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ANALYTICAL MODELS FOR EVALUATION OF THE TOKAMAK PLASMAS VERTICAL POSITION INSTABILITY GROWTH RATE *)

[1,2]Chukashev N.V., [1,3]Pustovitov V.D.

[1]National Research Centre Kurchatov Institute, Moscow, 123182 Russia
[2]Moscow Institute of Physics and Technology (State University), Dolgoprundy, 141700 Russia
[3]National Research Nuclear University Moscow Engineering Physics Institute, Moscow, 115409 Russia

To evaluate the growth rate of plasma vertical position instability, or Vertical Displacement Event (VDE), modern analytical theory uses equilibrium models of various levels of complexity [1-4]. The simplest one is based on the so-called “rigid rod” approximation, in which the plasma and the wall are replaced by parallel current-carrying wires [1, 2]. The interaction between the plasma and the wall is prescribed by Ampere forces acting on currents. This model allows to capture the qualitative patterns of the dynamics of a conductor that imitates toroidal discharge in a quadrupole magnetic field, but it predicts ideal MHD-instability even for the plasma surrounded by a conducting wall.

To take into account the vacuum vessel reaction to plasma’s vertical displacement, the Gajewski’s equilibrium model for a straight plasma column with an elliptical boundary and uniform current density was previously accepted [5]. The wall was considered as a thin shell with elliptically shaped cross-section that is confocal to the plasma boundary. There are only two examples in the literature [3, 4] where the mentioned approach was applied to calculate the VDE growth rate in a tokamak with a resistive wall, but both papers propose different results. At the same time, it is not possible to provide an exhaustive comparison of them, since in [3] the formula for the increment of vertical instability is given without derivation.

In such a situation, the only way to determine the correct result is to calculate the instability growth rate using an alternative method. In our work, we propose to use the Green's function method combined with recently developed equilibrium model [6]. Firstly, this allows to generalize previously obtained results to the case of an arbitrary current density in a plasma. Secondly, instead of the boundary condition relating the external solution of the equilibrium problem to the diffusion of magnetic flux through the resistive wall [3, 4], the integral equation for eddy current evolution is proposed. Its main advantage is the ability to get rid of artificial restrictions on the geometry of the task, such as confocality of the plasma boundary and the wall, and existence of the well-developed technique for finding analytical solutions [6].

References

[1]. Kiramov D.I., Breizman B.N., Phys. Plasmas, 2017, 24, 100702
[2]. Pfefferle D., Bhattacharjee A., Phys. Plasmas, 2018, 25, 022516
[3]. Wesson J.A., Nucl. Fusion, 1978, 18, 87
[4]. Barberis T. et al, J. Plasma. Phys., 2022, 88, 905880511
[5]. Gajewski R., Phys. Fluids, 1972, 15, 70
[6]. Pustovitov V.D., Chukashev N.V., Phys. Plasmas, 2023, 30, 042505

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