Developments in Plasma Cutting

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1. Introduction

For some time the principle of using cold jets of gas to pinch the plasma arc and to cool the top surface of the work-piece has been known and applied. More recently, water curtains have been used for the same purpose with some extra advantages claimed. Again, a different gas has been tried to provide a curtain or "focussing" means, for example, carbon dioxide as the curtain gas and nitrogen as the plasma gas.

Other developments follow the lines of using transpiration cooling to increase the thermal efficiency of plasma torches. Porous anodes are used in this type of equipment which is now used for brazing and surface heating. Welding and cutting torches based on this principle are being developed in the USA.

This document sets out briefly the technical features of these later plasma cutting refinements and assesses the current position.

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2. Water curtain systems

The use of a water curtain system is claimed to have the following features.

1. Expansion of the plasma jet (arc) can be restrained or, putting it another way, the arc is pinched or constricted further by the water curtain ;
2. The upper surface of the workpiece is cooled—hence there is less rounding of the top edge ;
3. Little or no dross is left on the bottom edges of the cut ;
4. Some of the water is dissociated into H_2 and O_2 which add heat lower down the workpiece i.e. heat is produced on re-association improving heat efficiency and increasing cutting speed ;
5. The consequence of effects 1 and 3 is to improve cut quality and reduce the bevel—i.e. cut sides are more parallel than with ordinary plasma cuts.

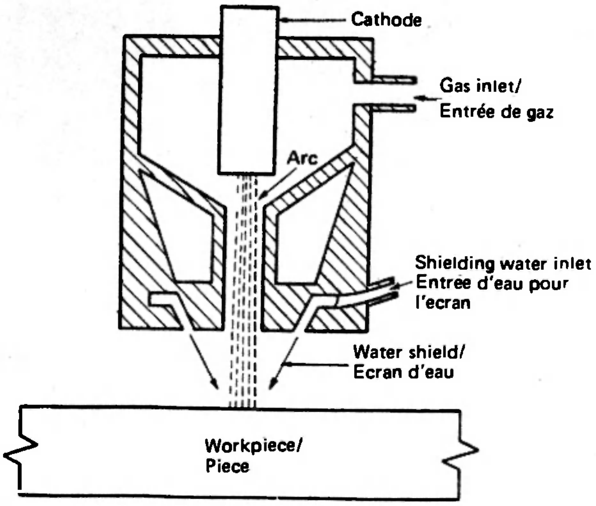


Fig. 1. Diagram of Water Shield System

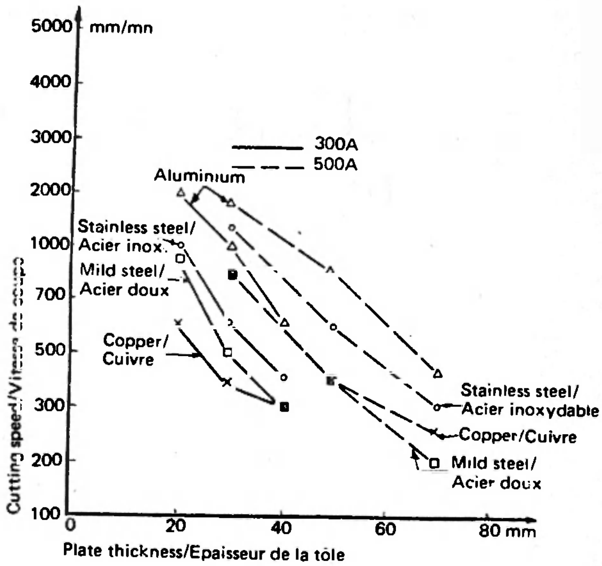


Fig. 2. Standard cutting speeds Vs thickness

The equipment used is similar to that for normal plasma cutting, except that the nozzle used has extra water passages and an annular water-nozzle as shown in figure 1.

The method of operation is to commence as for normal plasma cutting by striking the pilot arc. Once the torch is brought into the proximity of the work-piece (anode) the main arc strikes and a current relay is operated to switch on the water supply to the water curtain. Cutting speeds are claimed to be 20 to 40% higher than with standard plasma cutting and the standard cutting speeds obtained on various thicknesses of various materials are shown in figure 2.

This figure gives standard speeds for a 300 amp unit (maximum thickness 40 mm) and for a 500 amp unit (maximum thickness 70 mm). The maximum thickness quoted can be increased but with some loss in cut quality. Maximum cutting speed is from 20 to 40% higher than the figures given.

Some idea of the slope of the cut surfaces can be seen from Table 1, which gives actual measurements of cuts made on stainless steel, quoted in a Japanese paper.

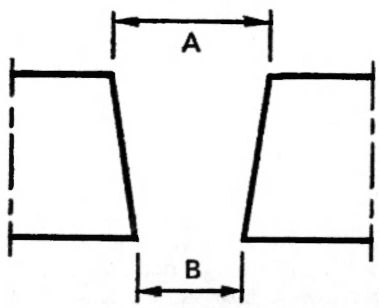
The photographs of the cut surfaces shown in the paper mentioned illustrate the points made above in comparing cuts made by normal plasma and by water curtain plasma. The improvement in smoothness of the cut surface is particularly marked at the higher thicknesses.

Apart from Japan, several firms in the USA have also introduced plasma cutting equipment employing water curtains.

One of these firms utilises a nozzle attachment which can be fitted to their standard plasma cutting torch. The maximum current to avoid double arcing

TABLE I

Current	*Plate Thickness (mm)*	*A (mm)*	*B (mm)*	*Slope of cut* $\frac{A-B}{2}$
	20	5.8	3.5	1.15
300 A	30	6.4	3.4	1.5
	40	6.1	4.2	.95
	30	7.0	3.1	1.95
500 A	50	7.5	4.5	1.5
	70	7.5	7.5	0



and to give reasonable nozzle life is 425 amp with this equipment. Suggested cutting conditions for this torch are given in Table II.

A diagram of the system used in the torch is given in figure 3. It will be noted that this particular torch differs from the Japanese pattern in that the water is introduced through the nozzle side-walls and not through the front face of the nozzle. The water shield is said to eliminate the fumes from plasma cutting, produce a narrower kerf and square edges without dross.

3. Dual gas systems

The use of gas jets, derived from the plasma gas, was a development used in welding and cutting torches in the USA. More recently the use of a separate gas to provide a curtain round the plasma arc has been marketed. This system uses carbon dioxide as the shielding (or curtain) gas the function of which is similar to that of the water curtain in the equipment described in section 2. It is also claimed to give faster welding and cutting speeds, narrower kerfs, better cut quality and squarer edges. This system has the advantage over the water curtain technique in that free water and/or steam is not liberally deposited in the surrounding atmosphere.

4. Transpiration cooling

The idea of this technique is to conserve heat by cooling the nozzle (or anode) with the plasma gas. In this way the heat is not lost, but, in effect, preheats the plasma gas. This effectively increases the efficiency of the non-transferred arc system which has certain advantages over the transferred arc system, particularly for cutting and welding by hand. These advantages lie in the fact that the device produces a plasma jet or flame, rather like a gas torch. This flame illuminates the workpiece so that the operator can see where to start and it is less sensitive to workpiece to torch distance. Also the workpiece is not in the electrical circuit and hence no problems occur from arc blow or from "double-arcing".

TABLE II

Material	*Thickness mm*	*Speed mm/min.*	*Current A*	*Power setting kw*
Carbon and stainless steel	6.3	5000	275	55
	12.6	2500	275	55
	25	1500	425	85
Aluminium	6.3	5000	275	53
	12.6	3800	275	55
	25	2400	425	85

Gas flow 70 1/min. of nitrogen
Curtain water flow 1.6 1/min.

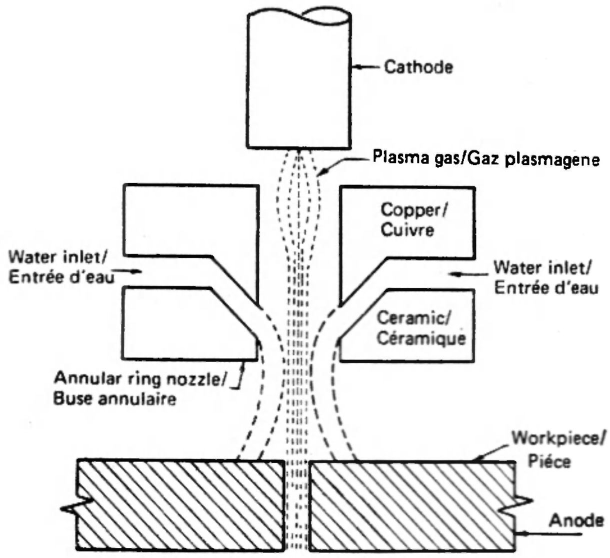


Fig. 3. Diagram representation of water curtain torch

A diagrammatic representation of a torch of this type is shown in figure 4.

5. General discussion

The currently used plasma cutting process offers high speed operation on many materials. It is characterised by a wider kerf than is obtained by oxygen cutting of mild steel and has, inevitably, a slight bevel because of the arc action. These factors are not important in many applications but can be a drawback in others.

The development of water curtain and dual gas equipment is said to give greater speeds, narrower kerfs and a squarer edge. For long straight cuts, speed increases and can give economic advantages but for profile cutting, speeds do not need to be lower ; but here the squareness of edge can be a great advantage.

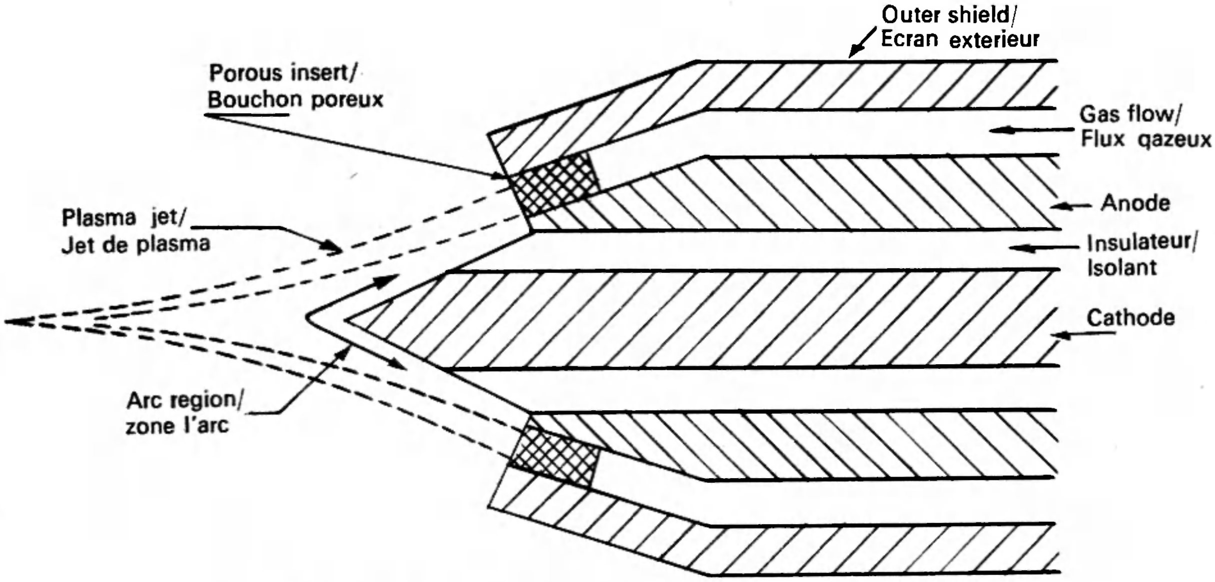


Fig. 4. Diagram of transpiration cooled (non-transferred arc)

The developments of water curtains and dual gas shielding add to the complexity of the equipment but improve cut quality and speed. Whilst it may be an overstatement to say that these techniques will revolutionise plasma cutting, they may well increase its usage in areas where higher quality is needed and where economics are in the balance with ordinary plasma equipment. This is because, in addition to any speed advantage, the gas costs may be lower because nitrogen only can be used instead of nitrogen-hydrogen or other gas mixtures. These developments and the progress of transpiration cooling should be kept under surveillance by Sub-Commission B 'Thermal cutting'' of Commission I.