Development of the 20 kA Joints for the Series Connected Hybrid


Introduction
The NHMFL Series Connected Hybrid (SCH) magnet will provide an energy-efficient 36 T to the DC user facility by employing a 20 kA superconducting outsert coil in series with a resistive insert. The electrical joints in the superconducting outsert require a low DC resistance to minimize the refrigeration requirement at the operating temperature of 4.5 K and low AC losses to ensure good stability against quenching during the fast ramps required by the users. A reliable, robust solderless joint technology has been developed at the NHMFL to address these essential requirements. The outsert coil consists of three concentric layer-wound sections using three different grades of Nb3Sn Cable-in Conduit Conductors (CICC): High Field (HF), Middle Field (MF) and Low Field (LF). There are four internal splice joints in the outsert, which are Nb3Sn to Nb3Sn joints made to the same design configuration. There are also two terminal joints between the Nb3Sn outsert and the two NbTi buslines, which connect the outsert terminals to the two current leads. The full size splice joint: High field – Middle field joint was tested after fabrication to (a) fully characterize both the DC and AC performance in operational field environments and (b) thermally and mechanically cycle the joint to confirm its long term reliability.

Joint Test Result
The result of the DC resistance test of the HF-MF joint is shown in figure 1 and shows a resistance of less than 0.6 nΩ up to 5 T. The fatigue test and the thermal cycle test were performed on the HF-MF joint. The background field is cycled 1000 times between 0.5 and 4 T, while the transport current in the joint sample was held constant at 20 kA. The thermal cycling was done by cooling the experiment to 4.2 K using liquid helium and then warming to room temperature. No degradation in joint performance was observed in the test.

Two different field pulse shapes have been applied in the AC test: a triangle pulse and a trapezoid pulse. In general there are four types of loss in a SC cable joint: (a) hysteresis loss of the SC wires inside the cable; (b) coupling loss of individual cable sections inside the joint box; (c) eddy current loss of metal parts inside the joint box; (d) inter-cable current loss, due to current induced by pickup from the main field via the loop in the joint. The hysteresis loss dominates at low ramp rates. The inter cable loss dominates at high ramp rates. Fig. 2 shows the total loss power as a function of ramp rate. The AC loss at the normal ramp rate of the SCH is quite small, less than 0.2 W, which is much less than the dc dissipation of the joint.

Conclusions
The test result confirmed that the Florida Solderless Joint technology has a low DC resistance and very low AC loss. The LF-Busline joint is in the fabrication process and will be tested in the near future.

References