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Spectroscopic determination of temperatures in plasmas generated by arc torches

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ABSTRACT

Two different arc plasma torches and especially their plasma jets are studied using optical emission spectra. Results include temperatures obtained from emission lines of atoms, ions and diatomic molecules in various distances along the axes of the plasma jets. Understanding of temperature distributions is complicated mainly in the downstream turbulent regions of the jets. Several common features are found during comparison of emission spectra and corresponding temperatures. It is shown that Boltzmann plot of rotational lines of OH can serve as a good thermometer in the downstream regions of both jets. It seems that even high temperatures exceeding 6 000 K may be measured efficiently by this method.

Keywords: arc plasma torch; optical emission spectroscopy; temperature; Boltzmann plot

1. INTRODUCTION

Optical emission spectroscopy is commonly used for evaluation of characteristics of thermal arc plasmas. Mainly temperature and composition can be obtained relatively simply, if emission spectra are available. Spectroscopic methods became even more popular in last years with appearance of wide range of spectrometers applicable in various conditions. Also industrial processes can be effectively monitored by spectroscopic methods as shown in [1]. In case of thermal plasmas, temperature is naturally one of the most important characteristics. However, determination of correct absolute value of temperature with requested space and time resolution is not always straightforward. Researchers often encounter situations, when utilization of different methods leads to different values of temperature for the same plasma source. Reasons of this discrepancy can be diverse: incorrect calibration of spectroscopic system, different signal to noise ratio of observed spectral lines, imprecise knowledge of spectroscopic constants, line-of-sight integration of radiation and impossibility or low accuracy of Abel inversion, optically thick environment together with self-absorption of spectral lines, high gradients of temperature in small plasma volume, departures from thermal or chemical equilibrium and possibly many others. Examples of temperature measurements for direct current electric arc plasmas, in which input parameters (torch geometry, applied arc current, plasma gas, surrounding pressure) influence measured temperature negligibly or substantially, can be found [2][3]. It also turns out that different stage of temperature accuracy is obtained in the centre of the arc and in the arc fringes or in the free jet.

Specific attention should be paid to the freely expanding recombining jets which often accompany arc plasmas. Determination of temperature in these jets is generally complicated mainly due to turbulent mixing of the hot thermal plasma with surrounding atmosphere. From the experimental point of view, as we move along the jet axis, we can face the necessity to measure temperatures in the range of two orders (from tens thousands of Kelvin down to hundreds of Kelvin) between the arc column and the regions in the distance of tens of centimetres downstream the arc. While in the arc column the plasma is usually fully dissociated with high degree of ionization, in the recombining jets various molecules can be formed. Also modelling of such plasma flows in order to obtain temperature maps is a difficult task. Complete temperature distributions with reasonable spatial resolution along such plasma jets are therefore presented rarely. Typically only measurements of radial profiles of temperatures in several positions in the jet or simple axial profiles are shown [4][5][6][7].