FULL AXIAL COVERAGE RADIOGRAPHY OF DEFORMABLE CONTACT LINER IMPLOSION PERFORMED WITH 8 CM DIAMETER ELECTRODE APERTURES*

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Abstract

We obtained full axial coverage radiography of a deformable contact imploding liner. This radiographic data indicates the feasibility of using a varying thickness in a long cylindrical solid liner, driven as a 12 megamp Z-pinch, to achieve factor ~ 16 cylindrical convergence, while using 8 cm diameter aperture electrodes. The Al liner was 30 cm long, with 9.78 cm inner diameter for its full length, 10.0 cm outer diameter for the central 18 cm of its length, and outer diameter increased linearly to 10.2 cm at 1 cm from either electrode, and to 11 cm at electrode contacts. The electrode apertures allow injection of Field Reversed Configurations in proposed future experiments on magnetized target fusion.

Index terms: capacitor bank, Field Reversed Configuration, FRC, Magnetized Target Fusion, MTF, imploding liner, radiography, megamp

I. INTRODUCTION

Magnetized plasma compression, also known as Magnetized Target Fusion (MTF) is a scheme for compressing and heating plasma to fusion conditions that uses magnetic inhibition of electron thermal conduction, which greatly reduces the required implosion velocity and density – radius product relative to un-magnetized inertial fusion concepts [1]. One version of MTF is to use reversed field theta pinch discharges to form the Field reversed Configuration (FRC) type of Compact Toroid, which ideally has only poloidal field, and no toroidal field, inject it into a metal shell or liner, and to implode that liner by magnetic pressure from either a high current Z-pinch or high current theta pinch discharge through the liner [1,2]. We report here on progress in developing the Z-pinch driven liner approach. We previously reported on the design and successful demonstration of an imploding aluminum liner with height to diameter ratio, radial convergence, uniformity, and implosion velocity suitable for compressing an FRC [3]. Our recent progress has been to replace the more standard sliding liner-electrode contacts with deformable liner-electrode contacts, which enables the use of large electrode apertures, suitable for FRC injection. See Fig. 1 for a illustration of this concept.

Research on the use of imploding liners to compress plasmas has been reported by a number of researchers. This includes suggesting the general concept of using liners to compress plasma, and research on shorter or lower velocity liner implosions [4-17], and implosion of a Cu-W liner with explosives to compress flux to 200 T [18].

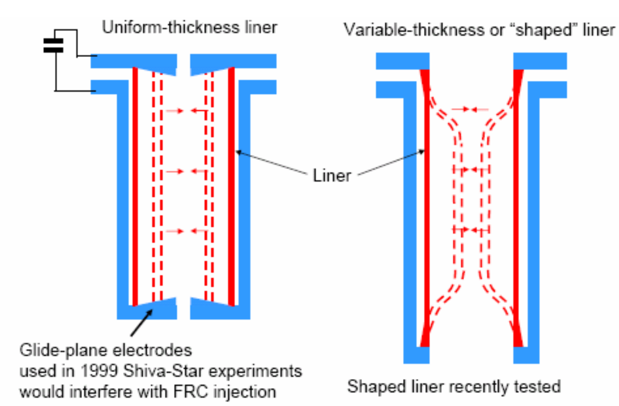

Fig 1: Imploding liner – electrode contacts: sliding shown on left, deformable on right.

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14. ABSTRACT
We obtained full axial coverage radiography of a deformable contact imploding liner. This radiographic data indicates the feasibility of using a varying thickness in a long cylindrical solid liner, driven as a 12 megamp Z-pinch, to achieve factor ~ 16 cylindrical convergence, while using 8 cm diameter aperture electrodes. The Al liner was 30 cm long, with 9.78 cm inner diameter for its full length, 10.0 cm outer diameter for the central 18 cm of its length, and outer diameter increased linearly to 10.2 cm at 1 cm from either electrode, and to 11 cm at electrode contacts. The electrode apertures allow injection of Field Reversed Configurations in proposed future experiments on magnetized target fusion. Index terms: capacitor bank, Field Reversed Configuration, FRC, Magnetized Target Fusion, MTF, imploding liner, radiography, megamp

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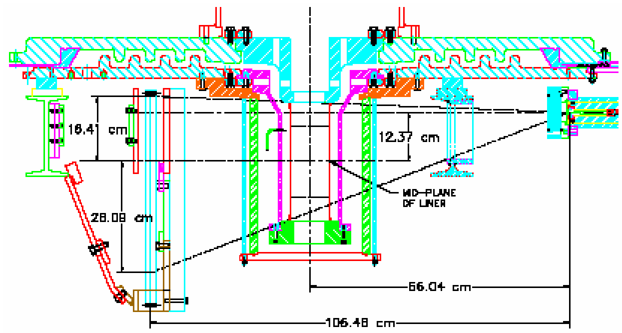

Fig.2: Experiment setup and geometry. 30 cm tall, 10 cm diameter Al liner and concentric outer conductor are in center. Radiography pulser tube shown on right, just below vacuum current feed. Armored film pack shown on left. Ray traces indicate radiographic coverage. There were two pulsers and film packs, with lines of sight 60 degrees apart.

II. EXPERIMENT DESCRIPTION:

We obtained near full axial coverage radiography of a deformable contact imploding liner, using the experimental setup and geometry illustrated in Fig. 2. The Al liner was 30 cm long, with 9.78 cm inner diameter for its full length, 10.0 cm outer diameter for the central 18 cm of its length, and outer diameter increased linearly to 10.2 cm at 1 cm from either electrode, and to 11 cm at electrode contacts. The two electrodes had 8 cm diameter holes or apertures, to allow injection of Field Reversed Configurations (FRC's) in proposed future experiments on magnetized target fusion (MTF). The Z-pinch geometry discharge was driven by the AFRL Shiva Star 1300 microfarad capacitor bank, charged to 84 kilovolts, with ~ 44 nanoHenry initial inductance, sub-milliohm external resistance, plus a safety fuse as described in [3].

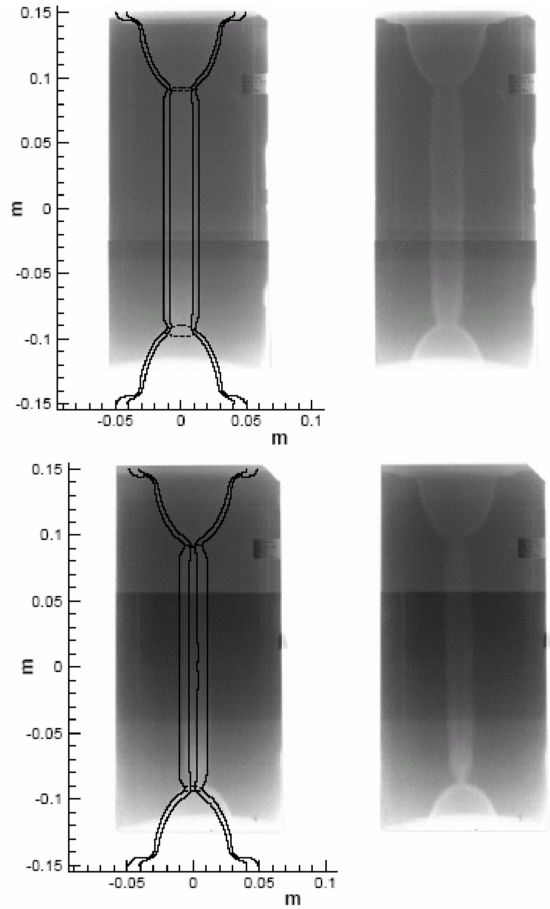

Fig 3: Comparison of 2d-MHD calculation of liner inner and outer boundary with radiographs at 21 μs (top) and 22 μs (bottom) after start of implosion discharge.

III. RESULTS

2D-MHD simulations as well as 300 KV, 5 KA, 30 nanosecond flash radiography, shown in Fig. 3, indicate that this varying thickness results in a deforming, nearly non-sliding, liner-electrode contact. The current history was similar to that for similar, uniform thickness long liner implosions with the more traditional sliding liner-electrode contact, reported in (3). The peak current was ~ 12 megamps with ~ 10 μs risetime. The implosion time was 22.5 μs. The inner surface implosion velocity exceeded 0.5 cm/μs, and kinetic energy was ~ 1 megajoule. This experimental data indicates the feasibility of using a varying thickness in a long cylindrical solid liner, driven as a Z-pinch, to achieve factor ~ 16 cylindrical convergence, while using large aperture electrodes.

We are investigating alternative liner thickness profiles computationally, using the 2D-MHD code Mach2 [19]. An analytic, smooth profile results in a diverging opening of the liner over its entire length, which would make it difficult to confine an injected FRC during compression. Such simulations indicate that the use of Gaussian thinning regions a few cm from the electrodes controls the diverging shape of the liner. Further variants of this are being investigated computationally.

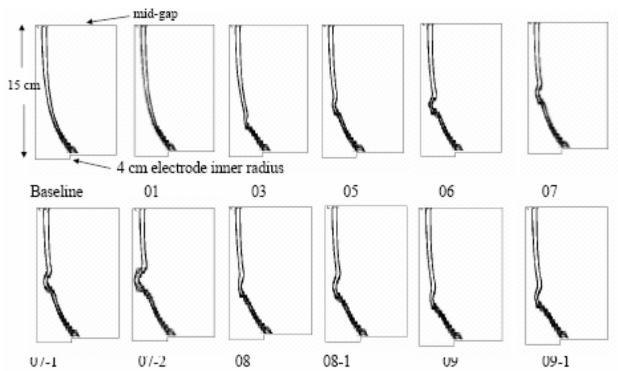

Fig.4: Contour plots of 2D-MHD simulations of liners with various thickness vs axial position profiles. Plots show half (15 cm) of 30 cm tall, 5 cm initial outer radius, Al liner position and shape at 21 μs after start of 1300 μf, 80 KV, 544 nanoHenry initial inductance Shiva Star discharge with standard safety fuse. Initial liner thickness is 1.1 mm at mid-gap (15 cm above lower electrode).

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