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Approximate Description of Local Deformations of Large Superconducting Toroidal Field Coils

H. Zehlein

Kernforschungszentrum Karlsruhe GmbH, Institut für Reaktorbauelemente, Postfach 3640, D-7500 Karlsruhe 1, Germany

The classic geometric ingredients for the design of large TF coils are

i) a D-shaped contour usually serving as the locus of centroids of

ii) suitably shaped cross sections of the winding and

iii) a set of reinforcements required for the diffusion of external support reaction forces.

The D-shape as derived by 1D-filament models carrying only tension hoop stresses as a child of the hope to achieve a smooth mean circumferential stress distribution. The finite extension of the cross section, however, then gives rise to considerably varying bending stresses even during normal operation. Therefore, sufficiently refined 3D finite element models are required for the stress analysis of such coils. Consequently the large size of those 3D models together with discontinuities like the finite extension of external supports or the gaps between coil components makes them prohibitively complex for direct application to the preliminary design of Tokamak reactors.

Therefore, a simplified description of the coil deformation seems mandatory. Unfortunately the combined effect of body and surface forces prevailing in the load-diffusing support regions leads to local cross section deformations which on principle cannot be described by 1D simple beam FE models. Furthermore the right superposition of basic deflection "modes" like bending, shear and torsional twist cannot be recognized from a 3D model which only can give the "correct" total displacements. The understanding of local mechanical effects due to cross section deformation was therefore developed by comparative interpretation of numerical results from a 1D and a 3D FE model. It is summarized by a new thumb rule which is valid for bucking post supports. It is then tentatively adapted to central supports which form a vault.

The paper is based on the experience gained during the design of the European LCT coil as well as on various proposals made during the INTOR reactor studies.