Voltage current and power relation in an arc plasma in a variable axial magnetic field

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Abstract. The variation of voltage, current and output power in a mercury arc plasma has been investigated in an axial magnetic field (0-1350 G) for three values of discharge current namely 3, 4 and 5 A. The voltage increases and current decreases almost linearly and the output power also increases with increase of the magnetic field. The conductivity value in magnetic field has been calculated and an analytical expression presented to represent the variation of conductivity in the magnetic field. Utilizing this expression the variation of output power with magnetic field can be explained.

Keywords. Voltage; current; power relation; arc plasma; axial magnetic field.

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1. Introduction

The variation of voltage, current and output power in an arc plasma under the action of a transverse magnetic field was investigated by Sen and Das (1973). Utilizing Beckman's (1948) theory and the modification introduced by Sen and Gupta (1971) regarding the variation of charged particle density and electron temperature in a glow discharge in the presence of a magnetic field the experimental results have been satisfactorily explained. It was further pointed out that the theoretical expressions deduced by Beckman (1948) as modified by Sen and Gupta (1971) are valid over a range of (H/P) values 1000 G/torr. Allen (1951) observed that in the case of heavy current pulsed arc discharge in hydrogen the voltage current characteristics showed a slight negative gradient over the arc current range of 25 to 80 A with no magnetic field but became increasingly negative with increase of magnetic field. The effect of an axial magnetic field upto 470 G on the arc stability, voltage and temperature has been studied by Goldman and White (1965) who observed that the field had no stabilizing influence on the arc whereas it led to an increase of voltage drop across the arc. No theoretical interpretation of the results was however provided. Forrest and Franklin (1966) described a theoretical model for a low pressure arc discharge in a magnetic field in which predictions have been made for radial electron number density profile and radial light emission profile. Current voltage characteristics of glow discharge in longitudinal magnetic field has been investigated by Sen and Jana (1977) and it has been observed that the discharge current increases and the axial voltage drop across the arc decreases with increase of axial magnetic field for the range of pressure investigated (0.685 to 0.925 torr). Assuming the radial distribution of particles as Bessalian it has been possible to explain the results qualitatively. The results also show that Bessalian...
distribution holds in the presence of magnetic field as well; electron temperature and its variation in an axial magnetic field (from zero to 1050 gauss) in a mercury arc plasma have been measured by Sadhya and Sen (1980) by a spectroscopic method. A model has been developed in which air plays the role of a quenching gas and it has been found that both atomic and molecular ions of mercury are present in this type of discharge. A distribution function for the radial electron density has been deduced. The results computed on this basis are in agreement with observed experimental data.

The results obtained by Sen and Das (1973) indicate that the theoretical (Beckman 1948; Sen and Gupta 1971) deduction regarding the variation of electron density and electron temperature in a transverse magnetic field in the case of glow discharge is valid in the case of an arc plasma as well. It is worthwhile to investigate whether the same model is valid in the case of an arc plasma when subjected to an axial magnetic field. The object is also to find out whether the properties as well as the plasma parameters in an arc plasma are dependent upon the alignment of the magnetic field with respect to direction of flow of arc current. It is hence proposed to investigate in the present work the variation of voltage, current and power relation in a mercury arc plasma in an axial magnetic field and to provide a theoretical treatment of the observed experimental results.

2. Experimental arrangement

A mercury arc has been investigated, the arc tube of which is cylindrical (length 9 cm and diameter 1.8 cm) and is excited by a stabilized d.c. source with a rheostat to control the current recorded by an ammeter. The mercury arc is cooled by the external circulation of air. The pressure inside the arc is maintained at 0.045 torr. To maintain the pressure constant dry air which acts as a buffer gas was introduced by a variable microleak of a needle valve. The mercury arc is placed between the pole pieces of an electromagnet energized by a stabilized d.c. source. The lines of force are parallel to the direction of the flow of arc current and the voltage across the arc is measured by a voltmeter with an accuracy of ± 0.5 V. The magnetic field has been accurately measured by a fluxmeter for magnetizing current varying from 1 to 5.5 A keeping the distance between the polepieces as 9.8 cm. The magnetic field varies from zero to 1.5 (kG). The schematic experimental arrangement is shown in figure 1.

3. Results and discussion

The variation of voltage across the arc, the arc current and power developed across the arc have been plotted in figures 2, 3 and 4, respectively for magnetic field varying from zero to 1.5 kG. It is observed from figure 2 that (a) the initial voltage across the arc for all the three arc currents investigated (3 A, 4 A and 5 A) is the same when no magnetic field is present which is consistent with our previous observation. (b) When the magnetic field is applied the voltage across the arc increases linearly with magnetic field. The rate of increase is however different for the three arc currents. Rate of increase is the highest for the lowest initial current and decreases with increase of current. (c) From figure 3, it is evident that with increase of the magnetic field the arc current decreases but the rate of decrease depends upon the initial value of arc current.