AZIMUTHAL CURRENT DENSITY DISTRIBUTION RESULTING FROM A POWER FEED VACUUM GAP IN METALLIC LINER EXPERIMENTS AT 1 MA

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A productive partnership......

**Investigation of radiative bow-shocks in magnetically accelerated plasma flows**

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We present a study of the formation of bow shocks in radiatively cooled plasma flows. This work uses an inverse wire array to provide a quasi-uniform, large scale hydrodynamic flow accelerated by Lorentz forces to super-critical velocities. This flow impacts a stationary object placed in its path, forming a well-defined Mach cone. Interferogram dil ~6, which may increase with radial position suggest imaging shows the formation of a thin (~06 m) 

$$T_e = 400 \text{K},$$

and rapid cooling behind the shock, position which appears consistent with a radiative dimensional simulations using the Gorgon MRID experiments. The simulations are also used to inves, demonstrating that the bow shocks have a high path is small. This consistent with experimental meas

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**Two dimensional triangulation of breakdown in a high voltage coaxial gap**

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We describe a technique by which magnetic field probes are used to triangulate the exact position of breakdown in a high voltage coaxial vacuum gap. An array of three probes is placed near the plane of the gap with each probe at 90° intervals around the outer wall of the coaxial geometry. The peak magnetic field values measured by the breakdown channel, and Ampère’s law we can calculate the azimuthal component of the magnetic field and are all in the central region. The magnetic probe results are then compared to the results of the magnetic probe experiment. The results show a good agreement between the two techniques.

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**Investigation of the effect of a power feed vacuum gap in solid liner experiments at 1 MA**

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We present an experimental study of plasma initiation of a solid metal liner at the 1 MA level. In contrast to previous work, we introduce a vacuum gap at one of the liners connections to the power feed to investigate how this affects plasma initiation and to infer how this may affect the symmetry of the liner in compression experiments. We observed that the vacuum gap causes non-uniform plasma initiation both azimuthally and axially in turnings, diagnosed by gated optical imaging. Using magnetic field probes external to the liner, we also determined that the optical emission is strongly linked to the current distribution in the liner. The apparent persistent of azimuthal non-uniformities may have implications for fusion-scale liner experiments. C–2015 AIP Publishing LLC.

[http://dx.doi.org/10.1063/1.4931049]
The presence of a gap at the cathode clearly has an effect on plasma formation and evolution.

Cathode gap data interesting but not ideal:

- Gap alignment not accurate
- Limited access to gap plasma
- Voltage breakdown at gap not detectable

COBRA liners with Cathode vacuum gap (2011-2013)

Gated optical images (10ns exposure) of Z-scale liners (300μm thick, 6.3mm OD and 10mm tall)
High Voltage Vacuum Gap Breakdown Experiment at UC San Diego

- Examines coaxial HV vacuum gap breakdown (15 – 30kV, 100-200 A)

- Use of bdot probes are multiple azimuthal positions allow triangulations of the effective current position

- \( R = \frac{\mu I}{2\pi B} \), for each peak B-field value to estimate the corresponding distance from breakdown. The R value corresponds to the distance the breakdown is from the probe
Development of a Bdot Triangulation Method

- For the typical single breakdowns in this experiment the method is very effective.

COBRA Liner Shots with an Anode vacuum gap

- Gap alignment more accurate and reliable
- Direct imaging access to power feed gap using gated (5ns) multi-frame optical camera
- Bdot array used to enable triangulation method
Testing of Bdot triangulation method on COBRA

- “Sanity check” of triangulation method uses a single Al wire offset to one side
- Provides a single and stationary current path
- Triangulation at peak current gives excellent correlation to wire location
Multi-frame optical camera is ideal for following plasma evolution

- Identical shots show similar behavior
- Initial breakdowns form multiple hotspots which evolve relatively slowly
- Alignment of gap seems excellent
Anode gap is not uniformly closed in any shot at any time

- No clear trend with gap size (electric field strength)
Bdot triangulation method correlated to imaging for COBRA liners

- In some shots, plasma one azimuthal position appears to dominate the profile for much of the current drive
- Effectiveness of the bdot triangulation links emission to current density
- This assumes all current at a single point
Investigations of current density as a function of axial position

- Probes well-protected and can be used for several shot before repair required
- Pre- and post shot calibration on repaired probes identical
- Using a 'trigger pin' determines initial breakdown position
dB/dt and integrated traces show clear changes in azimuthal current distribution.
SHOT 3675
Al liner with trigger pin

Top (1,4,7,10)

Middle (2,5,8,11)

Bottom (3,6,9,12)
SHOT 3678
Al liner with trigger pin

Top (1,4,7,10)

Middle (2,5,8,11)

Bottom (3,6,9,12)
“Visualization” of the current density distribution
Summary

- Presence of a vacuum gap in the power feed strongly affects plasma formation
- The azimuthal uniformity of the current distribution is directly affected
- Induced asymmetry at the vacuum gap does not become evolve to uniform current density distribution over >15 mm axially in >100ns.
- Limitations of the triangulation methods
  - Does not have high spatial resolution
  - On-going discussion about current distribution effect

Next Steps

- Simulation work: PERSEUS and GORGON. We have a good test problem with trigger pin loads
- Upgrade UCSD current driver and reduce electrode dimensions on HV breakdown expts to drive up current density. Will highlight driving factors and allow scaling arguments
• Is this issue a problem for MagLIF on Z?
  
  • Dependence on current density?
  
  • Time of first gap breakdown?
  
  • Effects are clearly less that 1MA level suggest or radiography study would likely show this
Possible issues in interpretation of the method

- The bdot triangulation looks very interesting but interpretation this depends on the processes dominating the current distribution

- Where is current?
  Bdot method not highly spatially resolved

- Current in liner of surface plasma?
  Resistivities likely very similar
  Inductance in plasma slightly lower, but little instability in plasma at late time

  In either case trying to form B field in a conductor. This may induce image currents in the liner, which affect interpretations

- 3D Simulations are the next step to guide and refine measurements.