§4. 3D MHD Equilibrium Calculations for Tokamaks with the HINT2 Code

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The application of Resonant Magnetic Perturbations (RMP) to tokamaks recently gained a lot of attention due to the possibility of ELM suppression or mitigation[1),2)]. The iron core tokamak TEXTOR with circular plasma cross-section is specially suited to study the 3D effects of RMPs due to its Dynamic Ergodic Divertor (DED) [3)]. The DED consists of 16 helically aligned perturbation coils installed in-vessel at the high-field side and can be operated in several base modes (m/n = 12/4, 6/2 and 3/1) with either DC or AC current supply. The addition of the RMP to an axisymmetric equilibrium perturbs the force balance

$$\nabla p \neq \vec{J} \times (\vec{B} \times \vec{B}_{pert}). \qquad (1)$$

To reestablish the force balance, we recalculate the 3D equilibrium including an equilibrium response to the perturbation field. A full penetration of the RMP is assumed and screening of the RMP is not taken into account. The converged 3D equilibria are compared with the simple vacuum superposition assumption.

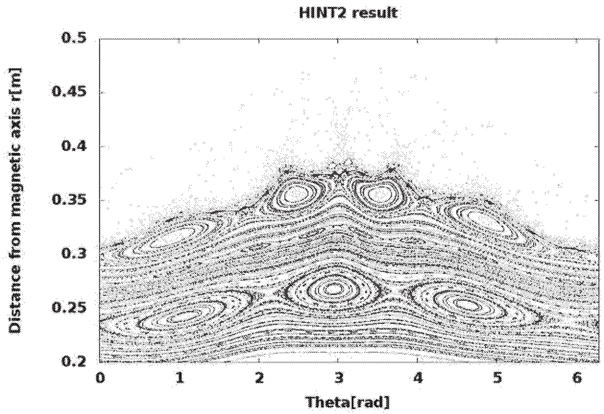
To investigate the resulting 3D equilibrium the HINT2 code [4),5)] is applied. This code is an Eulerian initial value solver which relaxes the given initial magnetic field configuration into an equilibrium by solving resistive MHD equations.

We calculated the 3D equilibrium for TEXTOR with the DED in 6/2 mode configuration for different DED currents, namely IDED = 1.5[kA/coil], 4.5[kA/coil] and 7.5[kA/coil] for an underlying 2D equilibrium with the following parameters: I_p = 245[kA], B_{tor}(@1.75) = 1.3[T] and a central axis pressure of p_{axis} = 16[kPa]. Due to the perturbation field symmetry only a half torus calculation was necessary. The resolution was chosen to be a spatial resolution of 1.02[cm] in a poloidal plane and about 1[deg] in toroidal direction.

Figure 1(a) shows the Poincaré plot representation of the resulting topology for the case with IDED = 7.5[kA/coil] for the HINT2 result. While the major structures are conserved in the HINT2 calculation, an additional ergodization around the X-points of the major islands (e.g. the 3/2 islands) appears as can be clearly seen in figure 1(b). Furthermore, appearing secondary structures in the islands are found, a feature already observed experimentally for 2/1 islands in DED 3/1 mode [6)]. These effects are caused by the modified Pfirsch-Schlüter current density distribution driven by the pressure gradient around the islands. These effects also affect connection length for an enlarged edge area and an increased island size in the HINT2 case. Furthermore, a statistical analysis shows an increase in short (≤1000m) and very long (≈16000m) field lines in the HINT2 case. This indicates a sharper transition from the confined core to the vacuum region.

For the TEXTOR case the HINT2 calculations show clear modifications compared to the vacuum superposition. For JET calculations will be necessary to obtain a clearer picture of the differences between the vacuum superposition and the HINT2 result.

(a)



(b)

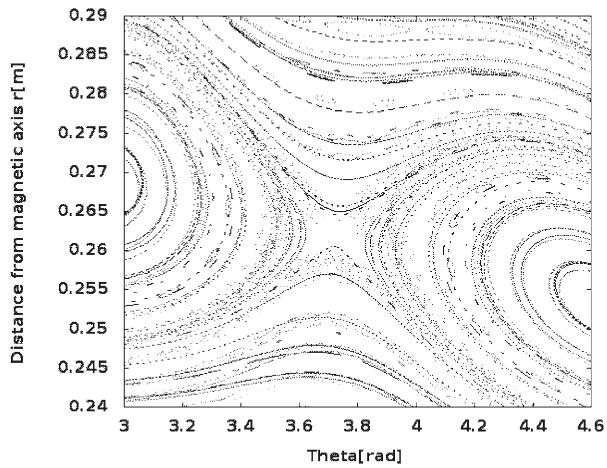


Fig. 1. Poincaré plots at f=0 for IDED=7.5[kA/coil]: (a) HINT2, (b) Vacuum superposition (black dots) superposed with the HINT2 result (red dots) around an X-point region.

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3) Finken, K. H. et al. : Energy Technology **45** (2005)
4) Harafuji, K. et al. : J. Comp. Phys. **81** (1989) 169
5) Suzuki, Y. et al. : Nuclear Fusion **46** (2006) L19
6) Liang, Y. et al. : Nuclear Fusion **47** (2007) L21