CHARACTERIZATION OF Nb_3Sn SUPERCONDUCTING WIRES UNDER STRAIN: TRANSVERSE STRESS AND BENDING EFFECTS

Makoto Takayasu, Luisa Chiesa, Andrea Allegritti, and Joseph V. Minervini (Massachusetts Institute of Technology, Plasma Science and Fusion Center)

Introduction

In order to study degradations due to transverse strain and bending effects on Nb_3Sn superconducting conductors, we continued transverse stress tests on 36-strand cables, and single-strand pure bending tests using the 20 T, 195 mm bore high-field large-bore DC magnet.

Transverse stress effect on the critical current of 36-strand Nb_3Sn cables

We have developed a device to study the effect of transverse stress on a sub-sized Nb_3Sn cable using a mechanical load that simulates the Lorentz loads in ITER conductors. The test sample is a single turn (about 110 mm diameter) circular coil composed of 36 superconducting strands (cabling pattern of 3x3x4). The transverse stress is applied to the cable using a conical wedge that converts a vertical force into a radial (transverse) force. Two samples of IGC wire used for ITER CS model coil and newly developed high-performance wire (Outokumpu) were investigated [1]. The two samples showed quite different behaviors to the applied transverse loads. The high-performance strand cable showed a stronger sensitivity to the applied load than the old CS model coil wire. The transverse load effects of the new high performance wire have been intensively studied taking a sequence of loading and unloading operations at 15 T. The cable is sensitive to the mechanical applied load, showing 5-10% degradation for loads lower than 20 MPa. By 100 MPa stress, the cable critical current was degraded to ~30% of its initial, unloaded value. We will continue the transverse load tests for various Nb_3Sn strand cables to understand operation degradations of Nb_3Sn conductors.

Single-Strand Variable Pure-Bending

A variable bending test probe for a single strand was developed last year [2]. This year we modified the bending device to apply pure-bending only without axial strain to a strand sample [3]. This device allows applying pure bending up to 0.9% over the sample of about 100 mm length in liquid helium. Bending properties of new ITER high performance Oxford and Outokumpu wires were tested. The bending was applied first up to 0.2% (-0.2%) and then to the other direction up to 0.8%. The critical currents at 15 T of the Oxford and Outokumpu wires degrade from 175 A to 63 A and from 133 A to 67 A, respectively, by the bending of 0.8%. After the 0.8% bending the critical currents of the Oxford and Outokumpu wires were irreversibly reduced to 114 A and 105 A, respectively. These values were 65% of the initial value for the Oxford wire and 79% of the initial value for the Outokumpu wire. Note that the oxford wire was much more sensitive to the bending than the Outokumpu wire. The initial critical currents of Oxford wire were much higher than that of the Outokumpu wire. However the critical currents at the 0.8% bending and also the reversible values resulted after 0.8% bending of these tested wires were very similar between the Oxford and Outokumpu wires. It is very important to figure out the high sensitivities against bendings and strains which are observed unexpectedly for the newly developed advanced Nb3Sn wires.

Acknowledgements

This work was supported by the U.S. Department of Energy, Office of Fusion Energy Science under Grant Number: DE-FC02-93ER54186.

References

[1] L. Chiesa, et al., "Experimental studies of transverse stress effects on the critical current of a sub-sized Nb3Sn superconducting cable,' ASC 2006, 4LG03, Seattle, Washington, September 2006.
[2] D.L. Harris, "Characterization of Nb3Sn superconducting strand under pure bending," MIT Mechanical Engineering master thesis, 2005.
[3] A. Allegritti, "Development and experimental test of a device for the measurements of the critical current of superconducting strands under pure bending conditions," University of Bologna, Department of Mechanical Engineering, Italy, 2006.