§17. Improvement of Superconducting Pulse Coils Using Tapes with High Aspect Ratio of Cross-section

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Superconducting coils for fusion devices have been wound with NbTi or Nb_3Sn superconducting conductors. In order to improve performance of the fusion device, however, it is necessary to develop superconducting coils with high stability and low losses. We have been investigating to improve performance of MgB_2 and NbTi wires. We have experimentally clarified that electromagnetic properties improve by forming into tape shape from round wires with circular cross-section. On the tapes, their critical currents increase and their ac losses decrease. In this study, stability of a test conductor composed of five MgB_2 tapes has been evaluated. And then, a new method using additional coils to improve performance of superconducting coils wound with the tapes mentioned above has been investigated experimentally [1].

Stability of a transposed conductor with five MgB_2 tapes has been calculated. The tapes are rolled from an in-situ wire with circular cross-section. The wire is composed of MgB_2/Nb/Cu. The aspect ratio of the tape is 2 ($1mm^w$x $0.5mm^t$). The tapes were assembled to the transposed conductors, and heat treatments were carried out after the conductor assembling. Positions of the tapes in the cross-section of the test conductors were changed in turns every 50 mm in direction of the conductor axis. Samples are straight with length of 400mm. A FRP holder covered these samples, and gaps between samples and the holder were filled epoxy. The cooling conditions of samples were simulated conduction-cooling conditions by immersing the sample holder in liquid helium. Note that, measured critical currents of the conductor were 215A under 5T in dc magnetic fields.

Stability of the conductor mentioned above has been evaluated by three-dimensional analyses using ANSYS®. In this study, thermal analyses were carried out on the conductor under bias magnetic field of 5 T. The calculations were carried out as follows: firstly, the conductor was locally heated by heater put on one strand at the center of the sample. The time of heating was 5 msec. During and after the heating, the temperature of the conductor was calculated. Minimum input energy to achieve a current sharing temperature was calculated as minimum quench energy (MQE). Results of calculations are shown by a solid line in Fig. 1. Measured data are also shown in Fig. 1. Ratios of transport current I_t to critical current, I_C were 0.8 (I_t = 172 A) and 0.6 (I_t = 108 A) at which the data were measured. These data were minimum input energy to generate electric fields of 1μV/cm when a carbon heater heated one strand of the conductor. The measured data are near the solid line. That indicates that our calculation is appropriate.

Next, effects of a method to suppress the change of magnetic fields using additional coils to reduce ac losses in the coil wound with a superconducting tape with high aspect ratio were investigated experimentally. In the additional coils, both ends of its winding were connected electrically to compose short circuit. In addition, the additional coils are insulated from main coil wound with the tape. The additional coils suppress the change of perpendicular magnetic fields applied to the winding tape of the main coil around the both edges of the coil. As the result, ac losses can be decreased. Fig. 2 shows the experimental results of ac loss measurements on a sample coil wound with Bi-2223 multifilamentary tapes. The experiments were carried out on the sample coil, in liquid nitrogen, which transported ac currents superimposed on dc bias currents. It was confirmed experimentally that ac losses reduce by 30 – 40 % by using the additional coils. Consequently, the validity of the method to suppress the change of magnetic fields using additional coils is confirmed.

1) T. Katayama, et al, Abstracts of CSSJ Conference, Vol. 87 (2013), p. 156.

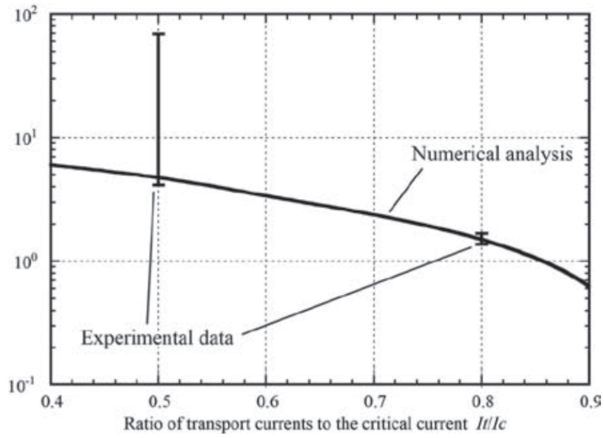

Fig. 1 MQE of MgB_2 transposed conductor.

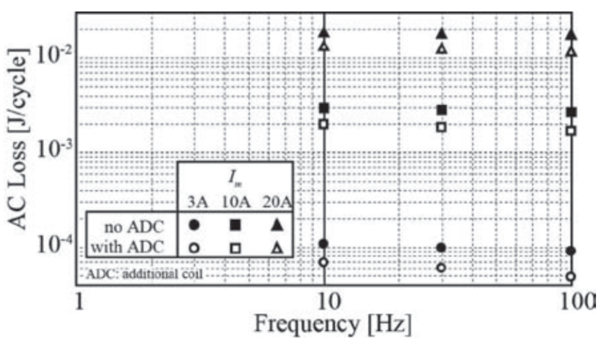

Fig. 2 AC losses in a sample coil with additional coils to suppress change of magnetic fields.