§12. Development of a New Conductor Controlled the Twist Angle to Improve the Performance of LTS Coils

Sumiyoshi, F., Kawabata, S., Kawagoe, A.
(Kagoshima Univ.),
Mito, T.

The development of SMES to protect from momentary voltage drops is conducted. In this SMES, conduction-cooled low temperature superconducting (LTS) pulse coils are used. The conduction-cooled prototype coil was fabricated and tested.[1,2] The coil was wound by new design method for coils, in which the twist angles around the axis of the conductor are controlled according to the coil shape. The results of the tests on the coil showed that the coil has high performances. In this coil, however, there are some problems, for example, the winding conductor is not optimized, and the special winding machine is needed for winding this coil. As a result, the cost of the coil is increased.

The purpose of this study is to develop the new conductors which are used as windings of conduction-cooled LTS pulse coils with both low ac loss and high stability. For the purpose, several kinds of NbTi/Cu multifilamentary tapes with high aspect ratio were fabricated. For these tapes, critical currents, magnetizations, coupling losses were measured.

The aspect ratio of the fabricated test tapes were increased by rolling the round wires composed of single matrix of cooper. Therefore, the conductors are expected to have high performances as follows: (1) Ac loss in the tape under changing transverse magnetic fields oriented to parallel to its flat face is reduced. (2) The stability increases because matrix of the tape is cooper and surface cooling is possible. (3) The cost is reduced, because the tape can be fabricated by simple fabrication process which is rolling the round wire.

The parameters of four samples are shown in Table 1. 'HA00' is before rolling. The other three samples are new tapes which are increased their aspect ratio by rolling the sample HA00. The sample HA11with the highest aspect ratio of 7.4 are most interest samples

When the transverse magnetic fields were applied parallel to the flat face of the new tapes with high aspect ratio, the measured critical currents of these samples were increased with increase in aspect ratio. Especially, the critical currents of the sample HA11 increased to1.19 times that of the sample HA00 at 8 T.

The magnetization curves of each sample were measured by VSM. The transverse magnetic fields applied perpendicular and parallel to the flat face of tapes. In the measured magnetization curves, the proximity effect was not observed. In addition, the effective diameter of filaments, d_{eff}, which were normalized ΔM by critical current densities, J_c, were obtained. When transverse magnetic fields applied parallel to the flat face of samples, the d_{eff} of HA00 was 4 μm, and one of HA11 was 2.8 μm. The d_{eff} of HA11 is smaller than that of HA00. Therefore, it is found that the hysteresis losses in the tape decrease in spite of increase in critical current by rolling process.

Coupling losses were measured. Measuring conditions are as follows: The measurements were carried out in liquid helium, at 4.2 K. The dc bias magnetic fields were 0.5 T and 1.0 T. Amplitudes and frequencies of the ac ripple magnetic fields are from 0.1 to 1.6 mT and from 0.7 to 335.5 Hz. Transverse magnetic fields applied to the samples in directions parallel to the flat face of the tape.

The coupling time-constants of each sample, which are obtained from measured their coupling loss properties, are listed in Table 2. The coupling time-constants are given by dividing measured coupling losses by $\mu_0 H_m^2 \pi\omega$, where H_m, μ_0 and ω are amplitude of applied magnetic fields, permeability of vacuum and angular frequency, respectively. The experimental values almost agree theoretical values. The coupling losses in the samples with high aspect ratio, HA09, HA10, HA11 are decreased by rolling process. Especially, coupling loss in the sample HA11 are 1/17 times that of the sample HA00.

Consequently, we found as follows: (1) The hysteresis losses were decreased in spite of increase in critical currents. (2) The coupling losses in the sample with high aspect ratio decreased greatly than the coupling loss in the round wire.

References

[1] T. Mito, et al., IEEE Trans. Appl. Supercond., Vol.15, No.2, pp. 1935-1938

[2] A. Kawagoe, et al., IEEE Trans. Appl. Supercond., Vol.15, No.2, pp. 1891-1894

Table 1 Parameters of samples

Sample	HA00	HA09	HA10	HA11
Dimension	$1.24mm^{\phi}$	$0.502mm^{t} \times 2.483mm^{w}$	$0.461mm^{t} \times 2.736mm^{w}$	$0.403mm^{t} \times 2.984mm^{w}$
Diameter of filament	16μm	–	–	–
Aspect ratio	1	4.9	5.9	7.4
Cu ratio	2.4	←	←	←
Twist pitch	27mm	←	←	←
RRR	50	39	37	37

Table 2 Coupling loss time-constants

Sample	HA00	HA09	HA10	HA11
Experiment [msec]	8.61	0.76	0.47	0.14
Theory [msec]	14.3	1.06	0.76	0.46
Experiment/Theory	1/1.66	1/1.41	1/1.61	1/3.24