CHARACTERIZATION OF Nb_3Sn SUPERCONDUCTING WIRES UNDER STRAIN

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A series of tests of the ITER CS model coils confirmed that design and fabrication methods for a large scale niobium-tin cable–in-conduit –conductors (CICC) magnet had been well developed for 13 T field operation with a 40 kA pulsed-current of 1.2 T/s. These tests, however, also indicate the importance of further understanding the strain effects of Nb_3Sn conductor cables, including longitudinal load strain and transverse bending effects on individual strands in the large conductor. Degradations due to transverse strain and bending effects on large Nb_3Sn superconducting cables like ITER conductors have been investigated in various ways; bending tests of strands and external transverse load tests of a sub-sized cable using the 20 T, 195 mm bore high-field large-bore DC magnet. This work will contribute to understanding strand and cable degradation effects which need to be included in design criteria and magnet performance analysis.

Fixed Strain Bending Test: Strand bending critical current tests of Nb_3Sn internal tin and bronze processed wires have been continued using two type of Nb_3Sn wires by the previously developed experimental method. The investigation has been expanded over a wide bending range up to 1.4 %. Nb_3Sn wires were heat-treated in straight form, and then mounted in a groove on a Ti-6Al-4V clamping-fixture at room temperature in order to bend the wire to a predetermined radius. The preliminary results of the critical current vs. bending show noticeable difference between the two wires. In the low bending range up to 0.4% the critical currents of IGC internal tin wire decrease, while those of Furukawa bronze wire increase. Microstructure cracking investigation of these bending strand samples have be carried out at the University of Wisconsin, Applied Superconductivity Center after the critical current test, in order to correlate the critical current results with filament breakage.

Single Strand Variable Bending Test: A variable bending device has been designed and constructed for characterizing the critical currents of Nb_3Sn superconducting strand under pure bending. This device allows applying strand bending during a test operation in liquid helium. The strand is placed on a support beam plate that is bent through an evolution of pure bending states. This device is capable to apply a large range of bending strain up to 0.7%. The principal mechanism is similar to the previous work of Goldacker, et al. with high temperature superconductor. The challenge to our device development was to establish a given uniform bending to a strand over a large range of applied strain under an electromagnetic force which was generated by the background field and the transport current of the test sample. Verification tests have been performed in the magnetic field of 12 T at 4.2 K. The measured bending distribution along the loaded beam over the sample of about 100 mm length remained within 20% of the intended bending strain. This work will be continued to characterize new ITER wires presently under development.

Effect of transverse stress on the critical current of a 36-strand Nb_3Sn cable: In this experiment, the transverse pressure is applied mechanically. The goal of the experiment is to investigate a critical current degradation of CICC Nb_3Sn cables due to a transverse load. The test cable is composed of 36 (3x3x4) strands resembling the sub-cable pattern 3x3x4x4x6 of an ITER CS cable. To measure the transverse load applied on the cable in the 10-20 MPa range, a strain gauge array is mounted along the outer surface of a sample holder ring while the cable is placed in a groove on the inner surface. The strain gauges measure the surface expansion strains due to the applied transverse load as well as the hoop force due to the electromagnetic Lorentz force of the cable itself. The transverse load is applied to the cable using a conical wedge which transfers a vertical force to a radial, horizontal force. The conical wedge pushes against the sample holder ring while the conical wedge is sliding vertically, so that the cable is squeezed between the ring and the conical wedge. The vertical force is provided with a linear actuator mounted on the top dewar cover flange. The critical current is measured as a function of magnetic fields between 14 T and 10 T at a fixed transverse load. The load is increased in steps. Preliminary tests have been performed and confirmed the probe functionality. A sub-cable of ITER CS model coil wire will be tested early next year.

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