Progress of HTS STARS Conductor Development for the Next-Generation Helical Fusion Experimental Device

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Abstract **—Large-current capacity High-Temperature Superconducting (HTS) conductors are being developed at National Institute for Fusion Science (NIFS). Three kinds of conductors, named STARS, FAIR, and WISE have been developed in parallel with different internal structures. For all these conductors, the target is to achieve 10-20 kA current at a magnetic field of 10-14 T and temperature 20 K with a high current density of 80 A/mm^2. In this paper, the progress of one of these conductors, STARS (Stacked Tapes Assembled in Rigid Structure), is described. The STARS conductor was originally developed to be applied to the helical fusion reactor FFHR with a 100-kA current capacity. A prototype conductor sample with a total 3-m length achieved 100 kA, having a 300-mm portion under 5 T magnetic field and 20 K temperature control. The STARS conductor uses REBCO HTS tapes simply stacked, imbedded in a copper (Cu) stabilizer and stainless steel (SS) reinforcement jacket. The conductor is mechanically robust without having any deformation in REBCO tapes due to non-twisting and non-transposing. Recently, a 20-kA-class STARS conductor is being developed to be applied to the next-generation helical experimental device. A 3-m-long sample was fabricated with laser beam welding successfully applied to the SS jacket, whereas bolts were used in the 100-kA prototype. The sample was tested in liquid nitrogen at 77 K with no external magnetic field. The critical current was measured at 3.9 kA, which was well explained by the sum of the critical current of a single REBCO tape considering the current density and magnetic field distribution among tapes. In the next step, this conductor sample was tested (with 2-m length) in the large superconductor testing facility at NIFS. A 20-kA current was stably transported at 8 T, 20 K. The critical current was observed at 11.2 kA with 8 T, 40 K. In parallel, another 3-m sample was fabricated having an internal electrical insulation between the Cu stabilizer and SS jacket. The critical current was observed in liquid nitrogen almost exactly at the same 3.9 kA with the former sample (having no internal insulation). This conductor will be extended to make a 6-m long sample which will be tested in 13 T, 20 K with a 600-mm diameter coiled structure (3 turns). In order to examine the feasibility of simple stacking, non-uniform current distribution was forcibly formed in a simple stacking of five REBCO tapes assuming a worst-case scenario. The sample was stably excited up to the critical current determined for the five tapes without quenching. A numerical simulation dealing with current distribution among these tapes reproduces the experimental observation, giving insights into the possibility that twisting and transposition might be optional.**

Keywords (Index Terms) **— Fusion, helical, HTS magnet, STARS conductor.**

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