A Study on Sensitivity Analysis for Process Parameters in GMA Welding Processes

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ABSTRACT Generally, the quality of a weld joint is strongly influenced by process parameters during the welding process. In order to achieve high quality welds, mathematical models that can predict the bead geometry to accomplish the desired mechanical properties of the weldment should be developed. To achieve this objectives, a sensitivity analysis has been conducted and compared the relative impact of three process parameters on bead geometry in order to verify the measurement errors on the values of the uncertainty in estimated parameters. The results obtained show that developed mathematical models can be applied to estimate the effectiveness of process parameters for a given bead geometry, and a change of process parameters affects the bead width and bead height more strongly than penetration relatively.

1. INTRODUCTION

Recently robotic welding systems have received a great deal of attention because they are highly suitable not only to increased production rate and quality, but also to decreased cost and time to manufacture for a given product. To get the desired quality welds, it is essential to have complete control over the relevant process parameters in order to obtain the required bead geometry and which is based on weldability. However, mathematical models need to be developed to make effective use of robotic arc welding. Previous work on the relationships between process parameters and bead geometry in arc welding process can be grouped into two distinct areas; empirical methods based on studies of actual welding situations [1]-[3] and theoretical studies based on heat flow theory [4]-[6]. An early attempt at The Welding Institute [2] succeeded in selecting a statistical approach to evaluate the relationships between submerged-arc welding variables and bead geometry. Chandel [7] first applied this technique to a GMA welding process and investigated relationships between process parameters and bead geometry of bead-on-plate welds deposited by a GMA welding process.

In this paper, a methodology for understanding relationships between process parameters and bead geometry, and development of mathematical models for the GMA(Gas Metal Arc) welding process is presented. The objective of the first part of this study is to find the optimal bead geometry in the GMA welding process. A statistical three-level factorial analysis for optimization of process parameters in bead geometry was performed. A sensitivity analysis based on the developed empirical equations has been carried out. Finally the sensitivity results have been compared to the experimental results.

2. GMA WELDING PROCESS

The chosen factors for this study were welding voltage, welding speed and arc current, and the responses were bead width, bead height and penetration. The 33 factorial designs provided the main effect and interaction effects of three parameters at three levels. The factorial design required 27 weld runs for development of the mathematic of models. The experimental materials for development of the mathematical equations were 200×75×12 ㎜ mild steel AS 1204 plates adopting the bead-on-plate technique. Steel wire with a diameter of 1.2 mm was employed as the welding consumable.

3. SENSITIVITY ANALYSIS OF EMPIRICAL EQUATION FOR BEAD GEOMETRY

The sensitivity equations are obtained by differentiation with respect to process parameters of interest such as arc current, welding voltage and welding speed that are explored here.

The purpose of this investigation is to show the effectiveness of process parameters by using the direct sensitivity analysis technique on these empirical equations. Results of bead width sensitivities for arc current, welding voltage and welding speed are shown in Table 1 for the S=330(mm/min). For these conditions, sensitivities of arc current and welding voltage on bead width are positive, and sensitivities of welding speed are negative. Positive values of sensitivities means that the arc current or welding voltage increases as the bead width increases and a negative value means that the welding speed increases as the bead width decreases.

Figs. 1~3 show the sensitivities of bead shape parameters (bead width, bead height and penetration) for process parameters, which are arc current, welding voltage and welding speed. The sensitivities of welding voltage and welding speed. The sensitivities of welding voltage on bead width are positive, but sensitivities of welding voltage on bead height are negative, Figs. 1~2.

Table 1 Bead width sensitivities of process parameters

S=330 (mm/min)			Sensitivity		
Voltage (Volt)	Current (Amp)	Width(mm)	dWdI	dWdS	dWdV
20.00	180.00	3.33	0.0063	-0.0045	0.1124
	260.00	3.78	0.0050	-0.0051	0.1275
	360.00	4.22	0.0040	-0.0057	0.1425
25.00	180.00	3.87	0.0074	-0.0052	0.1046
	260.00	4.39	0.0058	-0.0059	0.1187
	360.00	4.91	0.0047	-0.0066	0.1327
30.00	180.00	4.38	0.0084	-0.0069	0.0987
	260.00	4.97	0.0066	-0.0067	0.1119
	360.00	5.56	0.0053	-0.0075	0.1251

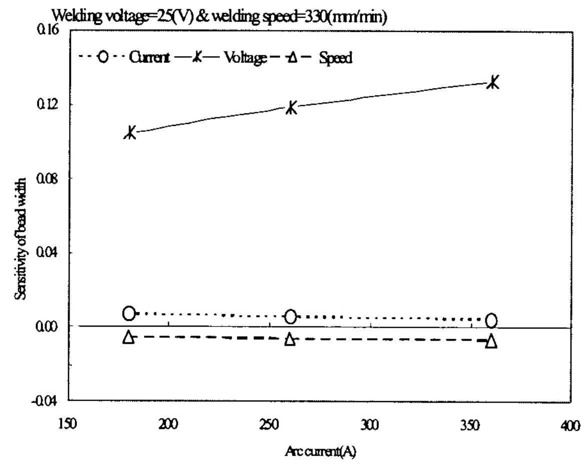

Fig. 1 Sensitivity of bead width

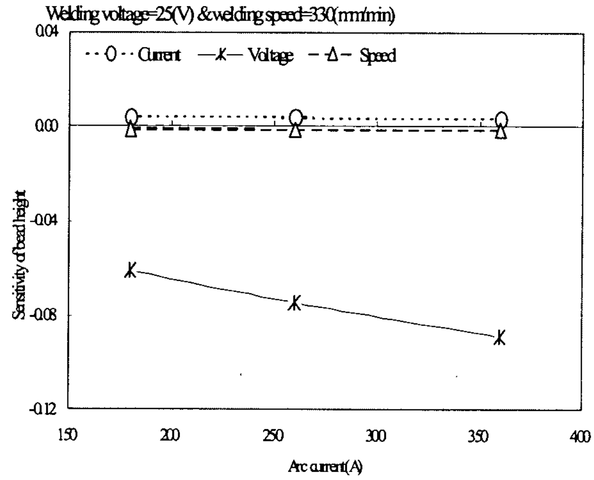

Fig. 2 Sensitivity of bead height

Since the sensitivity of welding voltage on bead width and bead height are much higher than those of arc current and welding speed, the change of welding voltage is more useful in control of bead width and bead height.

The penetration is less sensitive than other bead shape parameters (bead width and bead height). It appears that the change of process parameters affects the bead width and bead height more strongly than penetration, Fig. 3.

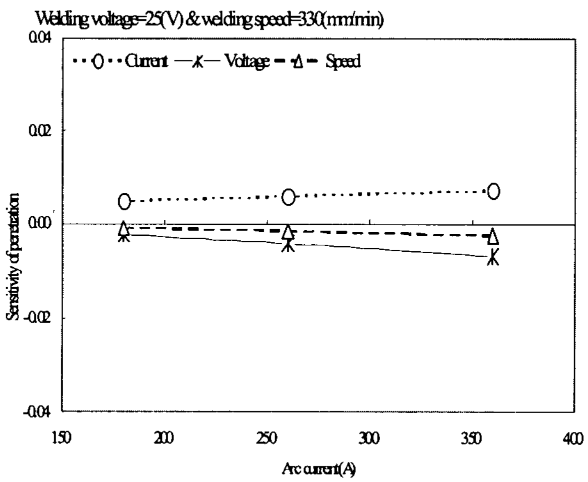

Fig. 3 Sensitivity of penetration

4. CONCLUSIONS

In this paper, the selection of the process parameters for GMA welding of AS 1204 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 width, bead height and penetration in GMA welding processes. Sensitivity analysis has been investigated to represent the effectiveness of the processing parameters on these empirical equations and showed that the change of process parameters affects the bead width and bead height more strongly than penetration relatively. The developed models should be put into perspective with the standard GMA welding power source that was employed to conduct the experimental work. Factorial analysis has the potential for more stringent sensitivity analysis and may be used for optimal parameter estimation for other mathematical models.

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