F011　Plasma Automatic Gouging

1. Introduction

Air carbon arc gouging is widely used in the manufacture of various welded structures. However, this method produces a large amount of noise, fumes, dust, and sparks during working, resulting in a harsh working environment and a heavy burden on workers. The use of carbon electrodes makes automation difficult, and most of the work is still done manually. On the other hand, the plasma arc gouging method can significantly improve the environment and is easily automated, so its application is steadily expanding.

In this issue, we report on the automation of plasma arc gouging used for back chipping of welded joints such as storage tanks.

2. Plasma arc gouging device

●2-1 Similar to general plasma cutting, the transferred plasma arc method is used, and gouging can be applied to all metals. Plasma arcs have a high density, high temperature, and high kinetic energy, with a temperature of 30,000 to 40,000 degrees Celsius and a flow velocity above the speed of sound. This method is highly efficient and minimizes deformation after gouging.

As shown in Fig. 1, the plasma arc gouging method uses a positive transitional plasma arc with an electrode serving as a cathode. The plasma gas is a mixture of argon and hydrogen, with a ratio of about 20% hydrogen. A pilot arc occurs between the nozzle and the tungsten electrode, making it easier to get started with work.

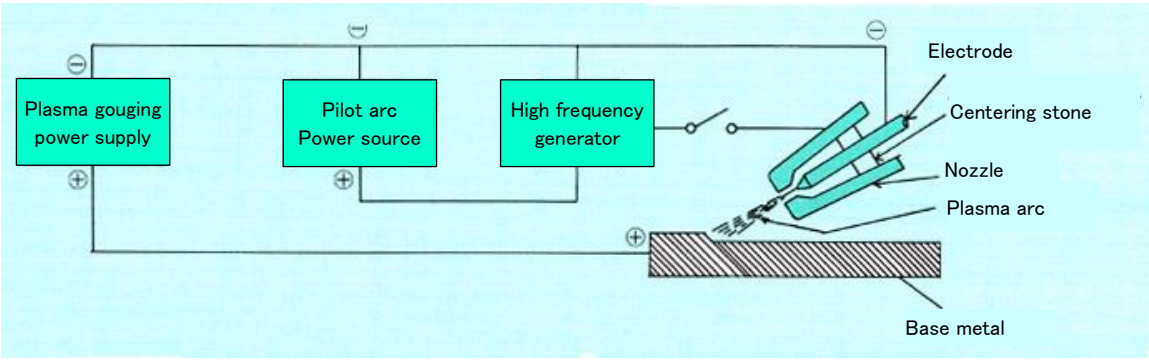


Fig. 1

To form a good gouging groove, the torch must have a 25° to 30° advance angle with respect to the workpiece. The torch is water-cooled. The welding rod can be used not only for manual operation but also for automatic operation when combined

with a wagon. Fig. 2 shows the position of the torch and the state of the arc during gouging.

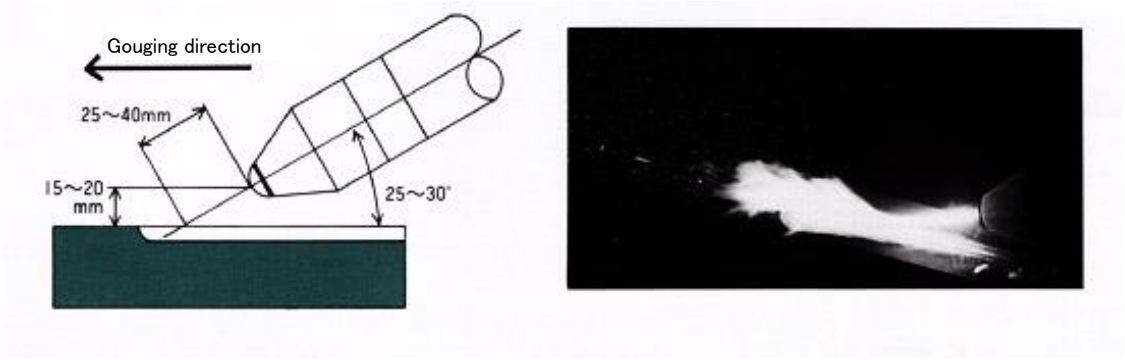


Fig. 2

●2-2 As shown in Fig. 3, the plasma arc gouging device mainly comprises a power supply and a torch.

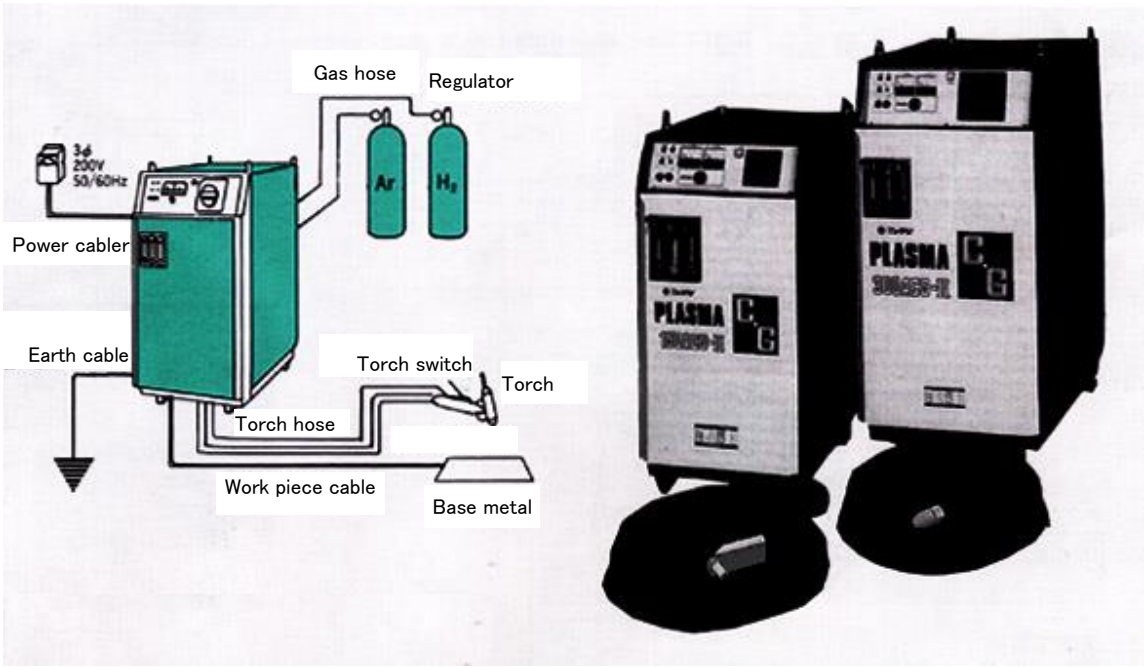


Fig. 3

(1)Power supply

The gouging power supply is a DC/constant current control (drooping characteristics) system. The maximum output current is 300 A.

In plasma arc gouging work, the arc length up to the groove bottom is usually 40 to 60 mm, so a power supply characteristic that can maintain a stable arc is required. In consideration of these operating conditions, the maximum output voltage is set to 240 V.

(2) Torch

An automatic (straight type) torch is used for automatic plasma arc gouging. Fig. 4 shows a 300 A automatic torch.

Fig. 4 shows the appearance of the torch and the basic structure of the main part. The torch tip consists of a nozzle, electrode, gas rectifier (centering stone), and a torch cooling unit. The nozzle uses a water cooling system with a cooling water circulation device built into the power supply in order to confine the plasma arc tightly and make it thinner and to extend the life of the nozzle. A tungsten electrode is employed, which is economical because it can be used repeatedly by polishing. In addition, the nozzle and electrode are indirectly water-cooled, so there is no water leakage when parts are replaced, and there are no issues caused by water.

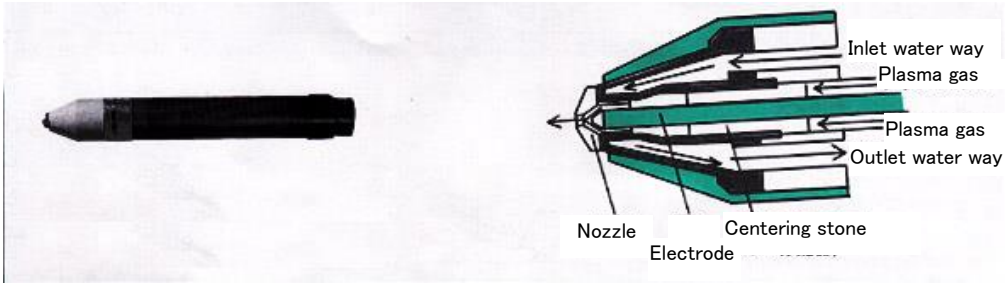


Fig. 4

(3) Plasma gas

To obtain a clean gouging surface layer, hydrogen gas is mixed with argon gas to be used as the plasma gas. Good gouging results can be obtained when the mixed ratio of hydrogen gas is about 20%.

(4) Control equipment

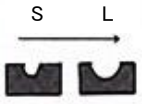
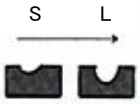
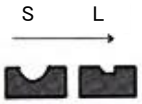
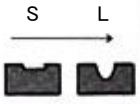
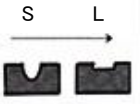
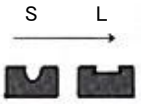
We have developed a device for automatic gouging that has a function for generating arc and a function for keeping the arc length constant to cope with irregularities on the workpiece surface and automatically follows the groove portion for gouging. See the latter part of this page for details.

3. Gouging work conditions

●3-1 Examples of basic work conditions

Variable elements in gouging include current, plasma gas, velocity, torch angle, arc length, and torch height. Table 1 shows trends in gouging groove formation due to changes in these variables. Fig. 5 shows the basic position of the torch.

Table 1

Result	Current A	Plasma gas ℓ/min	Gouging velocity mm/min	Torch angle Θ	Arc length mm	Arc length mm
Width / Depth	S L 	S L 	S L 	S L 	S L 	S L 
Remark	Excessive current disturbs the gouging groove. (The result is the same as under speed.)	When the gas flow rate is low, scattering of the molten metal becomes poor and it is difficult to form grooves.	Low speed disturbs the gouging groove. (The result is the same as excessive current.)	When the angle is increased, a cutting tendency is shown and it is less likely to cause gouging.	If it is too long, the generation of fumes increases and the arc becomes unstable.	If it is too high, the generation of fumes increases and the arc becomes unstable.

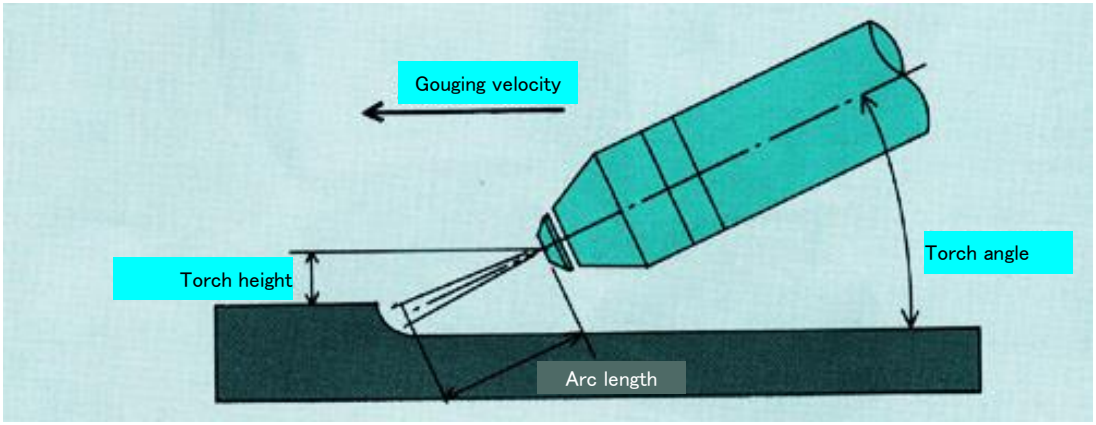


Fig. 5

●3-2 Basic work conditions for horizontal position gouging

In the gouging process of storage tanks, gouging is only available in the horizontal position from near the inside of the tank due to the nature of process, and the work conditions are different from downward gouging.

Basic work conditions for gouging in the horizontal position are as follows.

Basic conditions of lateral gouging.

Nozzle diameter	3.5mm
Gouging velocity	1.0m/min.
Gouging current	250A
Torch angle	25°
Torch height	15mm
Plasma gas	Ar＋H2 40＋10ℓ/min.

Fig. 6 shows the gouging groove shape and macro cross-section in this condition.

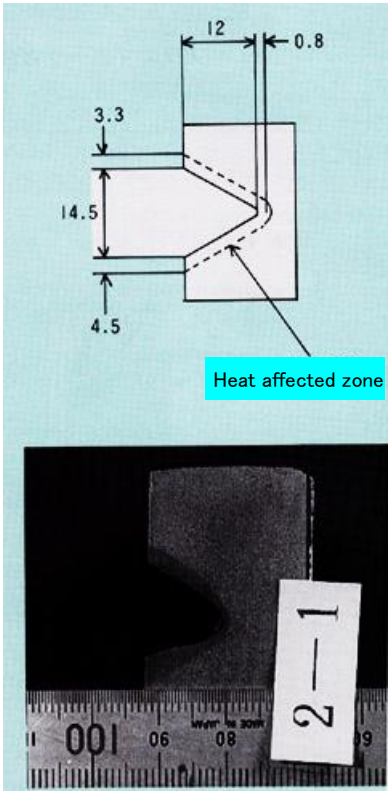


Fig. 6

4. Shallowness of automatic plasma arc gouging and application example

As mentioned above, plasma arc gouging is suitable for continuous and automatic work. To achieve this, it is necessary to ensure the ease of ignition at the start, to keep the arc length constant during work, and to accurately follow the groove where gouging is performed. By keeping the accuracy of aiming at the gouging portion, automation can be achieved by keeping the gouging width and depth constant.

●4-1 Control arc generation

The main plasma arc first generates a non-transferred pilot arc between the nozzle and the electrode, which generates a main plasma arc between the electrode and the workpiece. Since the length of the pilot arc is approximately 10 mm, approach the torch so that the pilot arc reaches the workpiece surface as shown in Fig. 7. As soon as it enters the main plasma arc, it is pulled up to a suitable distance for gouging. The approach of the torch to the workpiece can be detected by a limit switch or by detecting the transfer current of the main plasma arc.

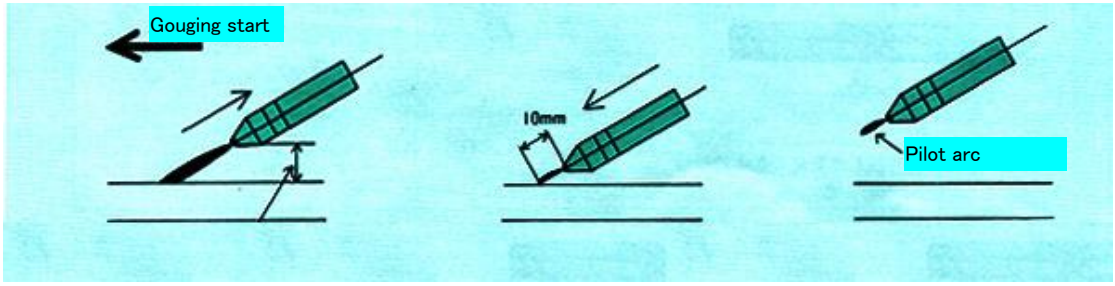


Fig. 7

●4-2 Control arc length

For plasma arc gouging, a DC power supply with drooping characteristics (constant current retention) is used. Since it can be assumed that the arc length changes in proportion to the arc voltage change, the plasma arc voltage against the torch height was measured.

The gouging position is horizontal, and as shown in Fig. 8, the arc voltage was measured when the torch was moved closer to the base metal and when the torch was moved away from the base metal. The results are shown in Fig. 10 and Fig. 11. Work conditions such as current, speed, nozzle hole diameter, and gas are the same. The arc voltage changes in proportion to the change in torch height.

Based on the above results, arc length control is possible by setting the servo control to compare the arc voltage value at the proper gouging torch position with the reference value, as shown in the block diagram of the arc length controller in Fig.

9. The accuracy and responsiveness can be set by adjusting the amplification and servo circuits.

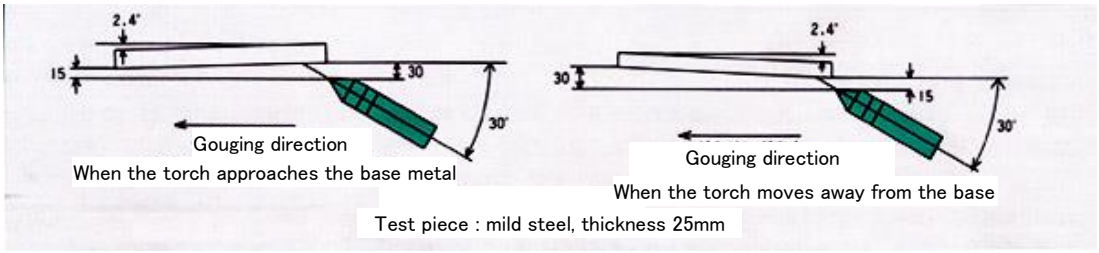


Fig. 8

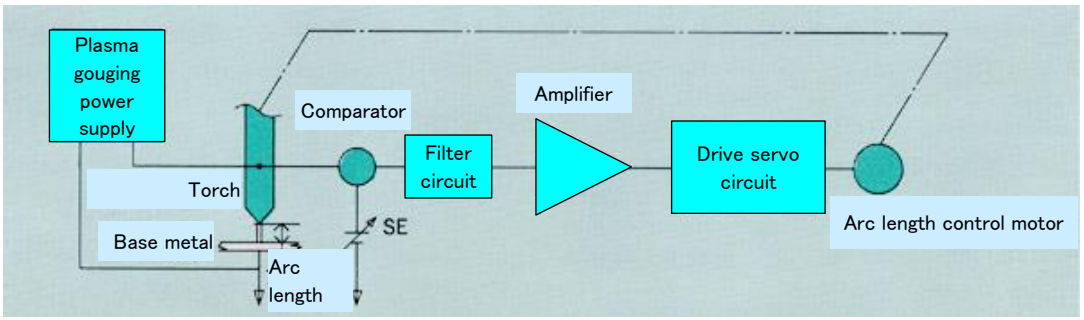


Fig. 9

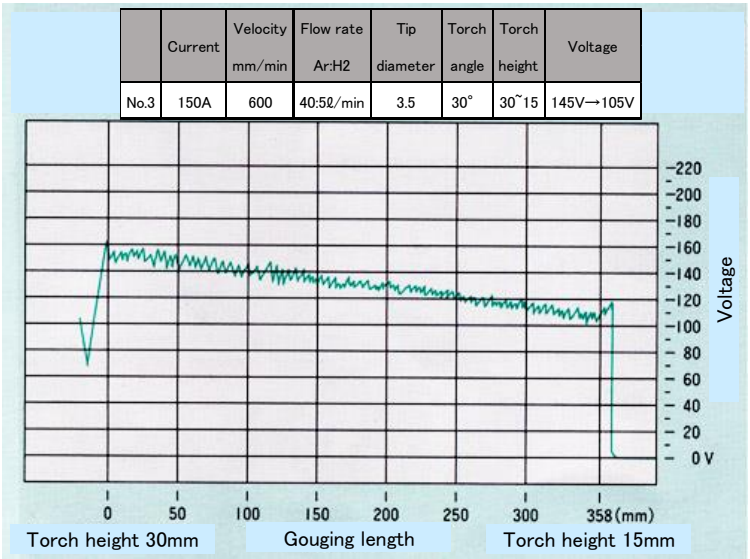


Fig. 10

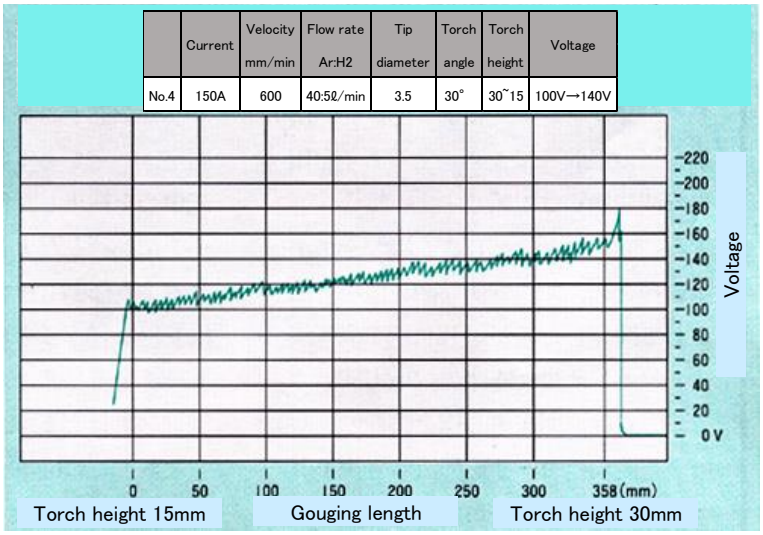


Fig. 11

●4-3 Groove profiling

When manufacturing a structure such as a storage tank, the X groove or V groove is formed in advance on a steel material, and then the grooves are joined together and welded from one side (front-side welding) and then from the other side (back-side welding). Perform back chipping before performing back-side welding to prevent weld defects and shape grooves.

5. Conclusion

1. The work conditions of plasma arc gouging, especially those of lateral gouging, were grasped, and the factors to be controlled caused by external factors were organized.
2. The arc generation method at the start and the arc length control, which can be applied by clarifying the arc voltage change due to the torch height change, have made it possible to automate plasma arc gouging.
3. Plasma arc gouging is particularly suitable for automation of welded structures.