INFLUENCE OF WELDING PARAMETERS ON GEOMETRY OF WELD DEPOSIT BEAD

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Abstract. Automatic weld surfacing is being employed increasingly in the process and power industries. Because of its high reliability, all-position capability, ease of use, low cost and high productivity, FCAW has become a natural choice for automatic surfacing. With increasing use of FCAW in its automatic mode, there will be increased dependence on the use of equations to predict the dimensions of the weld bead. Exponential technique to predict the geometry of the weld bead in the deposition of high chromium cast iron onto structural steel S235JR is presented.

Keywords: weld deposit, weld bead, penetration, width

1. Introduction

Weld surfacing techniques are employed mainly to extend or improve the service life of engineering components and to reduce their cost, either by rebuilding repeatedly or by fabricating in such a way as to produce a composite wall section, as in pressure vessels, whilst other desired properties obtained may include corrosion resistance, wear resistance etc. In recent years weld surfacing processes have developed rapidly and are now applied in numerous industries, e. g. chemical and fertilizer plants, nuclear power plants, pressure vessels, agricultural machines, railways and even in aircraft and missile components [9, 10, 11].

Various welding methods employed for surfacing are: Shielded Metal Arc Welding (SMAW), Submerged Arc Welding (SAW), Tungsten Inert Gas (TIG), Gas Metal Arc Welding (GMAW), Flux Cored Arc Welding (FCAW), etc. With the development of modern solid state welding power sources it has become easy to control the mode of metal transfer, making it possible to use GMAW and FCAW welding with high quality surfaced components. The chief advantages in using FCAW for surfacing are high reliability, all-position capability, ease of use, low cost and high productivity. With the growing emphasis on the use of automated and robotic system MIG welding, with its all-position capabilities, FCAW has been employed increasingly in mechanised surfacing in industry. In such mechanized and robotic applications, an accurate means of selecting the welding procedures and of predicting the shapes of the weld beads that will be deposited has become increasingly desirable: this means may be achieved by the development of mathematical expressions, which can be fed the computer, relating the dimensions of the weld beads to the important controllable process parameters affecting these dimensions. In addition, successful surfacing requires optimization of the process parameters to have low dilution, which necessitates a thorough understanding of the process characteristics affecting the technological and metallurgical characteristics of the overlays. Thus, it is essential to study, which the help of mathematical models, the main and the interaction effects of the various process parameters affecting the dimensions of the weld beads [1, 4, 5, 10].

With a view to achieving the above mentioned aim, statistically designed experiments based on the linear technique were used to reduce the cost and time involved as well as to obtain the required information about the direct and the interaction effects on the response parameters [1, 6, 7, 8].

2. Editing instructions

Automatic FCAW surfacing was carried out by depositing OK Tubrodur 14.70 electrode onto steel S235JR plate of 20 mm thickness, the observed data being utilised to develop the mathematical model. The controllable process parameters were kept in the optimum region for achieving the acceptable quality.

Chemical content of the alloy in electrode is shown in table 1.

Table 1 Chemical composition of electrode

C	Si	Mn	Cr	Mo	V
3.5	0.4	0.9	22	3.5	0.4

Hardfacing material was deposited onto steel substrate by weld current 200 A, 300 A, 400 A, arc voltage 30 V, 33 V, 36 V and welding speed 20 cm.min-1, 40 cm.min-1, 60 cm.min-1. For the curvilinear technique statistics were using 33 = 27 samples.

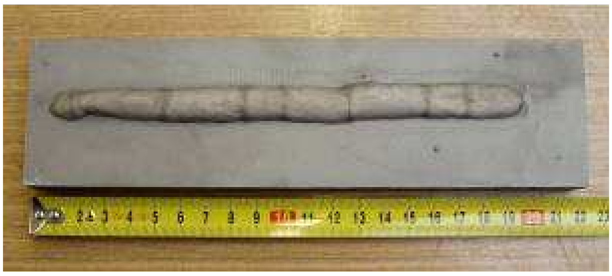

Figure 1. Weld bead onto steel

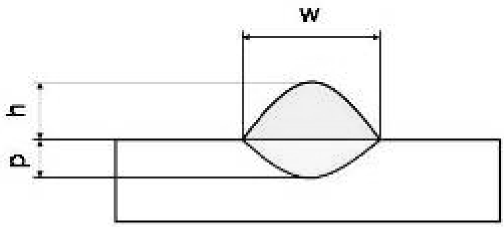

Figure 2. Scheme of the bead geometry

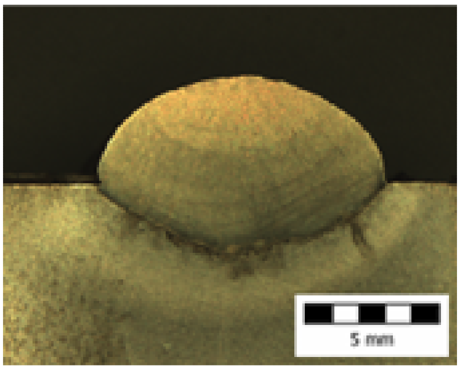

Figure 3. Metallographic cut of bead

Based on the results from the above curvilinear technique analysis was performed with the predictors that were found to be statistically significant against bead geometry. Suppose that the relationship between bead geometry as a depend parameter and process parameters including welding speed, arc current and welding voltage as independent parameters can be expressed by the following equation (1).

$$y = 10^{a_1} \cdot I^{a_2} \cdot U^{a_3} \cdot v^{a_4} \qquad (1)$$

where I is welding current (A), U welding arc voltage (V) and v welding speed (cm.min-1), a^1, a^2, a^3, a^4 are curvilinear coefficients to be estimated for the model.

This equation can be written as,

$$\log(y) = a_1 + a_2 \cdot \log(I) + a_3 \cdot \log(U) + a_4 \cdot \log(v)$$

Thus, the above can be expressed by the following linear mathematical form

$$Y = \beta_1 + \beta_2 \cdot x_1 + \beta_3 \cdot x_2 + \beta_4 \cdot x_3 \qquad (2)$$

Where Y is the logarithmic value of the experimentally measured response (bead geometry), β_1, β_2, β_3, β_4 are constants to be estimated, x_1, x_2, x_3 are logarithmic values of welding speed, arc current and welding voltage.

The commercial statistical package STATISTICA was utilized for all the multiple regression analyses in this research.

2. Results

The procedure employed resulted in the following predictive equation, Bead width (R^2=0,967):

$$w = 10^{-1.0908} \cdot I^{0.6153} \cdot U^{0.8878} \cdot v^{-0.4705} \qquad (3)$$

Bead height (R^2=0,951):

$$h = 10^{1.0901} \cdot I^{0.5405} \cdot U^{-1.0424} \cdot v^{-0.3268} \qquad (4)$$

Penetration (R^2=0,971):

$$p = 10^{0.6578} \cdot I^{0.7562} \cdot U^{-1.1006} \cdot v^{-0.3014} \qquad (5)$$

To ensure the accuracy of the developed equations and survey the spread of the values, results were again plotted using scatter graphs. These graphs of measured versus calculated values of bead dimensions are presented in figures 4 – 6 for bead width, bead height and penetration respectively.

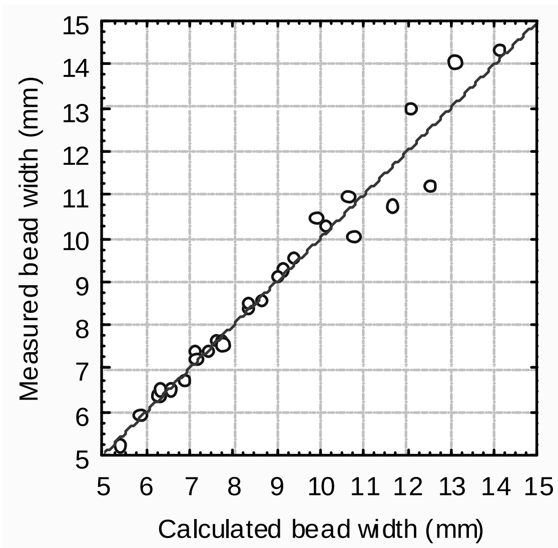

Figure 4. Bead model analysis graph for geometry parameters (width)

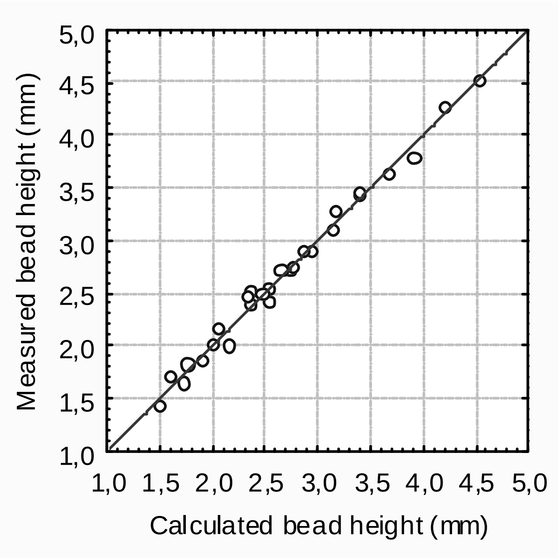

Figure 5. Bead model analysis graph for geometry parameters (height)

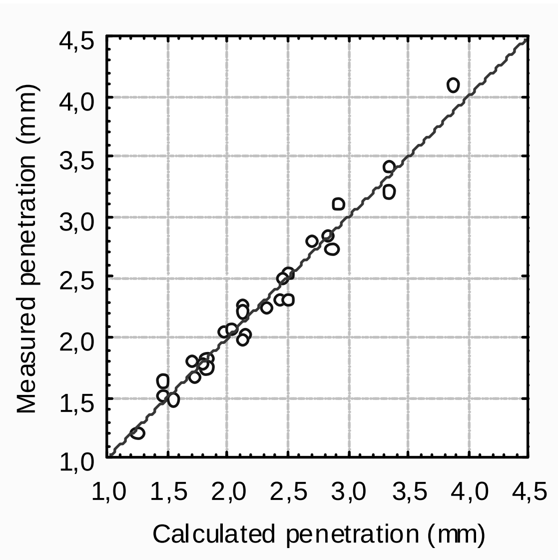

Figure 6. Bead model analysis graph for geometry parameters

Area of weld deposit layer can be described function:

$$G = \int_{\frac{-w}{2}}^{\frac{w}{2}} h + \left(-\frac{4 \cdot h}{w^2}\right) \cdot x^2 \cdot dx \qquad (6)$$

Area of penetration can be described function:

$$Z = \int_{\frac{-w}{2}}^{\frac{w}{2}} p + \left(-\frac{4 \cdot p}{w}\right) \cdot x^2 \cdot dx \qquad (7)$$

For prediction of chemical composition weld deposit bead can be used equation:

$$X_{i1} = G \cdot X_N + (1 - G) \cdot X_{ZM} \qquad (8)$$

For prediction of weld bead structure can be used equation

$$K(\%) = 12{,}33 \cdot C + 0{,}55 \cdot Cr - 15{,}2 \qquad (9)$$

Where C is weight percentage content of carbon and Cr is weight percentage content of chromium. Influence of welding parameters on final structure of weld bead is shown in figure 7 and 8.

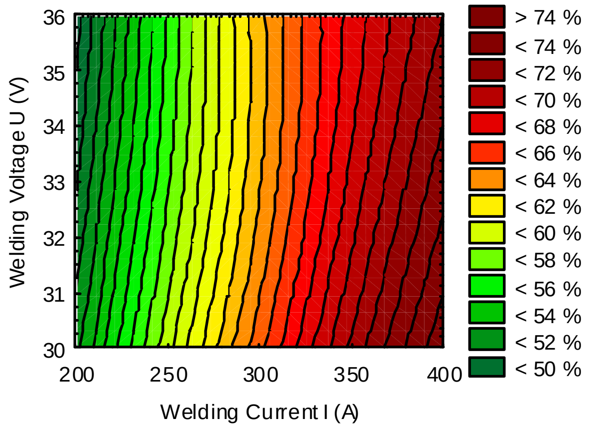

Figure 7. Influence of welding arc current and welding voltage on structure of hardfacing, welding sped was v = 40 cm.min^{-1}, contour shown ratio of carbide eutectic

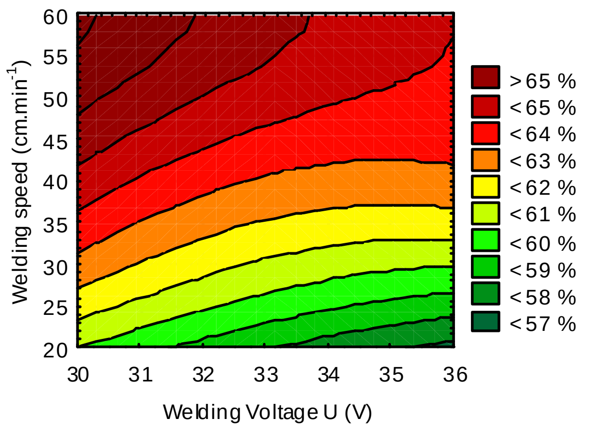

Figure 8. Influence of welding voltage and welding speed on structure of hardfacing by constant welding arc current I = 300 A, contour shown ratio of carbide eutectic

3. Conclusion

In this paper, the selection of the process parameters for FCAW welding of S235JR steel plates with bead geometry has been reported. The optimal bead geometry is based on bead width, bead height and penetration. The factorial design has been adopted to solve the optimal bead geometry. Experimental results have shown that process parameters such as welding speed, arc current and welding voltage influence the bead geometry in FCAW welding processes. Mathematical models developed from the experimental data can be employed to study relationship between process parameters and bead geometry and to predict the bead dimensions.

Experiments results we can summarize to three points:

1. With increasing arc current and welding voltage increasing width of welding bead, with increasing welding speed decreasing welding width, it is according with [2, 6, 12, 13].
2. With increasing arc current increasing height of welding bead and with increasing welding voltage and welding speed decreasing height of welding bead, it is according with [2, 3, 12, 13].
3. With increasing arc current increasing penetration of welding bead, with increasing welding voltage and welding speed decreasing penetration of welding bead, it is according with [2, 3, 12, 13].
4. Welding conditions were important influenced on final structure of weld deposit bead. Hence is important look for an optimal welding condition for hardfacing.

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