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ANALYSIS OF THE IMPACT OF THE TECHNOLOGICAL PARAMETERS PAD WELDING STEEL C45E WIRE CASTOMAG 4554S ON GEOMETRY PADDING WELD METHOD TAGUCHI

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Abstract

Using the pad welding technique it is possible to regenerate machine parts or improve surface properties such as abrasion, corrosion and aging resistance. The regeneration process with the use of pad welding can be performed using the same equipment, which we use for welding. Metals and their alloys with required properties in the form of wire, rod or powder are selected for the additional material. To ensure optimum processing conditions and economic efforts should be made, while providing a high deposition efficiency for the small amount of metal in the pad weld substrate. The pad welding process for the test subject should be carried out by preheating to evaporate the moisture and reduce the porosity of the weld. This treatment is required depending on the carbon equivalent. This article is an introduction to a series of investigations that will allow you to choose the best parameters of pad welding GMA (gas metal arc) method, steel C45E with wire CASTOMAG 4554S. Steel samples were prepared and preheated to 300°C. Using the orthogonal experiment plan, the influence of selected parameters on the geometry and depth of fusion was determined. The analysis was based on current and wire feed speed. The test was carried out for three current values: 60, 75, 90 A and wire feed rate of 1.5, 2, 2.5 m/min. The purpose of the analysis was to select appropriate technological parameters. Obtaining the smallest share of the base material in the weld pad and impact assessment parameters for welding seam geometries. For the analysis of the results of multiple regression was used.

Keywords: *pad welding, regression, analysis, GMA, padding weld*

1. Introduction

The following tests are an introduction to the study cycle of the selection of suitable pad welding parameters, substrate material for regeneration of shaft class components [1-3]. The first parameters taken into account for the variables will be the current and wire feed speed. The current of the pad welding current with the remaining values remains unchanged with the change of wire feeding speed. The increase in intensity results improve the performance of the pad welding, but also causes an increase in the size of the lake and the depth of the infiltration which results in a greater proportion of the substrate material in the padding weld [4].

The practicality and effectiveness of experimental research depends to a great extent on the ability to use and apply modern experimental planning methods that allow for a significant reduction in the number of experiments but also to provide valuable and reliable information about the subject matter of the research. The problem with the use of such methods is not only the choice of the appropriate method to solve the problem, but the correct interpretation of the results obtained in the conducted study. The benefits of using static methods of experiment planning are often discussed in scientific articles [1].

2. Materials and method

To carry out the research method GMA welding was used. To perform padding weld overlays were used welder MIG/MAG model 250 Magster, Company Bester Lincoln. Using a solid additional material wire CastoMag 4554S, which has the chemical composition of the chromium alloy, nickel and manganese, as stated by the manufacturer. The wire diameter was 1.2 mm. As a material of the substrate, in the form of steel C45E, were used pieces measuring 90×50×6 mm.

The tests were performed with parameters: arc voltage in the range 15-25 V, length of the electrode wire 12-15 mm, pendulum angle of inclination, direction of the left to right surfacing, polarity of the positive wire, curtain gas flow rate 16 l/min. The shielding gas was a mixture of argon 82% and 18% carbon dioxide. Other parameters i.e. current I and wire feed rate v_l were treated as variables. Depending on the variables, the application was applied at a velocity of 1.6-3.1 mm/s.

In order to assess the quantitative impact of arc welding parameters I, and wire feed velocity v_l on the contribution of the substrate material in the beverage (UMP) and the geometry of the weld (height, width and maximum infiltration depth). A randomized, orthogonal experiment plan was used, taking into account the trivalentity of the independent variables (predictors, explanatory, input) that predicted the execution of 9 experiments (Tab. 1) with five repetitions. The current rating for the C45E steels with CastoMag 4554S additive was associated with a short-lived (liquid) transfer of molten metal to prevent overfilling. Taking into account the value of the current varying from 60-90 A and the wire feed rate from 1.5 to 2.5 m/min, the STATISTICA statistical program generated a basic experiment plan consisting of 9 systems that were repeated five times in the study.

Using a measuring microscope Smart Zoom 5 ZEISS with integrated graphics system QA/QC surface area was measured, an exemplary image in a metallographic section metallographic cross-section of the sample of the digital microscope is shown in Fig. 1 [5]. After measuring the total surface area ratio of part of substrate material was calculated using the formula 1.

$$UMP = \frac{F_w}{F_w + F_n}, \tag{1}$$

where:
UMP – part of substrate material [%],
F_n – surface area of the nape liner [mm^2],
F_w – surface area of welding [mm^2].

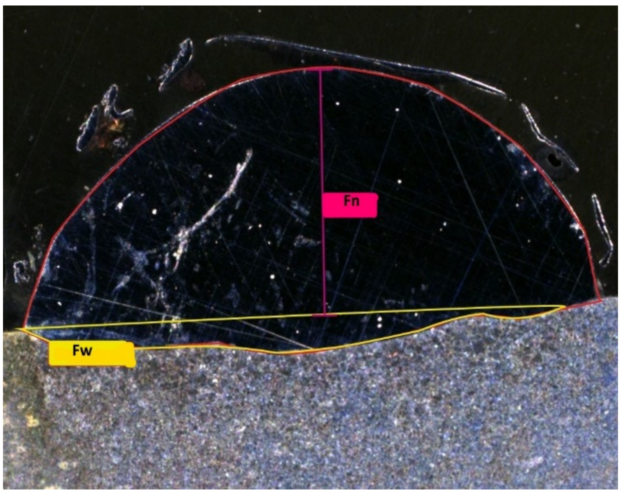

Fig. 1. Method of determination part of substrate material in padding weld of the test sample

During the test was also carried out measurements of the geometry of the deposit height, width and maximum penetration depth. These measurements are based on the aforementioned digital measuring microscope. The obtained results were analysed by the STATSTICA program. Fig. 2 shows the dimensions determining the geometry of the sample no. 8.

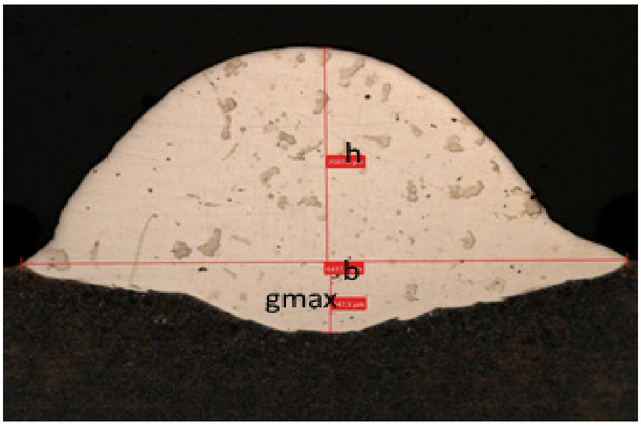

Fig. 2. The dimensions of padding weld geometry

3. Results

The following results are presented in Tab. 1.

Tab. 1. The results of research

Items	*I* [A]	v_l [m/min]	*UMP* [–]	*h* [µm]	*b* [µm]	g_{max} [µm]
1	60	1.5	0.082	2354.8	5776.9	245
2	60	2	0.117	2545.4	6206.4	736
3	60	2.5	0.032	4508.0	6943.0	850
4	75	1.5	0.113	2880.0	5925.0	352
5	75	2	0.149	2638.4	6317.0	816
6	75	2.5	0.184	3432.3	6651.0	1038
7	90	1.5	0.145	2329.4	5933.0	470
8	90	2	0.179	2587.6	6218.0	847
9	90	2.5	0.215	2781.3	6982.0	1238

The results of the F test, for multiple regression analysis, give the 96% probability of a statistically significant impact of the input variables on the dependent variable. The value of the multiple correlation coefficient R = 0.78 indicates the high correlation between the adopted input variables and the dependent variable (UMP). Considering the standardized values of the regression coefficients can be concluded that the current has a greater effect on the part of the support material in the weld pad than the feeding speed of the welding wire. At a given level of significance of $p = 0.05$, one can conclude on lack of statistical significance of the covariate v_l evaluated value parameter. This is evidenced by the results of the t-Student test. It can be assumed that this variable can be removed from the model [6]. Results of regression analysis for UMP in Tab. 2.

Tab. 2. Results of multiple regression analysis

R = 0.779 $R^2 = 0.607$ F(2.6) = 4.626 p < 0.04 Standard error of estimation: 0.039						
N = 9	BETA	Standard error – BETA	B	Standard error – B	t(6)	level p
Free term	—	—	–0.138	0.102	–1.356	0.224
Current	0.761	0.256	0.003	0.001	2.970	0.024
Wire feed speed	0.168	0.256	0.021	0.031	0.654	0.537
where: BETA – standardized regression coefficient, B – regression coefficients, t(6) – t-Student Significance Test, p – calculated level of significance.						

The verification of this hypothesis, determining the redundancy determined coefficients (collinear) predictors Tolerance and variance inflation factor – CIW (Tab. 3) Autocorrelation test of d Durbin-Watson was also conducted. Result of the test 2.06.

Tab. 3. Redundancy of independent variables

	Tolerance	R-square	Partial correlation	Semi partial correlation
I [A]	0.39	0.58	2.37	0.77
v_l [m/min]	0.97	0.03	1.03	0.26

The calculated values of the above coefficients and the test d do not allow removing the variable v_l from the statistical model. The prediction of the contribution of the substrate material to the coatings of the coatings can be accomplished by the following multiple regression equation:

$$UMP = -0.138 + 0.003I + 0.021v_l \pm 0.039\,. \tag{2}$$

Based on the results obtained, 92% of the data is in equation 4. The value of the multiple correlation coefficient R = 0.75 indicates the high correlation between the adopted input variables and the dependent variable. Considering the values of standardized regression coefficients, it can be concluded that the speed of welding wire feed has a greater effect on the height of the weld than the current. At the assumed significance level $p = 0.05$ can be concluded that there is no statistical significance of the explanatory variable I on the value of the evaluated parameter. This is evidenced by the results of the t-Student test. It can be assumed that this variable can be removed from the model [6].

The verification of this hypothesis, determining the redundancy determined coefficients (collinear) predictors Tolerance (Tab. 5)

Tab. 4. Results of multiple regression analysis

R = 0.752 R^2 = 0.566 F(2.6) = 3.909 p < 0.08 Standard error of estimation: 524.26						
N = 9	BETA	Standard error – BETA	B	Standard error – B	t(6)	level p
Free term	—	—	2215.228	1381.537	1.603	0.159
I [A]	–0.358	0.269	–18.999	14.268	–1.332	0.231
v_l [m/min]	0.661	0.269	1052.467	428.054	2.459	0.049

Tab. 5. Results of correlation for the obtained data

	Tolerance	R-square	Partial correlation	Semi partial correlation
I [A]	1.000	0.000	1.000	–0.478
v_l [m/min]	1.000	0.000	1.000	0.708

Autocorrelation test of d Durbin-Watson was also conducted. Result of the test 2.46. The calculated values of the above coefficients and the test d do not allow removing the variable I from the statistical model. The calculated values of the above coefficients and the test d do not allow removing the variable I from the statistical model.

The height prediction of a padding weld can be made using the following multiple regression equation:

$$h = 2215.23 - 18.99I + 1052.47v_l \pm 524.26\,. \tag{3}$$

On the basis of the results obtained can be concluded, 99% of the data is in equation 8. The value of the multiple correlation coefficient R = 0.96 indicates the high correlation between the adopted input variables and the dependent variable. Considering the values of standardized regression coefficients can be concluded that the welding wire feed speed has a greater effect on the width of the weld than the current. At the assumed significance level p = 0.05 it can be concluded that there is no statistical significance of the explanatory variable *I* on the value of the evaluated parameter [6]. This is evidenced by the results of the t-Student test. It can be assumed that this variable can be removed from the model.

The verification of this hypothesis, determining the redundancy determined coefficients (collinear) predictor variables: Tolerance (tab. 7) Autocorrelation test of d Durbin-Watson was also conducted. Result of the test 2.42. The calculated values of the above coefficients and the test d do not allow removing the variable *I* from the statistical model.

Tab. 6. Results of multiple regression analysis

R = 0.964 R^2 = 0.929 F(2.6) = 39.290 p < 0.01 Standard error of estimation: 135.78						
N = 9	BETA	Standard error – BETA	B	Standard error – B	t(6)	level p
Free term	—	—	4195.05	357.822	11.724	0.000
I [A]	0.068	0.109	2.297	3.696	0.621	0.557
v_l [m/min]	0.962	0.109	980.367	110.867	8.843	0.000

Tab. 7. Results of correlation for the obtained data

	Tolerance	R-square	Partial correlation	Semi partial correlation
I [A]	1.000	0.000	1.000	0.246
v_l [m/min]	1.000	0.000	1.000	0.964

The calculated values of the above coefficients and the test d do not allow removing the variable v_l from the statistical model. The height prediction of a nape can be made using the following multiple regression equation:

$$b = 4195.05 + 2.297I + 980.367v_l \pm 135.78\,. \quad (4)$$

The results of the F test, for multiple regression analysis, give the 99% probability of a statistically significant impact of the input variables on the dependent variable. The value of the correlation coefficient R = 0.98 indicates the high correlation between the input variables and the dependent variable (g_{max}). Considering the values of standardized regression coefficients can be concluded that the welding wire feed speed has a greater effect on the maximum penetration depth than the current. At the assumed significance level p = 0.01 it is possible to infer the statistical significance of both variables [6]. Results of regression analysis for g_{max} in Tab. 8.

Tab. 6. Results of multiple regression analysis

R = 0.976 R^2 = 0.952 F(2.6) = 59.306 p < 0.01 Standard error of estimation: 81.814						
N = 9	BETA	Standard error – BETA	B	Standard error – B	t(6)	level p
Free term	—	—	–1243.56	215.599	–5.768	0.001
I [A]	0.324	0.089	8.04	2.227	3.613	0.011
v_l [m/min]	0.920	0.089	686.33	66.801	10.274	0.000

Predictions of the maximum depth of fusion in a padding weld can be made using the following multiple regression equation:

$$g_{max} = -1243.56 + 8.04I + 686.33v_l \pm 81.814\,. \quad (5)$$

4. Conclusion

In this study, a wire pad welds carried out on steel CastoMag 4554S C45E demonstrate that current and wire feed speed differentially affect the part geometry and the substrate material in the weld pad. With the given parameters, it was proved that:

- the highest *UMP* value obtained is 22% with variable values of I = 90 A and wire feed speed v_l = 2.5 m/min.

Geometric values (height, width, and maximum depth of the weld are mainly influenced by the wire feed speed, I = 90 A and wire feed velocity v_l = 2.5 m/min). In order to obtain cost effective and best parameters for the regeneration process by welding, you must continue to study for other available materials and variable configurations.

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