



Experimental study of the AC magnetization loss in MgB_2 superconducting wires at different temperatures

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ABSTRACT

The temperature and external AC magnetic field dependence of AC magnetization losses of MgB_2 wires were studied. Temperature was varied from 18 K to 40 K and external magnetic field of frequencies 72 Hz and 144 Hz from 8 mT to 70 mT with orientation perpendicular to the wire axis. To clarify the influence of the wire construction on AC loss, single and six filament untwisted samples of length ~ 50 mm were examined. For this purpose unique experimental apparatus created by the combination of original calibration-free measuring system designed for ac magnetization loss measurement and non-magnetic vacuum vessel with two-stage cryocooler for sample cooling was used. It was found, that for monofilament sample hysteretic AC losses was dominated in comparison to untwisted six-filaments sample, where coupling losses confirmed by frequency dependence were dominated.

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1. Introduction

One of the main advantages of MgB_2 superconductor is the high critical temperature T_c , which makes this compound attractive in comparison to low-temperature superconductors because of easy and cheaper cooling down below T_c by cryocooler system. For AC applications such as power transmission cables, transformers, and fault current limiters, it is very important to study AC losses, because of their impact to required cooling performance and associated operating costs. In the recent years, several works have been published about the magnetization AC losses of MgB_2 wires at various temperatures. Young et al. [1] measured self-field and in-field AC loss in the stabilized multifilament MgB_2 tapes at various temperatures. They have found that while the self-field loss of Ni sheathed Cu stabilized multifilamentary MgB_2 tape is dominated by the ferromagnetic loss, the coupling current is dominated factor for the losses in applied field. The dependences of magnetization AC losses for bulk MgB_2 and Ni sheathed wires at various temperatures were measured by Yang et al. [2]. They stated that losses behavior is strongly dependent on the conductor's geometry for bulk MgB_2 samples. In superconducting wire the losses consist of contributions of MgB_2 and ferromagnetic sheath. Two types of six filaments MgB_2 wires were measured by Tanaka et al. [3] and compared with the results of a multifilament conductor model and hollow-cylindrical model. AC losses in MgB_2 multifilamentary strands with Nb barriers, Cu-inter-filamentary matrix with non-magnetic GlidCop and/or magnetic Monel sheath were investigated by

Majoros et al. at liquid helium temperature [4]. They found that for samples with no ferromagnetic elements present in their matrix there is a reasonable agreement of the losses with the critical state model in low frequency region. At higher frequency eddy currents in Cu matrix dominate the losses. Polák et al. have measured and analyzed AC losses of MgB_2 tape with 19 filaments surrounded by Ti barriers and embedded in copper stabilization, exposed to external magnetic field with frequencies from 30 mHz up to 1.4 Hz and amplitudes up to 0.8 T at 4.2 K. They have determined the contribution of hysteresis and coupling losses using the measured frequency dependence of the total AC losses [5].

In our work, we present experimental results of AC magnetization losses measured for two different MgB_2 wires at frequencies $f = 72$ Hz and 144 Hz and variable temperatures between $T = 18$ K and 40 K. External AC magnetic field was varied between $B_{\text{ext}} = 8$ mT and 70 mT in rms.

2. Experimental details

Two different MgB_2 samples were examined to investigate the influence of their construction on AC magnetization loss. First sample A was monofilament 1.07 mm thick and 50 mm long MgB_2 wire with Nb barrier. The cross-section of the wire is shown by optical micrograph in Fig. 1a. Second sample B was six-filaments 1.09 mm thick and 50 mm in length MgB_2 wire with Nb barrier and central Cu core. The cross-section of the wire is shown by optical micrograph in Fig. 1b. Both samples have been stabilized by GlidCop AL-60 containing 1.1 wt.% of Al_2O_3 . In situ procedure was utilized for wires A and B fabrication [7].

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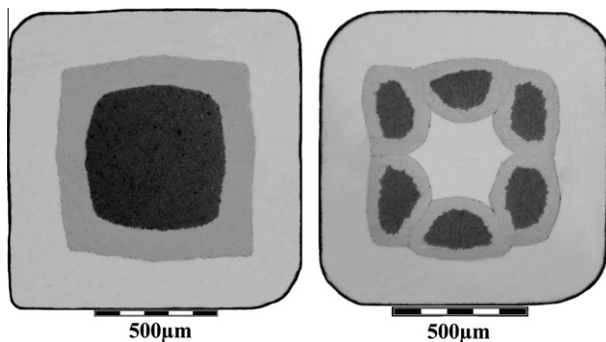


Fig. 1. Optical micrograph of (a) sample A – monofilamentary GlidCop sheathed MgB_2 wire with Nb barrier, (b) sample B – six-filaments GlidCop sheathed MgB_2 wire with Nb barrier and central Cu core [7].

AC loss measurements have been performed by the calibration free method [8], which is based on the measurement of a part of the power supplied by the AC source to the AC magnet generating the magnetic field in which the sample is placed. The measurement system consists from two identical AC magnets connected in series and two measurement pick-up coils wound in parallel with magnets windings, see Fig. 2. Sample is located in one of the magnet, the other one and pick-up coil serve as compensation. More details about the calibration free method for AC loss measurement are described in [6]. AC magnetization losses were measured by lock-in technique [9]. Schematic diagram of the measuring apparatus is shown in Fig. 2.

Two-stage Sumitomo cryocooler was used for the sample cooling, which was placed in a BNP-2 aluminum nitride heat conductive ceramic holder attached to the cold head by flat Cu braid to ensure heat conduction as is shown in Fig. 3. For temperature stabilization a heating coil was wound on the aluminum nitride holder. Cernox temperature sensor was located inside the holder to control precisely the temperature of the sample. Complete measuring device was placed into non-magnetic fiberglass vacuum vessel, see Fig. 4.

3. Results and discussions

The dependences of AC magnetization losses versus temperature measured at different external magnetic fields with $f = 72$ Hz for sample A (empty symbols) and sample B (full symbols) are shown in Fig. 5. The influence of differences in construction of samples A and B is clearly visible in presented dependences.

AC magnetization loss increases with temperature increasing from 18 K for both samples. It is caused by subsequent critical density J_c decrease and by magnetic flux penetrating deeper into the filaments at constant AC external magnetic field. Maximum of

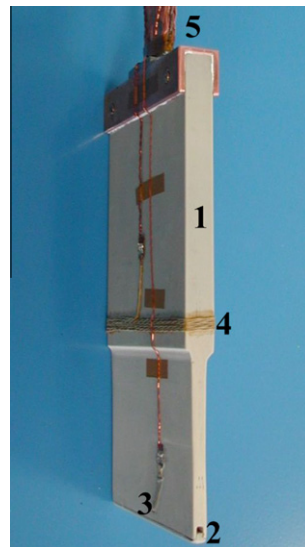


Fig. 3. Sample holder (1) BNP-2 aluminum nitride sample holder (2) place for sample (3) Cernox temperature sensor inside the holder (4) heating coil (5) thermal connection to the cold head.

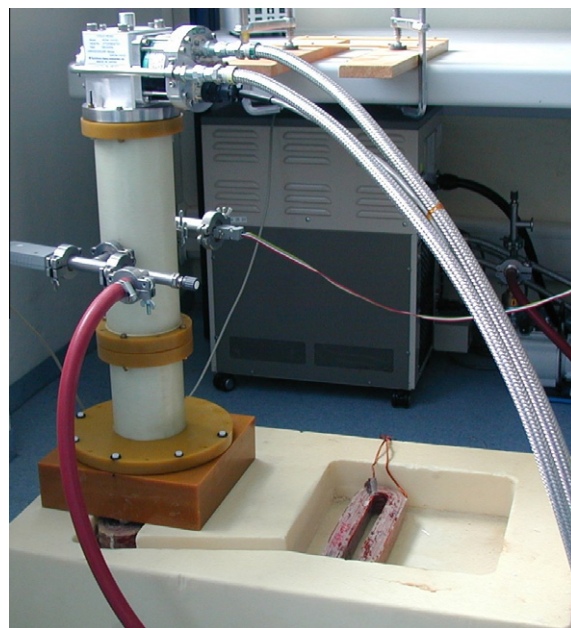


Fig. 4. Measurement system consists from copper magnets cooling by LN₂ and cryocooler with fiberglass vacuum vessel.

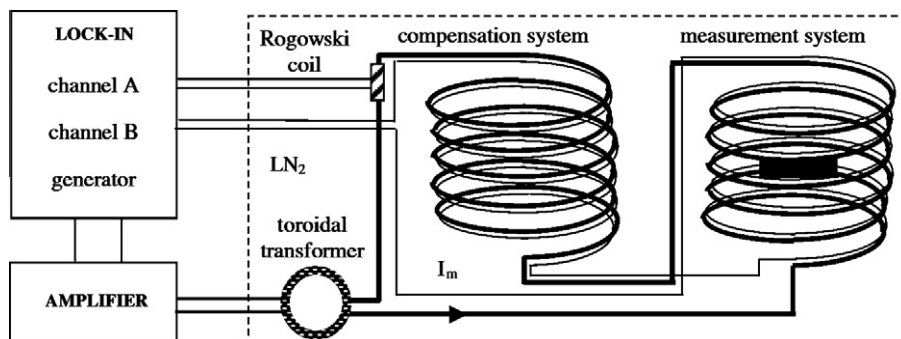


Fig. 2. Scheme of calibration free system for AC magnetization loss measurement [8].

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