On the efficacy of imploding plasma liners for magnetized fusion target compression

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Abstract. A new theoretical model is formulated to study the idea of merging a spherical array of converging plasma jets to form a "plasma liner" that further converges to compress a magnetized plasma target to fusion conditions. [Y.C.F. Thio, et al., "Magnetized Target Fusion in a Spheroidal Geometry with Standoff Drivers," Current Trends in International Fusion Research II, ed. E. Panarella, (National Research Council Canada, Ottawa, Canada 1999]. For a spherically convergent plasma liner shell with high initial Mach number (M = liner speed/sound speed) the rise in liner density goes as $\rho \sim 1/r^2$, for any constant adiabatic index $\gamma = d\ln p / d\ln \rho$. Accordingly, spherical convergence amplifies the ram pressure of the liner *on target* by the factor $A \sim C^2$, indicating strong coupling to its radial convergence $C = r_m / R$, where $r_m(R)$ = jet merging radius (compressed target radius), and A = compressed target pressure/initial liner ram pressure. DT plasma liners with initial velocity ~ 100 km/s and $\gamma = 5/3$, need to be hypersonic $M \sim 60$ and thus cold in order to realize values of $A \sim 10^4$ necessary for target ignition. For optically thick DT liners, $T < 2$ eV, $n > 10^{19} - 10^{20}\text{cm}^{-3}$, black-body radiative cooling is appreciable and may counteract compressional heating during the *later stages* of the implosion. The fluid then behaves as if the adiabatic index were depressed below 5/3, which in turn means that the same amplification $A = 1.6 \times 10^4$ can be accomplished with a reduced *initial* Mach number $M \approx 12.7(\gamma - 0.3)^{4.86}$, valid in the range $(10 < M < 60)$. Analytical calculations indicate that the hydrodynamic efficiency for plasma liners produced with current jets is < 4%. A new similarity model for fusion α-particle heating of the collapsed liner indicates that "spark" ignition of the DT liner fuel does not appear to be possible with low areal density (ρR) magnetized fusion targets.