§21. Development of a New Type Superconducting Conductor with High Stability and Low Losses

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Large inter-strand coupling losses are produced in superconducting conductor under changing transverse magnetic fields. Increasing contact resistance between strands is effective in reducing losses. However, the high crossover resistance tends to result in low stability because transport current shearing is also suppressed. In order to solve the dilemma of low losses and high stability, we proposed a new type Rutherford cable with the following structures: (1) The strand twist is the same direction as the cable twist. (2) The strand twist pitch is relatively longer than the cable twist pitch (3) The cable has good crossover contacts between strand pairs located near each edge of the cable cross-section. We have already shown decrease in coupling losses in a new type Rutherford cable by 2D-FEM analyses [1]. In this experiment, we fabricated four sample cables and measured coupling losses in these samples in order to confirm the reduction of inter-strand coupling losses in a new type Rutherford cable.

Parameters of samples are listed in Table I. We prepared samples without stainless steel tapes, NS, and with one, SS. Additional indices 'S' and 'L' represent short and long twist pitches of strands, respectively. As shown in this table, stainless steel tapes with a thickness of 25 μm are used to maintain a high resistive crossover contact between strands in cables. In the same cable, metallic bonding formed by annealing at 200 ℃ in nitrogen gasses under clamp pressure of 30 MPa is used to maintain low resistive crossover contact. Sample cables were formed into a straight cable by clamping 5 individual cables together using stainless steel boards and bolts. Clamp pressure was not released after measurement. We measured coupling losses in samples to which were applied small ac magnetic fields with amplitudes of $\mu_0 H_m$=8G and 16G. These small ac magnetic field were superimposed on dc bias magnetic fields of $\mu_0 H_{dc}$=0.5T. We can get coupling losses directly without any analysis of measured data, because hysteresis losses are usually negligible in our measurement. The loss is measured by magnetization methods with the transverse magnetic fields applied either perpendicular to or parallel to the broad cable face, the "face-on"(FO) and "edge-on"(EO) orientations, respectively.

Figure 1(a) shows the dependence of the coupling loss on twist pitches of strands at 0.01Hz, where losses for all samples are taken by extrapolating from data, and are proportional to frequency. The vertical and horizontal axes are the loss per cycle per unit volume normalized by $\mu_0 H_m^2$, W, and the twist pitch of strands L_s, respectively. Measured loss for transverse magnetic field applied with EO orientation, W_{EO} are represented as ▽. Four data of W_{EO} are thought to correspond to intra-strand coupling losses, W_s because they are on a line proportional to L_s^2. The solid symbols represent measured loss for transverse magnetic fields applied with FO orientation, W_{FO}. Inter-strand coupling losses, W_c are got by subtracting W_{EO} from W_{FO}. W_c are represented as open symbols. W_c are 25% and 50% reduced with increase in L_s for NS and SS, respectively. The solid line, broken line and chain line show calculated result of inter-strand coupling losses, total coupling losses and intra-strand coupling losses by 2D-FEM analyses, respectively. A good agreement between theory and experiment is seen

In this experiment, as a result of large intra-strand coupling losses we found no decrease in total coupling losses in samples. Therefore, in order to reduce total coupling losses in Rutherford cable, superconducting multifilamentary wires with complex structures must be used as strands. For example, a high resistive barrier is arranged to suppress coupling currents flowing around the outer region of the strands. We carried out 2D-FEM analyses using this strand. Results of this analysis are shown in Fig. 1(b) The solid line, broken line and chain line are total coupling losses, inter-strand coupling losses and intra-strand coupling losses, respectively. In this case, total coupling losses decrease with an increase in the twist pitches of strands.

In order to confirm the reduction of inter-strand coupling losses in our cable, we prepared test cables using our design method, and coupling losses in these cables were measured. A decrease in inter-strand coupling losses with increase in twist pitches of strands was confirmed. We found that total coupling losses decreased when multifilamentary wires with complex structures were used as strands in Rutherford cables.

Table I. Parameters of sample cables

Sample name	NS_S	NS_L	SS_S	SS_L
Cable				
Number of strand	18			
Twist pitch	56mm	56mm	55mm	55mm
Twist direction	Z			
Thickness of sheet	-	-	25μm	
Width of sheet	-	-	3mm	
Strand				
Diameter	0.59mmϕ			
Twist pitch	9.5mm	172mm	9.5mm	93mm
Twist direction	S	Z	S	Z

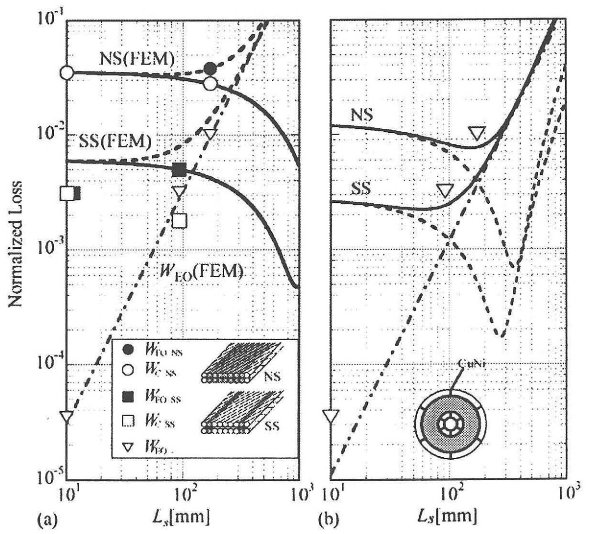

Fig. 1 Dependence of coupling losses on strand twist pitch.

Reference

[1] Gohda, T. et al., Proc. of ISS '99, 775-777 (1999).