Technical Note

Pulsed Laser Irradiation for Triggered Discharge in Arc Welding System

Masahiro TSUKAMOTO, Kensuke MURAI,* Manabu TANAKA, Nobuyuki ABE, Kazuhiro NAKATA, and Masao USHIO

Joining and Welding Research Institute, Osaka University, 11-1 Mihogaoka, Ibaraki, Osaka 567-0047

**Photonics Research Institute, National Institute of Advanced Industrial Science and Technology, 1-8-31 Midorigaoka, Ikeda, Osaka 563-8577*

(Received December 2, 2002)

We propose a new method that uses a plume produced by a pulsed laser for triggering arc discharge in a tungsten inert gas (TIG) arc welding system. When a pulsed laser is focused onto an aluminum alloy plate (anode) placed under a tungsten rod (cathode), an arc is discharged between the electrodes through a plume generated from the laser focusing spot. The disadvantages of the conventional triggering methods that require high-frequency generation, high-voltage pulse, or may cause sticking of the rod to the plate are removed in the new method. We also investigate the minimum laser energy required for triggering, and find that laser irradiation in Ar gas is preferable for triggering arc discharge in the TIG arc welding system.

Key Words: Arc welding, Pulsed laser, Laser-produced plume, Triggering arc discharge

1. Introduction

In the tungsten inert gas (TIG) arc welding system, arc plasma is produced between the cathode (tungsten rod) and the anode (workpiece).[1)] Technology for reliable triggering of arc discharge is very important for efficient productivity in manufacturing processes that use arc welding. Arc discharge is usually triggered with initial ionization of gas between the electrodes by a high-frequency generator or a high-voltage pulse generator.[2)] However, high-frequency radiation may disturb surrounding radio, electronic and computer equipment, and the high-voltage pulse method may require an additional electric circuit to prevent overload incidents.[2, 3)] Touch-starting is another method often used for triggering.[2)] In the touch-starting method, the rod is lowered to the workpiece until it makes contact, then the rod is quickly withdrawn a short distance to trigger the arc. This method does not require any power generators except for the welding power source. The advantage of the touch-starting method is its simplicity; however, the touch-starting method also has a disadvantage in that the rod tends to stick to the workpiece, causing electrode contamination by the transfer of tungsten to the workpiece.[3)]

The plume formed by pulsed-laser irradiation can also be employed to trigger an arc discharge. When a workpiece surface is ablated by the laser, a plume is ejected from the surface,[4)] and since the plume consists of vaporized materials including ionized particles, the plume can be used as an electrical path between the electrodes. To realize the condition, the rod is located above the laser focusing spot. When the plume reaches the tip of the rod, the workpiece and the rod are electrically connected. This laser-starting method compensates for the disadvantage of the touch-starting method. In the case where the workpiece has an oxide film on its surface, triggering arc discharge occasionally fails under conventional methods due to increased resistance on the workpiece surface. This passive oxide film is naturally formed in air on workpieces made of aluminum (Al) alloys or stainless steel. However, the laser-starting method can avoid this problem since pulsed-laser irradiation can vaporize the oxide-film. The vaporized oxide film becomes a part of the plume and is utilized for triggering the arc discharge.

In this study, we demonstrate the triggering of arc discharges, utilizing the plume produced by laser irradiation in the TIG arc welding system. An Al alloy plate was placed under a tungsten rod and irradiated by a laser pulse to generate a plume. Triggering reliability using this method depends on the reproducibility of the plume formation. To avoid oxidation, argon (Ar) or helium (He) gas is usually used to shield the rod and molten metal of the workpiece from air; therefore, formation of the plume is related to its interaction with Ar or He. Plume shapes were observed to evaluate their form. We also measured the minimum laser energies needed to trigger arc discharge as a function of distance between the electrodes.

2. Experimental conditions

Figure 1 shows the schematic diagram of the experimental setup. A direct current-type TIG arc welding system with maximum current of 300 A and a pulsed Nd:YAG laser were employed. This TIG arc welding system had a high frequency generation circuit to start arc discharge. In the experiments, we deactivated the high frequency generation circuit since it was not required in the method we have proposed. The cathode and the anode consisted of a 3.2-mm diameter tungsten rod and an Al alloy (AA5083) plate, respectively. The rod had a conical tip with solid angle of 60 degrees, and the welding torch holding the rod was equipped with a 12.7-mm diameter gas lens nozzle. Ar or He gas was ejected from the nozzle with a gas flow rate of

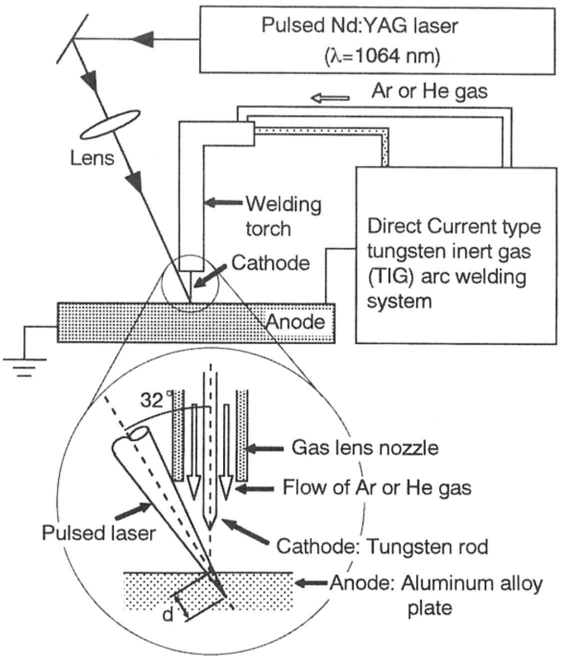

Fig. 1 A schematic diagram of the experimental setup to trigger arc discharge. A direct current-type TIG arc welding system and a pulsed Nd:YAG laser were employed. The cathode and anode of this system consisted of a tungsten rod and an Al alloy plate, respectively. The laser was focused onto the Al alloy plate by a 150-mm focal length lens at an incident angle of 32 degrees.

10 l/min. The wavelength, pulse width and diameter of the laser beam were 1064 nm, 7 ns, and about 8 mm, respectively. The laser energies ranged from 35 to 135 mJ. We focused the laser onto the plate with a 150-mm focal length lens at an incident angle of 32 degrees. The surface of the plate was placed 7.7 mm from the optimal focus position on the convergent side of the optimum focus (see *d* in Fig. 1). The laser spot on the plate was an oval shape, whose major and minor axes were 480 μm and 410 μm, respectively. Two CCD cameras were installed perpendicular to the rod to observe shapes and the reproducibility of the plume formation. A conical rod tip was placed at the edge of the plume, then an approximately 60-V bias was applied between the electrodes to trigger an arc discharge via the plume. Distance between the electrodes in TIG arc welding usually ranges from 2 to 3 mm. In our experiments, however, the distance between the electrodes was varied from 1.5 to 3.0 mm in 0.5-mm steps. We measured the minimum laser energy required for the triggering for each distance. Another setup, which was composed of a vacuum chamber and a pulsed laser, was assembled separately to observe the plume formation in a vacuum. The plate was installed in the vacuum chamber and irradiated by the laser under same laser focusing condition as the experiments in the shielding gas described above.

3. Experimental results and discussion

Figures 2(a), 2(b) and 2(c) show the plumes in a vacuum, Ar and He for the 60-mJ laser energy, respectively. As shown in Fig. 2(a), the plume expanded normal to the plate surface in a vacuum, and the plume's length was longer than 10 mm. Figures 2(b) and 2(c) indicate that plume sizes observed in Ar and He were smaller than that in the vacuum, and that the shape of the plume in Ar was different to that in He. These results indicate that plume expansion was suppressed by Ar and He. Observations of the plume show that plume formation in Ar was reproducible, although that in He was not. It is possible that differences in the shape and the reproducibility between the plumes in Ar and He could be caused by plume interaction with each gas. As indicated in Fig. 2(c), the plume in He had an irregular component, while Fig. 2(b) indicates that the plume in Ar did not have such a component. In both the 35- to 60-mJ and the 60- to 135-mJ ranges, we also found that plume formation in Ar was stable, whereas that for He was unstable. In addition, we noted that the size of the plume in Ar or He increased as the laser energy increased. Therefore, when the distance between both the electrodes is increased, the laser energy must be increased to trigger an arc.

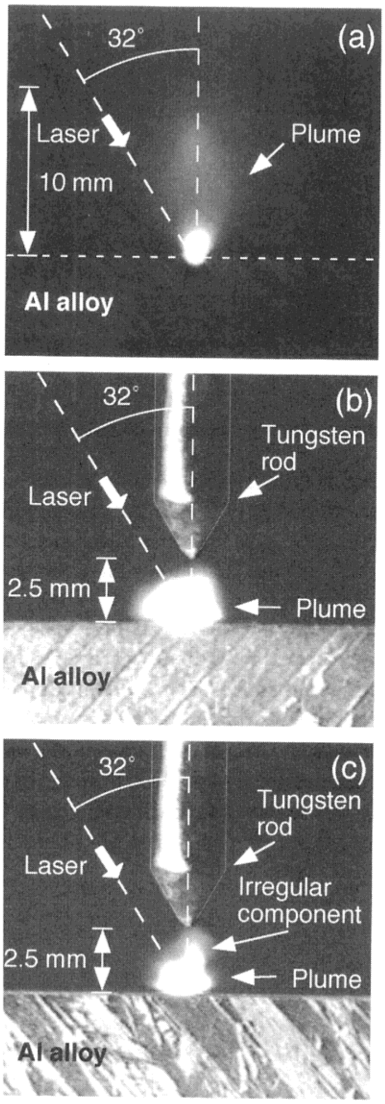

Fig. 2 Optical images of plumes produced by pulsed laser irradiation with energy of 60 mJ in (a) a vacuum, (b) Ar, and (c) He atmospheres, respectively.

Figure 3 shows the minimum laser energies required for triggering in Ar and He as functions of distance between the electrodes. The minimum laser energy increased as the distance increased, which has already been suggested from observations of

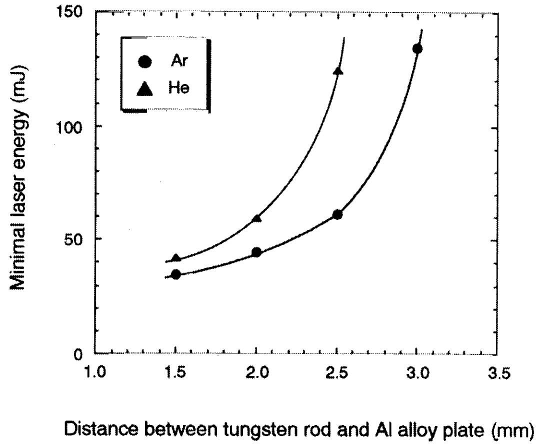

Fig. 3 Circles and triangles show minimal laser energies required to perfectly trigger arc discharge in Ar and He atmospheres as functions of distance between the tungsten rod and the Al alloy plate, respectively.

plume formation described above. As Fig. 3 shows, triggering in Ar can be performed with the lower laser energy than that required for triggering in He. This difference might be related to the unstable plume formation in He; as observation of the plume in He shows, the irregular component shown in Fig. 2(c) was unstable and did not always reach the edge of the rod. The same behavior was observed for each laser energy in the 35- to 135-mJ range. Occasionally, triggering occurred in He at the distances of 3.0 mm, 2.5 mm and 2.0 mm for the laser energies of 135 mJ, 62 mJ and 45 mJ, respectively, which are the same as the minimum laser energies for triggering in Ar, shown in Fig. 3. In these conditions, He cannot be used to trigger arc welding since it is not reliable, due to fluctuations of the plume.

4. Summary

We succeeded in triggering arc discharge in the TIG arc welding system with a plume produced by pulsed laser irradiation in Ar or He. When the distance between the electrodes is in the 2.0- to 3.0-mm range, reliable triggering occurred with the plume in Ar in the 40- to 130-mJ range of laser irradiation energy. We found that a much higher energy input is required to trigger arc discharge in He with any reliability for the 3.0-mm distance. Therefore, laser irradiation in Ar gas is preferable for triggering arc discharge in the TIG arc welding system.

References

1) R. L. O'Brien : *Welding Processes* (Welding Handbook, 8th ed., Vol. 2, American Welding Society, Miami, 1991) p. 74.
2) R. L. O'Brien : *Welding Processes* (Welding Handbook, 8th ed., Vol. 2, American Welding Society, Miami, 1991) p. 91.
3) T. Taisaku : Welding Technique No.2 (1997) 81 (in Japanese).
4) M. von Allmen and A. Blatter : *Laser-Beam Interactions with Materials* (Springer-Verlag, Berlin, 1995) p.39.