Mechanical Analysis of the Superconducting Outsert for the Series-Connected Hybrid Magnets

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Introduction

The NHMFL presently has three Series-Connected-Hybird (SCH) projects, two of which are entering a construction phase. The design of the SCH outsert magnets is based on a CICC configuration using cable of multi-filamentary Nb_3Sn and Cu strands inside a stainless steel jacket cooled by forced flow supercritical helium at 4.5 K. The outsert coil design is presented along with the design criteria for the evaluation of conduit and conductor insulation components. The results of detailed finite element analysis performed for normal, quench and fault load conditions are discussed to ensure the levels of stress and strain in conduit and insulations satisfy the design criteria. The conduit evaluation of fatigue life and fatigue crack growth rate is performed and the results are discussed for a possible cyclic lifetime and a minimum detectable flaw size for the SCH outsert.

Mechanical Design Criteria

We use the Fusion Ignition Research Experiment (FIRE) structural design criteria to address the details of design limits for conduit evaluation and conductor insulations under static loads and cyclic operations [2]. The measured yield and ultimate material strengths of the modified 316-LN stainless steel are 1168 MPa and 1506 MPa respectively at the 4.5 K service temperature.

Results and Discussion

An axis-symmetric finite element model was created using ANSYS. Conduit stresses under normal, quench (increasing temperature and pressure) and fault load (a short in half of all insert coils) conditions are calculated based on the combined loads of Lorentz force, thermal contractions and the helium pressures.

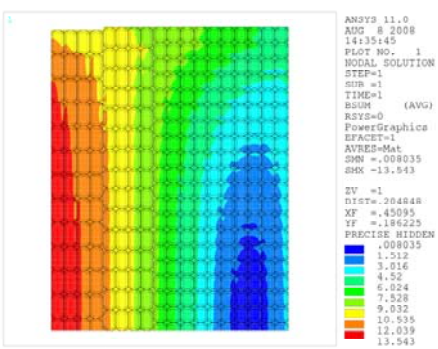

Fig. 1. Magnetic field distribution through the outsert of the SCH magnet (in Tesla).

Tab.1. Conduit stresses for normal, quench and fault loads (in MPa)

	Normal		Quench		Fault	
Category	Limit	Tresca	Limit	Tresca	Limit	Tresca
Membrane	502	480	498	474	602	495
Mem. + Bend.	754	561	747	556	903	777
Pri. + Sec.	1506	652	1494	618	1506	803

Conclusions

Evaluation for static loads under normal, quench and fault operations shows that the conduit and insulations are within the design limits. The design lifetime of 35,000 cycles is supported through the fatigue S-N curve and a flaw size of 0.24 mm must be detected during the fabrication.

Acknowledgements

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References

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[2] Zatz, I., FIRE (Fusion Ignition Research Experiment) Structural Design Criteria, Rev.0, (2001).