Predicting Critical Current As a Function of Magnetic Field in High-Temperature Superconductors

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Abstract

The Alcator C-Mod Tokamak at the Plasma Science and Fusion Center (PSFC) produces high performance research grade plasmas with temperatures approaching 100 million degrees centigrade. This device uses strong magnetic fields made by powerful electromagnets to confine this very hot plasma. The PSFC is exploring paths to achieve the highest possible magnetic field with superconducting technology which would lead to better confinement and greater fusion power. Recent advances in Rare Earth Barium Copper Oxide (REBCO) superconducting tapes could provide that path. REBCO tapes belong to a class of high temperature superconductors (HTS) that can be superconducting at liquid nitrogen temperatures (77K) as opposed to typical superconductors such as Nb3Sn which need to operate at liquid helium temperatures (4K). One important aspect of designing a super conducting coil is the ability to predict the critical current above which the conductor becomes resistive.

Critical current is affected by the magnitude and angle of the magnetic field the coil is exposed to. Test data defining this relationship can be used to predict the critical current for different HTS coil geometries and designs. COMSOL has been used to predict the critical current as a function of field and field angle in proposed coils. Data defining the critical surface for current as a function of field and field angle are input as interpolation tables, and a magnetic fields model is run to predict the field, field angle and critical current. This result can serve as a guide to predict the maximum current, and therefore the maximum field, that the coil can produce. In addition, using the magnetic fields (mf) interface to determine where the coil has become resistive allows us to use the electric currents (ec) interface to predict the path of the current if parts of the coil become resistive.

Results show that in a double pancake coil, the critical current is lowest at the inner diameter of the coil. This matches expectations since the fields are highest at this location. The coil is wound with no insulation between turns, and the models predict that as the higher fields cause the inner turns to become resistive, the current is able to move from the resistive turns into turns that are still superconducting.