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Effects of Induced Toroidal Plasma Rotation on Plasma Wall Locking in the Reversed-Field Pinch

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The Reversed-Field Pinch (RFP) configuration with a resistive shell is linearly MHD unstable to current driven modes. The effect of toroidal rotation in the resistive shell RFP is studied numerically by means of 3-D, non-linear, resistive MHD code DEBS.
In previous work, it has been found that a drag force induced toroidal rotation can produce mode rotation in an RFP with a resistive shell which has a stabilising effect [1-3]. In the present paper an external rotating magnetic field has been applied. Its effects on plasma wall-locking in the RFP are presented, in addition to other results concerning the wall-locking problem.

Velocity profile effects

The effects of the velocity profile resulting from the induced toroidal rotation was investigated. In [1,2] the drag force was applied uniformly over the plasma cross-section. Due to viscous and electromagnetic forces, the resulting velocity was sheared. When applying a drag force which increases with minor radius, less sheared velocity profiles were obtained. When, additionally, releasing the non-slip condition v=0 at r=a, an almost flat velocity profile was observed. Contrary to predictions made from linear analysis, it was observed from the simulations that shear was not advantageous for reducing the fluctuation levels of the externally resonant kink modes, as well as the fluctuation levels of the other modes.

External rotating helical magnetic field

Effects of an externally induced helical field on plasma-wall locking is presently studied. It is found that a toroidally rotating field resonant with the dominant dynamo mode can prevent the development of wall-locking and simultaneously reduce the fluctuations and the loop voltage to conducting case levels. In Fig. 1 is shown the time evolution of the radial magnetic field during a simulation with resistive wall. No drag induced rotation or external field was implied in this case. As seen from the figure a wall-locked mode pattern grows with time.

Fig. 2a shows the case of Fig. 1 with the addition of an external rotating (m,n)=(1,-5) field. As seen from this figure the external field does prohibit the growth of the wall locked pattern.

Experimental findings in RFX [4] indicate the importance of the (m,n)=(0,1) mode for the coupling between the RFP dynamo modes. An induced rotation of the (m,n)=(0,1) mode has thus been found to prevent wall-locking. DEBS code simulations confirm these results. In Fig. 2b is shown the time evolution of the radial magnetic field during a simulation with an external (m,n)=(0,1) magnetic field.

In Fig. 3 is shown the toroidal loop-voltage vs. time for the two external field cases of Fig. 2. For comparison is shown a drag induced toroidal rotation case together with the case of Fig. 1 and a conducting shell simulation. The resistive shell case shows an enhanced loop-voltage, as compared to that of a conducting shell. In both resistive shell cases with external rotating field, as well as in the drag-induced rotation case, the loop-voltage drops to the level of the conducting shell case.

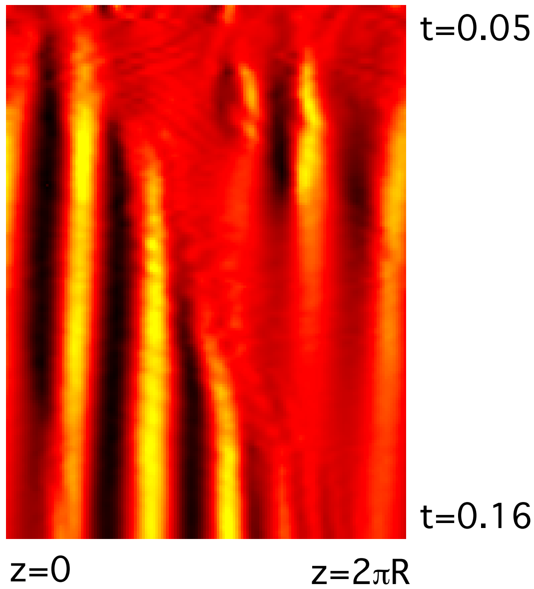
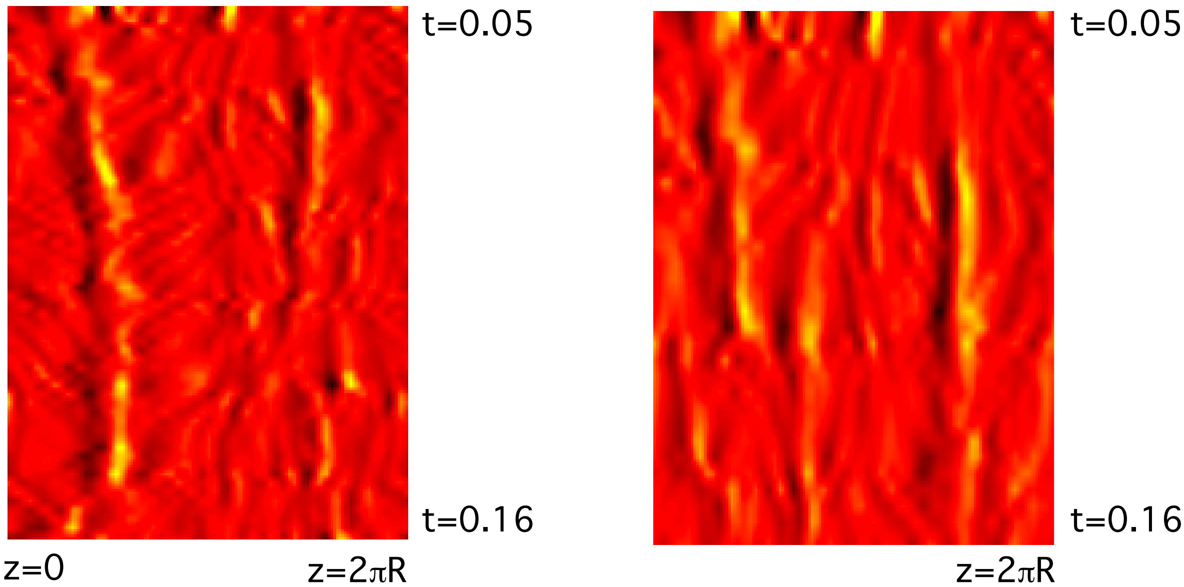


Figure 1. The fluctuating radial magnetic field b_r, at $(r,\theta)=(0.9a,0)$ vs. toroidal position $z=0$-$2\pi R$ (horizontal axis), and time t , normalised to t_R (vertical axis), with thin shell, $t_s=t_R/15$. No drag induced rotation or external field.



(a) (b)

Figure 2. The fluctuating radial magnetic field b_r, at $(r,\theta)=(0.9a,0)$ vs. toroidal position $z=0$-$2\pi R$ (horizontal axis), and time t , normalised to t_R (vertical axis), with thin shell, $t_s=t_R/15$. $V_f=0.1(R/a)$, $(m,n)_f=(1,-5)$ (a), $(m,n)_f=(0,1)$ (b).

In Fig. 4 is shown the time averaged m=1 energy spectra vs. the poloidal mode number n, for different cases of drag and external field induced plasma rotation, together with the case of Fig. 1 and a conducting shell simulation. In the wall-locked case the spectrum is dominated by the n=-5 mode, in agreement with the toroidal period of the wall-locked pattern of Fig. 1. The spectrum for the external field cases closely resembles that of a conducting shell case. Especially, this is the case for the levels of the externally non-resonant modes with a strong peak at n=2 in the Fig. 1 case. These were not fully reduced to the conducting case levels by drag-induced rotation.

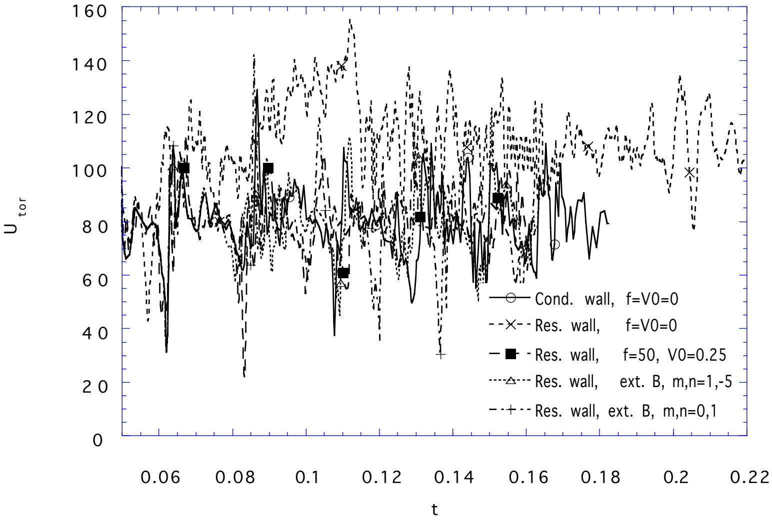


Figure 3. The toroidal loop voltage vs. time. Results are shown for conducting and resistive shell, drag induced plasma rotation and rotating external field cases.

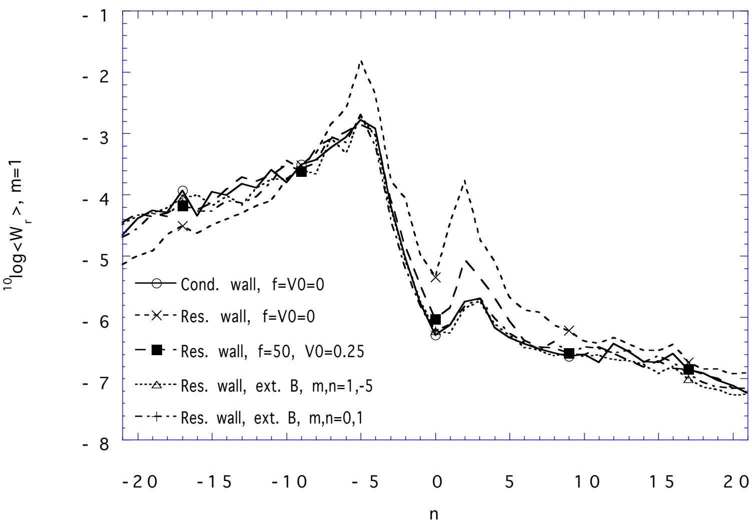
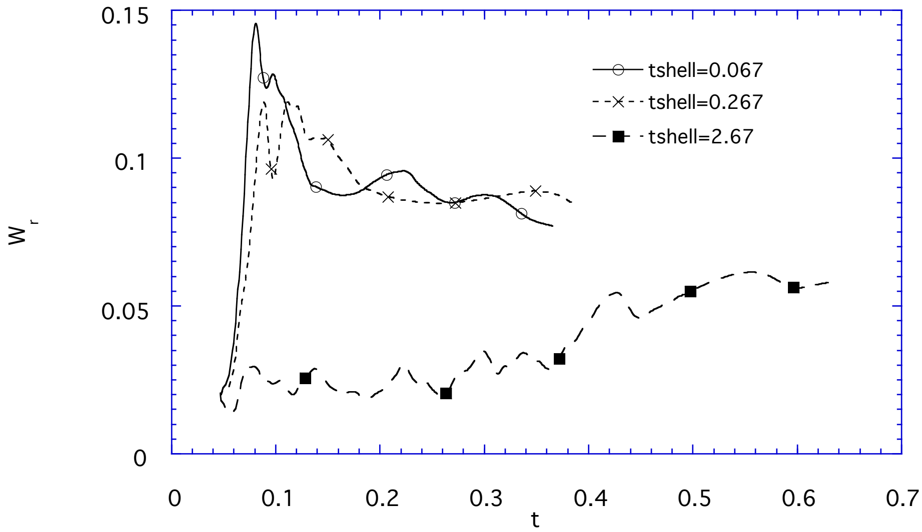


Figure 4. The time averaged b_r, m=1 energy spectra vs. the poloidal mode number n. Results are shown for conducting and resistive shell, drag induced plasma rotation and rotating external field cases.

Plasma-wall locking in a reversed field pinch with double resistive shell

Several RFP experimental devices such as the Extrap T2 and the RFX are constructed to have two separate resistive walls (liner and shell) with different field transition times. The DEBS code has been modified to perform simulations with up to two resistive walls and investigations are underway. First results show the possibility of delaying the wall-locking development, thus providing time for the application of methods to prevent the locking (induced rotation, externally applied magnetic field).



The volume-integrated radial magnetic field energy, against time for three different shell time cases. $r_{liner}=1$, $r_{shell}=1.09$, $r_{cond}=1.4$.

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