EVOLUTION OF THE PLASMA FLOW CHARACTERISTICS, DURING THE FIRST HOURS, AFTER REPLACING THE SET OF ELECTRODES

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ABSTRACT

It has been commonly observed that for plasma torches after replacing the set of electrodes by a new one, it takes a few hours to reach stable working conditions.This transient step has been studied for a plasma spray torch for which a special care was made for the electrode centering together with the design of the gas injection system. The evolution of different parameters is qualified by using new diagnostic techniques which are focusing on time resolved measurements of arc voltage, flow velocity and temperature.It has been found that the mean spot anodic location changes with time so that the wear of the anode finally takes place at a given position depending on the operating parameters.The results presented in this paper were obtained for a single set of working parameters but involved several different runs representing about twenty hours for the overall duration.The influence of the phenomena occuring at the cathode is discussed for their possible role in the arc behaviour.

INTRODUCTION

Among all the phenomena involved in the behaviour of arc plasma torches, the electrode erosion is one of the most worrying problem for the development of the plasma process.

For example, in the d.c. spray plasma torches, the arc strikes between the tip of the cathode and the anode-nozzle, and because of the existence of a fluid gas layer between the arc column and the anode wall, the arc terminus is submitted to the imposed flow which leads it to move continuously at the anode wall. This movement goes with electrical breakdowns which take place to a working mode called "restrike mode".

Different experiments [1,2] have been realized on spray plasma torches in order to bring out the different phenomena which occur near the electrodes surface and the results have shown, on the one hand that the arc root displacement depends on the surface roughness and oxidation, and on the other hand that the arc root attachment is responsible of the electrode erosion.

The aim of this paper is to present a systematic study of the influence of the anode wear evolution on the arc characteristics. In this way, only one working condition has been tested which corresponded with a 600 A arc current, a 45 slm Ar/15 slm H2 plasma gas flow rate and a 7 mm nozzle diameter. The evolution of the arc behaviour has been studied during several hours.

The dynamic characteristics of the arc have been determined by realizing time resolved measurements concerning the arc voltage, the temperature and the velocity of the plasma flow.

THE USED TORCH

The spray plasma torch has been designed and built in the laboratory. Its configuration is depicted in figure 1. This torch consisted of a thoriated (2 % in weight) tungsten cathode and of a copper nozzle, both of these electrodes being water-cooled.

An important effort has been especially made on the torch geometry in order to improve the arc stability and to increase the electrodes lifetime. In this goal, the angles of the cathode tip and of the anode cone were the same and equal to 40°. The plasma gas injection was modified so that the nozzle diameter could be increased without perturbating the arc behaviour (this diameter could reach 10 mm). Another modification is concerning the anode : its thickness as well as its length were increased. The exchange surface is then more important and thus contributes to a better distribution of the heat flux on the anode wall. Moreover, the position between the cathode and the anode could be adjusted during the torch assembly, that permitting to ensure a good concentricity of both electrodes, which is necessary to avoid a preferential attachment of the arc root in the arc channel.

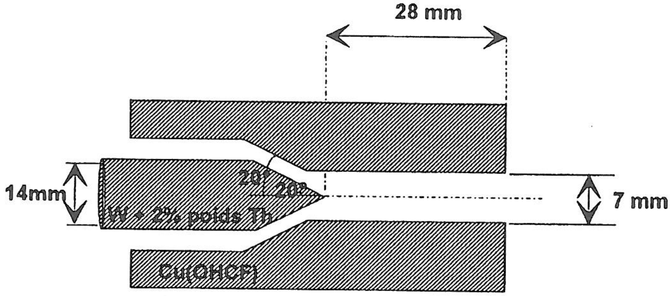

Figure 1 : scheme of the used plasma torch

THE DIAGNOSTIC TECHNIQUES

To characterize the dynamic behaviour of the torch, the arc voltage and the light fluctuations were systematically measured.

Arc voltage measurements :

The arc voltage was measured at the electrical connexions of the torch and was sampled with a digital oscilloscope operating at 10 μs / point sampling rate. Each recording signal comprised up to 8000 data points. A typical signal is presented in figure 2-a, where the saw-tooth shaped waveform indicated that the torch worked in the restrike mode [3].

Temperature measurements :

Assuming the plasma to be in local thermodynamic equilibrium, the temperature was determined by emission spectroscopy from absolute intensity of ArI line. The temperature measurement required an appropriate signal treatment taking into account both the effect of fluctuations and the non-linearities. The method used [4] for this work allowed to determine the radial profile of the stationary temperature as well the fluctuating component of temperature.

It was found that the temperature fluctuated together with the arc voltage (see fig. 2 a and b). The dimensionless fluctuations of temperature and of arc voltage, which both are determined by calculating the ratio between fluctuations and mean value are represented too. The temperature fluctuations appear to be weaker than the voltage ones this is probably due to a low pass filter of the temperature which is induced by the thermal inertia of the plasma.

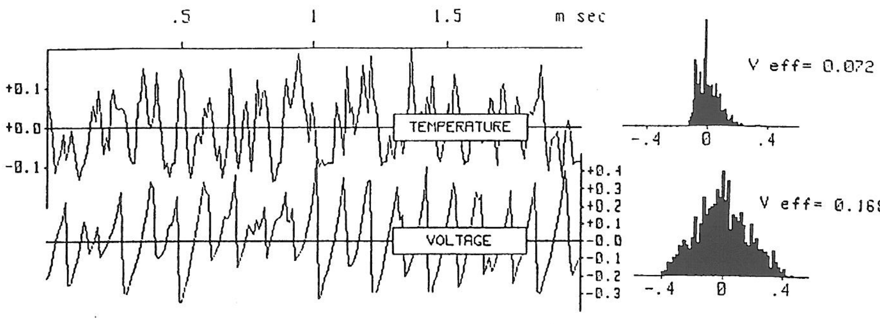

Figure 2-a and 2-b: typical recorded signals of temperature and voltage
d = 7 mm - I = 600 A - Ar : 45 slm - H2 : 15 slm

Two temperature profiles are presented in figure 3, the right profile corresponding with the first experimental results and the left one with the results obtained after several working hours.

The black line represents the stationary profile of temperature.

It can be noted that the stationary temperature profile is almost unchanged during experiments (11900 K to 11800 K) and that the standard deviations of fluctuations are almost the same (824 K to 830 K). That means that the temperature seems to be not influenced by the electrodes surface evolution, with a profile keeping its shape.

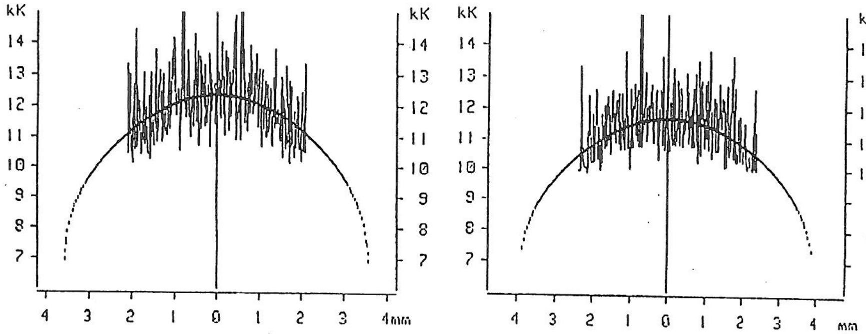

Figure 3 : radial temperature profiles versus the working time of the torch
d = 7 mm - I = 600 A - Ar : 45 slm - H2 : 15 slm
a) t = 30 mn b) t = 12 h

Provided operating conditions are kept constant, it could be concluded that the temperature results seem to be insensitive to the modification of the electrodes due to their erosion.

Velocity measurements :

The measurement technique is described in [5]. The results were obtained as radial profile of the axial component of the velocity. In the same time, the fluctuating component of the axial velocity was measured.

Three radial velocity profiles, obtained at 2 mm from the nozzle exit are presented in figure 4. The first profile is obtained during the first working hour of the torch, equipped with its new electrodes the second after four hours and the third after ten working hours.

On each profile, each height of the bar represents the standard deviation of the flow velocity obtained from a set of about 400 measurements.

It can be observed that there is no obvious similarity between the stationary temperature profiles and the velocity profiles.

It can be observed that the maximum velocity decreases (1780 to 1620 m/s) and at the same time, that the central part of the jet is slightly flattened and broadened.

This modification of the central part of the velocity profile could be attributed to the changes of the physical phenomena taking place in the cathode tip vicinity.

It was observed that the active area of the cathode tip increased with time because of erosion and of a modification of the composition due to the migration of doping thoria [6]. The current density, which is associated with the active cathode area for a given arc current, decreased and consequently the Lorentz forces, which are involved in the plasma gas momentum balance, decreased too.

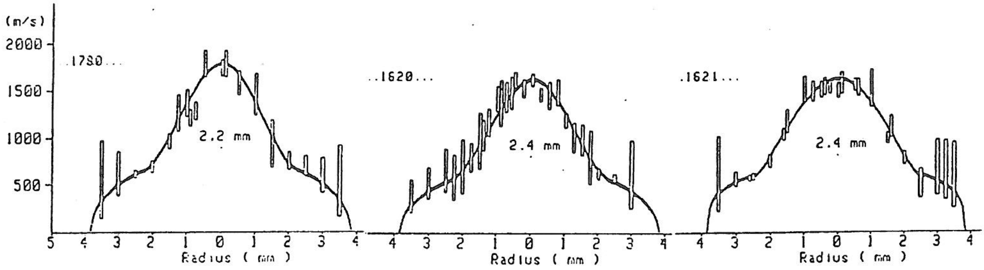

Figure 4 : radial velocity profiles versus the working time of the torch
d = 7 mm - I = 600 A - Ar : 45 slm - H2 : 15 slm
a) t = 1h b) 6h c) 12h

The velocities are measured 3 cm downstream of the cathode tip and it may be thought that the viscosity stresses are not sufficiently important to completely hide the magnetic body forces.

Consequently, the shape of the central part of the jet may be seen as a reflect of the phenomena which took place in the cathodic zone.

Observation of the anode erosion evolution:

After each experiment, a visual examination of the electrode surface has been systematically made in order to estimate the localization of the arc root attachment inside the nozzle. After the first experiment which lasted about 30 mn, no noticeable erosion was observed at the anode, excepted small traces left by the arc root without modification of a wall roughness.

In such circumstances, the spot may be thought to slide continuously in the flow direction.

Progressively, with increasing the working time, many clearly weared regions showed up, which finally merged together and became deeper and deeper, testifying of a more pronounced anchorage of the arc root.

This situation is accompagned of a severe and rather well located erosion. In the same time, the stability of the plasma jet is improved and consequently the whole characteristic features appeared to be better defined.

CONCLUSION

The study of the electrode surface state has been performed by analyzing the arc characteristics versus the working duration of the torch. The used torch has been especially designed to improve the centering of both electrodes and only one experimental condition has been tested in order to follow the time evolution of the arc features.

Arc voltage was systematically measured and both temperature and velocity distributions were determined.

It appeared that the stationary velocity profile slightly changed with the variation of the cathode configuration, at least in the case of a short nozzle channel.

It was observed that the fluctuations of the plasma jet parameters, mainly the temperature, are correlated with the arc voltage fluctuations, themselves linked to the degree of erosion and roughness of the nozzle channel.

In addition, it seemed that the erosion appeared to be a stabilizing factor.

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