Influence of moving and fixed cathodes on the vacuum arc

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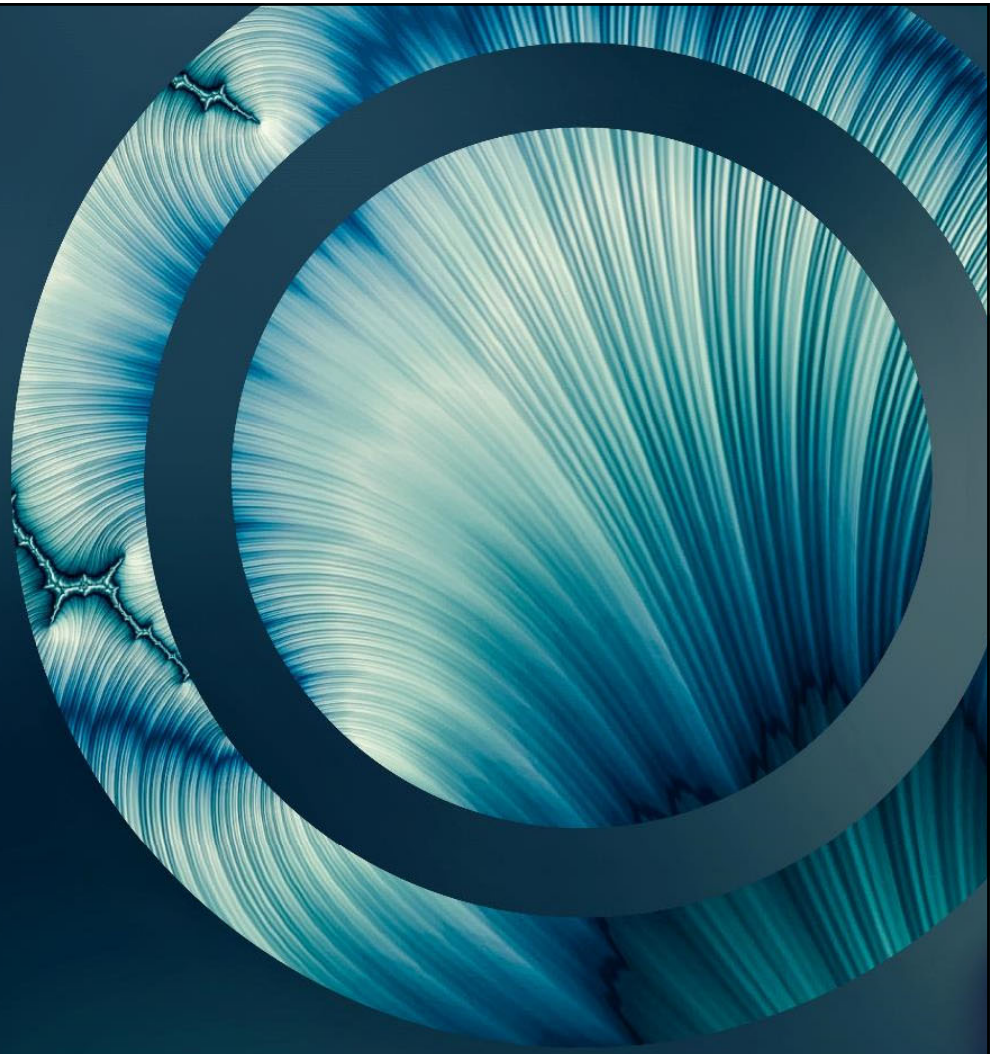

Content

1. Introduction
2. Experimental Setup
3. Results
4. Conclusion and Discussion

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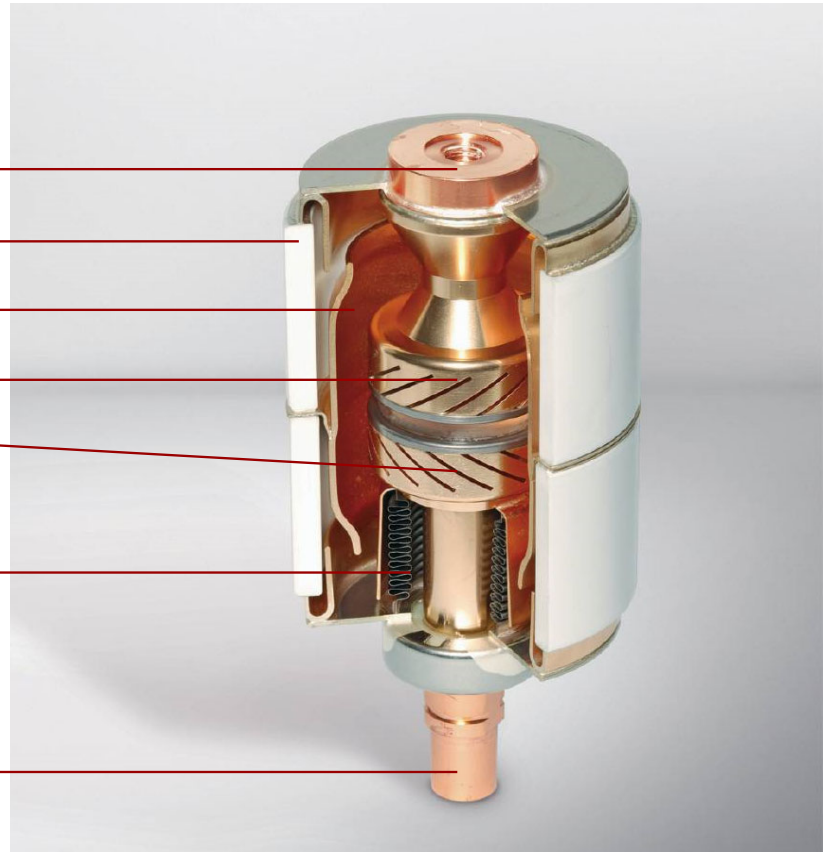
Introduction
Vacuum Interrupter Design



1. Introduction

- Difference in spectra depending whether the cathode or anode has been moved
- Movement in horicontal direction
- CuCr Butt contacts
- Opening velocity > 2m/s

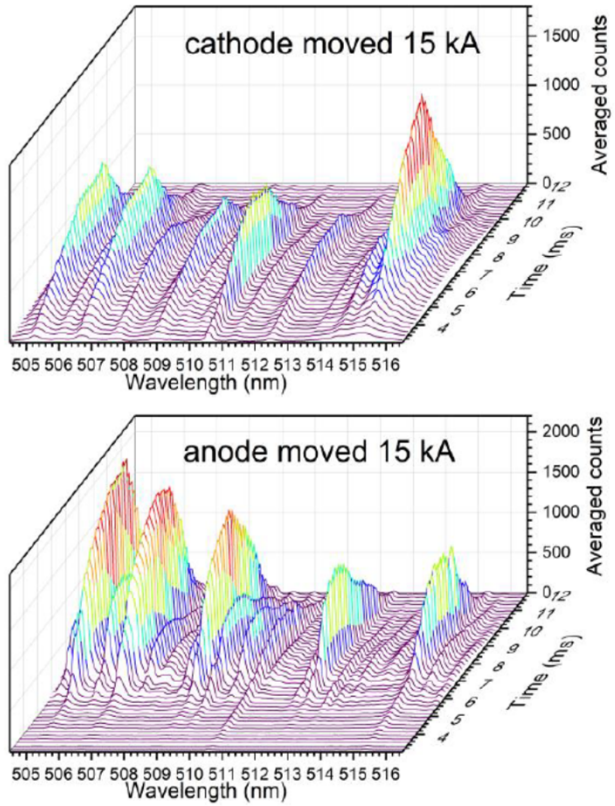


Figure 6: Spatially integrated optical emission spectra along the arc axis over time during the contact opening; top: moved anode, bottom: moved cathode.

R. Methling, T. Meyer, D. Uhrlandt, S. Gortschakow, M. Kurrat: „Optical and spectroscopic analysis of vacuum arcs in larger gaps“; 31st Int. Symp. On Discharges and Electrical Insulation in Vacuum, Chengdu, China (2025)

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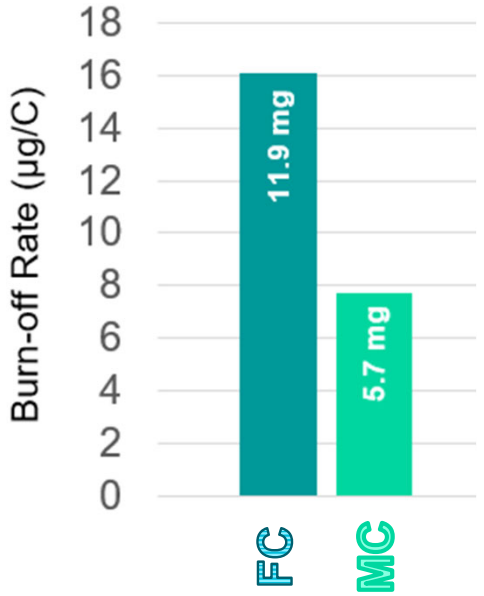
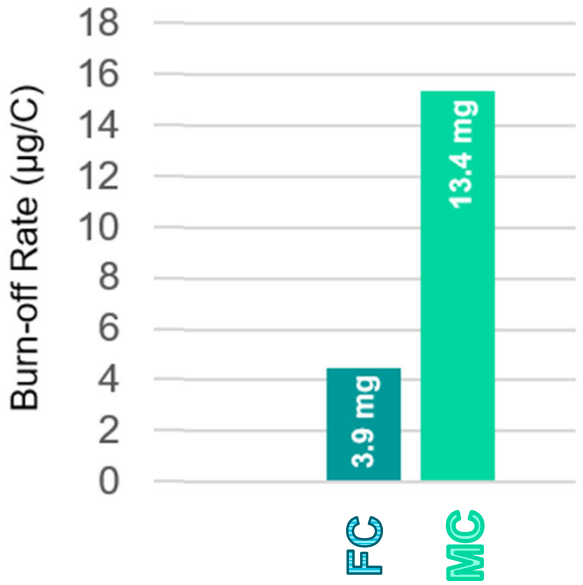
1. Introduction

- Difference in erosion rate depending on movement of the electrode
- Movement in vertical direction
- Movable contact below
- CuCr butt contacts
- Opening velocity ≈ 1.3 m/s
- Polarities are equally mixed



1. Introduction

- Fixed polarity: Anode fixed contact, Cathode movable contact
- Movement in vertical direction
- Movable contact below
- CuCr butt contacts
- Opening velocity ≈ 1.3 m/s
- Higher burn-off rate when cathode is moved

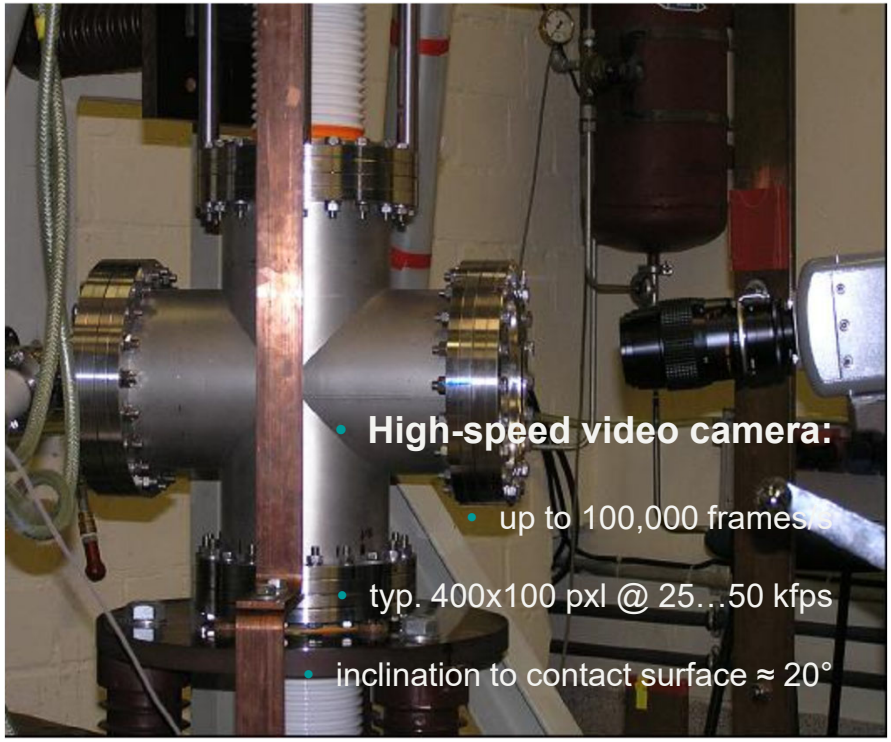


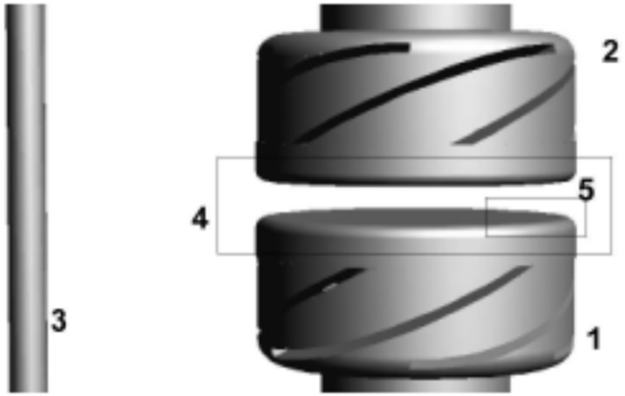
1. Open Question

Why does it make a difference whether a contact is moved or not?

Are gravitational forces really playing a role?

2. Experimental Setup





Drawing of AMF contact system and nearby current return conductor (“neighbor phase”)

1: fixed AMF contact
2: moving AMF contact
3: current return conductor
4: arc / electrode region visible in high-speed videos
5: enlarged region of high-speed videos

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3. Cathode

AMF cathode surface effects

- Diffuse (individual spots) and dense arcs exist simultaneously
- a thin surface layer of ca. 100 µm melts
- protrusions of >mm grow rapidly, bearing bright cathode spots on their top
- at their end of life, the cathode protrusions release droplets while the cathode spots disappear

3. Anode

AMF contacts after contact separation

- anode response at high current density is remarkably different from that of the cathode:
- anode melting is smooth and without protrusion growth
- no mechanisms related to spots are found on the anode
- the anode remains passive, collecting charged and neutral particles only

3. What have we seen so far

- Diffused arc and partly diffused arc investigated
- Fundamental differences between cathode and anode as fixed contacts
- These differences can play a role concerning the movement of the electrodes
- No magnification of moving electrodes
- Axial magnetic field superimposed => Go back to butt contacts

FC: Anode, MC: Cathode

2.5 kA rms, 20000 fps (exposure: 10 µs)

FC: Cathode, MC: Anode

2.5 kA rms, 20000 fps (exposure: 20 µs)

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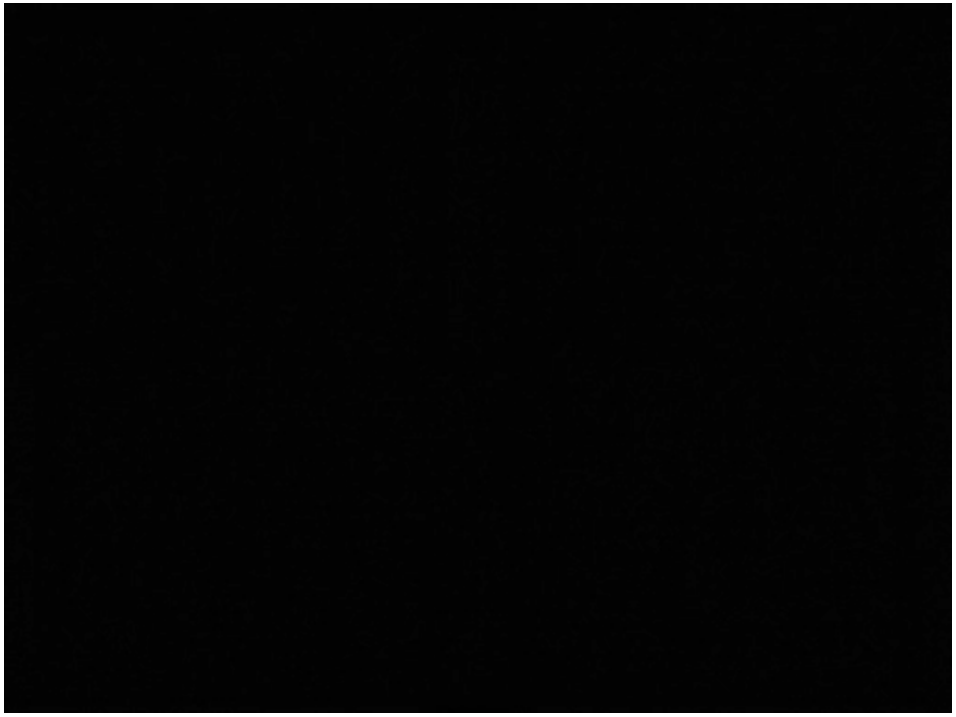
FC: Anode, MC: Cathode

3.1 kA rms, 50000 fps (exposure: 2.5 µs)



FC: Cathode, MC: Anode

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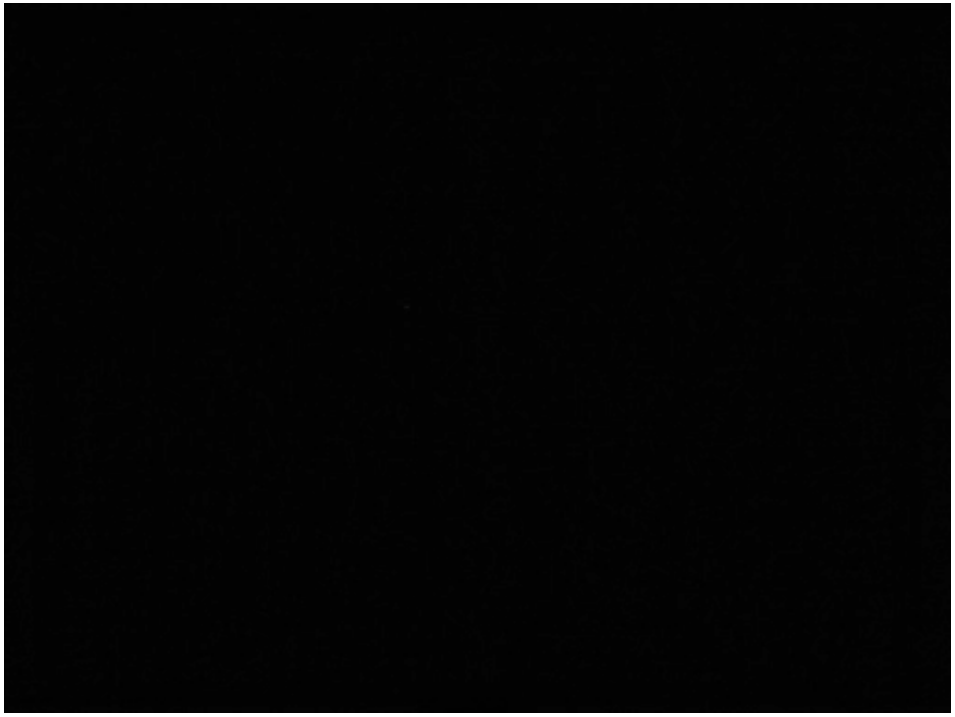

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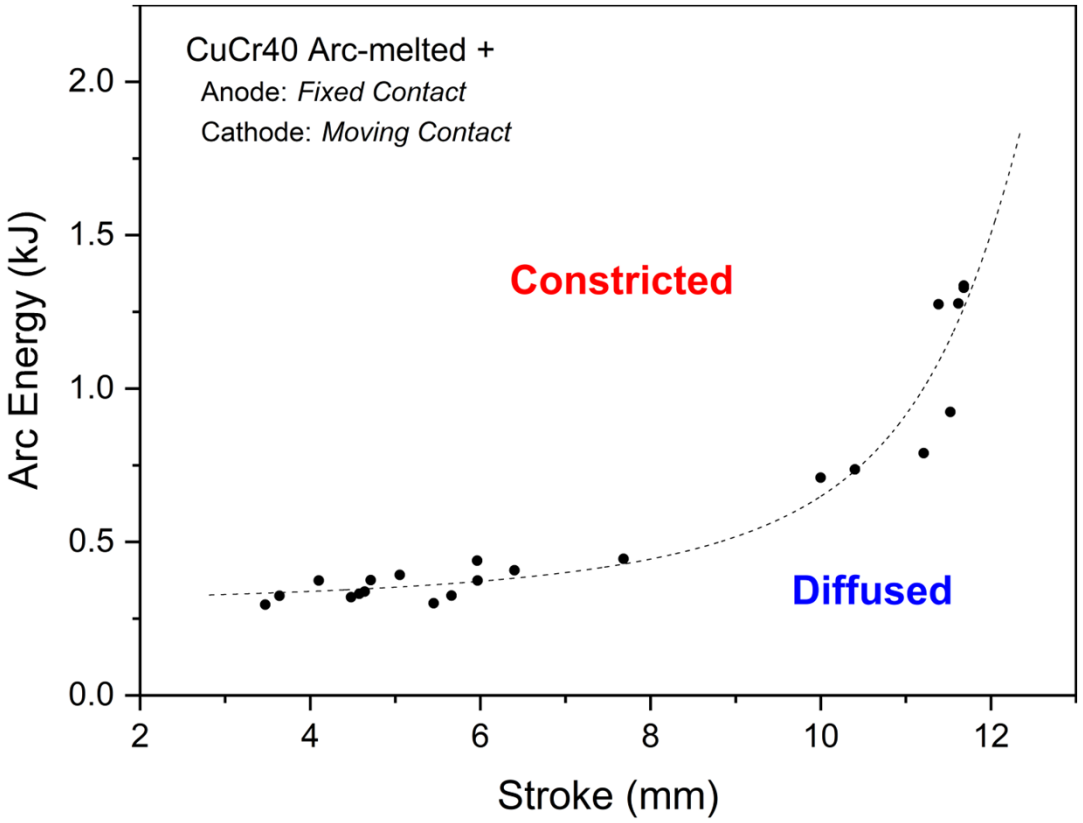
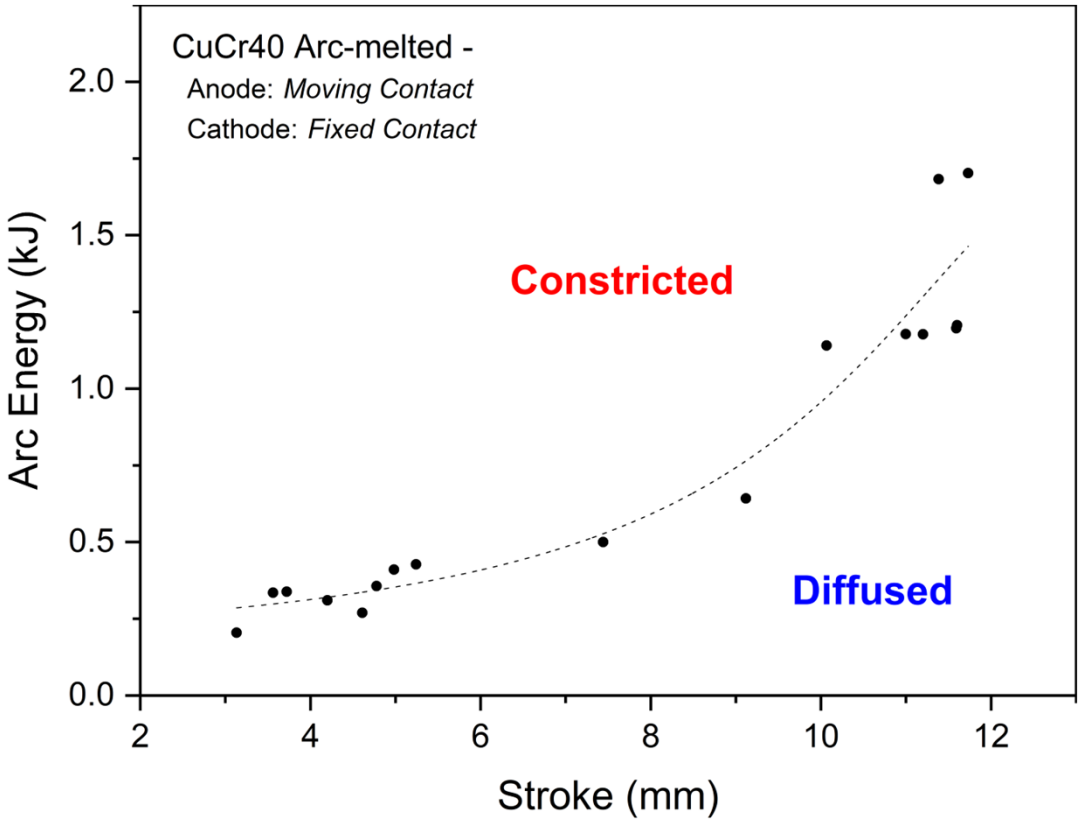
Comparison of arc modes





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Influence of moving and fixed cathodes on the vacuum arc

- With moving cathodes the regime of constricted arcs is considerably larger
- Anode spot is more pronounced with moving cathodes
- Liquid material on cathode is not smooth due to the cathode spots
- All this phenomena influence the burn off rate

Conclusion and open questions

- It makes a measurable difference whether the cathode is the moving or fixed contact
- Cathode spots on molten contact material play an important role
- Differences are measurable even at lower opening speeds down to 1 m/s
- The phenomenas are not fully understood
- As far as we know there is no significant influence on switching performance

Contact

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