§6. Study on Long Loops with Long Time Constants in Cable-in-Conduit Superconductors

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The superconducting coils wound with Cable-In-Conduit Conductors(CICCs) which are composed of several stages of sub-cable has been applied to large devices such as experimental fusion apparatuses and Superconducting Magnetic Energy Storage (SMES) devices because of its high mechanical and dielectric strength. In recent years there has been a growing interest in coupling loss with long time constants (> 1sec) which are not observed in test result using short sample conductor [1]. In addition, the extra increment of the loss with 15% is observed when the large electromagnetic force is applied to the conductor[2]. Our previous works revealed that the production of the coupling loss with long time constants is due to the line contact condition between strands. The loss is expected to be large as a result of the longer contact length, in other words, the lower contact resistance.

In this work, we investigate the change of the contact condition between strands induced by the electromagnetic forces by applying the transverse compression to the conductor.

Figure. 1 shows the experimental setup for the measurement of the change of the transverse resistance of the conductor. The sample conductor is the OV coil conductor of 210mm in length which consists of 486 ($3^4 \times 6$) NbTi strands. In order to apply the compression, the conduit of the conductor is removed of 70mm in length at both up and down side. Two Cu electrodes put pressure and feed the constant current to measure the transverse resistance. The resistance, deformation of the conductor and the applied pressure are measured through a data acquisition system.

The compression procedure is that the pressure is holded during 120sec at interval of 4kN/m from 0kN/m to 100kN/m, and repeated three times. Fig. 2 shows the deformation of the conductor versus applied load in each compression cycle. In the 1st cycle, the deformation range is large compare to other cycle. In the 2nd and 3rd cycle, the deformation does not start from 0mm. This indicates that the conductor deformed plastically at the first cycle. On the other hand, the deformation at all cycle converges to a fixed value.

Figure. 3 shows the transverse resistance versus applied load in each cycle. In the 1st cycle, the resistance decreased significantlly. But in the 2nd and 3rd cycle, the decrement was smaller than that in the 1st cycle. The initial resistance in 2nd and 3rd cycles were smaller than that in the 1st cycle.

It is predicted that the reduction of the resistance is caused by increment of inter-strand contact cross section. According to the Elastic theory, the contact width is expressed as the equation:

$$b = 1.6\sqrt{p\frac{d_f}{2}\left(\frac{1-\upsilon^2}{E}\right)} \qquad (1)$$

Where b is the contact width, p is applied load, d_f is strand diameter, ν is Poisson's Ratio of Cu and E is Young's Modulus. Assuming that the contact resistance is inversely proportional to the contact width, the resistance is proportional to $p^{(-1/2)}$. The $p^{(-1/2)}$ line is also shown in Fig. 3. The resistances with high pressure side in all cycle agree with the $p^{(-1/2)}$ line, it is indicated that the inter-strand contact conditions are subjected to the elastic deformation of strands. It is thought that the curves which are different from $p^{(-1/2)}$ line are caused by increment of the current pathes or contact length due to deformation of the strand positions.

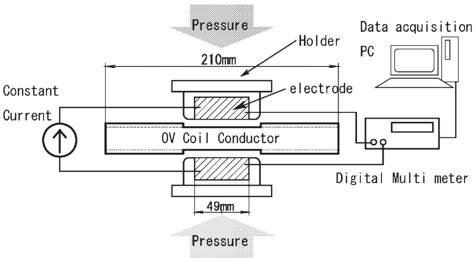

Fig. 1: Experimental setup for compression test

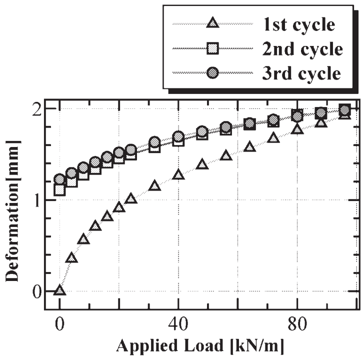

Fig. 2: Deformation of the conductor vs. applied load

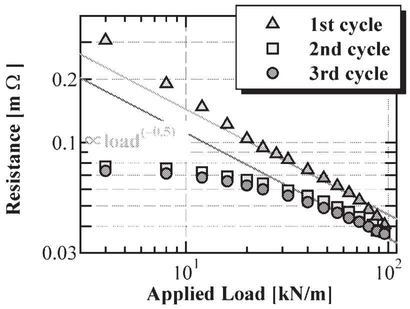

Fig. 3: Transverse resistance of CICC vs. applied load.

Reference

1) Hamajima, T., et al.: Cryogenics, **39** (1999) 947.

2) Hamajima, T., et al.: IEEE Trans. Appl. Supercond. **10**, (2000)812