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Homogenization of Winding Pack Properties for the Structural Analysis of Fusion Magnets

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As the experimental ITER fusion reactor faces its final construction phase, design activities of the next reactor DEMO that will supply net electrical energy to the grid are being conducted in Europe. DEMO will be significantly larger than ITER, and its magnet system will be key to confine the plasma and control its shape. In particular, the Toroidal Field (TF) Coils are necessary to generate the closed toroidal field lines that confine the plasma in a tokamak fusion reactor. The interaction of the current in these coils with the magnetic field produced by the poloidal magnet system induces out-of-plane forces that make unavoidable a three-dimensional structural assessment of the TF magnet structure. Moreover, Poloidal Field (PF) Coils are supported by the TF Coil casings and are to be included in the analysis of a global model of the magnet system. Nevertheless, Winding Packs (WP) in Fusion magnet coils are heterogeneous and rather complex structures, hence accounting for a detailed model of the WP with a fine mesh in a 3-D analysis of the magnet system can become extremely costly. Homogenization techniques are therefore commonly used to model the WP by means of a uniform elastic block with orthotropic thermo-mechanical properties. Several techniques exist for this purpose and indeed a variety of approaches are in use in the fusion magnet community yielding different values for the effective properties. This work describes homogenization techniques stemming from an energetic criterion and presents a comparison between them with the goal to contribute to the founded standardization of the structural analysis procedures in the fusion magnet field, with special emphasis in the challenging DEMO magnet coils. The mentioned standardizations are crucial if the design and construction of Fusion Magnets are to become widespread activities in the future.

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