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Ionisation Efficiency in a Pinched Cascaded Arc Channel

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1 Introduction

In the present study, we will focus on the improvement of the ion density at the arc outlet. Efficiency increases are necessary to obtain effective remote deposition, in which the plasma source and target area are decomposed. Remote deposition is easier to control than non-remote deposition and therefore preferable. The increase in the ionisation outflow will be obtained by creating a nozzle shaped cylindrical arc channel as sketched in figure 1.
Simulations were used to obtain the results.
The arc plasma expands supersonically into a low pressure vessel. To simulate the existence of the expansion, a Ma = 0.9 boundary condition is implemented at the arc outlet.

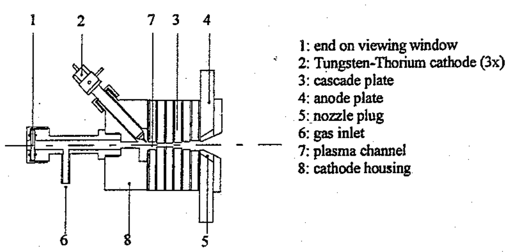

Figure 1a: *The cascaded arc: a thermal plasma at atmospheric pressure is created in a D.C. arc*

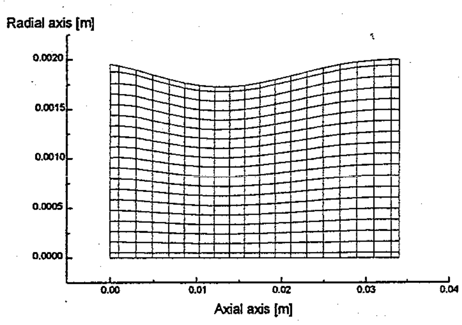

Figure 1b: *Generated arc channel grid*

2. Cascaded Arc Plasma Source Characteristics

Table 1 gives the operating characteristics used in the simulations.

Table 1: Operating parameters of the simulations

Gas used	Argon
Arc current (I_{arc})	25,40,50,60 and 75 A.
Total gas flow rate	10,20,30,65,100 and 150 sccs
Outlet diameter (2*R)	4 mm
Nozzle diameter (2*r)	1.5, 2, 2.5, 3, 3.5, 3.7, 4 mm
Arc channel length	34 mm or 60 mm

3 Ionisation efficiency

Gasdynamic laws were used to understand the pinch processes in the cascaded arc channel.
- Introducing a nozzle entails that the plasma flow is blocked. Slowing down the plasma at the arc inlet and increasing the electric field at the nozzle leads to a more efficient arc.
- Using Bernoulli's law together with mass conservation, we find that the ionisation rate decays exponentionally with the flow.
- The ionisation coefficient S_{cr}, for which the electron energy distribution is Maxwellian, distinguishing a bulk temperature T_b and a different tail temperature T_t, can be represented[1] by:

$$S_{cr} \sim T_t^2 \sim E^2$$

Considering the resistance between consecutive arc channel plates in agreement with Dahiya e.a.[2], we get:

$$S_{cr} \sim E^2 \sim I_{arc}^2$$

4. Simulations

Stationary two-dimensional Boltzmann Transport Equations for density, momentum and energy are solved using the magnetohydrodynamic approximation[3] (MHD). The 5-point Strongly Implicit Procedure (5SIP)[4] is used to solve the discretised equations. The system of transport equations is solved numerically, using the SIMPLE algorithm[5] for the pressure and flow fields. Due to the model's ability to use orthogonal curvilinear coordinates[6], we were able to adjust the geometrical configuration.

5. Conclusions

- Pinching the arc channel is an easy but rather not unlimited way of increasing the ionisation degree at the arc outlet.
- The typical flow and power dependence of the ionisation degree was found and explained.
- The ionisation coefficient S_{cr} increases with the square of the electric field. The flow dependence remains the same at all currents.
- Simulations indicate that ionisation takes place dominantly very near the arc inlet.
- Especially for small nozzle cross-sections, temperatures (coming closer to LTE) and electric field intensity increase inside the nozzle. However, ionisation remains to take place dominantly near arc inlet.
- The decrease (or 'saturation') in arc outlet ionisation degrees for strongly pinched arcs at low flows is expected to be caused by diffusion to the wall.

6. References

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