Magnetomechanical Compression Of A Solid Lithium Liner For Magnetized Target Fusion (MTF)

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Abstract

Magnetized target fusion (MTF) is a promising approach to achieve fusion conditions that relies on the heating of a magnetized plasma by the rapid compression of a magnetic flux conserver. The compression timescale must be significantly shorter than the plasma's thermal confinement time, and the plasma must remain magnetohydrodynamically (MHD) stable during compression to achieve efficient heating and reach fusion-relevant conditions. An experimental multi-year campaign, named LM26, is on-going at General Fusion to develop an electromagnetic compressor designed to achieve scientific equivalent breakeven based on the Lawson Criterion. The compressor is made of concentric coils and will compress a magnetized plasma produced by the currently operational PI-3 plasma injector [1] using a solid lithium liner. A scaled-down prototype of the electromagnetic compressor has been commissioned to validate numerical models, including a model developed using COMSOL Multiphysics. These models are crucial for defining the operating conditions that will lead to thermonuclear fusion conditions in MTF.

The compressor uses 16 coils to compress a solid lithium liner of approximately 40 cm diameter against an hourglass structure. The shape of the liner throughout compression is sensitive to its thickness, the number of coils fired, and the total input energy. As the liner contacts the hourglass structure, it undergoes plastic deformation, causing the material to converge towards its central shaft (as shown by the attached figures). At the peak of its compression, the liner equator can reach velocities exceeding 500 m/s. During compression, the circumference of the liner is tracked at various axial locations using lasers and cameras. This method facilitates precise monitoring of the liner's topology through a technique known as Structured Light Reconstruction.

The COMSOL Multiphysics couples the Magnetic and Electric Field physics to the non-linear plastic solid mechanics module. It also includes heat transfer in solids and electrical circuits for each coil. The liner trajectory predicted by the COMSOL Multiphysics model matches the reconstructed topology within reasonable tolerances. The coil currents predicted by the model exhibit rise times and amplitudes that are similar to those measured, demonstrating that parasitic inductances in the environment have a minimal impact on the results. Discrepancies between the model results and the measured data can be explained by the symmetry assumptions inherent in the use of a 2D axisymmetric model to represent the coils and the vessel structure.

Reference

[1] Epp, K, Rablah, R, Howard, S, Laberge, M, Reynolds, M, Ivanov, R, Carle, P, Young, W, Froese, A, Gutjahr, C et al. “Confinement Physics on Plasma Injector 3.” APS Division of Plasma Physics Meeting Abstracts, Vol. 2020: pp. ZP07–011. 020