Ferromagnetic destabilization of resistive wall modes in tokamaks

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Some dangerous instabilities in tokamaks can be suppressed or at least partially stabilized by a nearby conducting wall. The wall stabilization plays an important role in steady-state advanced scenarios developed for large tokamaks [1–3]. In the conventional stability analysis the magnetic permeability \(\mu\) of the wall is usually assumed the same as the vacuum one, \(\mu_0\), see [2] and references therein. However, the test blanket modules (TBM) in ITER will be made of ferritic steels [1], and prior to the ITER TBM testing the influence of ferromagnetic wall on the plasma will be studied in a large tokamak machine JT-60SA [4].

It is known that a ferromagnetic wall is not a good option from the viewpoint of plasma stability, though estimates show [5] that its destabilizing effect (compared to the wall with \(\mu = \mu_0\)) cannot be strong in tokamaks. Nevertheless, it may be large enough to be taken into account by feedback algorithms and therefore has to be studied in more details. Here we analyze the downward shift of the stability boundary of resistive wall modes (RWMs) at the presence of a ferromagnetic wall by using the dispersion relation for RWMs at \(\mu \neq \mu_0\), which is obtained [5] by solving the external task and hence can be coupled with any plasma model. This makes our approach essentially different from that in [6] and more universal. In our calculations here, a linear plasma response is assumed without other constraints on the plasma model. We compare our results against available data and discuss possible new experiments for studying the problem. Our analysis covers the range of \(\mu\) expected in a tokamak reactor and in the contemporary experiments [7, 8].