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Effect of Welding Positions on The Mechanical Properties of Manual Metal Arc Welding

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تأثير مواضع اللحام على الخواص الميكانيكية للحام القوس المعدني اليدوي

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Abstract:
In mechanical engineering and product design, welding is an essential technique that combines various parts and structures. One of the most challenging welding positions and a requirement for welder certification is the 6G position. The main objective of this investigation is to determine the mechanical properties of six low-carbon steel pipe butt joints in the 6G welding position at different locations after being welded using manual metal arc welding (MMA). At the six, twelve, three, and nine o'clock positions on each welded pipe intersection, samples were taken for tensile strength and hardness and tested. After all the data has been obtained and categorised into four groups, the SPSS ANOVA test was performed to determine if there are any significant differences. The findings reveal a minor difference in most of the dates collected for either tensile or hardness, with the exception of location three's tensile data, which is slightly lower than the other data groups. Low-heat input welded joints have high tensile strength; high-heat input joints have a relatively low tensile strength due to uncomfortable posture and difficulty maneuvering, which slows down movement.

Keywords: Tensile, Hardness, SPSS ANOVA,6G Position, Welding, MMA Welding.

الملخص
في الهندسة الميكانيكية وتصميم المنتجات، يعد اللحام تقنية أساسية في تجمع أجزاء الهياكل المعدنية المختلفة. كما يعد وضع 6G أحد أكثر أوضاع اللحام تحديًا ويتطلب الحصول على ترخيص لحام للقيام به. الهدف الرئيسي من هذا البحث هو تحديد الخصائص الميكانيكية لستة وصلات لحام تناكبية لأنابيب فولاذية منخفضة الكربون في وضع اللحام 6G في أوضاع مختلفة بعد اللحام باستخدام اللحام القوسي المعدني اليدوي (MMA). في مواضع الساعة السادسة والاثني عشر والثالثة والتاسعة على كل تقاطع للأنابيب الملحومة تم أخذ عينات اختبار لقياس لقوة الشد والصلابة. بعد الحصول على جميع البيانات وتصنيفها إلى أربع مجموعات، تم إجراء اختبار تحليل التباين SPSS لتحديد ما إذا كانت هناك أي اختلافات كبيرة. تكشف النتائج الشد والصلابة عن اختلاف طفيف في معظم مواضع اللحام، باستثناء بيانات الشد عند وضع الساعة الثالثة، والتي تكون أقل قليلاً من مجموعات البيانات الأخرى. تتمتع الوصلات الملحومة

ذات المدخلات الحرارية المنخفضة بقوة شد عالية؛ بينما الوصلات ذات المدخلات الحرارية العالية لها قوة شد منخفضة نسبيًا بسبب الوضع غير المريح وصعوبة المناورة، مما يؤدي إلى إبطاء الحركة.

الكلمات المفتاحية: الشد، الصلابة، SPSS انوفا، وضع G6، لحام (MMA).

1. Introduction

Welding is an important manufacturing process that is commonly used as a joining method in a variety of technological applications. Welding is used to join, cut, and recover mechanical components, and cannot be replaced by other processes in some situations due to its strength [1]. Pipe welding is widely used in the shipbuilding, nuclear power, chemical manufacturing, and natural gas transportation industries where manual metal arc welding (MMA) is a welding processes that uses electric arc as a heated source to melt the metals and the electrode. The heat source is continuously on throughout the welding operation, generating differences in the temperature distribution of the metal, resulting in uneven expansion and contraction. Residual stress and distortion will occur in the metal being welded as a result of the welding process [2].

Furthermore, the components to be welded are sometimes needed to be multi-layer/multi-pass and cannot always be available in perfect position; the position employed during the welding process has an effect on the welding quality and mechanical characteristics. Unlike flat surfaces, multi-layered and curved surfaces present challenges for the production of molten metal. As a result, welding on multi-layered and curved surfaces might be difficult when the welding gun travels in an inclined direction. gravity therefore influences the formation of molten metal, temperature surface distributions, weld appearance, and even weld imperfections. The quality and a uniformity of complicated surface welds are significantly impacted by these parameters. It was found that the different weld bead formations are determined by the effect of gravity on the welding operation because the molten pool behavior at each welding point influences the formation of the bead, and the weld metal microstructure changes [3].

The procedure of welding additionally influences quality and strength; a higher input current produces more heat input. The outcome is a decrease in the strength and quality of the weld [4]. On-site welding experience and data from pipeline construction projects indicate that hydrogen cracks in the weld metal are related to the weld position, particularly the 6 o'clock position of the pipeline circumferential weld being the most typical location for these cracks to form. Bending tests confirmed that the material was more prone to fracture at the six o'clock position. This is because welding overhead allows the weld metal to absorb more hydrogen, and due to the way in which residual stresses occur throughout the welding process, this can significantly affect crack susceptibility. These findings can have a major impact on the welding process preparation related to the prevention of cracks in the transverse direction in pipeline circumferential welds. [5]. This study examined the impact of welding position on the mechanical properties of weld metals (X20CrMoV11-1 steels (X20)). The findings demonstrated that the HAZ region's toughness measurements were greater than those of the welding zone and base metals, and that the welding position had no bearing on the bending and tensile test results [6].

2. Material and Methods

In this investigation, six low-carbon steel pipe butt joints were prepared for welding. The pipes used in the study had a diameter of 159 mm and a parent material thickness of 10 mm. Table 1 provides the chemical compositions of the base metals used in the welding process.

Table 1: Nominal Chemical Composition of the base metals

C%	Mn%	Si%	P%	Cr%	Ni%
0.248	0.409	0.191	0.016	0.078	0.041
Co%	W%	Ce%	Cu%	Al%	Fe%
0.013	0.023	0.119	0.018	0.055	98.672

*Nominal Chemical Composition of the base metals

The power source with constant electrical current manual metal arc welding (MMAW) has been used. The pipe joints were initially cleaned with a steel wire brush, then right before welding, each one was swabbed with acetone. The joints were then fixed with jigs and placed in the 6G position as is shown in Figure 1.

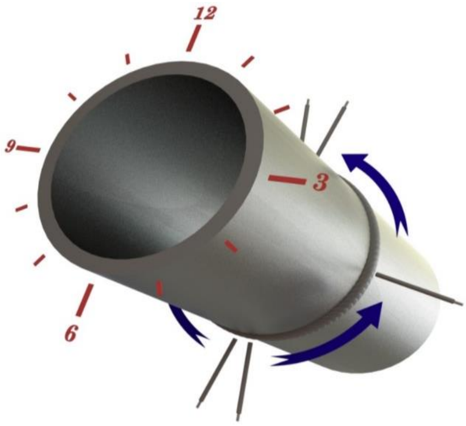
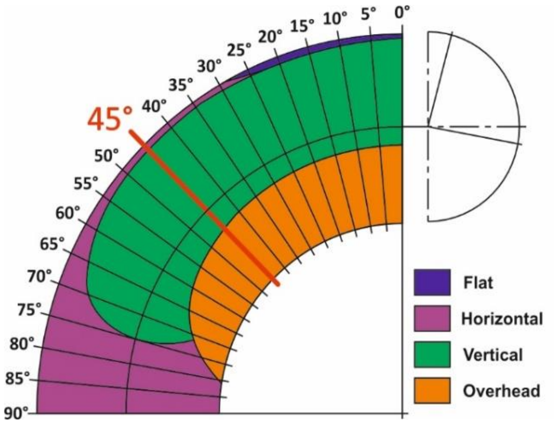


Figure 1: 6G (H-L045) welding position

The E 6010 electrode, with a diameter of 2.5 mm, was selected, and reverse polarity (DC+) with a current range of 60–90 A was used for the root pass. The filling and capping layers were welded using E 7018 electrodes, with a 3.25 mm diameter and a current range of 75-90 A with DC+ reverse polarity.

Pipe welding is uncomfortable position and technique when is it in restricted place. 6G Uphill/H-L045 position is the most challenge, because it involves three positions including overhead, vertical and horizontal as shown in the Figure 2. Beginning at the bottom, the welding gun moves along a curved path from overhead at six o'clock (0°), climbing vertically through the curvature path to pass through the region from three o'clock (280° to 360°) forward to the area of horizontal position, until it reaches the top at twelve o'clock. Return to the six o'clock position and perform the same steps on the other side.



Tabulation of Positions of Groove Welds				
Position	Diagram Reference		Inclination of Axis	Sector
Flat		F	0° to 15°	150° to 210°
Horizontal		H	0° to 15°	80° to 150°
				210° to 280°
Overhead		O	0° to 80°	0° to 80°
				280° to 360°
Vertical		V	15° to 80°	80° to 280°
			80° to 90°	0° to 360°

Figure 2: Tabulation of Positions of Groove welds

As a result, it is considered the most difficult to master which can be physically strenuous and need greater control and precision where the welder must be proficient in maneuvering in three different positions, starting from overhead, to the vertical position, and ending with the horizontal position as defined in the orientations of welds QW-461.1 in ASME BPVC.IX as shown in the Figure 3. The molten metal is being affected by the welder's body posture and gravity, which changed the fluid flow structure, temperature field distribution, bead geometry, and even welding velocity.

These changes in turn affected the mechanical properties and accuracy of the welding process. The next step was a qualified inspector examined the weld integrity using visual and radiography inspection techniques. Samples for the tensile and hardness tests were taken from each welded pipe intersection at the six, twelve, three, and nine o'clock locations. The tensile test was done according to ASTM- E8 of standard specification used ZWICK 1000 instrument and ASTM- E18 is used for hardness test in BULUT-BMS 201-R instrument.

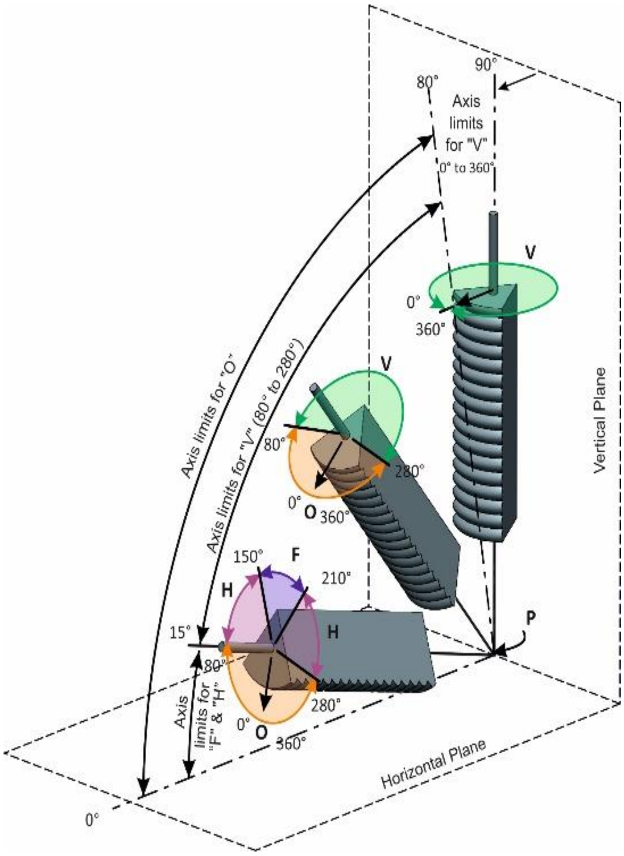


Figure 3: The orientations of welds

3. Experiment Result for Tensile and Hardness Test

On the basis of their locations on the welded pipe joints, the tensile and hardness data are collected and divided into four groups, as shown in the Table 2. With the exception of the tensile date that comes from location three, which is somewhat lower than the other date groups, the result shows that there is no significant difference between most of the dates obtained for tensile or hardness.

Table 2: Tensile and Hardness Test Results

sample location	Sample No	Tensile (N/mm2)	Hardness	sample location	Tensile (N/mm2)	Hardness
12	1	559.18	85.00	3	408.00	86.00
	2	515.47	82.00		566.37	83.00
	3	603.72	85.00		498.00	83.00
	4	572.83	86.00		517.07	81.00
	5	555.00	87.00		485.08	86.00
	6	574.86	87.00		492.07	79.00
6	1	485.15	87.00	9	555.50	83.00
	2	492.52	86.00		503.00	88.00
	3	601.99	84.00		585.67	86.00
	4	508.92	88.00		514.02	84.00
	5	578.12	83.00		567.00	82.00
	6	532.01	81.00		572.15	84.00

4. Tensile and Hardness Test Results

Statistical analysis performed to investigate if there is a difference among the groups and how the welding positions on circumferential pipe joints affected the tensile and hardness values obtained from four different locations. The SPSS ANOVA test was used to determine whether there were any differences in the group's means at the 95% confidence level. The data presented in Table 3 indicates that there is a statistically significant variation in the ultimate tensile strength across the groups, with

F=3.111 and p < 0.049. On the other hand, the hardness mean had a non-significant P value greater than 0.05.

Table 3: ANOVA Statistical analysis

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Ultimate Tensile Strength	Between Groups	16043.711	3	5347.904	3.111	.049
	Within Groups	34384.387	20	1719.219	-	-
	Total	50428.099	23	-	-	-
Weld Metal Hardness	Between Groups	18.167	3	6.056	1.065	.386
	Within Groups	113.667	20	5.683	-	-
	Total	131.833	23	-	-	-

The LSD test is a multiple comparison method in table (4) used to determine which mean value is different from another means value. According to the results of the tests performed, there is a significant difference between the tensile group of location 3 tensile group of location 12 (p = 0.009), and between the tensile group of location 3 and tensile group of location 9 (p = 0.032).

Table 4: ANOVA Statistical analysis

Multiple Comparisons						
Dependent Variable: Ultimate Tensile Strength						
LSD						
(I) locations	(J) locations	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
12	3	69.07833*	23.93895	.009	19.1426	119.0141
	6	30.39167	23.93895	.219	-19.5441	80.3274
	9	13.95333	23.93895	.566	-35.9824	63.8891
3	12	-69.07833*	23.93895	.009	-119.0141	-19.1426
	6	-38.68667	23.93895	.122	-88.6224	11.2491
	9	-55.12500*	23.93895	.032	-105.0608	-5.1892
6	12	-30.39167	23.93895	.219	-80.3274	19.5441
	3	38.68667	23.93895	.122	-11.2491	88.6224
	9	-16.43833	23.93895	.500	-66.3741	33.4974
9	12	-13.95333	23.93895	.566	-63.8891	35.9824
	3	55.12500*	23.93895	.032	5.1892	105.0608
	6	16.43833	23.93895	.500	-33.4974	66.3741
* The mean difference is significant at the 0.05 level.						

The effect and the influence of the welding positions on the ultimate tensile strength is illustrated in the means plots Figures 4. It can be observed that, when the positions of the samples were statically examined to the figures of the ultimate tensile strength, the sample at 3 o'clock showed a lower tensile strength compared to the samples at other places, while the sample at 12 o'clock showed higher values.

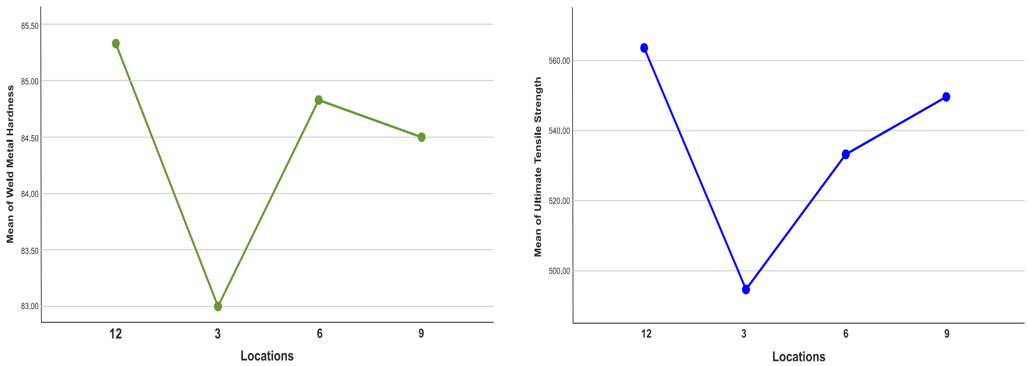


Figure 4: The influence of the welding positions on the ultimate tensile strength.

Welded joints with low heat input have high tensile strength and ductility, while the joints welded with high heat input have comparatively lower tensile strength and ductility (7). Low tensile values are the result of the welder's body being in an uncomfortable posture which decrease the velocity and the difficulty of manoeuvring at that point for those who use the right hand. On the other side, research into what might occur when left-handed welders perform 6G position at nine o'clock.

5. Conclusion

In this study, six circumferential multi-pass pipe butt joints made of carbon steels positioned in the 6G position were welded using manual metal arc welding (MMAW) with a constant current power source. The effect of welding positions on the mechanical characteristics has been studied using statistical analysis SPSS ANOVA test and the following is a report that summarises the conclusions obtained from the work**.** The result indicates that there is a slight variance in the majority of the dates gained for both hardness or tensile, with the exception of the tensile date from location three, which is somewhat lower than the other groups of data. According to the results of the SPSS ANOVA test, the sample at 3 o'clock shown a lower tensile strength compared to the samples at other places, whereas the sample at 12 o'clock showed greater values when the positions of the samples were statically analysed to the values of the ultimate tensile strength. Welded joints with low heat input have high tensile strength; however, joints with high heat input have comparatively low tensile strength due to uncomfortable posture and difficulties manoeuvring at 3 o'clock, which reduces velocity.

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