International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Investigate the Influence of Technological Parameters on Weld Tensile Strength with Industrial Welding Robots

Le Van Tan[1], Dao Van Duong[2*], Ngo Tan Loc[3]
[1]Dong Nai University, Dong Nai, Vietnam
[2]HCMC University of Industry and Trade, Ho Chi Minh, Vietnam
[3]Le Quy Don Technical University, Hanoi, Vietnam
[*]Corresponding author: duongdv@hufi.edu.vn

***Abstract*— *This paper focuses on investigating the influence of technological parameters on the tensile strength of the weld seam when performing a butt weld on an industrial robot arm with 6 degrees of freedom (6DOF). The Box-Behnken model is used to investigate three technological parameters including voltage, amperage and torch moving speed. The objective function to be affected is the tensile strength of the weld through the application of the Design Expert software (DE) with the ANOVA analysis module. The research results have important implications in studying the quality of the butt weld when using the industrial robot arm in the condition of changing the moving speed of the torch. This is valuable in improving machining productivity, reducing time costs while ensuring weld quality.*

***Keywords*— *Weld quality, industrial robots, tensile strength.*

I. INTRODUCTION

This The industrial revolution 4.0 has greatly affected the production process, outdated equipment is gradually eliminated. Industrial robots will play an increasingly important role in the process of industrial production in general and in mechanical production in particular. In manufacturing, productivity and quality determine everything. In order to increase output and minimize welding defects, equipping a welding robot is one of the selected solutions in line with the 4.0 industry trend. Welding robots bring many positive benefits and have long-term effects such as: oWTStanding productivity, unaffected by harsh working environment, ability to work accurately, ensuring uniformity and quality of the product range. Therefore, the use of robots in industry has increased in recent years. However, along with the above advantages, welding robots also need to ensure important criteria in evaluating product quality through the quality of welds. In which, it is necessary to mention the tensile strength of the weld. It reflects the mechanical properties of the weld.

Research on the influence of technological parameters on the quality of welds has had many published scientific works, both at domestic and abroad.

The graininess of the weld or the microstructure of the weld is considered in [1] when studying MIG welding for IS2062 (Group A) materials on industrial robots. The respond surface method (RSM) is used in [2] to optimize the parameters of GMAW welding technology with the optimal criterion of the graininess for the weld. The weld surface roughness is considered in [3] with the MIG welding method. Taguchi method is used in [4] to optimize the welding technological parameters for MS 6986 Fe410 material with MIG welding, the microstructure of the weld is a factor of interest to research. The weld tensile strength is covered in [5] on MIG welders for hot stamping die steel (HDS). The mechanical properties of welds (tensile strength and hardness) when welding between dissimilar metals (Stainless steel 304 and mild alloy steel) are considered in [6] based on experiments evaluating the influence of various technological parameters. The relationship between the technological parameters and the penetration of MAG welding for low carbon steel is considered in [7]. A mathematical model is proposed in [8] with the penetration, grain height and width as a function of the technological parameters. These authors claim that the accuracy of the models found varies from 0% to 25%. Correlation between weld graininess with current, voltage, weld speed and weld angle are considered in [9]. The authors demonstrate that the linear model provides better analytical results. The weld angle tested varies from 10 degrees to 20 degrees from the vertical, which is a typical range of applications in GMAW welding operations on industrial robots. Some authors use optimization algorithms for welding technology parameters. The genetic algorithm used in [10] Taguchi method is used in [11] to analyze each parameter of arc welding to the geometry of the weld microsphere and optimize each parameter individually. of weld granules. Analysis of variance (ANOVA) method was used in [12] to process and analyze data when welding spiral welded steel pipe.

This paper focuses on evaluating the influence of technological parameters including welding voltage, amperage and moving speed of the torch on the tensile strength of welds with CT3 alloy steel as welding material with the ABB 1520ID 6DOF robot. The Box-Behnken experimental model [13] was used to build the problem, the calculations and analysis were performed by the DE software with the ANOVA module.

II. METHODS AND MATERIALS

2.1. Experimental design

Le Van Tan and Dao Van Duong, “Investigate the Influence of Technological Parameters on Weld Tensile Strength with Industrial Welding Robots,” *International Research Journal of Advanced Engineering and Science*, Volume 9, Issue 1, pp. 169-173, 2024.

The butt weld in this study is described as shown in Fig. 1. Where, b_h is the width of the weld, h_c is the height of the weld and h_n is the depth of the weld. The tensile strength (δ_k) of the weld can be determined between the maximum tensile force ($F_{k\max}$) in the tensile test compared with the cross-sectional area of the weld (S_k) in the tensile test:

$$\delta_k = \frac{F_{k\max}}{S_k} \tag{1}$$

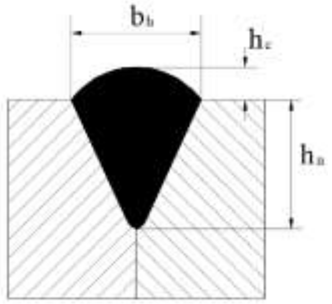


Figure 1. One-sided gapless butt weld

The higher the tensile strength, the better the weld quality in terms of mechanical properties. Therefore, the smaller the tensile strength inverse $\delta_{opt} = \frac{1}{\delta_k} = \frac{S_k}{F_{k\max}}$, the better. In most case studies, the weld height is usually a pre-determined value because it depends on the torch tilt angle, torch moving speed and wire feed rate. The experimental goal is defined as follows:

Evaluation of the influence of technological parameters on the weld tensile strength when MIG welding on industrial robot arms.

The order of conducting research includes the following steps:

Firstly, determine the empirical model, build the empirical matrix.

Secondly, perform experiments and measure related results.

Thirdly, build regression equations describing the relationship between welding parameters and tensile strength.

Finally, use the DE software and related algorithms to analyze and evaluate according to the above goals.

The experimental model is set up as follows:

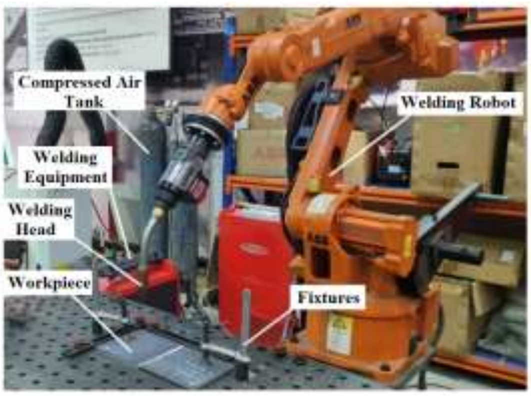


Figure 2. Experimental model

The experimental model is built on the basis of the input factors of the welding process on the industrial robot and the output targets after welding. The experimental system is described in Fig. 2.

The number of experiments is 15. The number of input parameters is 03 parameters. The output parameters are the geometrical dimensions and the mechanical properties of the weld.

TABLE I. Input parameters for experimental problem.

Items	Input parameters		Value	Unit
Welding materials	Workpiece material	Steel Marks	CT3	
		Workpiece dimension	150x150x8	mm
	Protective gas		CO_2	
	Welding wire	Material marks	GM-70S	
		Welding wire diameter	1.2	mm
Welding parameters	Welding current		100-140	A
	Welding voltage		22-26	V
	Torch moving speed		300-500	mm/min
	Protective gas flow		15	liters/minute

Tab. 2 and Tab. 3 describe the set of experimental parameters with the level and value of welding technological parameters for each specific experiment.

TABLE II. Parameters and value levels.

Parameters	Code	Level		
		-1	0	1
Welding voltage $U_h(V)$	A	22	24	26
Welding current $I_h(A)$	B	100	120	140
Torch moving speed $F_h(mm/\min)$	C	300	400	500

TABLE III. Experimental Matrix.

Ex	$U_h(V)$	$I_h(A)$	$F_h(mm/\min)$
Ex1	24	120	400
Ex2	26	100	400
Ex3	26	120	500
Ex4	22	100	400
Ex5	24	120	400
Ex6	24	140	500
Ex7	26	120	300
Ex8	24	100	300
Ex9	24	100	500
Ex10	24	120	400
Ex11	22	140	400
Ex12	22	120	300
Ex13	26	140	400
Ex14	24	140	300
Ex15	22	120	500

Welded workpieces are prepared with CT3 steel alloy, the size of each weld plate is 150x150x8 (mm), weld chamfer size: $4x45^0$. After cutting, the workpiece is cleaned, blunted with sharp edges and cleaned (Fig. 3).

Welding wire with code GM-70S (Fig. 4) according to TCVN 3223:2000 standard with equivalent standard AWS A5.18 ER 70S-6, JIS YGW1. The wire diameter is 1.2mm. The 6DOF ABB 1520ID welding robot (Fig. 2) is used with

MIG welding.

Figure 3. Steel workpieces CT3

Figure 4. Welding wire GM-70S

The measurement of weld size (width, height, depth) is carried out according to the following steps: cleaning the weld, cutting the weld plate by EDM (Electrical Discharge Machining) method, taking pictures to ensure 1:1 ratio, measuring on specialized equipment, and supported by computer software (Fig. 5).

Fig. 5. Dimensional and tensile measuring devices

After the samples are soldered, weld plates will be cut by the EDM according to the scissors pattern and measure the tensile strength. Tensile test specimens are cut to the profile and dimensions as shown in Fig. 6.

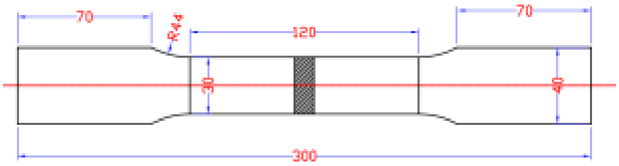


Figure 6. Drawing of tensile test piece

The samples after cutting are shown in Fig. 7.

Figure 7. Cutting test piece

The samples were tensile tested on a tensile tester and after tensile (Fig. 8).

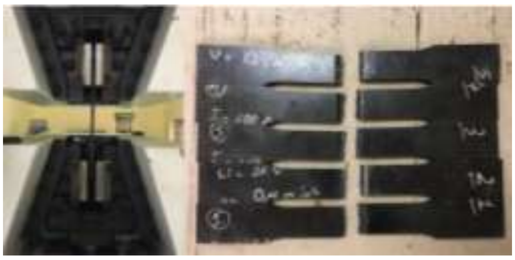


Figure 8. Tensile test process and results

After the sample was measured 3 times, the measured values took the average value and obtained the results as shown in Tab. 4.

TABLE IV. Experimental results of tensile strength.

Samples		Width	Height	Area	Results	
					Load	Tensile Strength
		mm	mm	mm^2	kN	N/mm^2
1	Ex1	29.90	5.60	167.40	54.08	323.49
2	Ex2	29.88	5.38	160.57	51.40	320.28
3	Ex3	29.92	5.43	162.31	60.34	371.98
4	Ex4	30.04	4.73	142.07	50.27	353.19
5	Ex5	29.93	5.62	168.03	57.70	343.41
6	Ex6	29.93	5.86	175.36	57.15	329.40
7	Ex7	29.95	6.18	184.92	62.33	337.04
8	Ex8	29.93	5.67	169.67	53.51	315.05
9	Ex9	29.91	5.03	150.42	44.70	296.40
10	Ex10	29.79	5.79	172.46	54.10	313.69
11	Ex11	29.80	6.47	192.78	54.00	280.08
12	Ex12	29.72	6.63	197.05	47.64	241.67
13	Ex13	29.72	6.36	189.02	66.20	350.23
14	Ex14	29.76	6.82	202.78	61.05	301.15
15	Ex15	29.85	5.00	149.23	44.90	300.92

2.2. ANOVA Analyzing

With the measured data results from Tab. 4, the data is entered into DE software as shown in Fig. 9. Select the regression equation model as polynomial of order second as shown in Fig. 10.

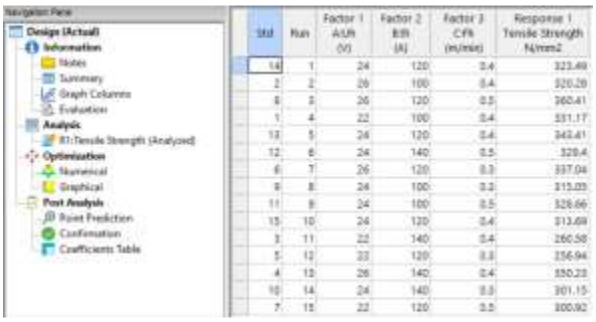


Figure 9. Data entry into the DE software

Le Van Tan and Dao Van Duong, "Investigate the Influence of Technological Parameters on Weld Tensile Strength with Industrial Welding Robots," *International Research Journal of Advanced Engineering and Science*, Volume 9, Issue 1, pp. 169-173, 2024.

International Research Journal of Advanced Engineering and Science

ISSN (Online): 2455-9024

Figure 10. Regression equation in the form of quadratic polynomial

The data is processed and analyzed in the ANOVA module as shown in Fig. 11.

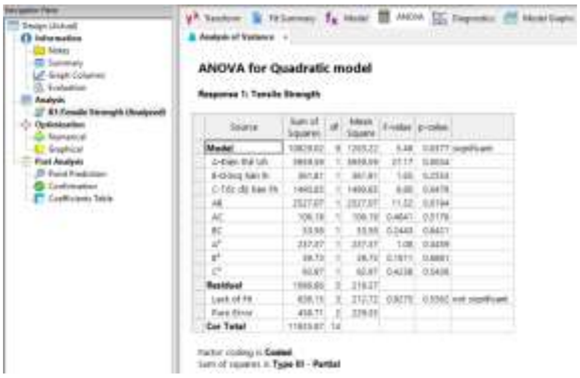
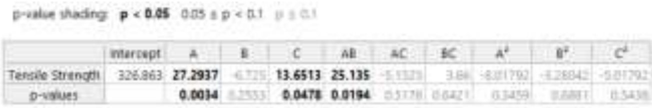


Figure 11. Parameter table in ANOVA analyzing

Fig. 12 describes the main influencing factors on the tensile strength of the weld.



p-value shading: **p < 0.05** 0.05 ≤ p < 0.1 p ≥ 0.1

	Intercept	A	B	C	AB	AC	BC	A²	B²	C²
Tensile Strength	326.863	**27.2937**	-6.725	**13.6513**	**25.135**	-5.1525	3.66	-8.01792	-8.28042	-5.01792
p-values		**0.0034**	0.2553	**0.0478**	**0.0194**	0.5778	0.6421	0.3459	0.6881	0.5438

Figure 12. Main influencing factors

The results of the ANOVA analysis of variance on the tensile strength prediction model are shown in Eq. 2.

$$WTS = 326.86 + 27.29x_1 + 13.65x_3 + 25.14x_1x_2 \quad (2)$$

Preliminary assessment of technological parameters influence on the weld tensile strength (WTS) shows that, when increasing the welding current (Ih), WTS values tend to decrease. Welding voltage (Uh) and welding feedrate (Fh) have a great influence on WTS. The WTS value tends to increase with increasing values of Uh and Fh.

2.3. WTS optimization based on PSO algorithm

The Particle Swarm Optimization algorithm (PSO) [14] is used to find the most suitable set of technological parameters to ensure the maximum tensile strength target. This algorithm is built on the basis of limiting conditions of variables ($-1 \le x_1, x_2, x_3 \le 1$) corresponding to the limits of technological parameters including welding voltage (Uh-x1) reaching $22 \le U_h \le 26(V)$, welding current (Ih-x2) reaching $100 \le I_h \le 140(A)$, welding torch moving feedrate (Fh-x3) is $0.3 \le F_h \le 0.5(m/\text{min})$. PSO algorithm parameters are described in Tab. 5.

TABLE V. PSO algorithm parameters.

S. No.	Parameters	Symbols	Values
1	Number of search iterations	MaxIt	100
2	Population size	npop	100
3	Inertia coefficient	w	1
4	Each individual Acceleration coefficient	C1	2
5	Swarm Acceleration coefficient	C2	2

III. RESULTS AND DISCUSSION

The calculation program is built on MATLAB software and gives results as shown in Figure 13.

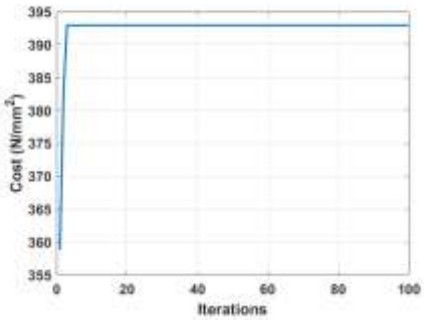


Figure 13. Objective function value

The optimal value after the 4th iteration was found with the tensile strength value $392.94(N/mm^2)$ corresponding to the values of the variables: $x_1 = 1,\ x_2 = 1,\ x_3 = 1$ or $u = 26(V),\ i = 140(A),\ f = 0.5(m/ph)$.

Fig. 14 describes the effects of welding current (Ih) and welding voltage (Uh).

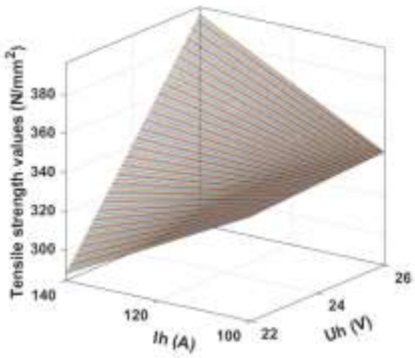


Figure 14. Effects of Uh and Ih

As Uh value increases, the value of WTS tends to increase. In the welding voltage range from 22V-24V, when the welding current increases, the WTS value tends to decrease, and in the range of 24V-26V it is the opposite. In terms of influence, the Uh value still has a the influence is greater than the Ih value and the greatest WTS value is achieved when simultaneously increasing values of the Uh to 26V and Ih to 140A.

Le Van Tan and Dao Van Duong, “Investigate the Influence of Technological Parameters on Weld Tensile Strength with Industrial Welding Robots,” *International Research Journal of Advanced Engineering and Science*, Volume 9, Issue 1, pp. 169-173, 2024.

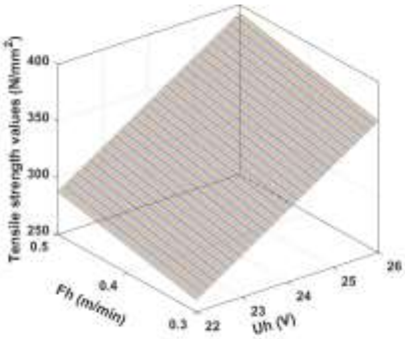


Figure 15. Effects of Fh and Uh

The effects of welding feedrate and welding voltage are shown in Fig. 15. It is easy to see that the Fh value has less influence than the Uh value. When keeping a fixed Uh level and gradually increasing the Fh, the WTS value will gradually increase. Meanwhile, if the Fhd is fixed and the Uh value gradually increases, the WTS value also gradually increases. When the Uh and Fh increase simultaneously, the WTS value increases and reaches its maximum when both parameters reach their maximum value.

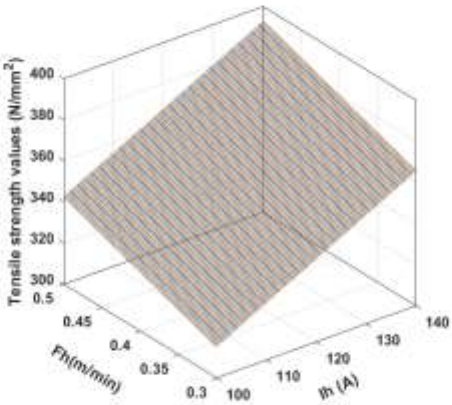


Figure 16. Effects of Ih and Fh

The effects of Ih and Fh are shown in Fig. 16. The influence of Ih value is greater than Fh value on WTS value. It tends to increase as these two parameters increase. The WTS value will reach its maximum when they reach their maximum value.

IV. CONCLUSIONS

In general, the influence of technological parameters including welding voltage, current intensity and welding torch movement speed on the weld tensile strength has been specifically analyzed. For each pair of parameters, there is always one parameter that has a greater influence than the other. Tensile strength value tends to increase with increasing voltage within a certain range. Welding voltage has a greater influence on tensile strength than the other two parameters. Welding current has the second largest influence after welding voltage. It is easy to see, with the appropriate selection of the welding voltage value and welding current intensity, the welding torch movement speed parameter has the opportunity to increase without too much impact on the tensile strength value. In some specific cases, if the weld needs to pay more attention to tensile strength than other quality criteria, the feedrate value of the welding torch can be increased. This is a good condition to increase machining productivity while weld quality can still be guaranteed.

REFERENCES

[1] ASME Section IX, (2007), "Welding and Brazing Qualifications", American Society mechanical Engineer.
[2] AWS D1.1, (2008), "Welding Structure Steel", American Welding Society.
[3] Copyright James Amanie (2011), "Effect of Submerged Arc Welding Parameters on the Microstructure of SA516 and A709 Steel Welds", the Department of Mechanical Engineering University of Saskatchewan Saskatoon.
[4] K. S. Kumaran, S. O. N. Ra, "Optimization of parameters involved in robotic MIG welding process based on quality responses", 2nd International conference on Advances in Mechanical Engineering, 402, (ICAME 2018).
[5] E. J. M. Conesa, J. A. Egea, V. Miguel, C. Toledo, L, M. Valdenebro, (2017), "Optimization of geometric parameters in a welded joint through response surface methodology", Construction and Building Materials, 154, pp. 105–114.
[6] G. A. John, (2014), "Investigate welding parameter optimization for weld bead surface quality using MIG technology", Thesis of Msc, Tun Hussein University, Malaysia.
[7] R. Sharma, J. Singh, (2014), "Parametric Optimization of MIG Welding for MS 5986 Fe 410 using Taguchi Method", Int. Journal of Applied Sciences and Engineering Research, Vol. 3, Issue 3.
[8] C. L. Kumar, T. Vanaja, K. G. K Murti, V. V. Prasad, (2017), "Optimization of Mig Welding Process Parameters for Improving Welding Strength of Steel", International Journal of Engineering Trends and Technology (IJETT), 50(1), pp. 26-33.
[9] H. Kutty, N. Naduthodi, S. Fithu, Vignesh, (2018), "Analysis and Optimization of Parameters of Dissimilar Metal Welding", International Journal of Science Technology & Engineering 4(9), pp. 10-15.
[10] E. Karadeniz, U. Ozsarac, C. Yildiz, (2007), The effect of process parameters on penetration in gas metal arc welding processes, Mater. Des. 28 649–656, http://dx.doi.org/10.1016/j.matdes.2005.07.014.
[11] L.S. Kim, C.E. Park, Y.J. Jeong, J.S. Son, (2001), Development of an intelligent system for selection of the process variables in gas metal arc welding processes, Int. J. Adv. Manuf. Technol, 18, pp. 98–102, http://dx.doi.org/10.1007/s001700170080.
[12] L.S. Kim, J.S. Son, I.G. Kim, J.Y. Kim, O.S. Kim, (2003), A study on relationship between process variables and bead penetration for robotic CO2 arc welding, J. Mater. Process. Technol, 136, pp. 139–145, http://dx.doi.org/10.1016/S0924-0136 (02)01126-3.
[13] K. S. Sangwan, G. Kant, "Optimization of Machining Parameters for Improving Energy Efficiency using Integrated Response Surface Methodology and Genetic Algorithm Approach", The 24th CIRP Conference on Life Cycle Engineering, 2017, pp. 517-522.
[14] Kennedy, J.; Eberhart, R.C. "Particle Swarm Optimization". Proceedings of IEEE International Conference on Neural Networks (1995).