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Pfirsch-Tasso versus standard approaches in the plasma stability theory

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The paper is devoted to theoretical description of plasma stability in toroidal fusion systems with a resistive wall. Its aim is elimination of contradictions between different approaches and between theory and experiment. The study is related to two predictions stated as theorems, see [H. Tasso and G. N. Throumoulopoulos, Phys. Plasmas 18, 070702 (2011)] and references therein. One is that an MHD-unstable configuration with a dissipationless plasma surrounded by vacuum and possibly superconducting walls cannot be stabilized by introducing walls of finite electrical conductivity. The other is that in the absence of dissipation in the plasma such as viscosity, it is expected that the flow cannot stabilize the system. Both predictions forbid the experimentally demonstrated long-lasting wall stabilization of the tokamak plasmas. In particular, they do not allow the rotational stabilization and the regimes with edge harmonic oscillations (EHOs) observed on the DIII-D tokamak. Besides, they cannot be reconciled with a number of theoretical studies on the plasma rotation effect on the stability. Situations when the results are incompatible with those theorems are not rare, but still remain unresolved compromising the conclusions of the both sides. The most known first theorem was published in 1971 (Nuclear Fusion, p. 259), but since then it has never been analyzed, confirmed or corrected by independent researchers. This task is addressed here. A missing chain of derivations is restored and earlier unknown limitations that restrict the applicability of the Pfirsch-Tasso theorems are established. Thereby, the disagreements with the models of the rotational stabilization are explained and shown to be amendable. Replacement of the Pfirsch-Tasso energy principle is proposed. The new result is free from the constraints implicitly imposed in the Pfirsch-Tasso proofs. It eliminates the contradictions and can be used with any plasma model (not necessarily ideal) and for arbitrary perturbations. The proposed extensions allow applications for the cases of practical interest such as feedback stabilization of RWMs, analysis of the rotational stabilization and optimization of the ITER scenarios. Examples are presented and consequences are discussed.

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