A supersonic arc jet

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A SUPERSONIC ARC JET

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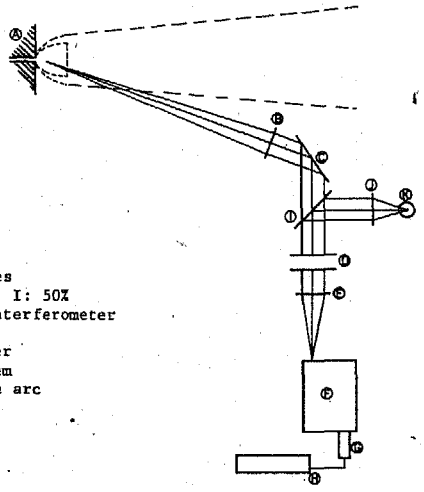
Introduction

In the plasma of a cascaded arc, with arc currents from 40 up to 100 A, arc voltage of about 100 V and an argon pressure of about 0.5 bar, the gas temperature equals the electron temperature of about 12000 K. The electron density ranges from 10(21) to 10(23) m-3, ionization degree is about 10%. The equilibrium of this kind of plasmas is well understood [1].

In the present experiment this arc plasma expands into a vacuum system through a hole with a diameter of 4 mm in the anode. To obtain a background pressure of roughly 1 mBar, large pumping speeds are needed. The expansion clearly shows supersonic behaviour and is limited by a shock front (Barrel-shock and Mach-disk). The experiments were done in a mixture of Argon (70 cc/sec) and Hydrogen (0,7 cc/sec). The plasma is used for plasma deposition [2]. To obtain information on the physical parameters an optical system was constructed that allowed the implementation of several diagnostics, see Fig. 1. Among others the gas velocity, the electron density and the gas temperature were determined.



A: cascaded arc
B, J and E: lenses
C and I: mirrors, I: 50%
D: Fabry-Perot interferometer
F: monochromator
G: photomultiplier
H: computer system
K: hollow cathode arc

Fig. 1. Optical system

Gas velocity

The gas velocity has been measured from the Doppler shift of the argon neutral (ArI) line 427.2 nm, this Doppler shift is measured by means of a Fabry-Perot interferometer. As a reference signal signal the unshifted spectral line of a small hollow cathode arc was used, see Fig. 1. The results of the gas velocity measurements are shown in Fig. 2.

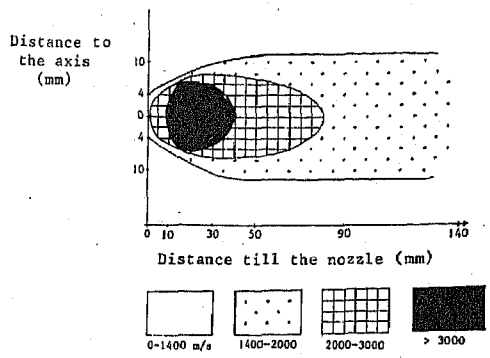


Fig. 2. A view of the velocity of the expending plasma

Electron temperature in the nozzle

In the anode nozzle the electron temperature can be determined by measuring the ratio of the intensities of continuum and line radiation of the 480.6 nm argon ionized (ArII) line [3] in where Local Thermal Equilibrium has to be assumed. The temperature from this calculation appears to be (11300 $\pm$ 200) K at the standard conditions of 50 A and 0.45 bar.

Electron Density

If the electron density is between 10(20) m-3 and 10(23) m-3, the electron density can be calculated from the measured Stark broadening of the H_β Balmer line. The electron density appears to be only slightly dependent on the distance from the nozzle: about 20% variation over 20 cm.

Conclusion

The axial and radial profiles and absolute values of velocity, temperature and pressure drop of the neutral atoms (ArI) appear to be in good agreement with free expansion calculations according to the Campargue theory [4]. The electron density profile however indicates that the charged particles (electrons and ions) cannot follow a free expansion but are kept together by ambipolar forces.

References

[1] C.J. Timmermans, Ph.D. Thesis, Eindhoven University of Technology, 1984.
[2] G.M.W. Kroesen, D.C. Schram, to be published.
[3] P.H.M. Vaessen, Ph. D. Thesis, Eindhoven University of Technology, 1984.
[4] H.C.W. Beijerinck et al., Chem. Phys. 96 (1985) 153.