Taguchi 방법을 이용하여 최적의 비드형상 예측에 관한 연구

A study on the optimized bead geometry using Taguchi method

김인주*, 김일수*, 박창언*, 손준식*, Yu Xye*, 성백섭**,강봉연***, 강문진***, 조선영****

* 목포대학교
** 조선대학교
*** 생산기술연구원
**** KR정밀㈜연구소장

ABSTRACT In this paper, the prediction for the optimized bead geometry such as bead width, height, penetration and bead area in the Gas Metal Arc (GMA) welding with Taguchi method is presented. An orthogonal array, and the Signal-to-Noise (S/N) ratio employed to investigate the welding quality characteristics together in the selection of process parameters in the GMA welding process, to analyze the effect of each process parameter on the bead geometry and to finally determine the process parameters with the optimal bead geometry. Experimental results from this research show that the Taguchi method provides an effective tool to enhance the accuracy of the optimized bead geometry

1. Introduction

The Taguchi method provides a mathematical tool called the orthogonal arrays, which allows the analysis of the relationships between a large numbers of design parameters using only a limited number of experimental runs [1-3]. A key concept to the Taguchi method to quality is to quantify 'losses' which occur because of poor quality, using 'loss functions' as quadratic in nature, with losses increasing in proportion to the square of the deviation of the performance from the target. In order to measure the quadratic loss function, Taguchi introduces the signal-to-noise (S/N) ratios for measuring the quality through orthogonal array based experiments, the most economical experimental design in terms of high accuracy and fast convergence speed at the smallest development cost can be accomplished. A class of statistics called S/N ratios has been defined to measure the effect of noise factors on performance characteristics. S/N ratios take into account both the variability in the response data and the closeness of the average response to target value. In the parameter design phase of this method, process parameters (factors) can be grouped into controllable and noise factors. The design and indicative factors belong to the class of controllable factors (variables) that can be controlled both in the simulation experiment and in the real world.

Tarng et. al. [4] have employed Taguchi method to select the process parameters to improve weld qualities for Submerged Arc Welding (SAW) in hardfacing and shown that the performance characteristics of the SAW process such as deposition rate, dilution, and hardness are improved together by using the Taguchi method. Juang and Tarng [5] presented the selection of process parameters for obtaining an optimal weld pool geometry in the Tungsten Inert Gas (TIG) welding of stainless and represented that Taguchi approach provides an effective means to enhance the prediction of the front height, front width, back height and back width of the weld pool in the TIG welding.

In this study, a Taguchi method which combine experiment design theory and the quality loss function concept, has been applied to establish the relationship of the optimal bead geometry (bead width, height, penetration and bead area) with respect to the process parameters and select the suitable process parameters such as wire diameter, arc current, welding voltage, welding speed on the optimal bead geometry in GMA welding process.

2. Welding Equipment and Procedure

In this study, the experimental materials were

200 × 70 × 12 mm steel SS400 plates. The chosen process parameters were wire diameter, arc voltage, welding speed and welding current with two levels. Their values can be seen in Table 1. The interaction effect between the process parameters is neglected. In this study, L_{16} orthogonal array with four columns and sixteen rows was employed. Each process parameter is assigned to a column, sixteen process parameter combinations being available.

When it comes to measure the bead geometry, the bead section was cut transversely from the middle position using wire cutting machine. The incised plane was the specimen and it should be polished. In order to assure the precision of the specimen dimension it was etched by HNO_3 3% and H_2O 97% nital solution. To evaluate the quality of GAM welding, the measurements of the bead geometry were performed. Basically, bead penetration must be achieved to ensure the weld strength. The bead width, bead height, bead penetration and bead area, therefore, have a lower-the-better quality characteristic [5]. Then we can get the dimension of the bead geometry and study the relationships between process parameters and bead geometry.

Table 1 Factors and their levels

Sample	Process parameter	Level 1	Level 2
A	Wire diameter (mm)	1.2	1.6
B	Arc voltage (V)	20	30
C	Welding speed (cm/min)	25	41
D	Welding current (A)	180	360

3. Experimental results and analysis

As described before here we have employed a 16 run two-level design. As discussed earlier, the quality characteristics, bead width, bead height, bead penetration and bead area were lower-the-better ones. The S/N ratio corresponding to the overall loss function is shown in Fig. 1.

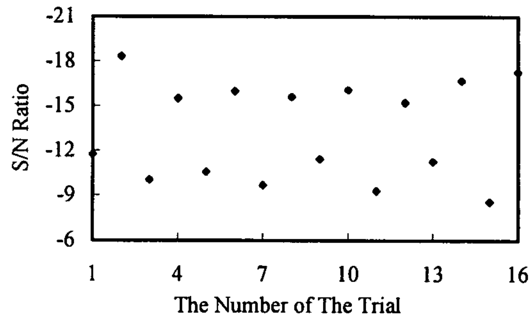

Fig. 1 S/N ratio for the bead geometry

Because the experimental design is orthogonal, the effect of each process parameter on the S/N ratio at different levels can be separated out and presented in Table 2. In addition, the mean of the S/N ratio at different level of the process parameters and the total mean of the S/N ratio for the 16 experiments are also shown in Table 2. According to the Taguchi method the larger is the S/N ratio, the better is the multiple quality characteristics for the bead geometry. The average S/N ration of various process parameters affecting the bead geometry and their levels were determined as listed in Table 2and Fig 1. As shown in Fig. 1, we can see that the S/N ratio of experiment 15 was the largest one and experiment 15 has the best multiple performance characteristics among the 16 experiments.

Table 2 S/N response table for the bead geometry

Symbol Process Parameter	S/N ratio		Max-Min
	Level 1	Level 2	
A: Wire diameter	-107.361	-105.761	1.6
B: Arc voltage	-107.571	-105.551	2.02
C: Welding speed	-112.013	-101.109	10.904
D: Welding current	-82.543	-130.579	48.036
Total mean value of the S/N ratio =-106.561			

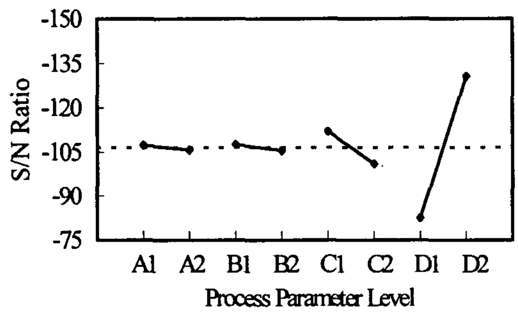

Fig. 2 S/N ratios for the bead geometry

Fig. 2 shows the S/N ratio graph where the dashed line is the value of the total mean of the S/N ratio. Due to that larger S/N ratio means better multiple quality characteristics for the bead geometry. It can also conclude from Fig. 2 that the optimal level of the process parameter is A_2, B_2, C_2, D_1. In other words, the optimal process parameters are wire diameter, arc voltage and welding speed at level 2 and welding current at level 1 (that is experiment 15). From Fig. 2 we can also see that the S/N ratios of wire diameter and arc voltage distribute around the S/N ratio mean value. And the S/N ratios of welding speed and welding current vary greatly with the changes of the level. So among the process parameters the welding speed and welding current have great effect on the bead geometry. The final step is to verify the experiment using the optimal level of the process parameters. Because the optimal prediction for the bead geometry is included in the experiments which were already executed, the process parameters with the optimal bead geometry are wire diameter, arc voltage and welding speed at level 2 and welding current at level 1.

4. Conclusions

The prediction for the optimized bead geometry in the GMA welding with Taguchi method considering multiple performance characteristics is presented. The optimal bead geometry is based on four lower-the-better quality characteristics, that is bead width, bead height, bead penetration and bead area. By using a weighting method we can integrate the four loss functions corresponding the four quality characteristics into an overall loss function. Thus in this way the optimization of the multiple performance characteristics can be greatly simplified. Then we can get a good prediction for the optimized bead geometry. And experimental results have shown that the welding speed and the welding current have great effect on the bead geometry in GMA welding.

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