CHARACTERISTICS OF PLASMA TRANSFERRED ARCS

T. MEHMETOGLU, W.H. GAUVIN and F. KITZINGER
Department of Chemical Engineering, McGill University, and Noranda Research Centre, Montreal, Quebec, Canada, H9R 1G5

Keywords Transferred Arcs, Plasma Diagnostics

Compounds Argon

ABSTRACT

The use of long DC transferred arcs offers the possibility of interesting applications in certain areas of extractive metallurgy. In a particularly promising version of this concept, the arc is struck between a cathode, the tip of which is protected by a sheath gas flowing around it and an anode consisting of a molten metal located at some distance (usually 10 cm or more) away from the cathode. The plasma stream thus created consists essentially of the sheath gas which enters it. The design of plasma reactors to treat finely-divided feed materials exposed to the plasma requires a knowledge of the plasma properties and characteristics under different operating conditions of current, arc length and sheath gas flowrate.

The first part of this study describes the effects of these operating conditions on the inter-electrode voltage, using argon as the plasma gas. These experiments were carried out in open air, as it was discovered early in the work that no air was admitted by entrainment in the cathode arc-root region, as long as sufficient argon was supplied to this region and as long as the arc was stable. The anode consisted of a water-cooled copper disc, 5.715 cm in diameter. The current was varied between 150 and 350 amperes, and the arc length between 4 and 10 cm. It was found that the voltage depended strongly on the arc length (60 volts for 4 cm and 100 volts for 10 cm arc length, at a constant current of 250 amperes) and much less on the current (83 volts for 350 amperes and 75 volts for 150 amperes, at a constant arc length of 6 cm). The power supplied to the arc during these experiments varied between 9 and 39 KW, and the fractions of this power: a) for cooling the cathode; b) dissipated to the cold surrounding by radiation from the plasma, and (c) released at the anode, could be measured. The fraction of the power lost to the cathode was invariably small, and almost constant with current and arc length. Depending on the arc length, the power radiated by the arc could be varied between 30% and 65%, independently of the current.

It was also observed that the inlet velocity of the plasmagen gas past the cathode tip (calculated as the gas flow rate divided by the free annular nozzle area) was an important parameter and should be used, instead of gas flow rates alone, if the results are to be generalized. The higher this velocity, the higher is the total voltage drop and the lower the percent of the total energy being released at the anode. Specifically, a 40% increase in gas flow rate causes only a 3% increase in arc voltage, while a similar increase in gas velocity causes a 15% increase in voltage.

To determine the velocity profiles within the arc, a sweeping micro pitot-tube technique was used. The sweep velocity (20 cm/s) was found adequate for good resolution, while avoiding ablation. The centreline velocity of the plasma hitting the anode was about 200 m/s for 250 amperes and 500 m/s for 400 amperes.

Finally, the measurement of the radial temperature profile within the plasma stream at various axial distances from the cathode tip was effected with a novel diagnostic technique based on the determination of the emission power of two spectral lines of the argon plasma, as the latter was rapidly swept by a blocking element which traversed the plasma radially at a known velocity (90 cm/s). A micro-processor was used to apply the necessary corrections and to process the data rapidly. This approach is probably less accurate than the conventional spectroscopic methods, but it offers the great advantage of simplicity, rapidity and the ability to examine plasmas which are not strictly isotropic or depart from the constraints necessary for an Abel inversion.

The radial temperature profiles obtained were approximately parabolic in shape, with a slightly higher temperature zone superimposed at the centre, indicating the presence of a hotter core of small diameter.

With a knowledge of the velocity and temperature profiles in the arc, mass balances could be established, which permitted an estimate of the amount of ambient gas entrainment into the cathode region of the arc.