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.

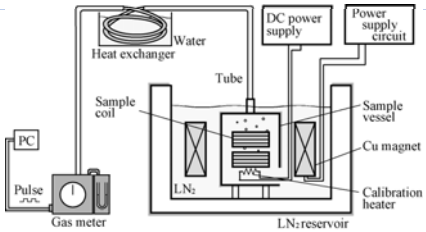
Conclusion

- 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 Setup

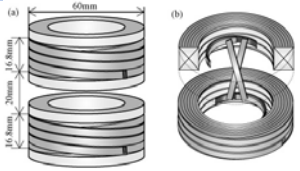
AC Loss Measurement System

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.

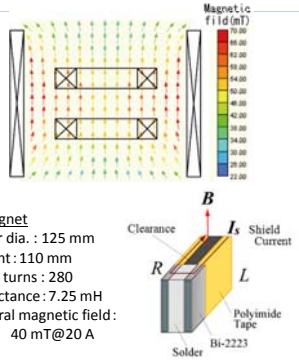
Stacked Conductors & Sample Coil



Bi-22223 tape
Ic@77K, s.f : 116 A
Width : 4.1 mm
Thickness : 0.21 mm

Sample coil
Inner dia. : 40 mm
Total turns : 33
Layer number : 11

Magnetic Field Distribution of Cu Mag.

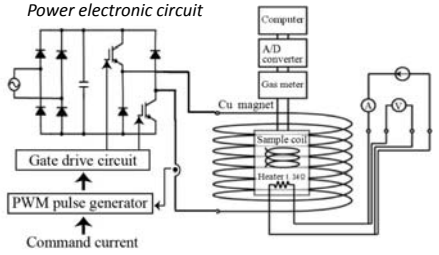


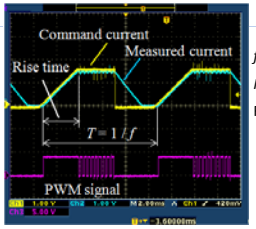
Cu magnet
Inner dia. : 125 mm
Height : 110 mm
Total turns : 280
Inductance : 7.25 mH
Central magnetic field : 40 mT@20 A

Experimental Circuit

Exciting current wave form of Cu magnet

- Sinusoidal wave
  Function generator + Power amplifier
  f = 50 Hz, 100 Hz, 150 Hz I = 5 ~ 20 Arms
- Trapezoidal wave
  Power electronic circuit





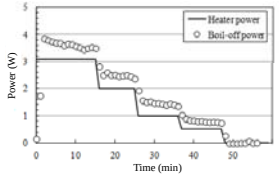
f = 50 Hz, 100 Hz, 150 Hz
I = 10 A, 15 A, 20 A
Rise time = 2 msec, 4.2msec

The power supply unit consists of an asymmetric H-bridge inverter system. The command current is provided by a function generator.

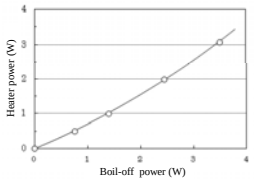
The PWM signals for IGBT control of the inverter are generated by comparing the measured current from a current sensor with the command current.

Calibration Test

Calibration Results of AC Loss Measurement System



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



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

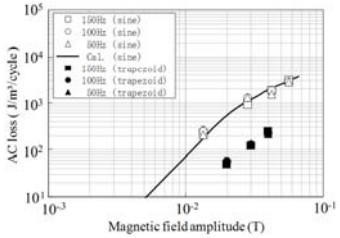
Since the polynomial regression curve and measured values show good agreement, it is assumed that high-precision measured results for AC losses can be obtained by using the relation between the boil-off power and the heater power.

This calibration test was done for every AC loss measurement.

Experimental Results

Magnetization Loss

Coil ends : opened



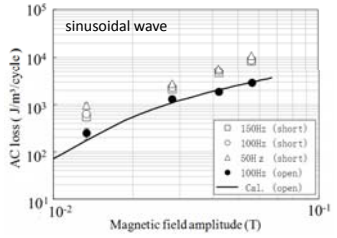
Magnetic field amplitude dependence of AC loss in the sample coil.

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

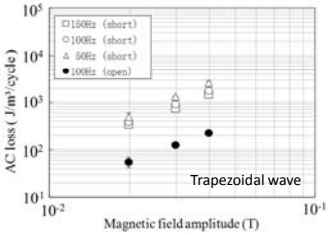
The solid line is a calculated value using the Bean-London model.

Additional Coupling Current Loss

Coil ends : Shorted



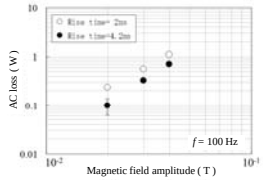
Magnetic field amplitude dependence of AC loss in the sample coil under sinusoidal field.



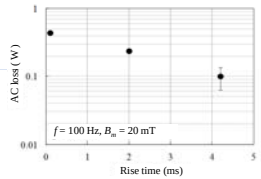
Magnetic field amplitude dependence of AC loss in the sample coil under trapezoidal wave field.

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.

Rise time dependence of trapezoidal wave



Magnetic field amplitude dependence of AC loss.



Rise time dependence of AC loss.

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