9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

Extended Stability and Plasma Shock Behavior in a Flow Through Z-pinch

B. Dempsie[1]
A. Smolyakov[1]
C. Xiao[1]
[1] Department of Physics and Engineering Physics, University of Saskatchewan
e-mail (presenter): brd638@usask.ca

Several coaxial gas-puffed z-pinch devices, also termed Sheared-Flow-Stabilized (SFS) z-pinches[1-3], have exhibited neutron production and a plasma discharge duration 1 – 2 orders of magnitude longer than theoretical Alfven transit times. These results generated renewed interest in the z-pinch as a potential candidate for fusion reactors and in uncovering new physics of z-pinch plasmas. The full dynamics of these devices are not yet fully understood, and the mechanisms of enhanced stability are still under discussion[4-5].

In this work a z-pinch device (built and operated by Fuse Energy Technologies in Quebec, Canada) with arrays of magnetic probes distributed in axial and azimuthal locations are used to measure the azimuthal magnetic field component and infer a current sheet/shock-front accelerated by the Lorentz force (Figure 1, left). The measured magnetic field signals reveal a current shock-front travelling downstream in the initial phase of the discharge, followed by a secondary "reflection phase" resulting in a backwards travelling magnetic field waveform (Figure 1, right). A loss of axially current downstream implies a radial current with the shock leaving a conductive wake between the inner electrode/z-pinch and outer electrode. A comparative analysis between different discharge conditions suggests this conductive wake plays a role in stabilization of the pinch and transport of plasma downstream which "fuels" or "ingests"[6] the pinch in the assembly region.

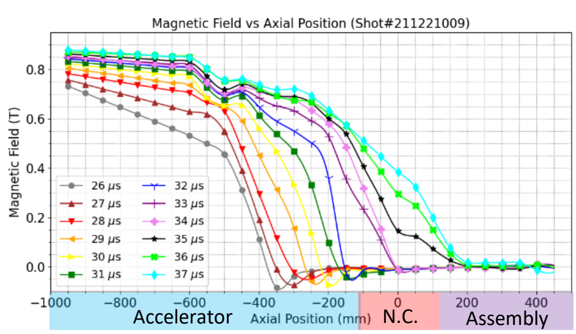
An equivalent electric circuit model similar to the Lee model[7] used for the DPF and other coaxial systems is proposed to reconcile differences in device parameters and includes the required physics to explain the "fueling" of a magnetic pulse, a phenomenon which has not yet been explained.

Combining this circuit model with the model of a quasi-DC pulse travelling in a transmission line encountering an impedance change appears to provide a theoretical framework for explaining the observed current shock front and reflection, thus including pulsed dynamics in our theoretical framework.

Quasi-stable m=1 kink modes have also been found to occur during the later phase of the declining discharge current.

We would like to acknowledge Ray Golingo and the Fuse Energy Technologies team for their contributions in building and operating the device, providing data, and many discussions.

References
[1] A.D. Stepanov *et al*, Phys. Plasmas **27**, 112503 (2020).
[2] U. Shumlak, J. Appl. Phys. **127** 2000901 (2020).
[3] U. Shumlak *et al*, Nucl. Fusion **49** 075039 (2009).
[4] J. R. Angus *et al*, Phys. Plasmas **27**, 122108 (2020).
[5] I. Paraschiv *et al*, Phys. Plasmas **17**, 072107 (2010).
[6] R. H. Lovberg *et al*, AIP Conf. Proc. **299** 59-68 (1993).
[7] S. Lee, J. Fusion Energ. **33**, 319-335 (2014).



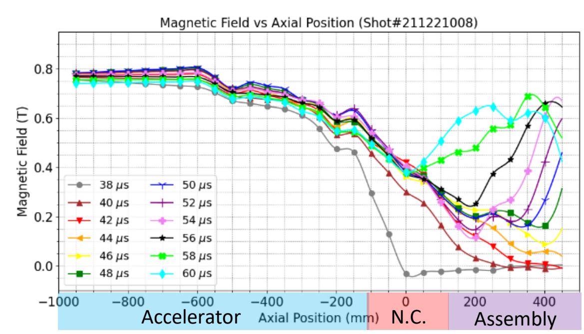


Figure 1. Magnetic field amplitude vs position at selected times obtained from an array of axial magnetic "bdot" probes. Left: The magnetic field profiles at earlier times as the shock front moves from the inner electrode (accelerator) region past the nose-cone (N.C.) region into the pinch assembly region. Right: The reflected magnetic field profiles at later times after the forward moving current shock front arrives at the end wall connected to the outer electrode.