ELECTRIC PROBES INVESTIGATION OF TURBULENCE IN THE INTERACTION ZONE OF THE PLASMA JET WITH THE AMBIENT AIR.

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1. Introduction

The structure of the jet, entrainment of ambient gas into the flowing plasma and production of turbulence play an important role in plasma processing applications, e.g. in plasma spraying or treatment of hazardous and persistent waste [1,2]. A complete understanding of the processes influencing plasma jet structure requires a detailed diagnostic of flow field in the plasma jet, especially the diagnostic of processes in a jet boundary. In this paper the possibility of application of electric probes for this diagnostic is illustrated on the study of production of turbulence in the boundary layer of oxygen-hydrogen thermal plasma jet.

2. Experimental set up

Plasma torch with the dc electric arc stabilized by water swirl was used for generation of the plasma in our experiments. The anode in the form of rotating internally cooled cooper disc was positioned outside of the arc chamber 2 mm downstream of the nozzle exit. The diameter of the nozzle was 6 mm. The torch is described more in detail in [3]. The total power of the torch was varied in the region 90 - 160 kW, total mass flow rate of plasma in the torch exit was 0.2 - 0.3 g/s, mean exit temperature was 13 500 - 15 500 K and mean exit velocity 1700 - 3 200 m/s.

An array of electrostatic probes was moved across the jet and probe signals of each probe were recorded. The probes were made of Mo wire with the diameter 1 mm, the length of the measuring tip was 1 mm. These dimensions determine the space resolution of the measurements. The probes were negatively biased and were operated in a ion saturation regime, where the probe potential is very sensitive to the fluctuations of plasma parameters [4]. Due to the considerable space and time fluctuations of plasma parameters the conditions in the probe sheath varied in a wide extent. Nevertheless as plasma was close to LTE, the probe current in each position was determined by the plasma temperature. Thus the space distribution of the probe signals provides information about the distribution of plasma temperature.

In most of the experiments the array of six probes was moved through the plasma jet with the velocity less than 1.5 m/s which was substantially lower than the plasma flow velocity. They were positioned 3-6 mm apart with various mutual arrangements. The probes arranged in the line perpendicular on the jet axis provide information about radial distribution of plasma properties, the probes located in different axial positions give data for evaluation of velocity and development of structure along the jet. From the recorded signals of several probes placed in a line at the same distance from the torch exit at different radial positions the curves of the same probe current density were evaluated. These curves show the structure of the flowing plasma which passes along the probes.

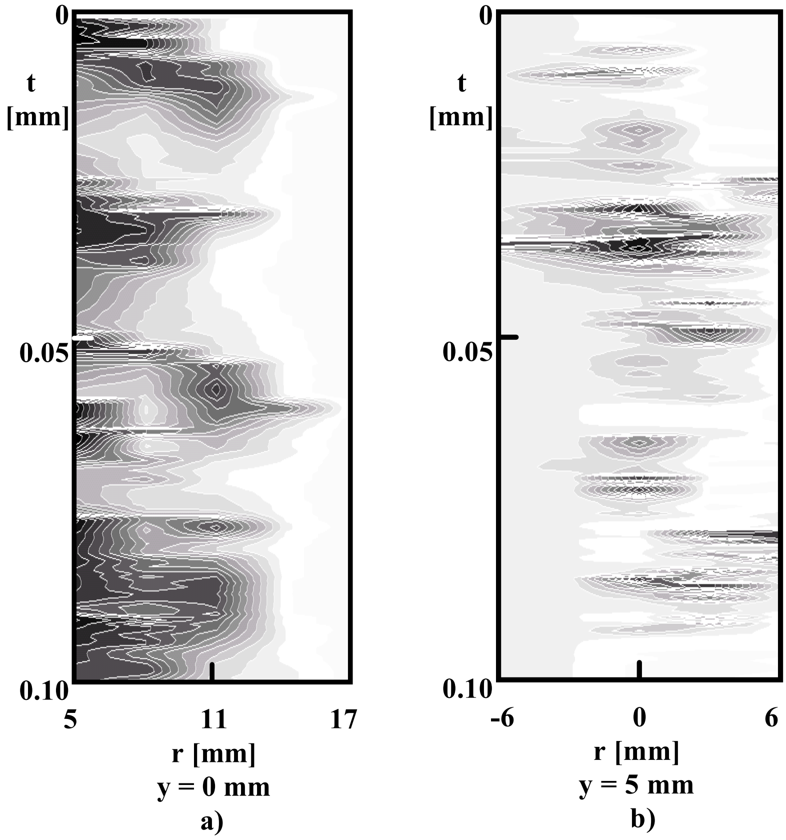

Figure 1.

3. Structure of plasma boundary

Fig. 1 shows the typical structure of the boundary layer at position z = 60 mm downstream of the torch exit in the radial positions 5 - 17 mm from the jet axis in horizontal plane passing to jet axis y = 0 (Fig. 1a) and in the radial positions (-6) - 6 mm in horizontal plane y = 5 mm (Fig. 1b). The dark zones correspond to high probe current and thus to higher temperature, light regions correspond to low probe current and colder gas. The boundary is disturbed at larger distances from the exit, entrainment of ambient cold gas into the jet and separation of eddies of plasma surrounded by colder gas are clearly seen at Fig. 1a. Fig. 1b shows, that the structures arise inhomogeneously in azimuthal direction around the jet axis.

In Fig. 2 the spatial structure of the typical eddy is shown was determined from measurements with the array of 6 probes, 4 probes in a line at axial position z = 70 mm, 2 probes 6.1 mm downstream. The axial coordinate z was determined from averaged velocity calculated from delay of signals of two probes by statistical analysis of correlation of the signals. The real size of structures in the jet boundary can be seen in the Fig. 2. The values of velocity evaluated from the probe measurements in various positions are also given.

It can be seen that local velocities in various points are different and thus the shape of individual structures continuously changes in flowing medium as it is shown in Fig. 3. These diagrams were evaluated from the signals of two lines of probes at two axial positions 4.3 mm apart. Upper diagrams shows the shape of structures, which are shown in lower diagrams.

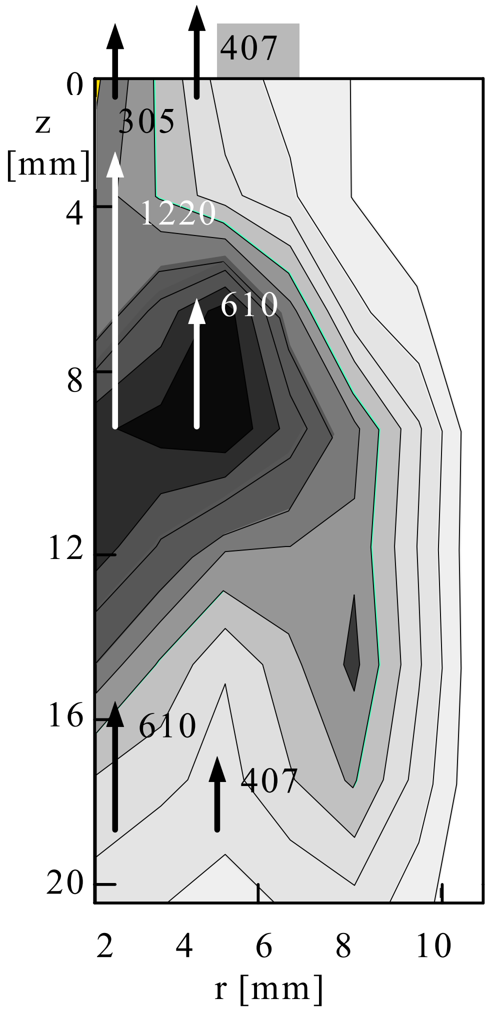

Figure 2.

4. Conclusions

The present paper has shown that the array of electric probes can be used as a relatively simple and efficient tool for local investigation of structure of flow field in thermal plasma jets, especially of production of eddies of plasma surrounded by colder gas. Possibilities of this method were demonstrated at three examples: for a study and visualization of structure of plasma jet in a different regions, for an evaluation of local velocities of plasma flow from the time delay of signals of probes positioned at different axial locations and the following

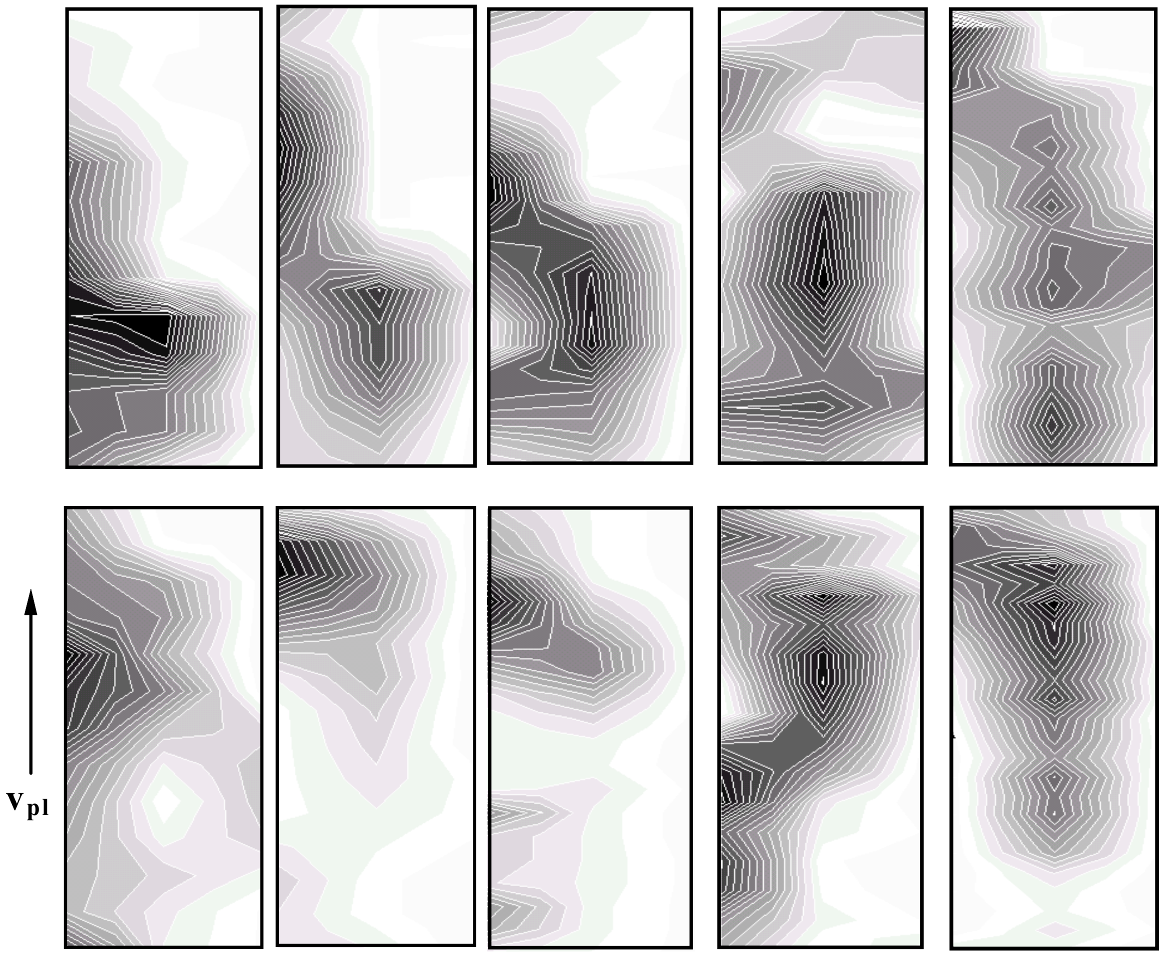

Fig. 3.

determination of the size of the eddies, and for a visualization of changes of shape of individual structures along the jet caused by differences in local velocities.

Acknowledgements

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