Research on Effects of Welding Amperage, Velocity and Voltage on Tensile Strength of Joint Welding Metal on Narrow Gap Welding SAW

Khac-Khanh Bui, Van-Thoai Le, Thanh-Phu Nguyen, and Van-Nhat Nguyen

Abstract This paper presents the optimization results of automatically welding technological parameters of joint welding for narrow gap welding SAW, including: Welding amperage (I_h), velocity (V_h) and voltage (U_h) to ensure the maximum weld tensile strength. After determining model, the welding is carried out according to Taguchi experimental design with L9 array together with analysis of ANOVA variance to optimize technological parameters and evaluate their effect on tensile strengths of welding metal. The results give an optimal technological parameter that improve the tensile strength and their influence. Reliability of the optimal results has been confirmed through control experiments.

Keywords Narrow gap welding · Tensile strength · Optimization · Experiments · Weld metal

1 Introduction

Automatic welding technology connected with narrow gap welding plays a very important role in welding large-dimensional parts from carbon steel and low metal. It is very necessary to study and define main technologies parameter (I_h, V_h, U_h) to ensure tensile for weld metal of narrow gap. Welding productivity can be improved by increasing the fill metal yield through increasing the number of electrodes during welding or by using the addition of filler metal powder during welding [1, 2]. In addition, the application of narrow gap bonding is an effective solution in increasing productivity and quality of the weld; Narrow gap connection is applied in many different welding methods such as: TIG, MIG, MAG, SAW… [3]. Narrow gap

---

K.-K. Bui (✉) · V.-T. Le · T.-P. Nguyen · V.-N. Nguyen
Faculty of Mechanical Engineering, Hung Yen University of Technology and Education, Hung Yen, Vietnam
e-mail: khanhutehy@gmail.com

B. T. Long et al. (eds.), *Proceedings of the 3rd Annual International Conference on Material, Machines and Methods for Sustainable Development (MMMS2022)*,
Lecture Notes in Mechanical Engineering,
https://doi.org/10.1007/978-3-031-31824-5_58

welding technology SAW has many outstanding advantages compared to conventional SAW technology [2, 4, 5]. Therefore, it is necessary to study Effect of technological parameters on mechanical properties of the weld. Through experimental results according to Taguchi L9 method, the optimization process is performed in combination with ANOVA analysis of variance to determine the optimal set of welding parameters and their Effect on tensile strength. From there, we can determine the Effect trend of parameters on studied value domain.

2 Experimental Procedure

2.1 Testing Material and Equipment

***Base material**: SS400 carbon steel plate (JIS G3101–2004 Japan) [6] used to weld the experimental joints of this study with thickness S = 20 mm, chemical composition and mechanical properties determined as in Table 1.

Welding material: AWS.17.EL12 welding wire have diameter d = 3.2 mm that is used for joint welding in the study. Chemical composition and mechanical properties are suitable for SS400 steel determined in Table 2. HJ431-GB/T5293-1999 welding solder has the same chemical composition as Table 3.

Welding equipment: Automatic welding machine "DC Dragon 1000SAW" that welding power can reach 1000 (A).

Table 1 Chemical composition and mechanical properties of SS400 steel (%)

Chemical composition (%)					Mechanical properties		
C	Si	Mn	Ni	Cr	Tensile strength (N/mm^2)	Yield strength (N/mm^2)	Elongation in 100–150 mm (%)
0.1946	0.868	0.8107	0.030	0.0276			
V	Cu	W	S	P	496	343	50
0.0025	0.0374	0.0035	0.0043	0.028			

Table 2 Chemical composition and mechanical properties of welding wire EL12 (%)

Chemical composition (%)			Mechanical properties			
C	Si	Mn	Tensile strength (N/mm^2)	Yield strength (N/mm^2)	Elongation in 100–150 mm (%)	Akv (J) -400c (KJ/cm^2)
0.04–0.14	≤ 0.1	0.25–0.60				
Cu	P	S	≥ 450	≥ 360	$1 \geq 29$	$2 \geq 80$
≤ 0.35	≤ 0.03	≤ 0.03				

Table 3 Chemical composition of welding solder HJ431

SiO2	Ai2O3 + MnO	CaO + MgO	CaF2	FeO	S	P
40–44	35–42	7–14	3–7	≤1.8	≤0.06	≤0.08

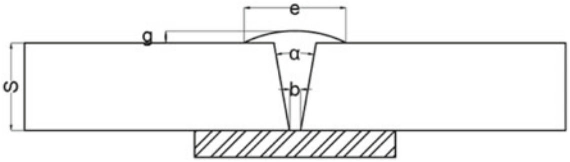

Fig. 1 Welding joint next to narrow gap

Fig. 2 Welding joint for testing sample

2.2 Welding Joint

In the welding joint of narrow gap, the chamfer angle of selected in the range of 1°–3° [7, 8], the width of weld groove depends on thickness of welding material and tip. SS400 steel plate has dimensions of 20 × 140 × 300 mm and is chamfered on one side with a chamfer angle of 2°. To evaluate penetration of the weld, a 20 × 140 × 300 mm steel plate from SS400 [2, 9] is used to make the bottom lining. Weld clearance b = 12 mm at the bottom of the connection (Fig. 1). The connection is mounted on the bottom plate, the weld size parameters are calculated according to the theory (weld width e = 22 mm, weld height g = 2.0 mm) and cleaned and guaranteed not have rust before welding (Fig. 2).

2.3 Conduct Experimental Welding

Technological parameters selected during the survey include: I_h (450, 500, 550) (A); V_h (16, 18, 20) (cm.min-1); U_h (30, 32, 34) (V) [4, 7]. The number of welding layers is calculated to perform in the experiment with n = 3 (layers).

Table 4 Welding parameters of samples

Test	Denominator	I_h (A)	V_h (cm/ph)	U_h (V)	Welding layers no.
1	1	450	16	30	3
2	2	450	18	32	3
3	3	450	20	34	3
4	4	500	16	32	3
5	5	500	18	34	3
6	6	500	20	30	3
7	7	550	16	34	3
8	8	550	18	30	3
9	9	550	20	32	3

(a) Welding source (b) Welding process (c) Joint after welding

Fig. 3 Sample welding test

The experimental process is conducted based on the value levels of welding parameters (I_h, V_h, U_h). These parameters consist of 3 levels and are arranged according to Taguchi's L9 orthogonal array as shown in Table 4 [8].

The welding process is carried out on the equipment (Fig. 3a) and took place as shown in Fig. 3b. After being welded, the welding sample is cleaned to cool in the air as shown in Fig. 3c.

3 Results and Discussion

3.1 Weld Metal Tensile Test

The joint after welding is processed for tensile test pieces with dimensions as shown in Fig. 4 [9]. After being machined and cut (Fig. 5), the samples are tested for tensile strength on a Super L device. 120/TO.

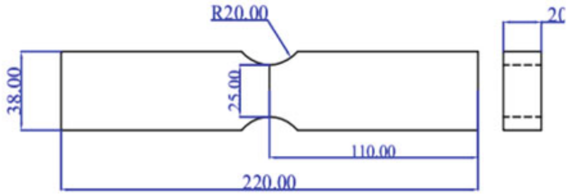

Fig. 4 Drawing of tensile test

Fig. 5 Tensile test of welding joint metal

After conducting to check the respective samples, sum up the pulling results and the S/N ratio. S/N values with larger quality characteristics are better calculated and presented in Table 5.

Table 5 Tensile strength measurement results and corresponding S/N ratio

STT	I_h (A)	V_h (cm.min^{-1})	U_h (V)	σb (Mpa)	*S/N*
1	450	16	30	526	54.4197
2	450	18	32	518	54.2866
3	450	20	34	535	54.5671
4	500	16	32	558	54.9327
5	500	18	34	542	54.6800
6	500	20	30	534	54.5508
7	550	16	34	555	54.8859
8	550	18	30	525	54.4032
9	550	20	32	545	54.7279

Table 6 Analysis of effect of I_h, V_h, U_h parameters on strength of welding joint

Level	Welding parameters		
	A	B	C
1	54.38	54.73	54.49
2	54.77	54.51	54.61
3	54.65	54.56	54.7
Effected no.	1	2	3

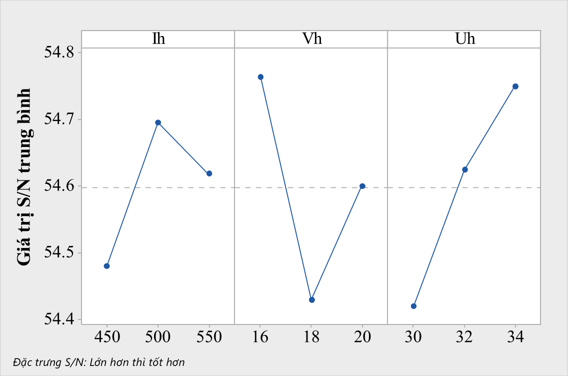

Fig. 6 Optimal scale chart of parameters on tensile strength of welding joint

3.2 Optimizing Information Mode Welding on Welding Tensile Strength

The average Effect of welding parameters on tensile strength is based on the S/N ratios of experimental results. Results of determination and classification of the effect of parameters on tensible strength are presented in Table 6 and illustrated in detail on the chart in Fig. 6.

Based on classification chart of the factors, we find that: With the requirement of higher quality characteristics, the better, the appropriate level of the elements to have the maximum tensile strength is $I_{h2} = 500$ (A), $V_{h1} = 16$ (cm.min^{-1}), $U_{h3} = 34$ (V). The optimum tensile value predicted by the Taguchi method is 559.9 Mpa.

3.3 Determine the Effect Ratio of Technological Parameters on the Tensile Strength of the Weld

To determine the Effect of each welding parameter, ANOVA analysis is used to evaluate. The results of ANOA analysis presented in (Table 7) show that studied welding parameters are main parameters because of their large effect of 27–38.9% while the Effect of the error is small with 1.4%. Welding current (I_h) has the greatest

Table 7 ANOVA analysis results of samples in tensible strength testing

Parameters	Degree of freedom	Sum of squares	Average squared	Value P	Affection level (%)
I_h	2	580.22	290.11	0.034	38.9
V_h	2	486.89	243.44	0.04	32.7
U_h	2	402.89	201.44	0.048	27.0
Error	2	20.22	10.11	–	1.4
Total	8	1490.22	–	–	100

effect with 38.9%; followed by welding speed (V_h) (32.7%) and welding voltage (U_h) with 27%. The P-index of the parameters with high confidence (95.2% 96.6%) proves reliability of analysis results and affected parameters are studied with values reaching the highest accuracy and reliability.

4 Experimenta*l* Verification

Experimentally verify the welding parameters with the level of $I_{h2} = 500$ (A), $V_{h1} = 16$ (cm.min^{-1}), $U_{h3} = 34$ (V) and conduct a tensile test for 557.5 Mpa. The above results are completely consistent with the tensile strength value predicted by the Taguchi method (result error is 0.43%), In addition to the tensile test, the control sample is also tested for impact toughness and durability. resulting hardness: impact toughness results in 114.6 (J/cm^2); hardness gives the result 151.5 (HV), which proves the reliability of the calculation result.

5 Conclusion

This study optimize and define Effect of welding parameters on the tesible strength of base metal S/N in automatic welding with narrow gap. Following conclusions can be obtained from this study:

- From optimal results, values of technological parameters to ensure the maximum weld tensile strength are defined as follows: Current strength $I_{h2} = 500$ (A); Welding speed $V_{h1} = 16$ (cm.min^{-1}); Welding voltage $U_{h3} = 34$ (V).
- Defining the Effect of technological parameters on tensile strength of welding joint as follows: The effect of current (I_h) is: (I_h) 38.9%; Welding speed (V_h) 32.7%; (V_h) 32.7%; Welding voltage (U_h) is 27%; error 1.4%.
- Results of tensile strength verification test are consistent with results predicted by the Taguchi method (error of 0.43%). It proves that the optimal result is accurate with a high reliability.

References

1. Layus P, Kah P, Martikainen J, Gezha VV, Bishokov RV (2014) Multi-wire SAW of 640 MPa arctic shipbuilding steel plates. Int J Adv Manuf Technol 2014(75):771–782. https://doi.org/10.1007/s00170-014-6147-2
2. Thomas PD (1986) Automatic submerged arc welding with metal power additions to increase productivity and maintain quality. Newport news Shipbuiding 4101 Washington avenue Newport news, va 23607
3. Loehberg R, Pellkofer D, Schmidt J (1986) Advantages and successful use of TIG narrow-gap welding. In: International conference on welding in nuclear engineering, 63–68
4. Yohei ABE, Takahiro FUJIMOTO, Mitsuyoshi NAKATANI, Masaya SHIGETA, Manabu TANAKA (2020) Development of a welding condition optimization program for narrow gap SAW. Proc Japan Welding Assoc 38(2):98–102
5. International Welding Engineer (IWE).
6. https://zh.scribd.com/doc/219973528/Jis-g3101-Ss-400-Steel.
7. Ngo Le Thong (2004) Electric fusion welding technology. Column I, II. Science and Technology Publisher, Hanoi
8. Taguchi G, Chowdhury S, Wu Y (2005) Taguchi's quality engineering handbook. Wiley, Hoboken, NJ
9. Nguyen, Duc, Thang (2009) Welding quality insurance. Science and Technology Publisher, Hanoi