Transverse Stress Effect on Nb_3Sn Superconducting Cables

Makoto Takayasu, Luisa Chiesa, Joel H. Schultz, Joseph V. Minervini (Massachusetts Institute of Technology, Plasma Science and Fusion Center), and John R. Miller (Oak Ridge National Laboratory)

Introduction

Transverse pressure has been applied mechanically to a sub-sized cable to simulate the effects of electro-magnetic forces of a superconducting magnet in order to evaluate the critical current degradation of Cable-in-Conduit Conductor (CICC) Nb_3Sn cables due to a transverse load. We have tested four samples of 36-strand cables made of ITER CS Model coil IGC wire (two samples), and ITER CS pre-production wires of Outokumpu and Oxford using the 20 T, 195 mm magnet (Cell 4) [1]. The initial I_c degradations of all these samples measured before applying a transverse load were much larger than expected. The initial degradations were about 35% and 50% for the two IGC cables, 35% for the Outokumpu cable, and 55% for the Oxford cable. This large amount of initial degradation has made evaluation of transverse load effects difficult. We redesigned the device and recently performed transverse load cable tests using the LTCTL split superconducting magnet facility (Cell 16). This magnet allowed us to use a straight cable sample of a hairpin shape instead of the previous circular coil sample. The sample fabrication and sample holder design and operation have been greatly simplified.

Experimental

A test sample of the U-shaped hairpin cable was inserted in the space of 70 mm x 30 mm between the split magnet coils. The transverse load was applied to two straight sections of about 135 mm long, using toothed wedge method. When the wedge was pulled upward, the test sections were squeezed horizontally through the transverse load bars which were positioned on both sides of the wedge. The wedge consisted of three teeth on the each side in order to apply a uniform load over the test sections. The sample was mechanically supported against the transverse load by a structural square frame. The sample holder was made of Ti-6Al-4V, and was used for both heat treatment and measurement. The single strand, 3-strand and 45-strand samples were made from ITER TF pre-production Oxford wire. The critical current degradations were measured at 12 T.

Results and Discussion

The experiment was performed at the end of 2007, so there has not been time to analyze the data. The preliminary results are as follows. The wedge loading mechanism worked quite well except for the single strand test, since the device was designed for a 45-strand sub-cable with 3-ton vertical force. The two tested leg sections of the single strand sample did not have a perfectly balanced load. However, both legs of the 3-strand and 45-strand cable samples were quite well equally loaded. The initial degradation of the single strand and 3-strand samples seemed to be negligible, but the initial degradation of the 45-strand cable was approximately 22% which was much smaller than the 55% observed in the previous Oxford CS cable test. After several load-unload cyclic tests the critical currents of the 3-strand and 45-strand cables degraded to 30% and 25% of the initial value, respectively, with a transverse load pressure up to about 100 MPa. When unloaded, the critical currents recovered to 40% and 30% of the initial value for the 3-strand and the 45-strand samples, respectively.

Acknowledgements

This work was supported by the U.S. Department of Energy, Office of Fusion Energy Science under Grant Number: DE-FC02-93ER54186 and the US ITER Project Office. We would like to thank Huub Weijers, George Miller, Bill Sheppard, Patrick Noyes, Mark Bird and Tom Painter for making the experiment possible using the LTCTL split superconducting magnet.

References

[1] L. Chiesa, et al., “Critical Current and Mechanical Behavior of Sub-Sized Nb_3Sn Superconducting Cables under Transverse load,” CEC-ICMC 2007, Chattanooga, Tennessee, July, 2007.