A Study of Gas Metal Arc Welding Affecting Mechanical Properties of Austenitic Stainless Steel AISI 304

Sittichai K., Santirat N., and Sompong., P

***Abstract*—**The objective of this research was to study influence parameters affecting to mechanical property of austenitic stainless steel grade 304 (AISI 304) with Gas Metal Arc Welding (GMAW). The research was applying factorial design experiment**,** which have following interested parameters: welding current at 80**,** 90, and 100 Amps, welding speeds at 250**,** 300, and 350 mm/min, and shield gas of 75% Ar + 25% CO_2, 70% Ar + 25% CO_2 + 5% O_2 and 69.5% Ar + 25% CO_2 + 5% O_2 + 0.5% He gas. The study was done in following aspects: ultimate tensile strength and elongation. A research study of ultimate tensile strength found that main factor effect, which had the highest strength to AISI 304 welding was shield gas of 70% Ar + 25% CO_2 + 5% O_2 at average of 954.81 N/mm^2. Result of the highest elongation was showed significantly different at interaction effect between shield gas of 69.5%Ar+25%CO_2+5%O_2+.5%He and welding speed at 250 mm/min at 47.94%.

***Keywords*—**Austenitic Stainless Steel AISI 304/ Mechanical Property/ Welding Gas Shield/ Gas Shield

I. Introduction

STAINLESS steel was the significant material to develop a country in terms of economic, social, and industrial revaluation especially in the 18th century. From that day, it was become changing to world society that stainless steel could be used in variety kinds of construction and industry such as railway, ship submarine, and machines [1]. Moreover, stainless steel development especially austenitic stainless steel to be used in different levels was existed. A study of mechanical and metallurgy for welding material was developed to be used in several different locations and environments [2]. Influence of heat occurred during welding process would affected to microstructure that will affect directly to mechanical property as well. Based on that information, the consideration of safety for using that product was accounted into the welding process [3]. Therefore, the objective of this research was to study factors affecting to mechanical property of austenitic stainless steel at the area of Fusion Zone, Heat Affect Zone (HAZ), and Based metal with Gas Metal Arc Welding (GMAW)

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II. Methodology

A. Material and Equipment

Material used for this research was austenitic stainless steel grade 304 (AISI 304) with dimensions of 65*80*3 mm. Example of machine and equipment were showed in Figure 1-2.

Fig. 1 Gas Mixer

Fig. 2 Tensile Testing Machine

B. Design of Experiment

Pilot study was designed to determine appropriate factor levels before actual experiment taking place. When result of parameter was analyzed, levels of parameters were set to be test and then experimental design was developed for actual experiment. The final experiment was showed in Table 1.

TABLE I
DESIGN OF EXPERIMENT

Gas	Current	Speed (mm/min)					
		250		300		350	
75%Ar + 25% CO_2	80	12	31	7	25	6	14
	90	3	18	49	17	13	24
	100	28	11	30	35	37	43
70%Ar + 25% CO_2 + 5%O_2	80	5	27	1	46	53	22
	90	40	23	41	10	44	54
	100	16	36	32	52	15	29
69.5%Ar+ 25%CO_2+ 5%O_2 +.5%He	80	48	4	42	8	2	39
	90	20	4	42	8	2	39
	100	9	38	26	51	21	50

C. Procedure

The steps of running the experiment for all 54 replicated were the same. Each replicate was randomly selected to be run and test in laboratory and data of tensile strength and elongation were recorded. Statistical data of mean, standard error of mean and analysis of variance (ANOVA) were applied to analyze for this experiment.

III. RESULTS

A. Pilot Study Result of Ultimate Tensile Strength

Normality test of pilot study of 12 replicates was analyzed to determine all of those factors and experiment appropriated to be fully run. The data of ultimate tensile strength was recorded and analyzed. , and result was showed in Figure 3. As result, factors testing for pilot study were currents at level of 80 and 100 Amp, welding speeds at 250 and 350 mm/min, and shield gases of 75%Ar + 25%CO_2, 70%Ar + 25%CO_2 + 5%O_2, and 69.5%Ar + 25%CO_2 + 5%O_2 + 0.5%He. Normality test showed p-value over .05, which was .975. This indicated that experiment was normal and ready to run the rest of replicates.

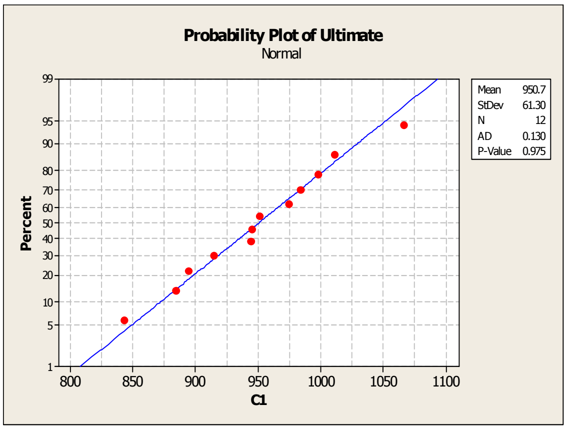

Fig. 3 Normality test of Tensile Strength for Pilot Study

B. Result of Ultimate Tensile Strength

After testing for pilot study, the rest of replicates were run and data were recorded and analyzed for normality test of ultimate tensile strength. Normality result of 54 replicates was showed in Figure 4, which p-value was showed at .793 indicating normality.

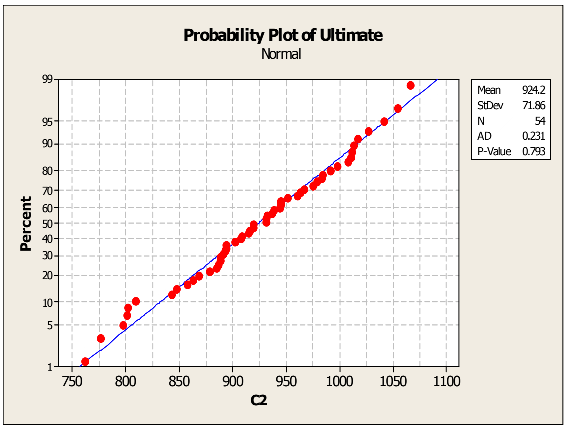

Fig. 4 Normality test of Tensile Strength for Experiment

Then, the analysis of variance (ANOVA) was performed and result of ultimate tensile strength was showed in Table II. As the result showed, only main factor of shield gas was showed significantly different at the level of .05. The rest of those factors including interaction effects were not showed any significant difference.

TABLE II
ANOVA RESULT FOR ULTIMATE TENSILE STRENGTH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	169051.81a	26	6501.993	1.678	.094
Intercept	4.613E7	1	4.613E7	1.190E4	.000
Gas	33128.404	2	16564.202	4.275	.024
Amp	1287.563	2	643.782	.166	.848
Speed	19012.322	2	9506.161	2.453	.105
Gas * Amp	36006.520	4	9001.630	2.323	.082
Gas * Speed	14074.523	4	3518.631	.908	.473
Amp * Speed	21886.563	4	5471.641	1.412	.257
Gas * Amp * Speed	43655.918	8	5456.990	1.408	.238
Error	104619.579	27	3874.799		
Total	4.640E7	54			
Corrected Total	273671.393	53			

Since main effect of shield gas was showed significantly different, least significant difference (LSD) has to applied to compare which one of shield was different from the others and result showed in Table III. Result was indicated that gas 75%Ar+25%CO_2 was significantly different from gas 70%Ar+25%CO_2+5%O_2 at the level of .01.

Figure 5 was showed the comparison of ultimate tensile strength among shield gas factor affecting to mechanical property of austenitic stainless steel AISI 304.

TABLE III
LEAST SIGNIFICANT DIFFERENCE OF SHIELD GAS

Gas	1	2	3
1		**	.165
2			.146
3			

** Significant at the level of .01

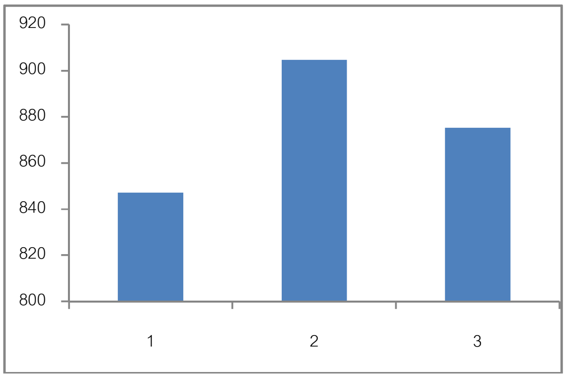

Fig. 5 Show Comparison of Shield Gas

Remark:1 mean shield gas of 75%Ar+25%CO_2
2 mean shield gas of 70%Ar+25%CO_2+5%O_2
3 mean shield gas of 69.5%Ar+25%CO_2+5%O_2+.5%He

C. Result of Elongation

Result of elongation that was generated from ultimate tensile strength was showed in Table IV. ANOVA results indicated that interaction effect between shield gas and welding speed was shoed significantly different at the level .05, and interaction effect between current and welding speed was showed significantly different at the level .05.

When interaction effect was showed significantly different, comparison of interaction effect graph would be drawn to indicate the appropriate level of each combination factor as showed in Figure 6 and 7.

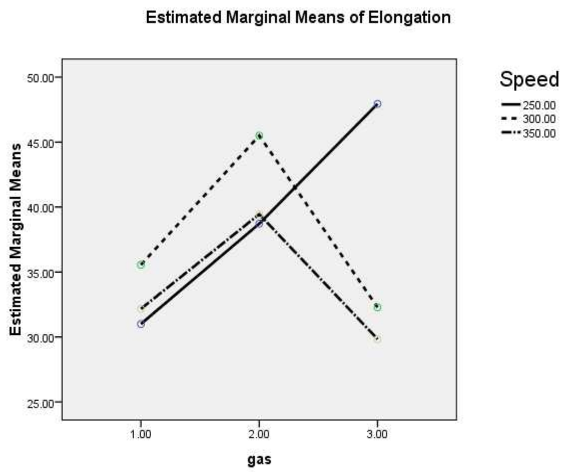

Fig. 6 Interaction Effect between Shield Gas and Welding Speed

Remark:1 mean shield gas of 75%Ar+25%CO_2
2 mean shield gas of 70%Ar+25%CO_2+5%O_2
3 mean shield gas of 69.5%Ar+25%CO_2+5%O_2+.5%He

TABLE IV
ANOVA RESULT FOR ELONGATION

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4990.945a	26	191.959	2.378	.014
Intercept	73679.785	1	73679.785	912.924	.000
Gas	623.903	2	311.951	3.865	.033
Amp	588.388	2	294.194	3.645	.040
Speed	282.140	2	141.070	1.748	.193
Gas * Amp	339.688	4	84.922	1.052	.399
Gas * Speed	1110.042	4	277.511	3.438	.021
Amp * Speed	950.903	4	237.726	2.946	.038
Gas * Amp * Speed	1095.882	8	136.985	1.697	.145
Error	2179.101	27	80.707		
Total	80849.832	54			
Corrected Total	7170.046	53			

Figure 6 indicated that interaction effect between shield gas and welding speed was had the highest elongation for the combination of shield gas 69.5%Ar+25%CO_2+5%O_2+.5%He and welding speed at 250 mm/min approximately at 47.94%.

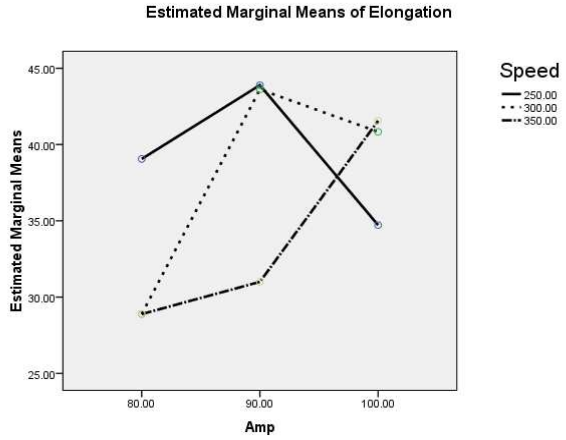

Fig. 7 Interaction Effect between Welding Speed and Current

Figure 7 indicated that interaction effect between welding speed and current was had the highest elongation for the combination of welding speed at 250 mm/min and current at 90 Amp approximately at 43.89%.

IV. CONCLUSION

As the result, it was concluded that factors that affected to ultimate tensile strength for austenitic stainless steel grade AISI 304 was the main factor of shield gas. The combination of gas that provided the highest ultimate tensile strength was shield gas of 70%Ar+25%CO_2+5%O_2. Moreover, the highest elongation was showed significantly different at interaction effect between shield gas 69.5%Ar+25%CO_2+5%O_2+.5%He and welding speed at 250 mm/min approximately at 47.94%.

REFERENCES

[1] S. Kaewkuekool and B. Amornsin “A Study of Parameters Affecting to Mechanical Property of Dissimilar Welding between Stainless Steel (AISI 304) and Low Carbon Steel” Proceeding of 1st WSEAS International Conference on MATERIALS SCIENCE (MATERIALS’08). Bucharest, Romania. November 7-9, 2008 pp. 105-109.

[2] Goodwin, G. M., April , “ The effects of heat input and weld process on hot cracking in stainless steel”, Welding Journal 67, pp. 1105.

[3] David , JR., 1999, ASM Specialty Handbook Stainless Steel, ASM International Materials Park, Ohio USA