LDA MEASUREMENTS UNDER PLASMA CONDITIONS

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EXTENDED ABSTRACT

A study was made of the application of Laser Doopler Anemometry (LDA) for the measurement of the fluid and particle velocities under plasma conditions.

The flow configuration, as shown in Figure 1, is that of a d.c. plasma jet called the principal jet, in which an alumina powder of a mean particle diameter of 115 μm and a standard deviation of 11.3 μm was injected using a secondary jet. The plasma jet immerged from a 7.1 mm I.D. nozzle while that of the secondary jet was 2 mm in diameter. The secondary jet was introduced at the nozzle level of the plasma jet directed 90° to its axis. Details of the nozzle and the gas flow system are shown in Figure 2.

The plasma gas used was a mixture of argon and nitrogen with 17.2% volume of nitrogen. The plasma and the powder gas flow rates were 28.5 l/min and 3.3 l/min respectively. The torch was operated at a 420 A current level and a voltage of 32.5 V. The net energy in the gas at the exit of the anode was about 5.87 kW. In order to be able to measure the gas velocity, the plasma gas was seeded with a fine alumina powder with a mean particle diameter smaller than 5 μm. While this powder passed through the torch, its influence on the torch operation was relatively small. This was manifested by an increase in the torch voltage by about two volts for the same current rating and a slight change in the colour of the flame.

The LDA system used was a Thermo Systems Incorporated (TSI) counter type model 1985 with a 35 mW Helium-Neon Laser. The unit was used in the forward scatter mode with a beam spacing of 50 mm. The focal length of the transmitting and receiving lenses was 247 mm. This gave rise to a measuring volume in the form of an ellipsoid of major and minor axis of 4.6 and 0.32 mm respectively. The interference fringe spacing was 3.2 μm. In order to protect the phomultiplier from the plasma radiation, a nar-

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row band interferance optical filter was placed as shown in Figure 1. The filter was supplied by Omega Optics Inc., it was centered on a wave length of 632.8 nm and had a half band width of 0.27 nm.

As a particle passed through the measuring volume, it produced a light burst modulated at a frequency in the range of 0.5-100 MHz which was a function of its velocity and the fringe spacing. The photomultiplier signal, after being processed by the signal conditioner and the counter module gave the time required for the particle to traverse a fixed number of fringes (32 in most cases). This information, as it become available at the digital data output of the unit, was transmitted to a Motorola 6800 microprocessor which stored it in its 36 k memory. The unit was programmed for the acquisition of any specified number of data points up to 10,000. Most of the results reported in this study were obtained with a minimum of 5,000 data points.

The number of fringes to be used could be set to either 2, 4, 8, 16 or 32. Increasing the number of fringes improved the accuracy of the measurement as well as the spacial resolution. In our case, by using 32 fringes. The measuring volume could be effectively reduced to on an ellipsoid with major and minor axis about 3.0 and 0.3 mm respectively. Another parameter which could influence the results was the setting of the low and high-pass filters on the signal conditioner. These served to remove the high frequency noise and signal pedestal respectively. Due to the relatively low noise level on the signals, most measurements were made with the low-pass filter in the "out" position. The high-pass filter was set between 0.3 and 3 MHz depending on the doppler frequency to be measured.

At the end of the data acquisition period which could last from a few seconds to one or two minutes, the microprocessor performed a complete statistical data analysis giving the minimum and maximum velocities, the mean velocity, the standard deviation as well as the probability density distribution function (PDF). This was displayed on an oscilloscope screen and was also printed in tabulated form. It should be pointed out that since the frequency limitation the counter module was about 100 MHz, the actuel velocity measuring capability of the system under these conditions was 320 m/s. While such a limit is high enough for most applications, we were operating not far from it when measuring the gas velocity within 10 to 15 mm from the exit of the nozzle. The uncertainty level in these measurements would, therefore, be higher than those in other regions of the flow.

Typical results in terms of the PDF obtained along the centerline of the plasma jet at different levels for the gas and particle velocities are given in Figure 3. It is interesting to note that the very fast decrease in the gas velocity with distance from the torch is accompanied by a substantial reduction in the width of the probability density function. This is opposit to what is reported for turbulent free jets where the level of turbulence in the initial and transition regions increases with distance from the nozzle. The difference is due to the continuous movement of the arc root in the anode region giving rise to the very high levels of turbulence measured (about 50 to 60%). The particles, on the other hand, showed an initial increase of their axial velocity component as they are entrained by the plasma followed by a gradual decrease in velocity further downstream.

A comparison of the mean particle and gas velocities along the centerline of the jet is given in Figure 4. The cross over takes place around 70 or 80 mm from the nozzle. The upper part of Figure 4 shows the variations of the intensity of turbulence of the gas as function of distance from the nozzle. It is noticed that at 150 mm from the nozzle the intensity of turbulence is down to 20 to 25%.

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NOMENCLATURE

d_p	particle diameter (μm)
D_o	nozzle diameter of the principal jet (mm)
D_s	nozzle diameter of the secondary jet (mm)
U	axial velocity (m/s)
U_o	exit centerline velocity of the principal jet (m/s)
U_p	axial partical velocity (m/s)
U_s	exit centerline velocity of the secondary jet (m/s)
x	distance along the x direction measured from the axis of the principal jet (mm)
z	distance along the z direction measured from the exit of the principal jet (mm)

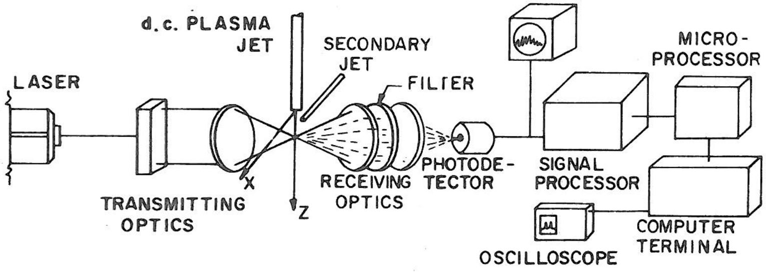

Figure 1. Experimental setup

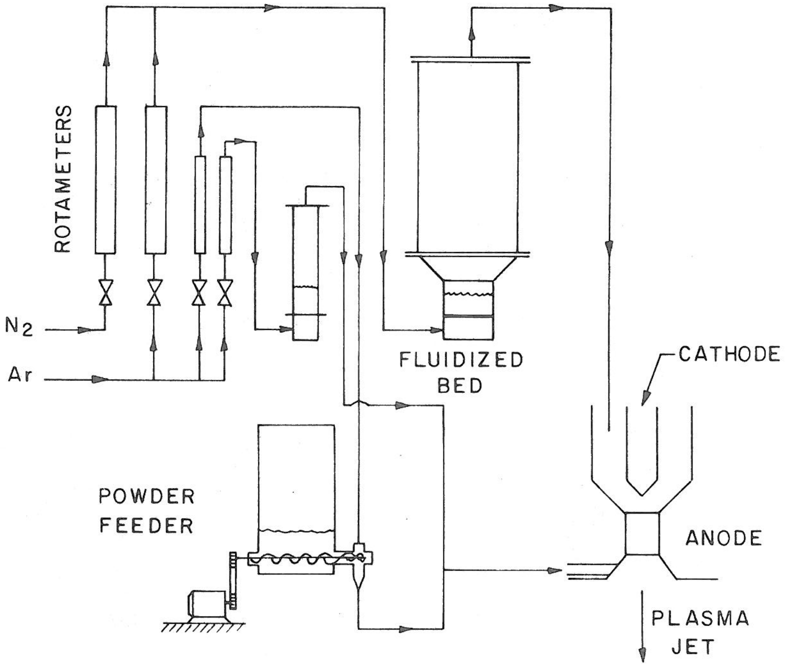

Figure 2. Details of the nozzle of the plasma torch and the gas flow system.

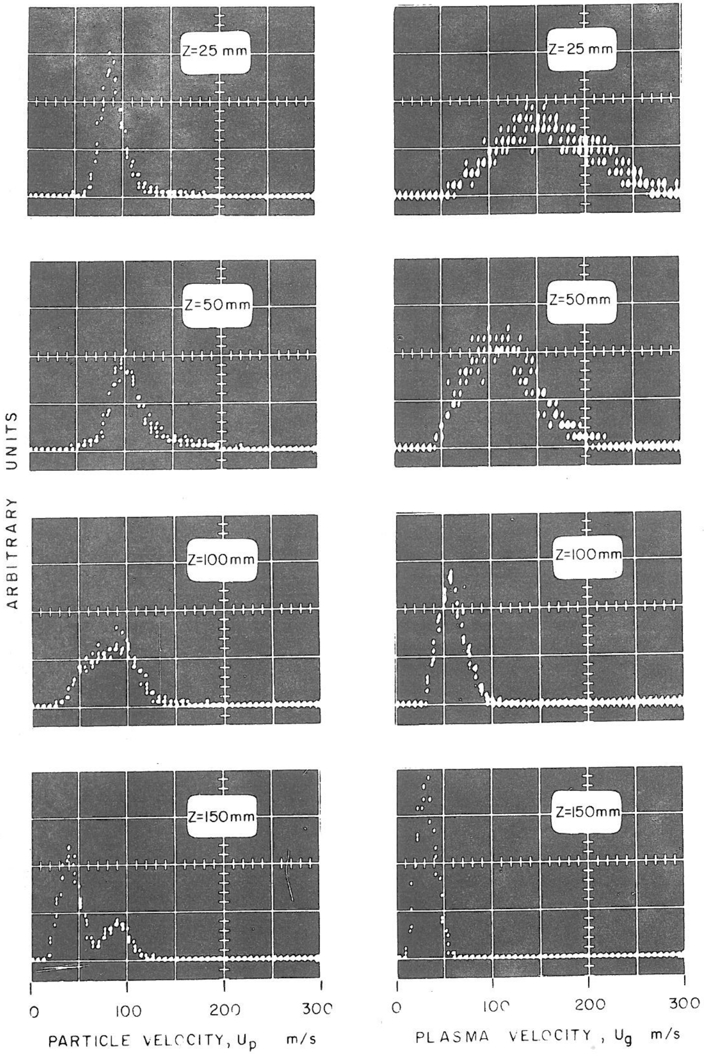

Figure 3. Probability density distribution function for the axial gas and particle velocities at different levels along the centerline of the plasma torch.

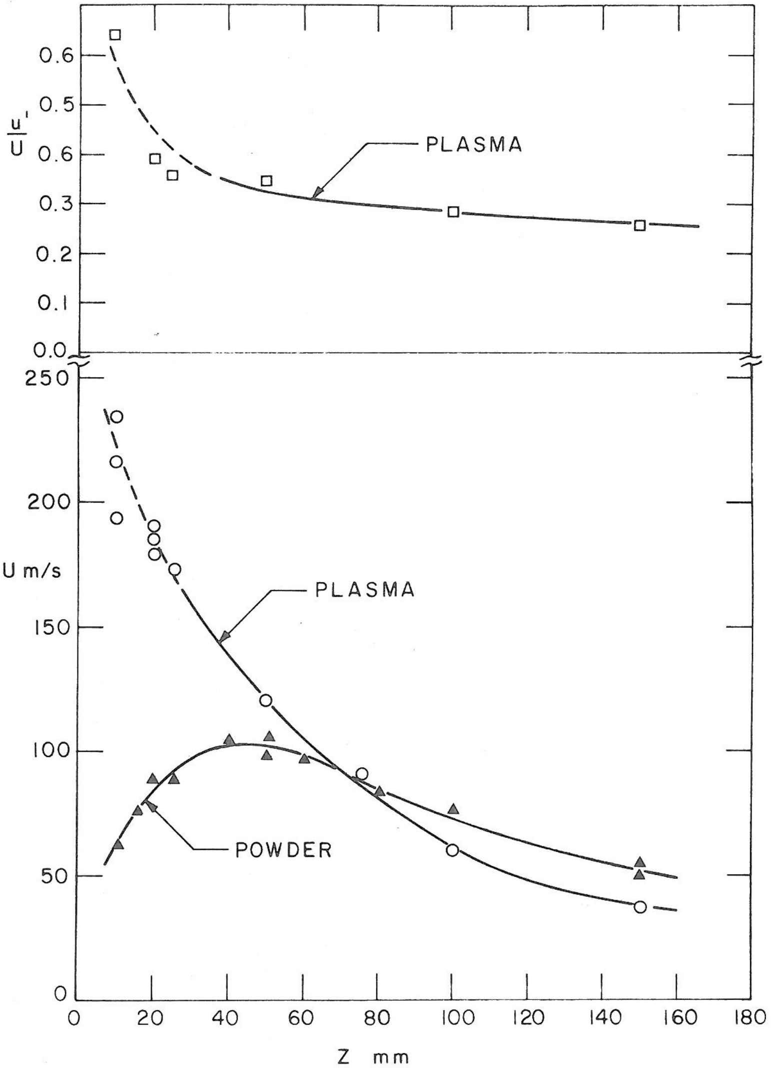

Figure 4. Axial gas and particle velocity and the intensity of turbulence along the centerline of the plasma torch.