Title	Study on plasma arc welding for stainless steel
Sub Title	
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Publisher	慶応義塾大学藤原記念工学部
Publication year	1969
Jtitle	Proceedings of the Fujihara Memorial Faculty of Engineering Keio University (慶応義塾大学藤原記念工学部研究報告). Vol.22, No.91 (1969.) ,p.187(39)- 189(41)
Abstract	
Notes	Summaries of Doctoral Theses
Genre	Departmental Bulletin Paper
URL	http://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=KO50001004-00220091-0039

Study on Plasma Arc Welding for Stainless Steel

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In recent years, greater welding speeds, better weld quality and less distortion of welding joint have been in demand for welding of various materials as progress of industry. The plasma arc devices have been used as head sources in various engineering applications. There are three types of plasma arc torch, i.e. transferred arc, non-transferred arc and semi-transferred arc.

In the non-transferred arc torch, the arc is formed between a water-cooled copper nozzle and a tungsten electrode inside the torch. The arc heat dissociates and ionizes the operating gas to form plasma jet, which issues from the nozzle. The non-transferred arc torch is used for spraying, high temperature chemical reaction and hyper-thermal wind tunnel, etc.

In the transferred arc torch, the arc is formed between the tungsten cathode and the workpiece anode. This torch transfers more heat to the workpiece than the non-transferred arc torch. In view of this, it is used for cutting and melting. In the semi-transferred arc torch, the non-transferred arc and the transferred arc are used jointly. This torch is used for surfacing.

Since the arc has the great energy concentration in all plasma types, it is expected that the plasma arc will permit higher welding speed and better weld quality. This thesis is a report on plasma arc welding of stainless steel.

Two plasma welding torches are made, one for thick plate and the other for thin sheets. In this plasma torch, the arc is formed between the water-cooled tungten cathode and copper anode nozzle. The arc column is stabilized by the vortex gas flow, which issues from the nozzle in the form of plasma jet. This torch has an outer gas ring through which the supplementary shielding gas is supplied to protect the well puddle from the atmosphere.

The efficiency of heat transfer and the heat flux distribution are observed by the calorimetric method respectively for three types of plasma torch, and then the total energy balance of the plasma torch is discussed.

The efficiency of heat transfer for the transferred arc is higher than that for the non-transferred arc. For each case of the arc, the efficiency of heat dispersion increases with increase in the gas flow rate, and the efficiency of heat transfer decreases with decrease in the flow rate of the operating gas.

In these experiments, the heat flux distribution for the transferred arc is higher than that for the non-transferred arc and that for the transferred arc is ten times as high as that for TIG arc.

For each type of the arc, thrust of the plasma jet is measured by strain balance and pressure probe.

The thrust increases with increase in the gas flow rate and heat input.

Single-pass square butt welds are made of stainless steel plates (3 mm and 6 mm thickness) and sheets (0.3 mm through 1.0 mm thickness). Edge preparation or biller metals arc not required in welding and argon or argon-hydrogen mixtures are used as the operating gas. Hydrogen, argon, or argon-hydrogen mixtures are used as shielding gas. An alumina coated backing plate is made for welding of thin sheets. For welding of thick plates backing plate is not used.

Welding joint evaluation includes X-ray, metallography, and mechanical property determination for strength, ductility and bend radie.

The mechanical properties are compared with those for parent materials.

For all weldments, joint evaluation reveals excellent results. X-ray quality is defect-free. Joint strength and ductility are nearly equal to those of parent metals. A penomenon called " heyholing action " is observed at the leading edge of the weld puddle during the welding of thick plates. In this case, the weld puddle is not disturbed by the force of the plasma jet, which passes through completely the heyhole of the workpiece.

The molten metal flows around the keyhole by surface tension and forms the welding bead. Keyholing action can be observed for thichness of 3 mm and 6 mm. However, keyholing action can not be obseved in welding of stainless steel less than 2 mm thick.

When the gas flow rate is too large, the keyhole becomes long and slender in the direction of welding, because the plasma jet pushes away the weld puddle behind the keyhole. In this case, under cutting is formed.

When the heat input is too large, the keyhole becomes wide and burnthrough takes place.

When the welding condition is suitable, the keyhole is small and satisfactory bead is produced.

(1) Keyholing action is observed during plasma arc weleing (thickness: above 3 mm). The thrust of the plasma jet is effective in this phenomenon. Then, the operating gas flow rate is in inverse proportion to the welding heat input for satisfactory keyholing action.
(2) The semi-transferred arc is effective for keyholing action.
(3) In the semi-transferred arc, its heating process is intermediate between those of the transferred arc and the non-transferred arc.
(4) In the plasma arc welding, its operating condition is insensitive to variation in arc length.
(5) For the welding of thin sheets, the use of the alumina coated backing plate

reduces the extent of undercutting compared to the case using a copper backing plate thus increasing the case of welding operation.

(6) It is found that the welding using hydrogen or argon-hydrogen mixture as shielding gas produces narrow bead width and better weld compared to TIG welding.

(7) By assuming that the heat flux distribution of the plasma arc followed the Gaussian heat source distribution, the relationship between the degree of plasma arc energy concentration and the rate of heat input necessary to melt the well nuget is analysed applying the heat conduction theory. The experimental results show a satisfactory agreement with the calculated figures.