INFLUENCE OF AN ALTERNATING MAGNETIC FIELD ON CURRENT FLOWING THROUGH A SUPERCONDUCTOR OF THE SECOND KIND

V. V. Sychev, V. B. Zenkevich, V. V. Andrianov, and V. P. Baev
Institute of High Temperatures, USSR Academy of Sciences
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It is known that hysteresis losses arise in a sample of a non-ideal superconductor of the second kind placed in an alternating magnetic field. In the absence of an extraneous current flowing in the sample, these energy losses are replaced, naturally, by the apparatus producing the alternating magnetic field. If direct current from some external source is made to flow through the sample, then the hysteresis losses should change somewhat, since the distribution of the induction in the sample material is changed. An essential question is whether this is accompanied by some effective resistance to the flowing direct current (whether part of the hysteresis loss is replenished by the current source), in other words, whether the transport current in the closed superconducting loop will attenuate when the magnetic induction in the loop material is changed.

The results of the experiment described below have made it possible to establish that an effective resistance to the direct current occurs only if the amplitude of the change in the intensity of the external magnetic field exceeds a certain threshold value $H_\rho > H_{c_1}$. The experiment has also revealed other regularities connected with the flow of direct current the flow of direct current through a non-ideal superconductor of the second kind located in an alternating magnetic field.

A diagram of the employed experimental setup is shown in Fig. 1. The investigated sample 1 is a piece of wire of the ternary alloy Nb-Ti-Zr (65BT) 0.26 mm in diameter and 200 m long, bifilarly wound on a dielectric core. This coil is part of closed superconducting loop, the second element of which is solenoid 2 having a known inductance.

The current was excited in this superconducting loop in the usual method, using a thermal switch. The generator of the alternating magnetic field was superconducting solenoid 3, connected to the external ac source. Occurrence of an effective resistance in the investigated sample led to attenuation of the current in the superconducting loop; this was measured with the aid of a bismuth pickup placed in solenoid 2. The effective resistance of the investigated and the fraction of the heat loss replenished by the current source (in this case, by the magnetic energy stored in the field of solenoid 2), could be calculated from the rate of decrease of the current in the loop. The investigated sample was placed in a tube, 5, connected to a gas flow meter. This made it possible to estimate approximately the total heat release in the sample.

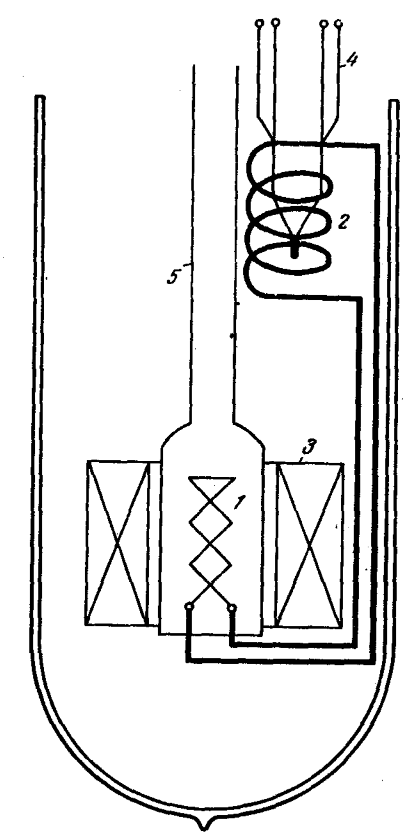

Fig. 1. Experimental setup

To prevent heating of the sample from affecting the experimental results, the magnetic field was varied at a low frequency (0.02 - 0.06 Hz).

By carrying out the experiment over a prolonged period of time, it was possible to measure with the aid of this setup quite small values of the average resistance. In an experiment performed in both directions, the resistivity sensitivity was 10^{-18} ohm-cm; allowing for the uncertainty connected with the nonlinearity of the parameters of solenoid 3, the error in the measurement of resistivities on the order of 10^{-14} ohm-cm amounted to several per cent.

In the performed experiments, the magnetic field varied cyclically about a zero mean value. The amplitude of the magnetic-field oscillations ranged from 0 to 7 kOe. No attenuation of the current in the loop was observed in stationary fields of this intensity.

The main results of our investigation can be formulated as follows:

1. At a current I_0 = 20 A in the sample, the threshold value of the magnetic-field amplitude at which an effective resistance is produced amounts to 2.1 kOe. The threshold value of the field amplitude increases somewhat with decreasing current. The exact form of the field amplitude increases somewhat with decreasing current. The exact form of the dependence of the field H_ρ on the current in the sample was not established, since the time required for the determination of small resistances near H_ρ is too long.

2. At amplitudes much higher than H_ρ (starting with 2.5 kOe in the case of I_0 = 20 A), the effective resistance increases linearly with increasing amplitude. Of course, a similar dependence holds also for the average power (at a given value of I_0) lost by the current source, and the average heat-loss power is proportional to the field oscillation frequency and the heat released per cycle is independent of the frequency (Fig. 2; a heat loss of 10^{-5} J/cycle by the current source corresponds to an average resistivity $\rho = 3.7 \times 10^{-13}$ ohm-cm at

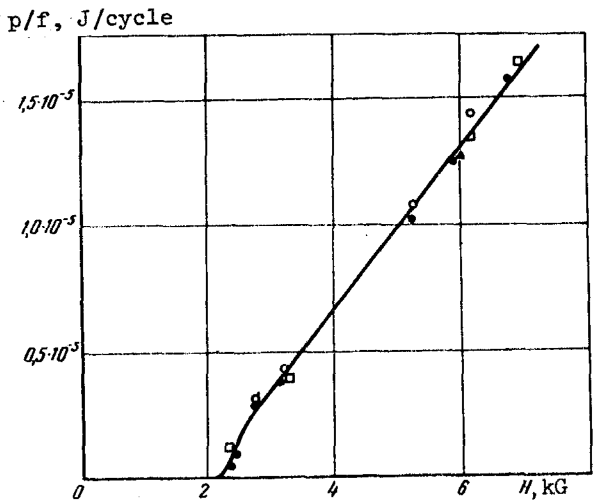

Fig. 1. Energy lost by current source per cycle vs. the amplitude of the alternating field. Initial current 20 A. o - 0.025 Hz, ● - 0.030 Hz, Δ - 0.040 Hz, □ - 0.050 Hz, ▲ - 0.060 Hz.

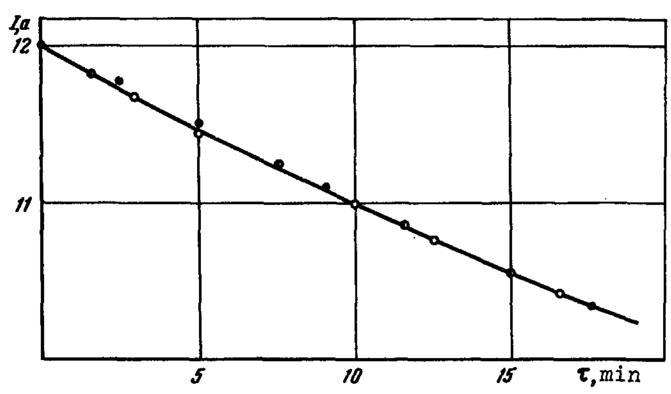

Fig. 3. Attenuation of current in the superconducting loop at different pulse waveforms of the alternating magnetic field: ⎍⎍ - o; ⎍⎍ - ◐; /\/\ - ●

a frequency 0.03 Hz).

3. In the region when the current-source power is linear in the field amplitude, the effective resistance is independent of the current flowing through the sample, within the limits of experimental accuracy (the current ranged from 2 to 20 A in the experiments).

4. The effective value of the resistance does not depend on the waveform of the field pulses and is determined exclusively by the amplitude of the variation of the field intensity. Figure 3 shows a characteristic example of the attenuation of the current in a superconducting loop for almost rectangular and triangular field pulses. Rectangular pulses of two different types of greatly differing rms field intensities were used. The amplitude of the variation of the field intensity was 6 kOe.

5. Measurements of the amount of evaporated helium has shown that the heat loss replenished by the current source does not exceed, in order of magnitude, 10% of the heat loss replenished by the field generator. The heat loss connected with the field generator does not experience a jump when the field amplitude drops below the threshold value.

The most closely related to our investigation is the work by Taquet [1], who observed the occurrence of resistance in a wire sample of a non-ideal superconductor of the second kind upon change of the external magnetic field. The presence of a threshold value of the amplitude of field variation was not established. The obtained experimental material did not enable Taquet to classify the occurrence of the resistance as an essentially new phenomenon different from the hitherto observed resistive states.

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[1] B. Taquet, J. Appl. Phys. 36, 3250 (1965).

BENDING OF TRAJECTORIES OF ASYMMETRICAL LIGHT BEAMS IN NONLINEAR MEDIA

A. E. Kaplan
Institute of Radio Engineering and Electronics, USSR Academy of Sciences
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In the study of the self-action of light beams in nonlinear media, the interest of the researches, starting from the trail-blazing work [1 - 3], has been focused mainly on the phenomenon of self-focusing and self-trapping of the light (cf., e.g., [4]). We can point out, however, at least one more interesting case of self-action of light, resulting from nonlinear refraction, namely the bending and "twisting" of trajectories of asymmetrical light beams in media showe refractive index depends on the field intensity. Indeed, unlike self-focusing, when the intensity is symmetrically distributed over the beam cross sections and all the rays tend to be gathered at the center of the beam (where the refractive index is maximal) as a result of the nonlinear refraction, in the case of asymmetrical distribution the beam will bend as a whole in the direction in which the refraction is maximal.

In the geometrical optics approximation, the radius of curvature of the beam trajectory at each point and the optimal distribution (from the point of view of appearance of the "pure" bending effect) of the intensity over the cross section follow directly from the fundamental