Self-field AC loss measurement of a four-tapes HTS stack using Fiber Bragg Grating sensors

Yancho Liu1,3, Z. Jiang2, R. Badcock2, J. Fang1, X. Yan1, W. Chen1, X. Fang1, and W. Zhou4
1. School of Electrical Engineering, Beijing Jiaotong University, 100044, Beijing, P. R. China
2. Robinson Research Institute, Victoria University of Wellington, PO Box 33436, Lower Hutt 5046, New Zealand
3. Key Laboratory of Magnetic Levitation Technologies and Maglev Trains, Southwest Jiaotong University, 610031, Chengdu, P. R. China
4. Institute of Magnetic Levitation and Electromagnetic Propulsion, China Aerospace Science and Industry Corporation, 100043, Beijing, P. R. China

Background

- AC loss plays an important role for the application of HTS magnet, therefore, it is necessary to measure the AC loss accurately.
- The method of transport AC loss measurement can be classified as electric method and calorimetric method, and calorimetric method is preferable for the situation when sample is with complex electromagnetic environment.
- Fiber Bragg grating sensors shows great advantages for calorimetric method due to their inherent property of immune to electromagnetic field interference and small size compared with the traditional electric temperature sensors.

Content

- The transport AC loss of a four-tapes stack was measured by three FBG temperature sensors with different coating and installation method.
- The calibration between power and wavelength was realized by a resistance heater.
- The FBG sensor measured loss values of the stack are compared with the electric measured results as well as the calculated Norris results.
- The effect of magnetic strain on loss measurement was evaluated by comparing the results of with and without thermal insulation.

Results

- We measured the self-field AC loss of a four-tapes HTS stack using three FBG sensors with different coating and bonding method.
- The fully bonded bare FBG and silver coated FBG shows much higher wavelength shift even in a small temperature rise of 1.5 K compared with bare FBG sensor.
- The calibration between wavelength shift and power also show that FBG1 and FBG3 have much higher loss sensitivity than FBG2, this is corresponding to the temperature sensitivity difference.
- The results of AC loss measured by FBG1 and FBG3 show good agreement with the electric measured results as well the Norris calculated results, the results of FBG2 shows a big deviation from FBG1 and FBG3 due to the low temperature sensitivity and the loose contact between tape and FBG.
- Magnetic strain of the four-tapes HTS stack has no effect on the AC loss measurement of FBG sensors.

Measurement Principle

- An FBG can work as a temperature sensor by measuring the shift of the central wavelength: \( \Delta \lambda = \lambda_0 - \lambda \)
- Calorimetric method in this work is based on the measurement of local temperature rise of the sample due to AC loss dissipation using FBG sensors: \( \Delta T = T - T_0 \)
- The AC loss can be transferred by the measured FBG wavelength shift: \( \Omega_\lambda = \Delta \lambda / \Delta T \)

Experimental Method

- Four AMSC 8700 wires with 5% Ni-W substrate were used for the stack preparation;
- Two bare FBG sensors and a silver coated FBG sensor were attached to the top of the stack. One of the bare FBG is single end pasted named FBG2 and the other one is fully bonded named FBG1, the silver coated FBG sensors named FBG3 was also fully bonded;
- The relationship between power and wavelength was calibrated by a 120 \( \Omega \) resistor heating;
- The sample were insulated by two polystyrene foam thermal insulations to get a measurable small temperature rise;
- The loss measurement was carried out 67 Hz and 89 Hz, and also fully bonded and calibrated by a 120 \( \Omega \) thermal insulations to get a measurable small temperature rise;
- The electric measured AC losses in the stack are compared well with the electric method results, and the loss sensitivity is approximately 188 W/m^3.

References