Antiferromagnetic resonance investigation of the magnetoelastic interaction in hematite

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(Submitted January 17, 1973)
Zh. Eksp. Teor. Fiz. **65**, 657–667 (August 1973)

The effect of magnetoelastic interaction of the quasiferromagnetic mode of AFMR in the hematite (α-Fe_2O_3) is studied at room temperature by uniaxial pressure up to 2000 bar. The additional absorption peak is ascribed to variation of the equlibrium sublattice configuration at a certain value of the uniaxial pressure if it is parallel to the external field, the latter being oriented in the easy plane. The natural frequencies of quasielastic oscillations of hematite single crystal spheres are measured by the AFMR technique. In accordance with the theoretical predictions, the dependence of the velocity of sound on field strength is found to be quite significant, ($\Delta\nu_s/\nu_s \approx 8\%$ when H varies from 2 to 8 kOe). A strong dependence (of a magnetoelastic origin) of the velocity of sound in hematite on the magnitude of uniaxial pressure in the basal plane is also predicted.

INTRODUCTION

In antiferromagnets (AF) whose magnetic-crystal anisotropy in certain directions is small for some reason or another, at least one branch of the spin-wave spectrum ω_{1k} has a gap ω_{10} of negligible magnitude. Any interaction (for example, hyperfine or magnetically-elastic) that increases this gap can be characterized by a certain additional anisotropy field H'_A. Its contribution to the quantity $(\omega_{10}/\gamma)^2$ is described by a term $2H'_A H_E$, i.e., it is enhanced by the exchange field H_A, which is large as a rule. Therefore antiferromagnetic resonance (of cyclic frequency ω_{10}) is a powerful means for quantitative study of small interactions of the antiferromagnetically ordered spins with other systems of the crystal in substances of this type.

An extensive class of such AF is made up by AF with anisotropy of the "easy plane" type (AFEP), see[1]. These include also the high-temperature ($T_M \approx 260°$ K $< T < 950°$ K $= T_N$) phase of hematite α-Fe_2O_3, the exchange interaction in which is particularly large ($H_E = 9.2 \times 10^6$ Oe). The effect of magnetoelastic interaction, and particularly of unidirectional compression **p** in the basal plane (111) of the crystal, on the spectrum of the low-frequency antiferromagnetic resonance was investigated in[2-4]. It turned out that this interaction leads, owing to "antiferromagnetic striction," to the appearance of a gap in the function $\omega_{10}(H)$ and, in addition, to a strong dependence of this gap on **p**. The results of these investigations are expressed by the formulas

$$(\omega_{10}/\gamma)^2 = H(H+H_D) + 2H_E H_{mes}, \tag{1}$$

where H is the external magnetic field applied to the basal plane, H_D is the effective Dzyaloshinskiĭ interaction field (H_D = 22 kOe for hematite at 300° K), H_{mes} is the effective field of the static magnetoelastic interaction (i.e., the interaction obtained without allowance for the vibrations of the elastic system of the crystal), namely,

$$H_{mes} = H_{mes}(0) - Rp\cos 2\psi, \tag{2}$$

where $H_{mes}(0)$ is the effective field of the spontaneous striction, amounting to (0.7 ± 0.1) Oe for hematite at room temperature, ψ is the angle between **p** and **H**, and R is a coefficient determined by the elastic and magnetoelastic parameters of the crystal.

We were interested in the possibility of causing H_{mes} to vanish and then of reversing its sign by directed compression, something possible at ψ = 0, i.e., at **p** ∥ **H**. To this end it was necessary to make the range of pressures much larger than in[3,4]. The first part of the paper is devoted to the effect of uniaxial pressures **p** ∥ (111) in a wide range $0 \le |\mathbf{p}| \le 2$ kbar both along and across the field **H** ∥ (111) on the position of the AFMR lines relative to the field at a constant working frequency ω_W.

In the second part, again using antiferromagnetic resonance, we attempt to study one of the dynamic manifestations of magnetoelastic interaction in AFEP, namely the dependence of the speed of sound in hematite on the magnetic field.

1. STATIC MAGNETOELASTIC INTERACTION AND RESONANCE UNDER CONDITIONS OF STRONG DIRECTED COMPRESSION

1. Experimental Setup. Samples

The experimental setup for the direct measurement of $H_{res}(\mathbf{p})$ at **p** ∥ **H** (ψ = 0) is shown in Fig. 1. A similar setup was used for the case **p** ⊥ **H** ($\psi = \pi/2$), see also[5]. The measurements were performed at room temperature at $\lambda_{UHF} \approx 8$ mm in a standard waveguide section 3, in which a directional coupler (attenuation 10 dB) and a matched load were used to produce a traveling wave mode. Sample 6 was a cylinder of height h = 4 mm and diameter d = (2 ± 0.5 mm), made of single-crystal hematite grown from a solution in the melt by R. A. Voskanyan (Crystallography Institute, USSR Academy of Sciences). The C_3 axis of the crystal was perpendicular to the cylinder axis within ± 2°. The width of the AFMR line for the better of the two samples employed by us was ΔH_{10}

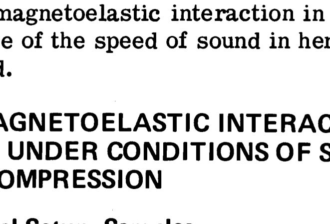

FIG. 1. Experimental setup for the study of the effect of unidirectional compression on the spectrum of low-frequency antiferromagnetic resonance ($\mathbf{p} \parallel H \perp C_3$): 1—electromagnet; 2—support; 3—waveguide; 4—sleeve; 5—rod; 6—sample; 7—Hall pickup; C_3—direction of the ternary axis of the single-crystal hematite; P_{UHF}—microwave energy flow.

≈ 350 Oe. This, in view of the large dimension of the sample, points to a satisfactory quality of the initial single crystal (spheres made of the same piece, with diameter d = 1.5 mm, had ΔH_{10} = 175 Oe, see below).

The unidirectional compression was produced with a bronze rod 5, gliding without skips in a guiding sleeve 4 (the dry-friction coefficient threshold was negligibly small in comparison with the employed loads), and a lever, to one end of which a load F was applied. The end surfaces of the sample 6 and of the rod 5 were carefully lapped.

2. RESULTS AND DISCUSSION

A. Figure 2a shows typical plots of the antiferromagnetic resonance lines at different values of the directed compression for the case $\mathbf{p} \perp \mathbf{H}$. In agreement with the data of[2], an increase of pressure shifts the antiferromagnetic-resonance line towards weaker fields in accord with formulas (1) and (2). If $\mathbf{p} \parallel \mathbf{H}$, the line shifts towards stronger fields (Fig. 2b). The experimental data were used to plot the displacement of the resonance line as a function of the compression (Fig. 3). The curve in the lower right of this figure corresponds to the appearance of an additional absorption peak at $\mathbf{p} \parallel \mathbf{H}$, and will be considered later on. The vertical bars represent the changes of the antiferromagnetic line width. We see that the linear character of $H_{res}(\mathbf{p})$ remains in force for the main peak, within the limits of measurement accuracy ($\sim\Delta H_{10}/10$ in the field, ~ 1% in pressure), up to pressures ~2 kbar.

The coefficient R in (2), averaged for the two samples, is equal to R = (6 ± 0.6) Oe/kbar. It exceeds by 30% the value calculated in[1] from the elastic constants of hematite and from the data of[4], where the shift of the antiferromagnetic-resonance line (λ_{UHF} = 12.5 mm) was investigated as a function of the strain. This discrepancy is relatively small, if it is recognized that in[4] the transfer of the deformations to the hematite sample could have been incomplete and, in addition, the residual stresses and the impurity contents of the employed samples were different.

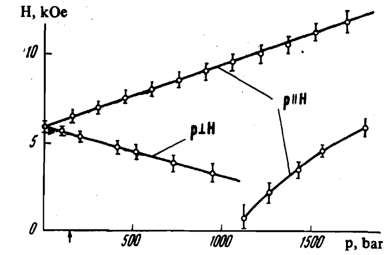

FIG. 3. Position of antiferromagnetic resonances lines (λ_{UHF} ≈ 8 mm) vs. the magnitude and direction of the compression, plotted from the experimental data (Figs. 2a and 2b). The arrow shows the maximum pressure used in [2,4]. The vertical bars represent the changes in the line widths.

As seen from Figs. 2 and 3, an appreciable broadening of the antiferromagnetic resonance lines is observed with increasing pressure. To determine the cause of this broadening, a control experiment was performed on the same sample, but with a narrower waveguide. In this case only the central part of the sample (~1 mm high) was in the microwave field, so that the influence of the strain inhomogeneities, which could arise near the surfaces where the sample is in contact with the rod 5 and the base 2, was eliminated. The picture of the broadening and shift of the antiferromagnetic resonance line was not changed in this case. This indicates that the line broadening occurs locally (microscopically), and is not a result of macroscopic inhomogeneities of the strain. One of the causes of the broadening of the antiferromagnetic line following application of an external stress may be the increase (which is uniform over the entire volume) in the dislocation density, the latter being known to be proportional to the external stress[6]. When the pressure is removed, the width and position of the antiferromagnetic resonance line returned to their initial values.

B. If the pressure parallel to the field exceeds a certain value $p_c(\omega_w)$, then an additional absorption peak appears in the weak-field region (see Fig. 2b). With increasing pressure this peak shifts towards stronger fields at a rate faster than the shift of the mean peak (Fig. 3).

To explain the cause of this peak we investigated the dependence of the absorption picture on the microwave signal frequency at a fixed value $p > p_c(\omega_w)$. The results are shown in Fig. 4. The horizontal segments designate the line width. It can be concluded from this behavior of the peaks that at a certain $H = H_c(p)$ a change seems to occur in the equilibrium state of the magnetic system of the crystal.

To explain this, we can start from the model proposed in[7] for the equilibrium state of the elastic and magnetic systems of hematite. We consider first the distribution of the deformations and the orientation of the equilibrium antiferromagnetic vector $\mathbf{l}_0$ in the basal plane at p = 0 and $\mathbf{H} \to 0$, under the assumption that the sample remains single-domain. Assume that in the paramagnetic state (at $T > T_N$) the sample has the shape of a disk whose plane is parallel to the basal plane. In the AF state at T ~ 300° K in a weak field $\mathbf{H} \parallel (111)$, a single-domain structure with $\mathbf{l}_0 \parallel (111)$ and $\mathbf{l}_0 \perp \mathbf{H}$ is established in the crystal owing to the weak ferromagnetic moment m_0. Then, according to[7], the antiferromagnetic striction causes the sample to assume the form of an ellipse elongated along $\mathbf{m}_0$. This distribution of the equilibrium elastic deformations, having no cylindrical symmetry, does indeed lead to a magnetostriction gap

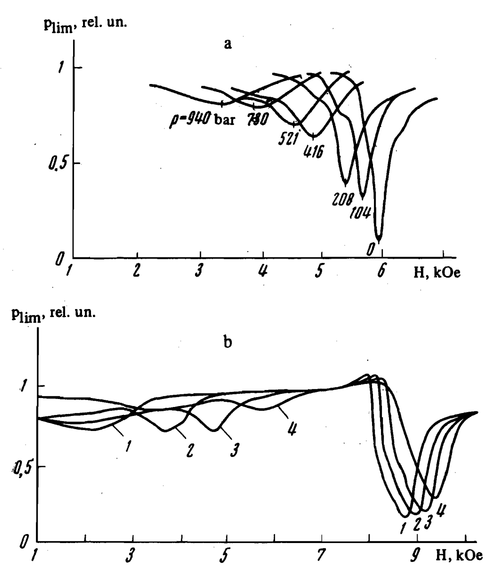

FIG. 2. Typical plots of AFMR lines at different values of the directed compression $p \perp C_3$ H: a) $p \perp H$; b) $p \parallel H$. Curves: 1) p = 460; 2) 1420; 3) 1560; 4) 1860 bar. In case (b), an additional absorption peak appears in the weak-field region if the compression is large.

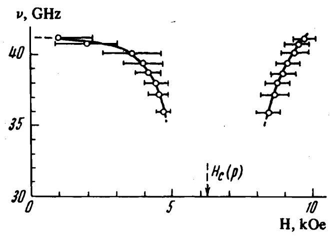

FIG. 4

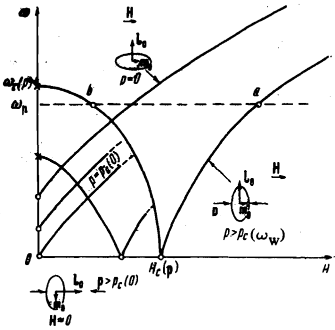

FIG. 5

FIG. 4. Experimental frequency dependence of the position and width of the antiferromagnetic resonance absorption lines at a fixed pressure $p = 1520$ bar $> p_c(\omega_W)$, $\mathbf{p} \parallel \mathbf{H}$; circles–line positions, horizontal bars–widths.

FIG. 5. Character of variation of the spectrum of the low-frequency antiferromagnetic resonance in hematite under the influence of directional compression $\mathbf{p} \parallel \mathbf{H} \perp C_3$. The equilibrium configurations of the vectors $\mathbf{m}_0$ and l_0 for different $\mathbf{p}$ and $\mathbf{H}$ are shown in the ovals.

ω_{10} ($H \to 0$, $p \to 0$) in the quasiferromagnetic (see[8]) branch of the antiferromagnetic resonance, see the $p = 0$ curve on Fig. 5. Compression of the sample along $\mathbf{H} \to 0$ decreases the eccentricity of the ellipse and by the same token decreases the size of the gap. With further compression at $p \geq p_c(0)$, the vector $\mathbf{l}_0$ becomes oriented along $\mathbf{H} \to 0$ ("magnetic-sublattice flipping induced by directional compression"). The resultant situation is analogous to that thoroughly investigated earlier in orthoferrites[9,10], namely, the Dzyaloshinskiĭ vector $\mathbf{D}$ is perpendicular to the $\mathbf{n}$ axis, which is the easy axis for the antiferromagnetic vector, while $\mathbf{H} \parallel \mathbf{n}$. If now we increase H at $p > p_c(0)$, then the vector $\mathbf{l}_0$ deviates from $\mathbf{n}$, and the field dependence of the frequency of the quasiferromagnetic mode of the antiferromagnetic resonance acquires the characteristic form shown in Fig. 5. On the other hand, if we measure the microwave absorption at a fixed generation frequency ω_W = const, then at $p > p_c(\omega_W)$ there appears, besides the usual absorption peak in strong fields (point a in Fig. 5), an additional peak in weak fields (point b), which was indeed observed by us (see Fig. 2b and Fig. 3). The experimental curve of Fig. 4 is likewise in qualitative agreement with the proposed scheme.

On the other hand, the quantitative relations of[9,10] can have only a limited applicability to the considered case, since the change of the orientation of the vector $\mathbf{l}_0$ and of the distribution of the elastic deformations, which determine the anisotropy that is effective in antiferromagnetic resonance, occurs in a self-consistent manner. When this circumstance is taken into account, the low-frequency antiferromagnetic-resonance spectrum $\omega_{10}(H)$ can have at $p > p_c(0)$ a more complicated form than shown in Fig. 5 (in particular, it may contain jumps). The development of a complete theory of the statics and dynamics of hematite under the conditions of strong directional compression may also be complicated by the fact that magnetoelastic domain structures can be formed at $H \to 0$ if $p > p_c(0)$ and at $0 \leq H \leq H_c(p)$ if $p > p_c(0)$.

3. DYNAMIC MAGNETOELASTIC INTERACTION AND SPEED OF SOUND IN HEMATITE

The phenomenon described in Sec. 1 can be interpreted not only qualitatively but also quantitatively, without taking the oscillations in the elastic system of the medium into account. They are governed by the so-called "static magnetoelastic coupling." In a more detailed analysis it is necessary to set up the equations for the coupled magnetoelastic oscillations. This problem was solved theoretically in[11,12] for AFEP, and experimental investigation of magnetoacoustic resonance in AFEP with Dzyaloshinskiĭ interaction were performed by V. Gakel'[13], using $MnCO_3$ as an example. Most results of[11,12] are valid also for the easy-plane phase of hematite. The quantitative relations between the values of the exchange and elastic interactions in hematite, however, lead to a situation that differs somewhat from the magnetoelastic phenomena both in ferrites (see[14]) and in AFEP of the $MnCO_3$ type. In hematite, owing to the high Neel temperature T_N, the spin-wave velocity becomes quite large as $k \to 0$ if the anisotropic interactions are neglected, so that the spectra of the "pure" phonons and magnons do not cross at any value of the wave vector $\mathbf{k}$, with the exception of $\mathbf{k} = 0$ (see Fig. 6). If the static magnetoelastic coupling is taken into account, the maximum approach of the spectra occurs also as $\mathbf{k} \to 0$, so that the dynamic magnetoelastic interaction should have the strongest influence precisely on waves with $\mathbf{k} \to 0$, i.e., on the "antiferromagnetic resonance" frequency and on the speed of "sound" (we use quotation marks since these oscillations are no longer pure spin or pure elastic when the dynamic magnetoelastic coupling is taken into account). In particular, it follows even from the qualitative scheme proposed in Fig. 6 that the speed of "sound," i.e., the slope of the quasiphonon mode of the spectrum of the coupled magnetoelastic oscillations, should increase with increasing magnetic field as $\mathbf{k} \to 0$.

The dispersion equation obtained in[12] for the coupled magnetoelastic vibrations, at the relation $\omega_{2k} \gg \omega_{1k} \gg \omega_{sk}$ which holds for hematite at room temperature (ω_{2k}, ω_{1k}, and ω_{sk} are respectively the frequencies of the quasiantiferromagnetic, quasiferromagnetic, and quasiphonon branches), and leads as $k \to 0$ to the following relation for the quasiphonon velocity:

$$v_s = v_{s\infty}\left[1 - \frac{2H_E H_s^{med}(\theta_k, \varphi_k)}{(\omega_{10}/\gamma)^2}\right]^{1/2}, \tag{3}$$

where $v_{s\infty}$ is the polarization sound velocity s in the formal limit as $H \to \infty$; $H_s^{med}(\theta_k, \varphi_k)$ is the effective field of the dynamic magnetoelastic interaction, is proportional to the square of the magnetostriction constants, and depends on the phonon polarization and on the direction of its wave vector $\mathbf{k}$.

Expression (3) shows that the velocity of quasisound in hematite should depend noticeably on the magnetic field, owing to the field dependence of ω_{10}. The degree of this dependence is determined by the polarization and by the quasisound propagation direction. The influence of

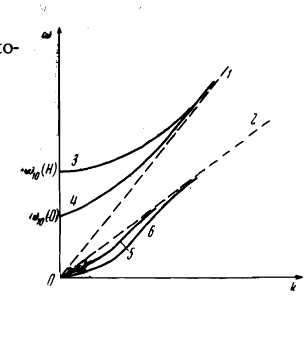

FIG. 6. Spectrum of coupled magnetoelastic waves in α-Fe_2O_3 at $T_M < T < T_N$ (approximate picture): 1—spectrum of "pure" magnons in zero field; 2—spectrum of "pure" phonons; 3, 4—spectra of quasimagnons for different values of the magnetic field H; 5, 6—the same for quasiphonons (3, 4, 5, 6—with allowance for both static and the dynamic magnetoelastic couplings).

the quasiantiferromagnetic branch ω_{2k} on the spectrum of the phonons with $\mathbf{k} \to 0$ can be noticeable at small values of ω_{20} (for example, in hematite in the immediate vicinity of the Morin point, where $\omega_{20} \to 0$, see[15]), and is of independent interest.

From (3), (1), and (2) it follows also that the speed of sound in easy-plane hematite depends on the unidirectional compression in the basal plane, since ω_{10} depends on p via H_{mes}. We note that v_s depends on p in hematite because of the magnetoelastic interaction, without allowance for the anharmonicity of the elastic system. Knowing H_s^{med} from the $v_s(H)$ dependence at p = 0 for the concrete quasielastic wave or vibration, we can estimate the magnitude of the effect (at a certain weak field $H \to 0$, but sufficient to make the sample single-domain). Thus, for example, if $H_s^{med} = 0.7$ Oe (see below), we obtain for the compression along the field

$$\frac{d\ln v_s}{dp}\left(\begin{matrix} p\to 0 \\ H\sim 1\ \text{kOe}\end{matrix}\right) \sim -6\cdot 10^{-4}\ \text{bar}^{-1}.$$

Estimates for the corresponding variation due to the elastic anharmonicity give a quantity of the order of $-10^{-5}\ \text{bar}^{-1}$, i.e., a much lower value.

Measurement procedure. An expression analogous to (3) can be derived in principle also for the natural frequencies ν_{nml} of the quasielastic vibrations of a body with finite dimensions, say a sphere (see below). The dynamic magnetoelastic interaction is described in this case by an effective field H_{nml}^{med}, where n, m, and l are indices determining the type of the natural oscillations. Information on the $v_s(H)$ dependence can be obtained from measurements of $\nu_{nml}(H)$ since, generally speaking, the connection between the frequencies of the natural elastic vibrations, on the one hand, and the dimensions of the body and the sound velocities, on the other, is known (see, for example,[16]).

When analogous phenomena are investigated in ferrites, extensive use is made of the induction method,

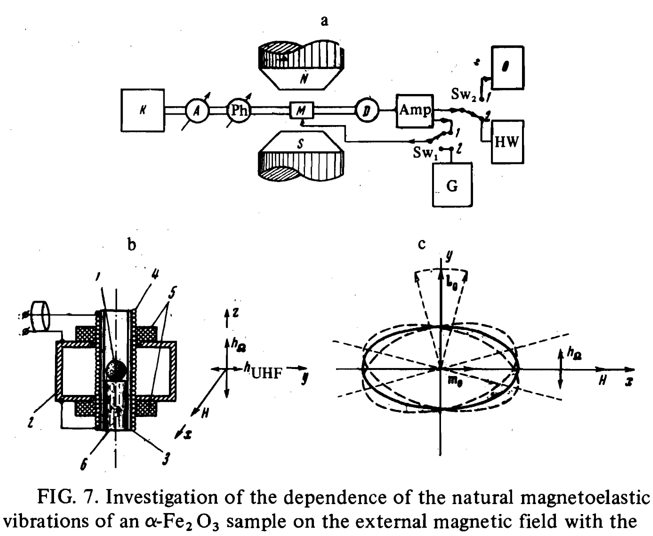

FIG. 7. Investigation of the dependence of the natural magnetoelastic vibrations of an α-Fe_2O_3 sample on the external magnetic field with the aid of antiferromagnetic resonance. a) Block diagram of setup: K–klystron generator; A–attenuator; Ph–phase shifter; M–waveguide segment with modulating coil and sample; D–microwave detector; Amp–broadband amplifier; G–high-frequency generator; HW–HF heterodyne-wavemeter; O–oscilloscope; Sw_1, Sw_2–switches, b) Section through waveguide segment M with sample (1–sample; 2–7.2 × 3.4 mm waveguide; 3–quartz tube; 4–modulating coil; 5–centering washers; 6–quartz support) and field geometry at which the experiment was performed. c) Explanation of the mechanism whereby the natural magnetoelastic vibrations of a spherical sample are excited with the aid of the modulating coil.

which has many advantages[17]. Owing to the large influence of magnetoelastic interaction on the low-frequency branch of the antiferromagnetic resonance in hematite, the natural frequencies of a hematite single crystal of finite dimensions can be measured also with the aid of antiferromagnetic resonance, and only slight modification of the installation used by us earlier[18] was needed for this purpose.

The measurements were performed at room temperature. The block diagram is shown in Fig. 7a. A microwave signal in the 8 mm band from a GZ-38 generator was fed through a decoupling attenuator A and a phase shifter Ph into measuring waveguide segment M. Figure 7b shows a section through this segment at the location of the sample, and the field geometry at which the measurements were performed. This mutual orientation of the fields ensures excitation of low-frequency antiferromagnetic resonance ($\mathbf{h}_{UHF} \perp \mathbf{H}$) and a sufficiently effective coupling between the field of the modulation coil and the sample magnetization vibrations. The mechanism whereby the natural magnetoelastic vibrations of the sample are excited by the alternating field $h_\Omega \cos \Omega t$ of the coil is explained in Fig. 7c. When the frequency $\Omega/2\pi$ coincides with the natural-vibration frequency ν_{nml} of the sample, the sample becomes resonantly excited.

The sample was a polished sphere of single-crystal hematite, placed freely in a thin-wall quartz tube with inside diameter 2 mm. A single-layer coil was wound on the tube (approximately 60 turns of wire of 0.2 mm diameter) and was mounted with the aid of bakelite centering washers in holes cut in the broad walls of the waveguide. The plane of the turns of the coil was perpendicular to $\mathbf{E}_{UHF}$, so that the screening of the sample by the coil was minimal.

The permanent magnetic field was set to the point of maximum slope of the resonance-absorption curve. Under these conditions, the magnetoelastic vibrations of the sample, modulating the resonant frequency of the antiferromagnetic resonance at a frequency Ω, alter at the same frequency the signal picked off the microwave detector, and the change is stronger the smaller the antiferromagnetic resonance line width (in our case the total width is $\Delta H_{10} = 175$ Oe). Transition to a new value of the magnetic field called for changing the operating frequency of the microwave generator in accordance with the resonance formula (1).

The detected microwave signal was fed through a broadband amplifier USh-10 and was displayed on an OK-17 oscilloscope. The frequency Ω of the microwave-signal envelope was measured with a heterodyne wavemeter. The circuit could operate in two modes (Fig. 7a): 1) amplification of the oscillations (switch Sw_1 in position 2), in which case the natural magnetoelastic vibrations were excited with the aid of a GSS-100I generator, the signal from which was fed to the coil; 2) generation regime (switch Sw_1 in position 1), in which case the signal from one of the outputs of the amplifier USh-10 was fed back to the coil (feedback loop). The principal measurements were performed in the generation regime, since the frequency stability of the GSS-100I generator was insufficient, in view of the high Q of the excited oscillations. To avoid frequency "pulling," the gain was set near the excitation threshold.

In view of the high Q of the natural magnetoelastic oscillations of the freely lying sphere, and the sufficiently good resolution, the identification of these oscil-

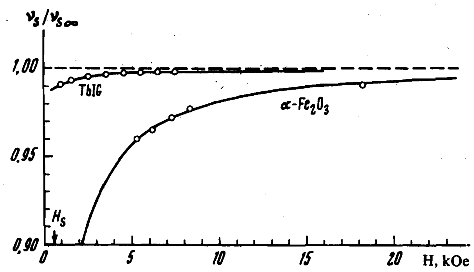

FIG. 8. Relative frequency of natural magnetoelastic oscillation of small sphere of single-crystal α-Fe_2O_3 vs. external magnetic field (S_{21} mode). Sphere diameter 1.5 mm, $\nu_{s\infty}$ = 2430 kHz, H_{nml}^{med} = 0.7 Oe. A similar plot for TbIG [17] is shown for comparison.

lations following discrete variations of the field cause no particular difficulties.

Measurement results and discussion. The points of Fig. 8 show the experimental field dependence of the frequency of one of the highest-Q modes of the natural quasielastic oscillations of a sphere of 1.5 mm diameter of single-crystal hematite, plotted in the generation regime. This plot can be satisfactorily described by the formula

$$\nu_{nml}=\nu_{nml}^{\infty}\left[1-\frac{2H_EH_{nml}^{med}}{(\omega_{10}/\gamma)^2}\right]^{1/2}, \quad (4)$$

if the values ν_{nml}^{∞} = 2430 kHz and H_{nml}^{med} = 0.7 Oe are fitted by least squares. On the basis of the excitation method, the high Q and intensity, and also the frequency, the observed oscillation can be identified with the oblate-oblong mode S_{12} of an elastic sphere (using the notation of[14]).

For comparison, Fig. 8 shows a similar curve for terbium iron garnet (PbIG), plotted from the data of[17]. We see that for hematite the dependence of the frequency of the quasielastic oscillations on the magnetic field is much stronger than for TbIG. This is connected primarily with the amplifying action of the large exchange field, an action characteristic of antiferromagnetism.

We have briefly reported the main results of this part of the investigation in[19]. Simultaneously, analogous investigations of the ν_{nml}(H) dependence for hematite were performed by Seavey[20], who obtained a value H_{med} $\approx$ 0.5 Oe for the long-wave mode of quasielastic oscillations of a thin plate.

The strong dependence of the velocity of the quasisound and of the frequencies of the natural quasielastic oscillations on the magnetic field, which was observed in hematite, can be of definite technical interest. It is important therefore to investigate the mechanisms whereby quasielastic oscillations relax in hematite.

CONCLUSION

Owing to the specific participation of the exchange field, the influence of magnetoelastic interaction in antiferromagnets on their static and dynamic properties is much more strongly pronounced than in ferrites. A convenient way of investigating this interaction is provided by antiferromagnetic resonance. Owing to the magnetoelastic interaction, the equilibrium configuration of the magnetic moments of the sublattices and the frequencies of their resonant oscillations are functions not only of the external field **H**, but also of the external elastic stresses σ_{ik}, and a situation is possible wherein the "sublattice flipping" is induced by an external (unidirectional) pressure, as was observed by us for hematite. In addition, the velocity of the quasisound in antiferromagnets is a function of H and σ_{ik}, and the changes induced by the field n (or by the stresses) can in many cases be quite appreciable also because of the amplifying action of the exchange forces.

We are deeply grateful to I. K. Kikoin for interest in this work. We are sincerely grateful to R. A. Voskanyan for supplying the samples and to A. S. Borovik-Romanov, R. Z. Levitin, and E. G. Rudeshevskiĭ for useful discussions.

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Translated by J. G. Adashko
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