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A new viewpoint for linear theory of tearing instability

Tohru Shimizu[1]

[1] RCSCE, Ehime University

shimizu@cosmos.ehime-u.ac.jp

The linear perturbation equations of the tearing instability derived in the FKR's theory (Furth, et.al., Phys. Fluids 1963) and Loureiro's theory (Loureiro, et.al., Phys. Plasmas 2007) are examined by direct numerical studies as an initial value problem (Shimizu, KDK Report 2017), where the inner and outer regions are seamlessly resolved under the rigorously uniform resistivity assumption. Modifying the traditional treatment of the resistivity in those two theories, the uniform resistivity in the outer region plays an important role to essentially change all conclusions obtained in those theories. To set the rigorous equilibrium in the FKR theory, the current sheet thickness is assumed to be infinity but the Loureiro's theory is examined with the finite thickness. The fatal inconsistency between those theories can be explained as the differences of the equilibrium, i.e. the zeroth order current sheet, and the spatial scaling of the current sheet thickness assumed there.

As the most important result, the FKR theory fails because the physically acceptable perturbation solution is not found, where the local maximum points of psi (=B_{x1}) are seem to be located at the infinity x for the highest growth rate mode. In other words, the local maximum point of the perturbation solution is not localized in the vicinity of the neutral point for the higher growth rate. Then, the perturbation solutions newly found in the Loureiro's theory are classified into the spontaneous reconnection model and the externally driven reconnection model which are well-known in the numerical full MHD simulations. Like the FKR, the new perturbation solution is not localized around the neutral sheet for the higher growth rate. In contrast to the Loureiro's report, the highest growth rate dose not exceed a unity which means that the tearing instability grows at less than the Alfven speed but not super Alfvenic. Also, the zero-resistivity limit (e=0) has a finite growth rate which is non-zero. These results are completely different from those two theories. It means that the inner region traditionally treated in those two theories is in fact not localized in the current sheet for higher growth rate.

In addition, these new results are applied to the full MHD simulations of the Plasmoid Instability with uniform resistivity. Then, it is shown that some features obtained in the new viewpoint of the linear theory of the tearing instability are consistent with the simulation results (Shimizu, PoP2017) and also will be partially applicable for the magnetic diffusion region in the anomalous resistivity model (Shimizu, EPS2016)

References

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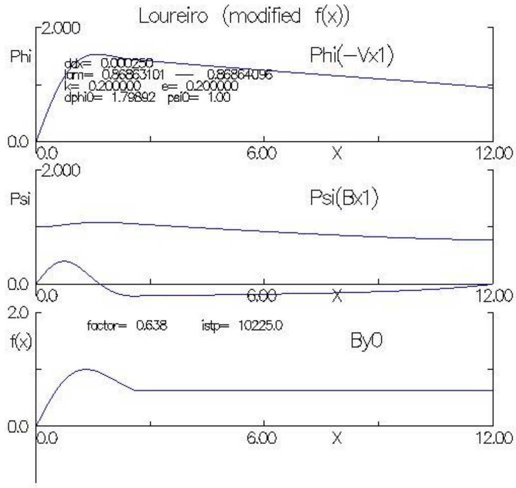

Figure 1: An example of the zero-converging perturbation solution numerically found in Loureiro's equilibrium. From the upper, phi, psi, dpsi/dx, and f(x), where the zeroth order magnetic field f(x) was slightly modified from the Loureiro's original f(x).

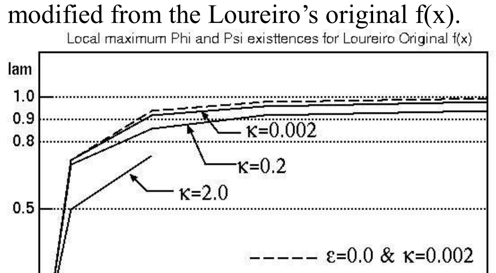

Figure 2: The upper limit of the linear growth rate (=lam) predicted from the local maximum point of phi and psi found in 0<x<Xb, where k is the wave number and e is the resistivity. The normalization of k and e is the same as that of Loureiro's paper (PoP2007). The spontaneous model corresponds to Xb=1.307.

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