 0.984. Finally, the ANOVA test result shows that there is no significant difference in the modulus of elasticity of the samples since p-value is 0.57.

It is therefore evident that the welding processes have significant impact on the break point of the welded mild steel plates while the impact on modulus of elasticity was not significant.

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