SPECTROSCOPIC ANALYSIS OF A DOUBLE FLUX TIG ARC PLASMA COLUMN, CORRELATIONS WITH THERMAL MEASUREMENTS. (+)

D. DEGOUT, P. RECOURT, G. SALINIER, A. CATHERINOT.

Université de Limoges (°), FRANCE, E.T.C.A. (°), ARCUEIL,
FRANCE, L’Air Liquide (°), JOUY-EN-JOSAS, FRANCE.

ABSTRACT: Comparison between spectroscopic measurements in an Arc TIG-Plasma (Argon and Helium sheath gases) on the one hand and thermal measurements on the workpiece on the other hand have been performed. Results show two distinct plasmas: Rare gas plasma near the TIG cathode and a metallic vapour plasma in the vicinity of the molten anodic bath.

1. INTRODUCTION: Most of the studies describing TIG (Tungsten Inert Gas) Arc Plasmas have been devoted to macroscopic parameter measurements /1/, /2/, /3/. However, no realistic correlations have been done between the plasma parameters and the thermal transfer to the workpiece in welding process /4/. Our purpose in the present paper is to do a comparison between emission spectroscopy measurements in the plasma and calorimetric measurements performed on the workpiece during the welding operation. Then, an extensive study of the spectral lines emitted by the arc column have been performed for Argon and Helium sheath gases. In this paper, results obtained on Argon plasma /5/, and on Helium plasma are compared. Moreover, these results are correlated to thermal measurements performed on water cooled copper workpiece and stainless steel molten bath /6/. The spectroscopic investigation shows a similar structure for the arc column of the both Argon plasma and Helium plasma. Typically, two plasma regions: a rare gas plasma near the TIG cathode and a metallic plasma (Iron species for stainless steel workpiece) in the vicinity of the molten anodic bath. In the experimental conditions under study, the electronic density value is 30% lower in the Helium case than in the Argon case. The most important distinguishing in TIG-Argon and TIG-Helium is a metal-metallie plasma temperature value. This value is higher in Helium case than in Argon case, that for identically running conditions of the arc (U, I, arc length,...). These results are correlated to calorimetric measurements and especially to thermal flux to the workpiece. Results obtained on the copper solid workpiece and stainless steel workpiece with liquid anodic bath indicate a greater thermal flux for Helium sheath gas than for Argon. In comparison with electronic density values deduced from spectroscopic measurements, we can assume that the electrons are not the only contribution to the thermal flux to the workpiece in the arc welding process.

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2. EXPERIMENTAL: Figure 1 is a schematic representation of the spectroscopic set-up. The arc plasma is observed through the focalisation lens L1, positioned at twice its focal length from the arc column axis. It forms an image of the plasma on the entrance slit of a monochromator (JOBIN-YVON, 1.5 m, Very High Resolution ~150 000, Czerny-Turner Type). The spectral light is analysed by means of an optical multichannel analyser (OMA II, 1216, ISIT VIDICON-P.A.R.). The output signal is then fed to a microcomputer (H.P. 9845). The absolute intensity of the light emitted by the plasma is deduced from the comparison with an etalon W ribbon lamp. Then, the local emission coefficient and the local spectral line width are deduced after Abel Inversion /7/. The arc transferred plasma is produced by means of a TIG plasma torch (Double flux) (A.L. SP 90 DF). Gas sheath flow is ensured by a ceramic pipe of 20 mm in diameter. The transfer plate (positive ground) used in the spectroscopic measurements is a water cooled stainless steel (304 L). The cooling is adjust in view to obtained a steady state molten bath. The experimental conditions are reported in table 1.

3. RESULTS: The distributions of the excited states of the species of the plasma have been calculated along the plasma axis. The values are deduced from absolute local spectral line intensity. The local density of these species (excited states) on the plasma axis is shown in figure 2. The two plasma regions appear clearly and more strongly for Argon TIG plasma. The electronic density distribution (N_e) has been calculated from the Stark broadening of the Hα spectral line of Hydrogen introduced in plasma (ppm) and from Stark broadening of ArI or HeI spectral line. Calculus have been performed using the parameters proposed by Griem /8/. Results are shown in Figure 3. We can note a perturbation of the electronic distribution in the rare gas-metallic vapour mixing region. From absolute line intensity, under local thermodynamic equilibrium assumption (LTE) for Argon plasma and Helium plasma, the local temperature values have been calculated. These results have been compared with excitation temperature values obtained from the ratio of spectral line intensity (Argon and Iron). Temperature on the plasma axis for these different cases is reported on the Figure 4. These results show that the assumption of LTE is valid in the rare gas plasma. On the contrary, a disequilibrium and a deviation from saha-equilibrium in the mixing plasma region is obvious (see Saha temperature value for Iron on figure 4). Now, if these results are correlated to thermal measurements, we can deduce some conclusions concerning the effect of the appearance of the metallic species in the arc column. Indeed, the calorimetric measurements /6/ exhibit greater thermal flux for TIG Helium process than for Argon. Otherwise, the total thermal efficiency of the TIG system is quite different for copper anode (solid) and for stainless steel anode (molten).

From our spectroscopic measurements, the electronic density and rare gas temperature are found to be similar (30% closely) in both Argon and Helium case. The only plasma parameter that is found significantly changed is the Iron excitation temperature value near the molten anode. These results indicate that the electrons are not the only contribution to the thermal flux to the workplace as assume by many authors /9/, /10/. This fact may be ascribe to the well know better thermal conductivity of the Helium gas compare to the Argon gas, but also
to the more efficient energy transfer between Helium plasma and metallic plasma as suggested by the curves presented in Figure 2 which indicate a better interpenetration of the two plasmas in the TIG Helium case than in the TIG-Argon case. These results show that the correlation between thermal and spectroscopic measurement leads to, at least a qualitative understanding of welding efficiency for atmospheric arc plasma process. Now, more refined studies are necessary in order to obtain a quantitative modeling connect with usual heat transfer description.

REFERENCES:

/1/. Denny F., Rev. Hautes Temperatures et Refract., 1, (1964)

\[\text{FIGURE 1: EXPERIMENTAL SET-UP}\]
TABLE 1: Arc parameters.

<table>
<thead>
<tr>
<th></th>
<th>Arc Voltage</th>
<th>Arc Current</th>
<th>Arc Length</th>
<th>Sheath gas flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V (V)</td>
<td>A (A)</td>
<td>mm</td>
<td>extern.</td>
</tr>
<tr>
<td>Argon TIG</td>
<td>25 - 30</td>
<td>25 - 35</td>
<td>4</td>
<td>5 - 7</td>
</tr>
<tr>
<td>Helium TIG</td>
<td>27</td>
<td>35</td>
<td>4</td>
<td>8 - 10</td>
</tr>
</tbody>
</table>

FIGURE 2: EXCITED STATES DISTRIBUTION.

FIGURE 3: ELECTRONIC DENSITY DISTRIBUTION, □ Argon case, ● Helium case.
Figure 4: Temperature Distributions with Symbols;

- Excitation temperature of Argon
- Equilibrium (L.T.E.) temperature of Argon
- Excitation temperature of Helium
- Excitation temperature of Iron for Argon case
- Excitation temperature of Iron for Helium case
- Saha temperature of Iron in Argon case