MECHANICAL DESIGN OF THE SERIES CONNECTED HYBRID MAGNET SUPERCONDUCTING OUTSERT CONDUIT

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Introduction

An innovative hybrid magnet configuration is being developed at the NHMFL, consisting of a Florida-Bitter resistive magnet nested within a cable-in-conduit conductor (CICC) superconducting magnet to provide high fields for less power than traditional hybrid magnets. The resistive and superconducting magnets, connected in series, will be capable of producing 23.1 T and 13.8 T respectively for a total central field of 36.9 T. The CICC uses a cable of multifilimentary Nb_3Sn/Cu strands inside a superalloy jacket that confines flowing supercritical helium in direct contact with the cable strands. The design of the magnet system is presented along with the design criteria used to evaluate the superconducting magnet and its integral components. The results of a structural analysis performed using finite elements for normal operational and fault loads are discussed for the most critical component, the conduit.

Design Criteria

Design criteria are established to set consistent standards on the allowable stress levels of structural components and the magnet windings. Possibly the most common set of standards is the Boiler and Pressure Vessel Code (B&PVC)[1] developed by the American Society of Mechanical Engineers. The criteria have been reviewed extensively over several years, are very conservative, and are well accepted. However the B&PVC does not address the details of magnet systems such as their loading conditions and material behavior at cryogenic temperatures. The fusion community has created design standards[2] that are also well reviewed, specific to magnet technology, and are an adaptation of the B&PVC. The design criteria applied to the SCH superconducting outsert and cryostat are a further evolution of those standards.

Results and Discussion

The highest stress regions occur in the corners of the conduit, the next highest is on the mid-side edges as shown in Fig. 1 with the contour stress plot of the first three layers just above the mid-plane. In all, there are 18 layers of conductor with 39 turns per layer. The corner stress is at a structural discontinuity and therefore is considered to be local stress, which allows for a higher stress limit. Table 1 summarizes the stress during normal operation for the highest stressed corner and edge regions for the primary and primary + secondary stress as well as their respective stress limits. The stress is an integration of the Tresca stress at the region through the wall of the conduit. All stresses are within the limits set in the design criteria.

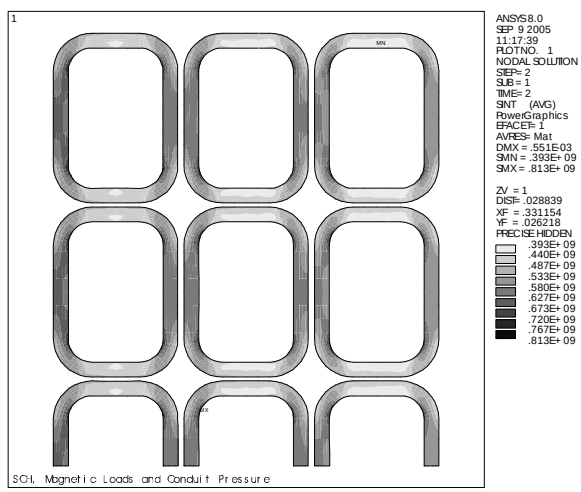

Fig. 1. Tresca stress through the first three layers of the outsert, near the coil mid-plane. The units are in Pa.

Table 1. Stress at the Conduit Corner and Edge

Stress Category	Edge		Corner	
	Tresca Stress (MPa)	Stress Limit (MPa)	Tresca Stress (MPa)	Stress Limit (MPa)
Membrane	633.7	656	620.7	984
Mem. + Bend.	653.8	984	802.9	984
Pri. + Sec.	660.5	1968	769.3	1968

Acknowledgements

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References

[1] ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Alternative Rules, ASME (2004).
[2] Zatz, I., "FIRE (Fusion Ignition Research Experiment) Structural Design Criteria, Rev. 0," (2001).