STOCHASTIC ANALYSIS OF PLASMA REFLECTION

Y. Ma, B. Losch, and Y. M. Zhang

Welding Research Laboratory
Center for Robotics and Manufacturing Systems and
Department of Electrical and Computer Engineering
College of Engineering, University of Kentucky
Lexington, KY 40506

Introduction

Keyhole arc welding (KAW) achieves deep narrow penetration. If it can be controlled such that the heat input be minimized while at the same time the desired full penetration is guaranteed, it could become an effective yet affordable technology to improve productivity. However, the key in developing such a controlled KAW technology is the sensor which can detect the evolution of the keyhole. Preliminary study shows that the plasma reflection could lead to a practical yet accurate sensor. In this study, the dynamic plasma reflection is modeled as a stochastic process to predict the evolution of the keyhole.

Procedure

To explore the possibility to monitor the establishment of the penetrated keyhole based on the behavior of the reflected plasma, a high speed image system was used to observe the plasma arc and its reflection during welding 4.5 and 6.5 mm thick plates using keyhole plasma arc welding. The angle of the reflected plasma, referred to as reflection arc angle (RAA), was extracted using an image process algorithm. The RAA series was then analyzed as a stochastic time series.

Results and Discussion

It is found that the development of the keyhole has three states or periods, the stable non-penetrated keyhole period, the instable transition period, and the stable penetrated keyhole period. During the stable non-penetrated period, the RAA fluctuates around a small degree with small amplitudes. Once the development enters into the instable transition period, the RAA fluctuates around a larger degree with larger amplitudes. After the stable penetrated keyhole state is established, the RAA increases and is stabilized at an even larger degree.

Despite the characteristics of the RAA in different states, the RAA series is too stochastic to determine the state. It appears no explicit function into which the data set fits. The histogram for the RAA suggests some random distribution for the data set. Therefore, the data set should be considered a stochastic process.

To determine the state of the keyhole from the stochastic RAA series, the RAA is modeled using an auto-regressive moving-average (ARMA). The parameters of the ARMA model are recursively estimated and then used to recursively calculate the frequency response of the ARMA model in two selected frequencies, one low frequency and one high frequency. The ratio between the high-frequency response and low frequency response is used as a discriminator function. It is found that the discriminator function gives accurate determination of the state of the keyhole. Since the reflection plasma can be sensed using a metal cup attached to the welding torch, it is possible to develop a practical and compact sensor based on signal processing to accurately detect the state of the keyhole during KAW.

Conclusions

The frequency response of the ARMA system has different characteristics in different states. Based on the characteristics in the frequency response, a discriminator function can be formed to simplify the decision-making in detecting the state of the keyhole and improve the detection accuracy and robustness.