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# The movement of the optical inhomogeneities and the velocity of the plasma jet

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Movement of the plasma jets during transient operation flow is accompanied by a large-scale turbulence, caused by twisting of the plasma flow needed to increase the resource life time of the cathode and the anode, the disruption of the boundary layer at the exit of the divergent nozzle of the plasma torch, the features of the current flow in the plasma jet and its binding to the electrodes, the roughness of the walls of the anode vortex channel, etc. When the plasma jet is registered by the video camera with high frequency $\nu \geq 1\cdot10^4$ Hz and low exposure time $\tau_e \leq 20$ µs, the "instant" structure of the turbulent flow can be obtained, with a typical size of turbulent moles of 5 – 10 mm, which is comparable to the radius of the jet. Therefore, in such flows the velocity measuring method could consist of measuring the velocity of plasma emission's optical inhomogeneities that are caused by the turbulization of the jet.

The proposed method of introducing a localized inhomogeneities in the plasma stream [1] consists of placing in the desired longitudinal coordinate along the diameter of plasma jet a source of plasma clumps, micro- and nanoparticles, that will move in the plasma stream without slipping and that will have a different luminous intensity when compared to the surrounding environment. The plasma stream with a temperature 7000 – 8000 K that is generated by the plasma torch is incident on the rod that is placed across the centre of the plasma stream. The formed sublimate moves away from the rod and forms fragments and clumps that are characterized by a bright luminescence, compact form and their weak change over time that allows to track the geometric centres or forefronts of these clumps. Optical inhomogeneities are recorded with one or two high-speed cameras, which with the necessary field depth, the scale of M = 1:5 and spatial resolution of 30-59 microns perform frame by frame video recording of the extended paraxial region of the stream with a frequency of $(0.5\text{-}10)\times10^4$ frames/s and selected exposure time $\tau_{exp}$ = 2-50 µs, which is determined by the luminosity of inhomogeneities and their velocity. The velocity of these clumps' forefronts was determined by the scale of their displacement from frame to frame, and the time length between adjacent video frames $\tau=1/\nu$, where $\nu$ – the frame rate.

Local measurements of the velocities of the microparticles that are ablated from the graphite rod's surface and are lying in the center plane can be accomplished by the synchronous illumination of this plane by "laser sheet" with a width of 1-1.5 mm and length of several diameters of the plasma jet, and front video registration of this plane. The pulse duration of a repetitively pulsed laser and the exposure time of the camcorder are selected in accordance with the luminance and diffusing capacity of the particles and the speed of their movement.

To test the effectiveness of this method a quantitative analysis was carried out on the results of high-speed video recording of optical inhomogeneities in the nitrogen plasma jet with a diameter of about 20 mm without the marker rod and with graphite, copper and tungsten rods with their diameters varying in 0.7 – 1.0 mm range. The aggregate value of the velocity of the plasma's "own" inhomogeneities and the velocity of inhomogeneities introduced by the rod that was placed at z = 20 mm in the zone z ≥30 mm have similar values and show a reduction in the speed of the plasma jet as it propagates downstream from 160 m/s at z=30 mm to 100 m/s at z = 70 mm.

To analyse the perturbing influence of the graphite sublimate on the temperature of the plasma jet a registration of the plasma emission spectra was performed at 1-2 mm downstream from the rod.

The first results of the use of optical inhomogeneities introduced into the stream by graphite rods for measuring the speed of the plasma jet, show the suitability of the proposed method and merit further development.

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[1] Russian Federation patent application №2016150439, MPK9 G 01 P 5/20, (2016).