Modeling of the Performance of Nb_3Sn CICCs for High Field Magnet Design

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Introduction

Performance degradation of Nb_3Sn cable-in-conduit-conductors (CICCs) is a critical issue in large-scale magnet design such as the series-connected-hybrid (SCH) magnets currently under development at the NHMFL. Strain sensitivity of the Nb_3Sn superconductor and strand irreversible damage due to filament fracture are believed to be the main reasons for low CICC performance with respect to expectations from strand data. Traditional model assumes strands are straight in a CICC cable and strands have uniform axial compression. We present the Florida electro-mechanical cable model (FEMCAM) and demonstrate that it is a self-consistent model incorporating important bending effects caused by differential thermal contraction and accumulated magnetic force and effects due to filament fracture to better predict CICC performance.

Model Description

We simplify the geometry of a multi-stage helix by assuming a sinusoidal strand shape and solve deflection of strands under thermal contraction with beam-column theory. The thermal bending model is incorporated into an electromagnetic bending model that describes strand mechanical interactions in a CICC by bending of clamped beams and contact stress at strand crossing. The total bending strain due to thermal and magnetic load is used to compute transverse load degradation from the Summers scaling law and Ekin integration. We assume the filament critical current drops to zero if filament strain is greater than the strand irreversible limit.

Results and Discussion

Fig. 1 presents correlation of the FEMCAM predicted transverse load degradation of *Ic* on the 1st cycle with various CICC tests. Fig. 2 presents additional degradation with cyclic loading versus the excess strain computed by FEMCAM. The higher the excess strain, the more additional Ic degradation occurs under cyclic load with a critical values being ~0.6%.

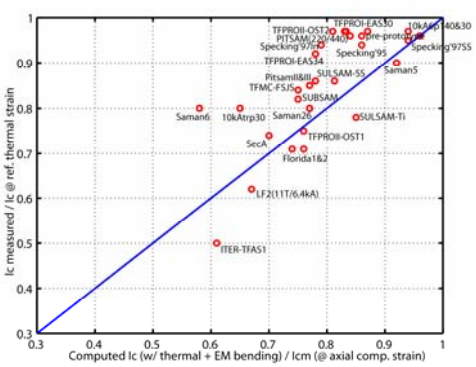

Fig. 1. Correlation of FEMCAM with CICC tests.

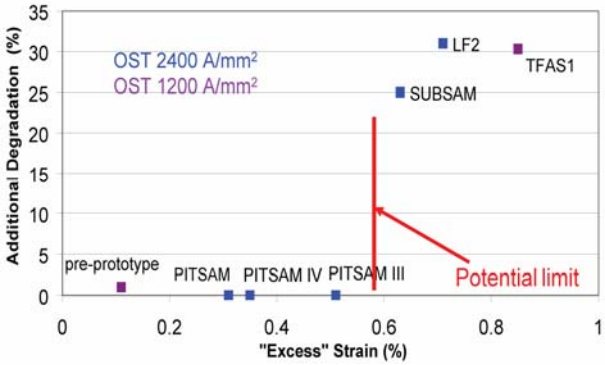

Fig. 2. Correlation of additional degradation under cycling with excess strain.

Conclusions

The new model combines thermal bending, electromagnetic bending and effects due to filament fracture. FEMCAM results are compared with experiments for 27 different conductor tests with good correlation. For the SCH magnet, we predict 17-20% degradation on the 1st cycle and negligible degradation on subsequent cycles.

Acknowledgements

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References

[1] Zhai, Y. and Mark D. Bird, 20th Biennial Int. Conf. on Magnet Technology (MT-20), Philadelphia, PA, #J04 (2007).