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Modelling of FRC experiment with large safety factor[1]

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A field-reversed configuration (FRC) with a modest toroidal field can have a large safety factor. Although the toroidal field is relatively small, the flux-surface elongation can be large. Both factors contribute to q, and large elongation can compensate for small toroidal field. Internal field measurements in FRCs formed by ejection in the Translation, Confinement and Sustainment (TCS) facility at the University of Washington indicate both q > 2 at the edge and significant forward magnetic shear (gradient of q). With this q profile and the low-aspect ratio the FRC bears a strong resemblance to a spherical tokamak, albeit without a center column. These results are interpreted using the "nearby-fluids" model, a flowing, two-fluid equilibrium where the ion flow surfaces and the magnetic surfaces are "nearby" but do not coincide. Flow is necessary because the plasma exhibits a significant rotational speed of $\sim$ 40 km/s. A two-fluid model is needed because a single-fluid model cannot reproduce the observed toroidal field structure. Two-dimensional computations are presented relevant to both the TCS experiments (relatively large ion skin depth) and in larger-size plasmas (small skin depth). The former have significant forward shear throughout the plasma, and a q = 1 surface in the interior, as inferred from TCS. The latter show significant reversed shear and q > 1 throughout the plasma. The computations also indicate that strong poloidal flows of the same order as the toroidal flows appear in the TCS experiments. The poloidal flow may figure in the observed stability. The stability of FRC experiments has generally been attributed to finite-Larmor-radius (FLR) effects. FLR becomes ineffective when the plasma is scaled up to fusion–relevant size. However, the possibility that a very high-beta plasma can satisfy conditions for global kink (q > 1) and local instability (sufficient gradient of q) is an exciting new prospect for FRCs and fusion research.

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