

Ionisation efficiency in a pinched cascaded arc channel

Citation for published version (APA):

Burm, K. T. A. L., Goedheer, W. J., Mullen, van der, J. J. A. M., & Schram, D. C. (1997). Ionisation efficiency in a pinched cascaded arc channel. In M. C. Bordage, & A. Gleizes (Eds.), *Proceedings of the XXIII International Conference on Phenomena in Ionized Gases, ICPIG, 17-22 July 1997, Toulouse, France : Contributed Papers : Vol. II* (pp. 108-109). EDP Sciences.

Document status and date:

Published: 01/01/1997

Document Version:

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

Ionisation Efficiency in a Pinched Cascaded Arc Channel

K.T.A.L.Burm, W.J. Goedheer*, J.A.M. van der Mullen, and D.C. Schram

Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven

*F.O.M. Institute for Plasma Physics 'Rijnhuizen', P.O. Box 1207, 3430 BE Nieuwegein

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.

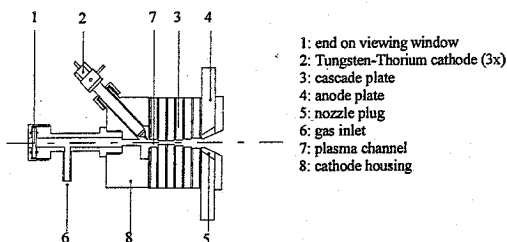


Figure 1a: The cascaded arc: a thermal plasma at atmospheric pressure is created in a D.C. arc

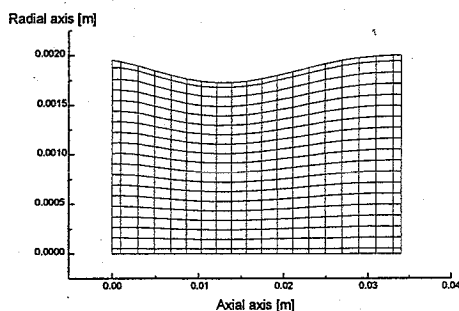


Figure 1b: Generated arc channel grid

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 exponentially 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

- [1] K.T.A.L.Burm, report VDF/HG 95-09 Eindhoven University of Technology; F.A.S. Ligthart and R.A.J. Keijser, *J. Appl. Phys.* **51** (10) oct. 1980.
- [2] R.P. Dahiya, M.J. de Graaf, R.J. Severens, H. Swelsen, M.C.M. van de Sanden, and D.C. Schram, *Phys. Plasmas* **1** (6), June 1994.
- [3] D.A. Benoy, thesis Eindhoven University of Technology (1993).
- [4] G.E. Schneider and M. Zedan, *Numerical Heat Transfer* **4**, 1-19 (1981); H.L. Stone, *Journal Numer. Anal.* Vol. **5**, No 3, 530-558 (1968).
- [5] S.V. Patankar, editor '*Numerical Heat Transfer and Fluid Flow*' McGraw-Hill, New York (1980).
- [6] Mobly, C.D. and R.J. Stewart, *Journal of Comp. Phys.* **34**, 124-135 (1980); S.B. Pope, *Journal of Comp. Phys.* **26**, 197 (1978); J.F. Thompson, F.C. Thames, C.W. Mastin, *Journal of Comp. Phys.* **24**, 274-302 (1977); H.J. Haussling and R.M. Coleman, *Journal Comp. Phys.* **43**, 373-381 (1981).