AC Loss Measurement of High-Tc Superconducting Coil Wound with Stacked Conductors under the Various Electro-magnetic Conditions

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Background
For the practical application of High-Tc superconducting (HTS) power machines and devices with high performance, it is necessary to develop HTS conductors with low losses and large current capacities. The HTS conductors with large current capacities are made by stacking HTS tapes. Therefore, it is important to minutely investigate AC losses of HTS coils wound with stacked conductors.

On the other hand, an application field of superconducting technology is expanding, so it is also necessary to investigate the AC loss characteristics of the HTS coil driven by power electronic circuits.

Objectives
- The purpose of this study is to elucidate the AC loss characteristics of HTS coils wound with stacked conductors.
- In this paper, we measured AC losses of Bi-2223 sample coil under the various electro-magnetic conditions.

 experimental setup

AC Loss Measurement System
Nitrogen Boil-off Method

AC loss measurement was performed by a nitrogen boil-off method. We measured the magnetic amplitude dependence and the frequency dependence of AC losses of sample coils under external magnetic fields, and evaluated the magnetization loss and additional coupling current loss.

experimental results

Calibration Test
Calibration Results of AC Loss Measurement System

The time variation of the relation between boil-off power and the heater power.

The relation between the boil-off power and the heater power.

Since the polynomial regression curve and measured values show good agreement, it is assumed that high-precision measured results for AC losses can be obtained by using the relation between the boil-off power and the heater power.

This calibration test was done for every AC loss measurement.

Stacked Conductors & Sample Coil

Magnetic Field Distribution of Cu Mag.

Experimental Circuit

Exciting current wave form of Cu magnet
- Sinusoidal wave
  Function generator + Power amplifier
  \( f = 50 \text{ Hz}, 100 \text{ Hz}, 150 \text{ Hz} \)
  \( f = 5 \sim 20 \text{ Arms} \)
- Trapezoidal wave
  Power electronic circuit

The power supply unit consists of an asymmetric H-bridge inverter system. The command current is provided by a function generator. The PWM signals for IGBT control of the inverter are generated by comparing the measured current from a current sensor with the command current.

Objectives

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- In this paper, we measured AC losses of Bi-2223 sample coil under the various electro-magnetic conditions.

Conclusion

- In order to elucidate AC loss characteristics of High-Tc superconducting coil wound with stacked conductors, we measured AC losses of Bi-2223 sample coil under the various electro-magnetic conditions by a nitrogen boil-off method.
- Since measured results and the calculated results of magnetization loss were in good agreement, we found that AC loss can be measured with sufficient accuracy by our measurement system.
- By measurement using power electronic circuits, we could clarify the difference in the AC loss characteristics when sinusoidal wave magnetic fields and trapezoidal wave magnetic fields are applied to the sample coil, respectively.

Experimental Results

Magnetization Loss

Coil ends : opened

Magnetic field amplitude dependence of AC loss in the sample coil.

Since measured results and the calculated results are in good agreement, we find that AC loss can be measured with sufficient accuracy.

The solid line is a calculated value using the Bean-London model.

Coil ends : Shorted

sinusoidal wave

Magnetic field amplitude dependence of AC loss in the sample coil under sinusoidal field.

Coil ends : open circuited

Magnetic field amplitude dependence of AC loss in the sample coil under sinusoidal field.

When the coil end is short-circuited, measured AC losses increase due to additional coupling loss as compared with the values when the coil end is open circuited.

Additional Coupling Current Loss

Rise time dependence of trapezoidal wave

Magnetic field amplitude dependence of AC loss.

Rise time dependence of AC loss.

Magnetic field amplitude dependence of AC loss in the sample coil under trapezoidal wave field.

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