Characteristic Resistance Measurement of No-Insulation REBCO Pancake Coil under Different Conditions

So Noguchi[1], Takahiro Tasuta[2], Daisuke Nishikawa[2], Hiroshi Ueda[2], and SeokBeom Kim[2]
1. Hokkaido University, Japan 2. Okayama University, Japan

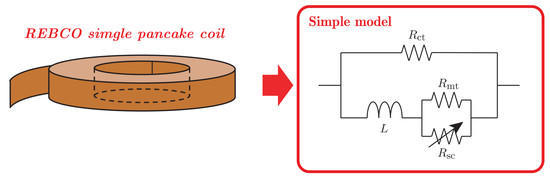
Introduction

The turn-to-turn contact resistance is a very important factor to a no-insulation (RE)$Ba_2Cu_3O_y$ (REBCO) pancake coil. It characterizes the stability and charging delay of NI REBCO pancake coils. However, the conventional sudden-discharging method cannot measure the turn-to-turn contact resistance under different conditions, such as an operating current, a temperature, and an external magnetic field. Since the turn-to-turn contact condition is strongly affected by the pressure inside of the NI REBCO coils, the feature of the contact resistance must be clarified to estimate the stability of NI REBCO coils.

We have proposed a new method to measure the turn-to-turn contact resistance applying a low-frequency AC current. The theory and the measurement results are also shown. The turn-to-turn contact resistance was measured at DC currents of 0, 10, 40, and 80 A. In addition, the contact resistance change was also investigated during heating the NI REBCO coil.

Proposed Measurement Method

The pancake coil is represented by the following equivalent circuit.



When R_{sc} = 0, the coil impedance to AC current is

$$Z = \frac{j\omega L R_{ct}}{R_{ct} + j\omega L}$$

When $\alpha = \left| \frac{R_{ct}}{j\omega L} \right| \ll 1$,

$$Z = R_{ct}$$

The coil impedance Z for AC component corresponds to the contact resistance. However, when the frequency is too high, the measured contact resistance is affected by AC loss. The frequency is better in the range of 5 to 100 Hz.
The validity of the proposed method has previously been confirmed by comparing the results of sudden discharging method.

SPECIFICATIONS OF MEASURED NI REBCO PANCAKE COIL

Inner daimeter (mm)	60
Length (mm)	4
Number of turns (turn)	60
Measured inductance L (mH)	0.414
REBCO tape	Super Ox 2G HTS wire

MEASURED TURN-TO-TURN CONTACT RESISTANCE AND RESISTIVITY

Measurement method	Sudden-discharging	Proposed
Contact resistance R_{ct} (mΩ)	0.208	0.236
Contact resistivity ρ_{ct} (μΩ cm^2)	29.2	33.2

Characteristic Resistance at DC current operation

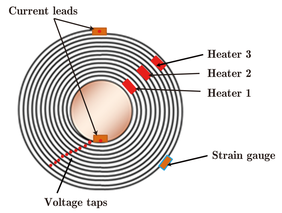
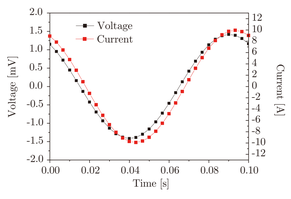


TABLE I
SPECIFICATIONS OF NI REBCO PANCAKE COIL

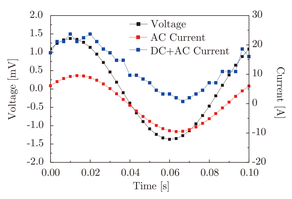
i.d.; o.d. [mm]	60.0; 62.9
REBCO tape thickeness [mm]	0.144
REBCO tape width [mm]	4
Number of turns	10
Inductance L [μH]	12.2

TABLE II
CONTACT RESISTANCES AND RESISTIVITIES

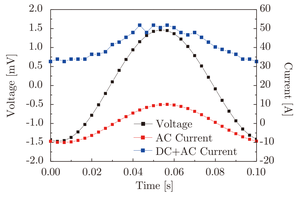
DC current [A]	0	10	40	80
Contact resistance R_{ct} [μΩ]	142.6	143.9	146.3	146.3
Contact resistivity ρ_{ct} [μΩ · cm^2]	122	123	125	125



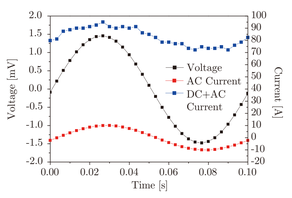
0 A DC current



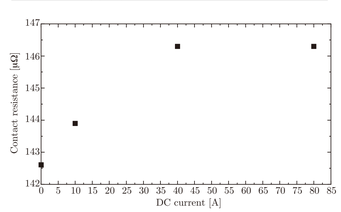
10 A DC current

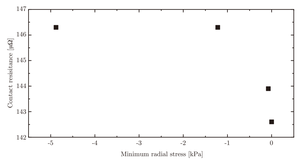


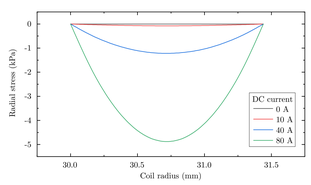
40 A DC current



80 A DC current



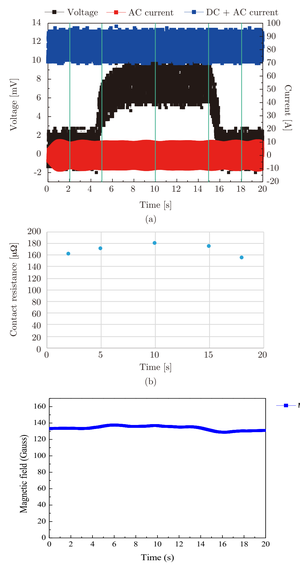




The turn-to-turn contact resistance was measured by superimposing AC current (10 A, 10 Hz) to DC current. It corresponds the AC component of impedance, Z_{AC}.

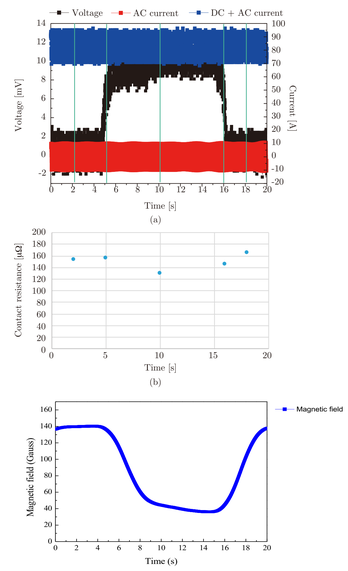
Characteristic Resistance Change by Heating

Heater 1 (10 W, 10 s)



The center field was constant. The azimuthal current would be induced in the outer turns. Therefore, the characteristic resistance increased.

Heater 2 (10 W, 10 s)



The center field dropped largely. The azimuthal current would decrease mostly. Therefore, the characteristic resistance decreased.

Conclusion

We have proposed a method to measure the turn-to-turn contact resistance of no-insulation (NI) REBCO pancake coil. The coil impedance corresponds to the turn- to-turn contact resistance when an AC current with low frequency is applied. However, a high-frequency current produces an AC loss. From the simulation results, it is confirmed that the adequate range of the frequency is 5 Hz to 100 Hz.

We measured the turn-to-turn contact resistance at different DC current by superimposing an AC current of 10 A, 10 Hz. In addition, it was also measured during heating the NI REBCO coil. To explain the phenomenon, an accurate multi-physic simulation must be performed in near future.