Filament representation of the plasma in the tokamak disruption studies

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It is well known that the plasma-produced poloidal field outside the tokamak plasma can be quite accurately approximated by the field of a set of the distributed toroidal currents (filaments or circular loops) [1]. This is justified by referring to the fact that the tokamak plasma looks like a toroidal current and needs a proper electromagnetic treatment for suppressing the outward expansion. An additional argument in favour of such image is that, with a desirable axisymmetry, the magnetic field due to the plasma poloidal current always remains completely 'hidden' inside.

The force balance requires that this current must vary reacting on the plasma changes. It will inevitably generate the poloidal electric field outside, which is not accounted for in the models with plasma replaced by current filaments. Such models are often used in calculations of the disruption-induced forces on the tokamak wall [2–5]. Here we analyze the accuracy of this approach.

We treat the problem within the standard large-aspect-ratio tokamak model assuming that both the plasma and the wall are circular in the perpendicular cross-sections. The magnetic pressure on the wall during thermal quench (TQ) and current quench (CQ) is analytically calculated by following the approach described in [6]. The rapid events are considered when the penetration of the plasma-driven perturbation through the vessel outwards is weak due to the skin effect in the wall. The derived formulas allow comparison of the disruption-induced forces calculated differently: with plasma described by the MHD equilibrium equations as opposed to the plasma modelled by a set of filaments. The differences in the results are discussed and explained. It is explicitly demonstrated that the filamentary model of the plasma (or disregard of the poloidal current in the plasma) gives unacceptably large errors in the simulated forces for both TQs and CQs.

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