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Sensitivity Analysis for Process Parameters in Cladding of Stainless Steel by Flux Cored Arc Welding

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Abstract

Austenitic stainless steel cladding is generally used to attain better corrosion resistance properties to meet the requirements of petrochemical, marine, and nuclear applications. The quality of cladded components depends on the weld bead geometry and dilution, which in turn are controlled by the process parameters. In this investigation, the effect of cladding parameters such as welding current, welding speed, and nozzle-to-plate distance on the weld bead geometry was evaluated. The objective of controlling the weld bead geometry can easily be achieved by developing equations to predict these weld bead dimensions in terms of the process parameters. Mathematical equations were developed by using the data obtained by conducting three-factor five-level factorial experiments. The experiments were conducted for 317L flux cored stainless steel wire of size 1.2 mm diameter with IS:2062 structural steel as a base plate. Sensitivity analysis was performed to identify the process parameters exerting the most influence on the bead geometry and to know the parameters that must be most carefully controlled. Studies reveal that a change in process parameters affects the bead width, dilution, area of penetration, and coefficient of internal shape more strongly than it affects the penetration, reinforcement, and coefficient of external shape.

Keywords: *Cladding, Flux Cored Arc Welding, Weld Bead Parameters, Coefficient Weld Shapes, Response Surface Methodology, Sensitivity Analysis*

Introduction

In many critical industries such as the power and petrochemical industries, bi-layer components in the form of cladded plates are used due to their superior environmental/mechanical properties (Khodadad Motarjemi and Kocak 2001). The mechanical and metallurgical characteristics of these corrosion-resistant layers are not only controlled by the chemistry of the stainless steel wire but to a greater extent by the process parameters applied during cladding. Also, engineering components in many industrial applications are subjected to wear and corrosion, which dictate frequent maintenance and jeopardize reliability. The replacement cost of many of these components is extremely high; consequently, extension of service life can result in significant savings (Alam et al. 2002; Heston 2000; Missori, Murdolo, and Sili 2004).

Cladding is a process of depositing a relatively thick layer of filler material on a carbon or low alloy steel base metal (Alam et al. 2002; Murugan and Parmer 1995). It is possible to achieve high economic gains by fabricating components from the stainless steel surfaced low carbon steel for use in important applications in chemical, fertilizer, thermal, and nuclear power industries. Based on these considerations, low carbon structural steel (IS: 2062) is cladded with austenitic stainless steel (317L). The former is extensively employed as a construction material in nuclear power plants and fertilizer industries and the latter for depositing buffer layers (Murugan 1993; Stewart 1981). Rolling, explosive welding, or fusion welding are commonly employed for cladding. Fusion welding is readily accepted by the engineering industry owing to its easy and versatile application and no legal implications of safety, pollution, and noise (Rajasekaran 2000). Among the fusion welding processes, flux cored arc welding (FCAW) has been widely used for cladding due to several advantages, such as high deposition rate, high-quality weld metal deposits, low fume generation, excellent weld appearance (smooth, uniform welds and excellent contour of horizontal fillet welds), relatively high electrode metal utilization, relatively high travel speeds, gasless variations that can be used outdoors, the possibility of welding in all positions, and reduced distortion compared to shielded metal arc welding (Cary 2002; Raja, Rohira, and Samidas 1999; Sakai et al. 1989; Cornu 1988). Principal applications of FCAW include steel fabrication, public works (e.g. bridges), naval works, boiler making, tube/pipe welding, heterogeneous assemblies, and so on.

The selection of the welding procedure must be specific to ensure that an adequate clad quality is obtained (Kim, Son, and Jeung 2001). Further, it is essential to have complete control over the relevant process parameters to obtain the required bead geometry (*Figure 1*) and shape relationships on which the integrity of a weldment is based (Chandel and Bala 1986). It has also been reported by some researchers that in FCAW process quality can be represented by the bead shape, and the weld pool geometry plays an important role in determining the mechanical properties of the weld (Kang et al. 2003; Kim, Rhee, and Park 2002; Chen et al. 2000; Juang and Tarng 2002). Therefore, it is very important to select and control the welding process parameters to obtain optimal clad geometry.

Numerous attempts have been made to develop mathematical models relating the process variables and clad geometry for the selection and control of the process variables (Kim et al. 2003; McGlone 1982; Allen et al. 2002). The Welding Institute and Chandel and Bala (1986) pioneered in attempting these types of modeling. The results show that the mathematical models so derived from experimental results can be used to predict the bead geometry (Kim, Son, and Jeung 2001; Kim et al. 2003).

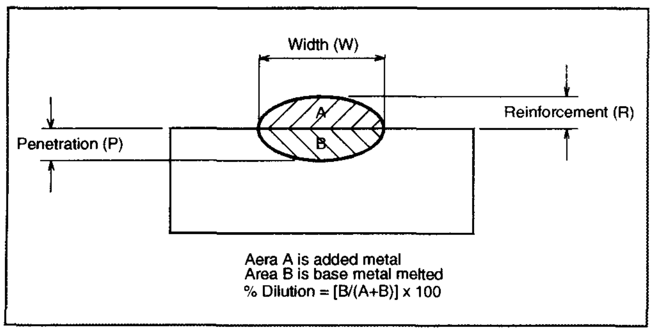

Figure 1
Weld Bead Geometry

Also, it has been proved by several researchers that efficient use of statistical design of experimental techniques allows the development of an empirical methodology, which incorporates a scientific approach in establishing a welding procedure (Kim et al. 2003; Allen et al. 2002; Chandel and Bala 1986; Marimuthu and Murugan 2005; Subramaniam et al. 1999; Murugan and Parmer 1994).

In this work, investigations were carried out to study the effect of the process parameters on bead formation and their sensitivity. The qualitative and quantitative effectiveness of process parameters can be determined using sensitivity analysis. By this analysis, critical parameters can be identified and ranked by their order of importance. This will help plant engineers to select the process parameters efficiently and to control the bead geometry effectively without much trial and error, resulting in savings of time and materials.

The study was carried out in two steps. In the first step, experiments were conducted with different process parameters using design of experiments to develop statistical models for the prediction of weld bead geometry. In the second step, sensitivity analysis was carried out based on the empirical equations developed.

The chemical compositions of the low carbon structural steel, IS: 2062, substrate and the austenitic stainless steel type, AISI 317L, filler material used in this study are given in *Table 1*.

Experimental Procedure

The independently controllable process parameters were identified. They are welding current (I), weld-

Table 1
Chemical Composition of Materials Used

S. No.	Materials Used	Element, % weight C	Si	Mn	P	S	Cr	Mo	Ni	N_2	Cu
1	317L (flux cored wire)	0.021	0.89	1.38	0.016	0.007	18.46	3.18	13.10	0.057	0.007
2	IS: 2062	0.180	0.180	0.980	0.016	0.016	–	–	–	–	–