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인슐레이션을 제거한 초전도 코일의 특성 평가

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Characteristic evaluation of an insulationless superconducting coil

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Abstract - This paper reports advantages of an insulationless high temperature superconductor (HTS) pancake coil compared with an insulated HTS pancake coil. The various characteristics of the insulationless HTS pancake coil were evaluated under charge-discharge conditions. Also over-current test was performed and the results were analysed to demonstrate that in terms of stability insulationless HTS pancake coil outperforms existing insulated HTS pancake coil.

1. Introduction

Superconductivity has been an enabling technology for many advanced applications. Also, the recent development of superconductivity has driven many of the advances including insulation which is an essential element in the superconducting magnet. Development of a insulation by using diverse materials is being achieved in order to increase insulation strength and decrease volume of insulation [1], [2].

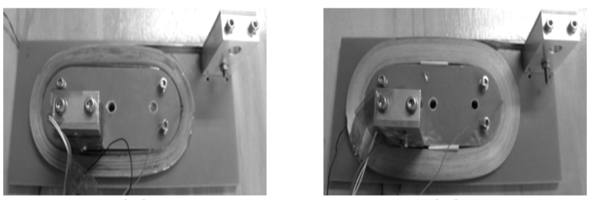
The superconducting magnet without insulation also has been investigated because of zero resistance in superconducting magnet. The insulationless HTS coil has many advantages that it is not only easy to create but also decrease the volume of HTS coil compared with an insulated HTS coil. But first of all, the big advantage of an insulationless HTS coil is that it doesn't need quench protection system because its stability is higher than insulated HTS coil. Stability and protection from a quench are very important for design and operation of HTS magnet [3-5]. So the elimination of insulation will benefit the properties of superconducting magnet, particularly its stability.

In this paper, a comparison study was performed on the insulationless and insulated HTS coils in liquid nitrogen at 77 K. Specific aspects of each HTS coils were investigated under charge-discharge and over-current conditions, and insulation dependent stability characteristics of HTS coils are described.

2. HTS racetrack pancake coil test

2.1 Two types of coil: Insulated and Insulationless

Fig. 1 shows the racetrack pancake test coils. Table 1 summarizes parameters of the test coils. Both coils were wound with BSCCO wire and the number of turns of insulated racetrack pancake coil is 50 and the insulationless racetrack pancake coil is 60. Kapton tape is used for the insulation of insulated HTS racetrack pancake coil.



(a) (b)

<Fig. 1> Racetrack pancake test coils: (a) Insulation winding with kapton tape, (b) insulationless winding

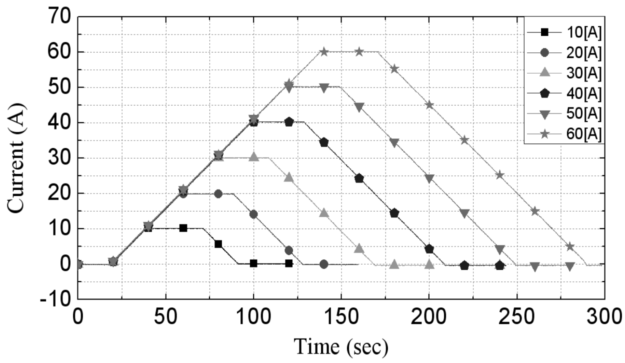
The critical currents of the insulated and insulationless HTS racetrack pancake coils are 32 A and 30 A, respectively. A hall senor is placed on a separate plate and positioned at the center point of each coil. All tests were performed in liquid nitrogen at 77 K.

<Table 1> Parameters of the racetrack pancake test coils

Parameters	Insulated	Insulationless
Wire type	BSCCO wire	
Wire width; Thickness [mm]	4.2; 0.23	
I.d.; O.d.; Height [mm]	20; 31; 4.2	20; 33.2; 4.2
Length of straight [mm]	60	
Total wire length of coil [m]	14.1	17.3
Insulation	Kapton tape	x
Insulation width; Thickness [mm]	4.2; 0.026	N/A
# of Turn	50	60
Quench voltage [V (mV)]	1.41 (0.00141)	1.73 (0.00173)

2.2 Test result and analysis

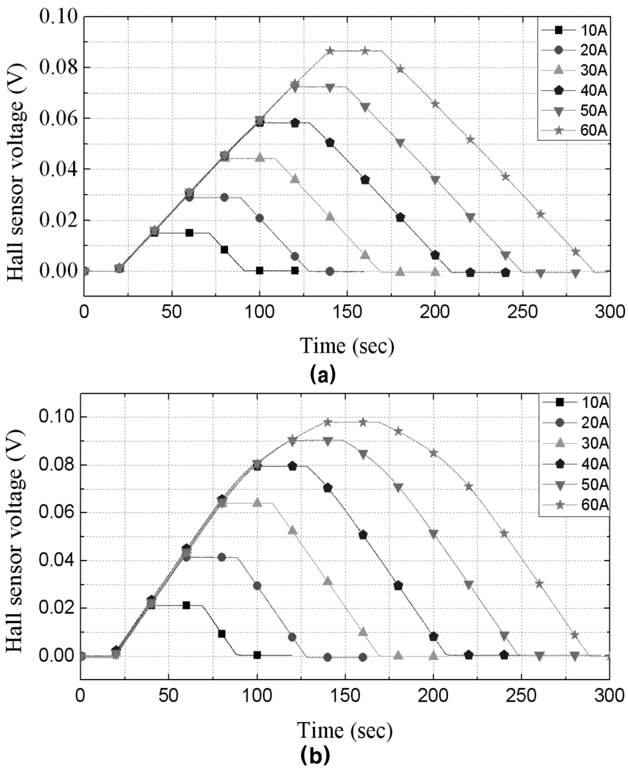
Fig. 2 shows the charge and discharge current of test coils. The current flows with an increment of 10 A to 60 A through the insulated and insulationless HTS coils.



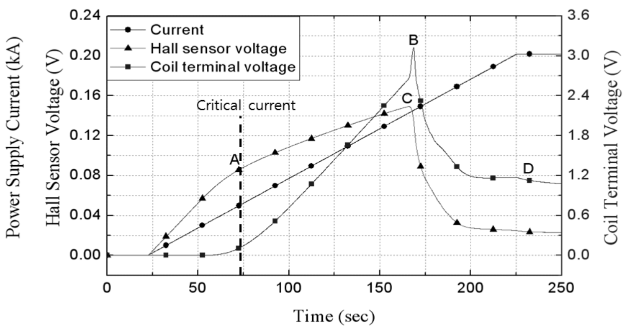
<Fig. 2> Charge and discharge current of the test coils

Fig. 3 presents the hall sensor voltages according to the charge and discharge current for these coils. The hall sensor voltage in an insulated HTS coil increases linearly in proportion to the current as shown in Fig. 3 (a). But the inclination of the insulationless HTS coil changes after 30 A as shown in Fig. 3 (b). It means that the current bypassed through the turn-to-turn contacts of the insulationless HTS coil. And the both coils keep stable charge and discharge patterns under the critical current.

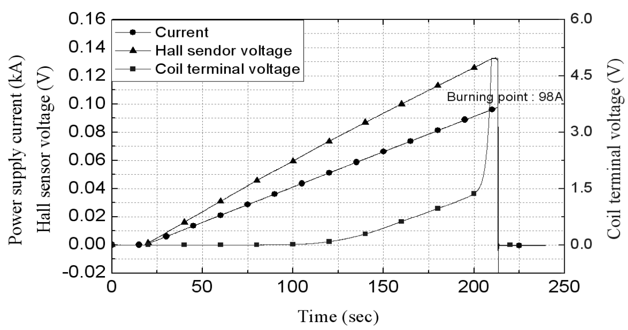
Fig. 4 presents the over-current test result of the insulaionless HTS coil. The circle-marked line stands for the power supply current, the square-marked line shows the coil terminal voltage, and the triangle-marked line represents the hall sensor voltage. At point "A", the inclination of hall sensor voltage relieves because the current exceeds the critical current. At point "B", and "C", the hall sensor voltage and coil terminal voltage starts to decrease sharply. It means that the current reaches the critical current and then the primary current-sharing occurs at the stabilizer layer of coil which changes the current density. So the inclination at point "B", and "C" was changed. At point "D", the coil reaches "steady-state" condition. For comparison, an insulated HTS coil test of the same conductor has been carried out, the test coil was burned out at 98 A as depicted in Fig. 5. This over-current experiment demonstrates that an insulationless HTS coil may have better over-current characteristics than a conventional insulated HTS coil.



<Fig. 3> Hall sensor voltages of the test coils: (a) Insulated HTS coil, (b) Insulationless HTS coil

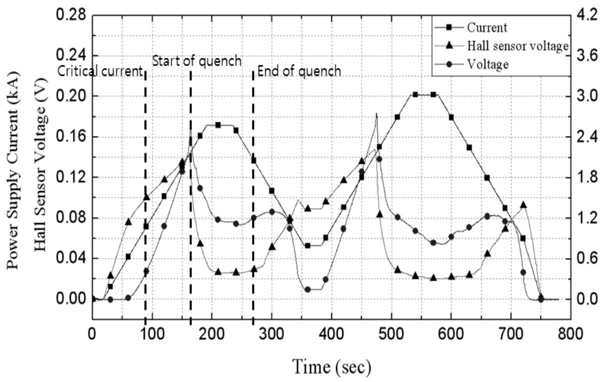


<Fig. 4> Over-current test result of insulationless HTS coil up to 200 A



<Fig. 5> Over-current test result of insulated HTS coil

Fig. 6 presents the results of two times of charge and discharge for the insulationless HTS coil. The primary charge current is 170 A and 200 A for the second charge. The insulationless HTS coil operated stably at the currents higher than the critical current due to the characteristic of magnetic field recovered after the quench by the current-sharing. It is confirmed that the insulationless HTS coil wasn't influenced by the quench and the normal charge-discharge could also be repeated.



<Fig. 6> Over-current test results of the insulationless coil under continuous charge and discharge

3. Conclusions

The insulated and insulationless HTS pancake coils were tested. Charge-discharge and over-current tests were performed. Based on the test results and analysis, the authors may conclude as follows.

The insulationless HTS test coil was successfully operated with stable charge-discharge behaviors. And although the insulated HTS coil was burned out at 98 A, the insulationless HTS coil with the same conductor carried 200 A without damage. Therefore the characteristic of the insulationless HTS coil is better than the insulated HTS coil under the over-current condition. Finally, this results prove that the insulaionless HTS coil may enable a HTS magnet with better over-current stability.

Acknowledgement

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