Plasma Cloud Charge Sensor

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Introduction

A dynamically controlled pulse keyhole plasma arc welding process can minimize the heat input with guaranteed full penetration. To implement this process, reliable detection of the keyhole is fundamental. Because the reflection plasma changes as the keyhole develops from non-penetrated to fully penetrated, monitoring the behavior of the reflection plasma may provide an effective method to detect the development or the state of the keyhole. This study thus aims at developing a compact sensor, referred to as the plasma cloud charge sensor, to monitor the charge effect of the dynamic change of the plasma cloud above the workpiece surface.

Procedure

A metal cup was attached to the welding torch as the probe in order to sense the space charge effect produced by the reflection plasma cloud. The efflux plasma exit from the keyhole on the backside of the workpiece was recorded as the accurate measurement of the keyhole state. The plasma cloud charge signal was then experimentally compared with the efflux plasma under different states of keyhole. The sensitivity and accuracy of the metal cup based sensor were analyzed and experimentally verified.

Results and Discussion

When the keyhole was non-penetrated, the plasma cloud was very strong and the deflection angle was large. The rear edge of the longitudinal section of the cavity (non-penetrated keyhole) was very steep. When the fully penetrated keyhole was established, the intensity and the deflection angle of the plasma cloud both decreased significantly. Also, the slope of the rear edge decreased significantly. When the penetration state of the keyhole was further improved by

decreasing the travel speed, the slope of the keyhole rear edge further reduced and the plasma cloud became too small and too low to be observed.

Because the intensity and deflection angle of the plasma cloud are dependent on the state (shape) of the keyhole, it is possible to monitor the state of the keyhole by monitoring the plasma cloud for real time control of pulse keyhole PAW process.

The sensitivity and accuracy of the plasma cloud charge sensor is dependent on the location of its probe (metal cup) which is specified by its distance from the axis of the electrode and its distance from the surface of the workpiece. Experiments showed that 8 to 12 mm and 3 to 6 mm were the appropriate ranges from the distance between the probe and the axis of the electrode and the distance between the probe and the surface of the workpiece, respectively. Within these ranges, the sensitivity and accuracy of the sensor are sufficient to detect the keyhole state. In addition, such ranges also provide the probe sufficient distance from the plasma jet and the workpiece to avoid possible overheating and collision.

Conclusions

The proposed metal cup probe makes it possible to form a desired compact sensor which requires no back-side access to the workpiece. Such a sensor is insensitive to the arc radiation and the variable surface conditions and is much more robust than other sensors such as CCD cameras. Experiments have verified the effectiveness of the proposed sensor in detecting the state of the keyhole and its capability in pulse keyhole process control.