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A STUDY ON THE FACTORS AFFECTING THE FLARE OF THE WELD WHEN WELDING THE STEEL WIRE

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ABSTRACT

In this study, an equation for adjusting the parameters affecting the flare of the weld on the welding product was established. Based on the empirical research results, the factors affecting welding flux after using bending machines have been studied. It has showed that the factors like the press force, the welding mode, the welding current, and the welding time were the main factors afftecting directly the flaration of the weld. For the standard of the flare of the weld of 3.3 mm, the welding current was 22A, the welding time was 5 deci-seconds, and the press force was 2.78 Kg/cm2. The results showed that the automatic steel-wire welding after improving the welding machine and mode had a productivity of 5.8 times higher and reduced 20% of energy consumption compared to traditional welding methods. Compared with unmodified automatic welding, the productivity increased by 5.8%, energy decreased by 7%, and the weld quality was more stable.

KEYWORDS

welding flare, welding current, steel wire.

1. INTRODUCTION

Currently, companies and enterprises increasingly expand the business market and invest in machinery and equipment to improve product quality. The use of advanced automatic production lines brings much efficiency, suitable to the scale and production level of the enterprise [1]. The requirement to use automation machines in welding wire and steel wire to improve productivity and product quality as well as to reduce labor is also a worth-mentioning problem [2,3]. Realizing how to make steel wire ring by automatic bending and welding machine for productivity, product quality is not stable, accuracy is not high, thus, increasing production cost and product cost [4,5]. In order to overcome the above problems, it is necessary to have a working structure with appropriate parameters, to meet the flare and accuracy requirements of the product, we must conduct the experimental process to find make the appropriate technical parameters affecting the weld flare of automatic wire bending machine to improve productivity and product quality, to increase competitiveness andôt meet the highest requirements for product [6,7]. The contact welding method relies on the principle of heat generated when welding current passes through a resistor at the contact surface of two welding components that heat the weld to a plastic state, then disconnects the current and forces a force suitable for making welds that connect two parts to be welded together [8-10]. During the welding process, the molten metal part is under the force of pressure, the two ends of the part blend into each other to create the excess workpiece [11]. The residual after machining between the two ends is called the flux degree of the weld, which is described as Figure 1.

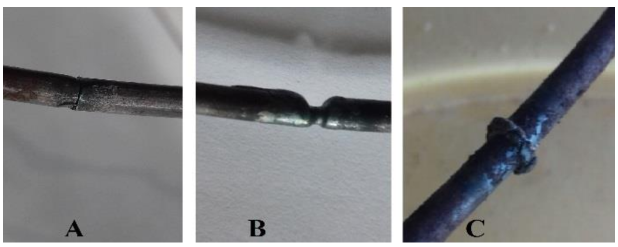


Figure 1: The flaring degree of the weld

Figure 1A shows that welds do not meet the technical requirements of adhesion, Fig.1B has a weld flared smaller than the diameter of steel wire, and Figure 1C has a greater flare than the steel wire diameter. The flare of the weld directly affects the beauty of the steel wire. During the production process, the steel wire also goes through many subsequent stages to produce the finished product, so it requires a high level of weld flaring [11,12]. The flare of the weld must be within 3.2mm to 3.3mm to ensure machining. The diameter of the flare must ensure the standard level to ensure the connection strength of the steel wire. In the process of wire machining, ensuring the output of flared welds is suitable in the fastest time possible while ensuring the product quality is less damaged [13,14]. Thereby improving the productivity and quality of welds of bending machines, and automatic steel-wire welding. Contact welding is a form of pressure welding, which uses heat by converting electricity into thermal energy by passing a high-intensity electric current through the contact surface of the two welding components to heat the metal [15]. The factors affect the mechanical properties of contact point welds such as welding current strength, welding time, welding force, physical characteristics of welding position and mechanical properties of welding [16]. Use the key load and absorb the energy of the weld at the contact point during the test of cutting and compression to describe the weld properties. Seeing that the weld size, failure mode, and durability, ductility of the failure point are the main factors affecting the peak load and energy absorption of the contact weld, the influencing factors to improve performance and quality were mentioned [17]. It shows that the current, the time and the welding force are considered the main influencing factors of the process [18-20]. The paper has studied the influence of parameters of automatic wire bending and welding machines on productivity and product quality. This paper has determined the parameters affecting welding flare of automatic wire bending machine to limit energy consumption and damaged products.

2. MODEL SETUP

Automation technology in place of human resources is being researched and applied in many countries, in addition to improving labor productivity, automation mechanics also helps to improve product quality and release labor force. and reduce production costs and product costs. The method of making steel wire ring by the traditional manual method is not high dynamic productivity, product quality is unstable, consuming a lot of resources, increasing production costs and reducing competitiveness in the market, resulting in increasing production costs and pushing up product prices. The application of automation technology has become more and more popular, requiring higher accuracy and product quality. Therefore, the study of improving the parameters of automatic machines to improve product quality becomes an urgent and indispensable need. According to the diagram in Figure 2, the process of manufacturing steel wire rings consists of 4 steps: Analysis and selection of solutions for continuous embryo feeding; Accurate workpiece positioning process on the machine; Research and application of modern workpiece structure; Perfecting automatic welding and draining technology.

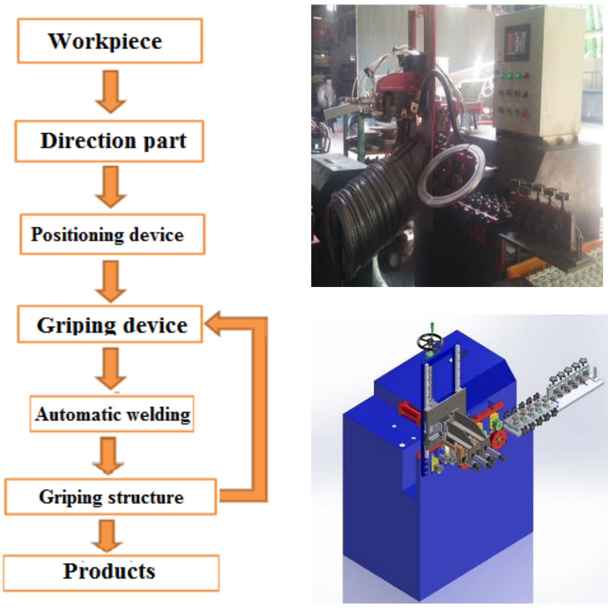


Figure 2: Automatic bending and welding machine for steel wire

In the experiment, measuring the flared diameter of the weld. Use electronic clamp ruler Inside 150mm to make measuring device as shown in Figure 3. Measuring the diameter of the weld in the longitudinal direction from the outside towards the center of the steel ring is carried out in this study. The result is shown on the screen of the electronic clamp ruler.

Figure 3: Measurement of the flare diameter of the weld

3. RESULTS AND DISCUSSION

3.1 Effect of factors on the weld flare

In fact, the dependent variable Y is governed by many independent factors X1, X2, X3 ... Which factors affect the most flared, we do not know. Therefore, the modeling method with many different tests helps us determine the most important influencing factor, based on that; we set the forecasting model according to the influential variables [14].

Y: The degree of flaring of the weld; X1: Welding pressure force (pressure), X2: welding time, X3: welding current

Table 1: Values affecting welding flare

Parameters	Lowest	Highest
Welding pressure force,Kg/cm^2	2.5	3.5
Welding current, A	18	22
Welding time, deci second	5	7

The experimental matrix was randomly generated by an experimental data processing program. Output parameters: the flaring degree of the weld, denoted by Y, is a characteristic parameter for research purposes. This quantity is affected by a series of input parameters and noise. The weld flux is measured directly by the electronic clamp ruler. The average value of weld flux is calculated by the formula (1) [5]:

$$m_x = x = \frac{\sum_{i=1}^{N} x_i}{N} \quad (1)$$

X_i – Random quantitative measurements x in the i experiment; N – Number of samples

In each experiment, 50 samples were taken with 15 changes of parameters. The type of steel wire used is CT3 steel with a diameter of 3.2mm, with 0.1mm of error. After performing the sampling of the steel wire loop, use an electronic clamp to measure the diameter of the welding flux as shown in Figure 3. For each experiment performed measurement and taking the average value we get the results in Table 2. The data obtained after computational analysis are included in the experimental matrix as data for the coefficients of the model. Through data processing, the regression model is obtained as follows.

Table 2: Experimental results

No	Welding pressure force	Welding time	Welding current	Flare
	Kg/cm^2	Deci-second	A	mm
1	2.5	6	20	3.27
2	2.5	5	22	3.29
3	2.5	7	22	3.32
4	2.5	7	18	3.26
5	2.5	5	18	3.16
6	3	5	20	3.23
7	3	6	18	3.27
8	3	6	20	3.29
9	3	6	22	3.45
10	3	7	20	3.34
11	3.5	5	18	3.19
12	3.5	5	22	3.34
13	3.5	6	20	3.33
14	3.5	7	18	3.29
15	3.5	7	22	3.58

3.2 Effect of press force on the flare of weld

Table 3: Standard factors

Parameters	Estimation	Standards Error	T Statistic	P-value
Constant	3.26			
Press pressure	-0.036			
Press pressure^2	0.016			

Dependent variable: weld flare degree

Independent variable: Pressure, polynomial = 2

Table 4: Analysis of differences

Output	Mean	Df	Average	F-Ratio	P-Value
Type	0.00181067	2	0.000905333		
Excess	0.0	0	0.0		
Total	0.00181067	2			

The pressure between the two ends acting on the weld has a linear effect at the magnitude of the effect and is shown in Figure 4. With R-squared = 100%. The variation described the relationship between the pressure and the flare of the weld based on the polynomial equation (2) of the second order:

Y = 3.26-0.036*X1 + 0.016*X1^2; (2)

R-Squared statistics Tables 3 and 4 indicate that the variation model reaches 100.0% of weld flaring. R statistics are adjusted, more suitable to compare models with different independent variables of 0.0%. The mean absolute error (MAE) is 0.0. Since the value of P is greater than 0.05, there is no serial correlation in the 95% confidence level.

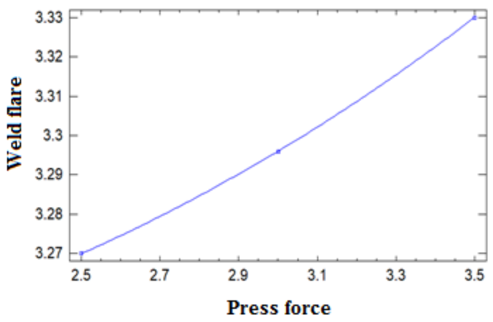


Figure 4: Influence of press force on weld flare

3.3 Effect of welding time on weld flare

Table 5: Standard elements

Parameters	Estimation	Error	Statistic	P-value
Constant	2.654			
Welding time	0.161			
Welding time^2	-0.009			

Dependent variable: weld flare degree

Independent variable: welding time, polynomial = 2

Table 6: Differential analysis

Output	Mean	Df	Average	F-Ratio	P-Value
Type	0.005672	2	0.002836		
Excess	0.0	0	0.0		
Total	0.005672	2			

The welding time affects linearly to the point where the welding fllare is shown in Figure 5 with With R-squared = 100%. The variation is described as the relationship between the time for the flaring degree of the weld based on the second-order polynomial equation:

Y = 2.654 + 0.161*X2 - 0.009*X2^2; (3)

R-Squared statistics tables 5 and 6 indicate that the variation model reaches 100.0% of weld flare. R statistics are adjusted, more suitable to compare models with different independent variables of 0.0%. The mean absolute error (MAE) is 0.0. Since the value of P is greater than 0.05, there is no serial correlation in the 95% confidence level.

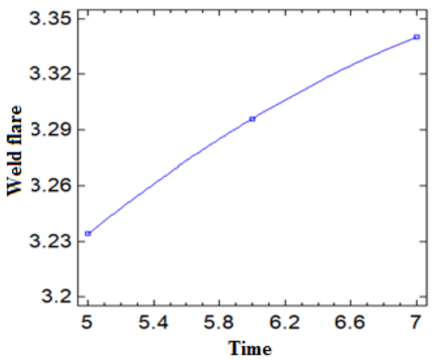


Figure 5: Effect of time on weld flare

3.4 Effect of welding current on weld flare

Table 7: Regression coefficients

	Least squares	Standards	T	
Parameters	Estimation	Error	Statistic	P-Value
Boundary value	2.48667	0.396801	6.26678	0.1007
Slope	0.04275	0.0197742	2.1619	0.2758

Table 8: Differential analysis

Output	Mean	Df	Average	F-Ratio	P-Value
Type	0.0146205	1	0.0146205	4.67	0.2758
Excess	0.00312817	1	0.00312817		
Total	0.0177487	2			

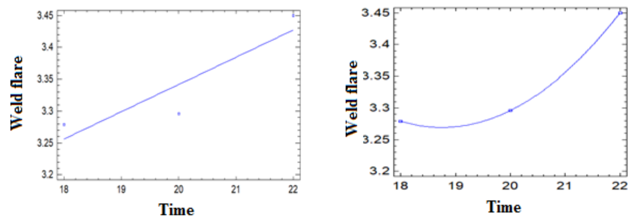
Correlation coefficient = 0.907608; R- squared = 82.3752%; R- squared = 64.7504%; Standard error = 0.05593; Average absolute error = 0.0304444; Influence level = -0.666667

The welding current has a linear effect on the high degree of weld stability shown in Figure 6 with R- squared = 82.37%. The variation described the relationship between the current and the flared degree of the weld based on the first-order polynomial equation as shown in Figure 6a.

Y= 2.48667 + 0.04275*X3; (4)

Since the P-value in the analysis is greater than or equal to 0.05. There is no statistical significance between weld flare and current at 95.0% or higher. R statistics are adjusted, more suitable to compare models with different independent variables of 0.0%. The mean absolute error (MAE) is 0.0 because the P value is greater than 0.05, achieving a 95% confidence level. The R-Squared statistics shown in Tables 7 and 8 show that the variation model reaches 82.3752% of weld flare. The correlation coefficient is 0.907608, indicating the close relationship between the influential variables. The standard error indicates that the standard deviation of the rest is 0.05593. The MAE is 0.0304444.With R-squared = 100%. The variation is described as the relationship between the current and the flared degree of the weld based on the second order polynomial equation and shown as Figure 6b.

Y = 9.291 - 0.64225*X3 + 0.017125*X3^2; (5)



(a) Influence of electric current on weld flare in first-order equation

(b) Influence of electric current on weld flare in second-order equation

Figure 6: Influence of current flow to weld flare

Results showed that an order polynomial model as equation (4) is not appropriate for describing the relationship between the diameter of the weld parameters main influence. Therefore, the equation describing the nonlinear quadratic form as (2), (3), (5) a more accurate depiction of the impact of each factor on the diameter of the weld characteristic is the flare.

3.5 Effect of press force, welding current, welding time on weld flare

The degree of influence of the parameters represented by the graphs has shown in Figure 7 and Figure 8 with the parameters in real form; this chart is drawn when other factors are fixed.

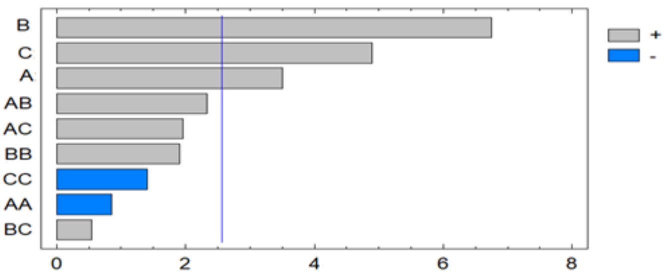


Figure 7: Diagram of the effect of parameters on weld flare

Based on the chart in Figure 7, the input factors of the study affect the flux of welds at different levels, the degree of influence on weld flaring is arranged in descending order: time, welding current, press force when welding.

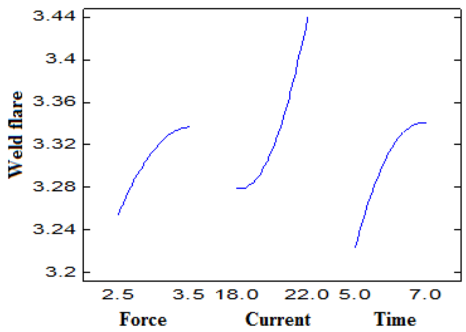


Figure 8: Variation of influencing factors

The graph in Figure 8 shows the influential parameters in descending order from the experimental results; it can see that the flare of the weld has a proportional effect on the elements. When any 1 of the three influencing factors increases, the flare of the weld increases.

Table 9: Factors affecting the flare

Input	Square	Df	Mean	F- ratio	P- value
A: Press force	0.0173056	1	0.0173056	12.30	0.0172
B: Current	0.0641601	1	0.0641601	45.60	0.0011
C: Time	0.03364	1	0.03364	23.91	0.0045
AA	0.00101717	1	0.00101717	0.72	0.4340
AB	0.007688	1	0.007688	5.46	0.0666
AC	0.005408	1	0.005408	3.84	0.1072
BB	0.00511753	1	0.00511753	3.64	0.1148
BC	0.0004205	1	0.0004205	0.30	0.6081
CC	0.00278146	1	0.00278146	1.98	0.2187
Error	0.00703541	5	0.00140708		
Total	0.142681	14			

Table 9 shows the extent of the factors to the flare of the weld into individual parts for each effect. Then, it is examined the statistical significance of each factor by comparing the mean square with the estimate of experimental errors. In this case, the three effects with P values are less than 0.05, indicating that they are different from 0 and at the 95.0% confidence level. The statistics of mean square values indicate that the model reaches the significance level of 95.0691% of the variation of the weld flared. Adjusting statistics is more appropriate to compare models with different independent variable numbers of 86.1936%. The standard error of the estimate indicates that the standard deviation of the rest is 0.0375111. The mean absolute error (MAE) is the average of the 0.0188741 balances. Durbin-Watson (DW) statistics check the balance to determine whether there is a correlation based on the order in which the data file appears. Since the P-value is greater than 5.0%, the effect in the rest is at the 5.0% significance level.

Table 10: Prediction of the weld flare

Effects	Estimation	Standard Errors	V.I.F.
Mean	3.31511	0.0201616	
A: Press force	0.0832	0.0237241	1.0
B: Current	0.1602	0.0237241	1.0
C: Time	0.116	0.0237241	1.0
AA	-0.0397778	0.0467846	1.2963
AB	0.062	0.0265243	1.0
AC	0.052	0.0265243	1.0
BB	0.0892222	0.0467846	1.2963
BC	0.0145	0.0265243	1.0
CC	-0.0657778	0.0467846	1.2963

Table 10 shows that each impact and interactive estimate showed are standard errors in measurement sampling. The natural factor is the largest variable (V.I.F.) equal to 1.2963. For optimal measurement experiments, all elements will be equal to 1. Factors equal to 10 or greater are error factors due to an error in measurement or setting of laboratory sampling parameters.

Table 11: Correlation matrix between influential variables

	A	B	C	AA	AB	AC	BB	BC	CC
A	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
B	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AA	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.4000	0.0000	0.4000
AB	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
AC	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000
BB	0.0000	0.0000	0.0000	0.4000	0.0000	0.0000	1.0000	0.0000	0.4000
BC	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
CC	0.0000	0.0000	0.0000	0.4000	0.0000	0.0000	0.4000	0.0000	1.0000

The correlation matrix shows the correlation between the columns of the matrix in the experimental design. Good experimental design will show a cross-matrix like a table 11 with the number 1 on the diagonal and zero of the diagonal. Any value on the diagonal shows that the estimation of the effects corresponding to that row and column are related. In this case, there are three pairs of columns with correlations other than 0. However, since no value is greater than or equal to 0.5, the result is highly reliable.

Table 12: Predicted values when increasing values affecting weld flare

Press force	Current	Time	Flare
(Kg/cm²)	*(A)*	*(deci giây)*	*(mm)*
3.0	20.0	6.0	3.31511
3.11363	21.0	6.25639	3.39342
3.20894	22.0	6.41278	3.4925
3.295	23.0	6.52936	3.61606
3.3755	24.0	6.62515	3.76502
3.45231	25.0	6.70841	3.93973

Table 12 shows the path to a higher level from the original test values. This is the path from the center of the current test area along which the estimated response changes most rapidly with the smallest change in the experimental factors. Point out good locations to run additional tests if the goal is to increase or decrease the flared level. Currently, six values have been generated by changing the welding current with a step increase of 1.0 A. Determining the other factors must be changed to correspond. Calculate the estimated flared level at each point along the increased path to easily compare your results if you run those points. Conduct an experimental variance analysis that shows the flared descriptor of weld Y by influencing factors X1, X2, X3 with regression coefficients ensure reliability. The significance level is 95.0691%, with standard deviation error.

Table 13: Regression with the flare degree

Parameters	Estimation
Constant	7.70862
A: Press force	-0.371467
B: Current	-0.520811
C: Time	0.224167
AA	-0.0795556
AB	0.031
AC	0.052
BB	0.0111528
BC	0.003625
CC	-0.0328889

Table 13 shows the regression equation of weld flux when assigned to data. Calculation results of mathematical model in real form have a function that describes flare (6) (mm):

Y = 7.70862 - 0.371467 * X1 - 0.520811 * X3 + 0.224167 * X2 - 0.0795556 * X1^ 2 + 0.031 * X1 * X3 + 0.052 * X1 * X2 + 0.0111528 * X3 ^ 2 + 0.003625 * X3 * X2 - 0.0328889 * X2 ^ 2; (6)

The optimization problem is built on the basis of mathematical functions which are regression equations determined by experimental planning method with polynomial of type II. Equation (6) defines the objective function with specific parameters for research purposes.

4. CONCLUSION

Based on the empirical research results on the factors affecting welding flare for the process of automatic steel wire welding, the achieved results have shown that the pressing force, the welding current is the main affecting factors. The equation described the degree of influence of each element is established. From the regression equation, the appropriate setting parameters for the machine with the required flare degree of 3.3 mm, a welding current of 22 A, the welding time of 5 deci-seconds, welding force of 2.78 Kg / cm along with 2.5% error was selected.

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