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MAGNETOELASTIC DOMAINS AND DYNAMICS OF DOMAIN WALLS IN TETRAGONAL ANTIFERROMAGNETS

Specialty 01.04.07 – Physics of the Condensed Matter

ABSTRACT
Thesis on competition of a scientific degree
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This work was made on chair of Theoretical Physics of Bashkir State University.

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Dissertation General Characteristic

The Theme Actuality. The conjecture that in some cases the antiferromagnets can be divided into macroscopic areas (magnetic domains), was made by the Néel in 1948 [1]. The experimental research of domain structure in antiferromagnets was initiated in 1960 [2, 3].

The investigations have shown, that there are some reasons causing origin of domain structure in antiferromagnets. For example, in samples with many equivalent axes of an antiferromagnetism the domain structure can be generated during a magnetic ordering. For some antiferromagnets in a defined interval of temperatures the entropy term of free energy can exceed an increase of energy in domain wall, then the formation of domain structure is favorable from a thermodynamic point of view [1, 4].

The interaction between magnetic and elastic subsystems of a crystal plays the important role in formation of domain structure of real crystals [4, 5]. Generally, a formation of domain structure in antiferromagnets without a weak ferromagnetism energetically is not favorable. Domain structure in antiferromagnet corresponds not absolute, but relative minimum of free energy. The magnetoelastic forces together with forces of a magnetic anisotropy aspires to keep spins in defined directions. The presence of nonuniform stresses can results in situation when in different areas of a magnetic sample these directions will differ, i.e. there are premises for formation of the domain structure.

In recent time in different science journals many works with result of investigation of the multiaxial tetragonal antiferromagnet $FeGe_2$ was published [6, 7]. It is well known, that domain structure makes essential influence on different characteristics of magnetic crystals. It is rather difficult to grow up a chip without internal defects. The presence of defects results in appearance nonuniform internal stresses in a magnetic sample. Experimental researches [8, 9] have shown that presence external and internal stresses both uniform and nonuniform exerts essential influence on stability of magnetic phase and on domain walls dynamics.

In this connection there is a necessity of study of a domain structure statics and dynamics in tetragonal multiaxial antiferromagnets from the point of view of presence of nonuniform mechanical stresses.

The purpose of this work is the development of the theory of domain structure in easy-plane tetragonal antiferromagnets with taking into consideration influence of the spontaneous magnetostrictive and internal nonuniform mechanical stresses, and also an exterior magnetic field and uniaxial mechanical pressure. Construction of a magnetization curve in the view of reconstruction of a domain structure both under an operation of an exterior magnetic field, and under an operation of exterior pressure. An essential moment is the investigation of dynamics of domain walls with taking into consideration the dependence of translation and pulse oscillations of domain walls on the above-stated interactions.

The scientific novelty of this dissertation work is, that a theoretical research of influence of an exterior uniaxial mechanical stresses, an exterior magnetic field, and internal nonuniform mechanical and magnetostrictive stresses on characteristics of domain structures of different types in easy-plane tetragonal antiferromagnets is carried out for the first time. Reconstruction process of 90-degree domain structure in 180-degree one and back, and also influence of exterior effects, and internal nonuniform mechanical stresses on processes of magnetization and reconstruction of domain structure is considered in details for the first time. In paper is shown, that the characteristics of translation and pulse oscillations of domain wall can be changed in rather significant limits both under an influence of a magnetic field and uniaxial stresses and at change of nonuniform internal mechanical stresses.

Practical importance. The obtained results expand existing representations about domain structure and processes of magnetization of easy-plane antiferromagnets, allow to understand the mechanism of interaction of exterior and internal stresses with a magnetic subsystem and to describe experimental curves of magnetization. The obtained results can be used at development of devices of an estimation of materials quality, at constructing devices with easy manageable by parameters and also ultrasonic generators. The practical importance of paper is determined also by that the developed theory can be used for explanations of features of magnetization curves of multiaxial antiferromagnets, and also forms the basis for the further development of nonlinear magnetoelastic dynamics of domain walls in multiaxial antiferromagnets.

Defended Items:

1) The theory of magnetoelastic domain structure in tetragonal easy-plane antiferromagnets sequentially taking into account spontaneous magnetostriction and internal nonuniform mechanical stresses.
2) Results of a investigation of dependences of critical fields of 90-degree and 180-degree domain structures reconstruction on amplitude of internal nonuniform mechanical stresses and magnitude of the exterior unidirectional pressure.
3) Curve of magnetization of a tetragonal antiferromagnet in an exterior magnetic field obtained within the framework of the micromagnetic theory. A prediction of existence of a characteristic leap on the curve of the magnetization caused by presence of magnetostrictively charged 90-degree walls.
4) Theoretical investigations of domain walls dynamics in an external magnetic field. Prediction of reduction and vanishing of frequency of pulse os-

cillations of a 180-degree domain wall at an approximation to a field of disintegration of a 180-degree wall on two 90-degree ones.

Approbation of dissertation. The basic results of this work were reported at XV-th and XVI-th the All-Russia schools - seminars "New magnetic materials of a microelectronics" (Moscow, 1996, 1998), at All-Russia scientific conference "Physics of the condensed matter" (Sterlitamak, 1997), at Republican scientific conferences of the students both post-graduate students on physics and mathematician (Ufa 1997, 1998), at Regional conference "the Resonance and nonlinear phenomena in the condensed environments" (Ufa, 1999), at II-nd integrated conference on a magnetoelectronic (Ekaterinburg, 2000), at The XXVIII International winter school of the physician-theorists "Kourovka-2000" (Ekaterinburg, 2000).

The publications. The results are published in 12 printed papers.

Structure of this Thesis. There are introduction, four chapters and conclusion in this work. It is includes 116 pages with 32 figures and 73 bibliographic references.

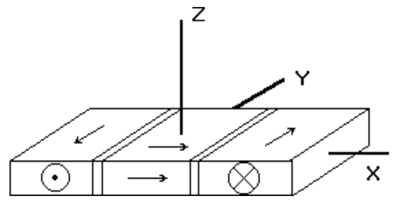
Brief Contents of the Thesis

<u>In Introduction</u> the urgency of the chosen subjects is justified. There the purpose and basic defended Items of the thesis are formulated. The some information on structure and contents of this work are given.

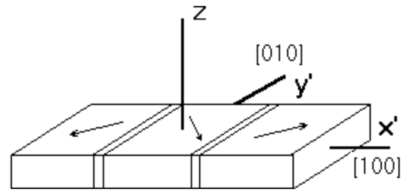
<u>In the first chapter</u> the review of the literature on a theme of the thesis is carried out. The necessary items of information on free energy of antiferromagnets, types of possible domain walls, processes of reconstruction of domain structure and magnetization of magnets here are briefly stated. The characteristics, and also review of experimental works on magnetization of a monocrystal $FeGe_2$ is given. In the conclusion of the chapter on the basis of a given material the tasks of this thesis are specified more finely.

<u>The second chapter</u> is devoted to a results of investigation of interaction nonuniform magnetostrictive strains and stresses in an easy-plane tetragonal antiferromagnet with different types of domain structures. Detailed phenomenological review was carried out for a case of a positive fourth order constant of a magnetic crystallographic anisotropy K_4. In this situation, axes of an antiferromagnetism are the axes of <110> type, laying in an easy plane (001). The system axes are directed along axes of an antiferromagnetism, the exterior and internal nonuniform mechanical stresses are directed along the [110] axis.

There three domain structures with different type of domain walls (see fig.1): $S^{\perp a}$ – DW perpendicular to the basal plane and axis <110>-type, $S^{\perp b}$ – DW perpendicular to the basal plane and axis <100>-type, $S^{\parallel}$ – DW parallel to the basal plane are investigated. The increment of magnetoelastic energy related both with magnetostrictive, internal and external mechanical stresses. For each of domain structure this energy increment will be written as:



a)



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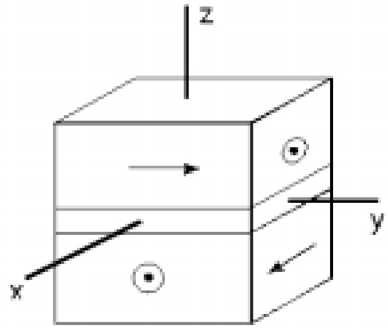

c)

Fig.1 The Models of domain structures that are investigated in paper: a) $S^{\perp a}$ – DW perpendicular to the basal plane and axis <110>-type; b) $S^{\perp b}$ – DW perpendicular to the basal plane and axis <100>-type; c) $S^{\parallel}$ – DW parallel to the basal plane

$$\Delta E^{\perp a} = \frac{1}{2}K_{ms}^{\perp a}\left(\cos 2\varphi - \langle\cos 2\varphi\rangle\right)^2 - K^{\perp a}\left(\sigma - \langle\sigma\rangle\right)\left(\cos 2\varphi - \langle\cos 2\varphi\rangle\right) + F^{\perp a}\left(\sigma^2\right),$$

$$\Delta E^{\perp b} = \frac{1}{2}K_{ms}^{\perp b}\left(\sin 2\varphi - \langle\sin 2\varphi\rangle\right)^2 - K^{\perp b}\left(\sigma - \langle\sigma\rangle\right)\left(\sin 2\varphi - \langle\sin 2\varphi\rangle\right) + F^{\perp b}\left(\sigma^2\right),$$

$$\Delta E^{\parallel} = \frac{1}{2}K_{ms;1}^{\parallel}\left(\cos 2\varphi - \langle\cos 2\varphi\rangle\right)^2 + \frac{1}{2}K_{ms;2}^{\parallel}\left(\sin 2\varphi - \langle\sin 2\varphi\rangle\right)^2 + $$
$$ + K^{\parallel}\left(\sigma - \langle\sigma\rangle\right)\left(\frac{d\varphi}{dz}\right)^2 + F^{\parallel}\left(\sigma^2\right).$$

Here φ is the angle between the [110] axis and an antiferromagnetism vector $\vec{l}$, K_{ms} – constant of magnetostriction, $K^{\parallel}, K^{\perp a}, K^{\perp b}$ – some combinations of components of elastic and magnetoelastic interactions tensor. Some conclusions follows from the analysis of magnetoelastic energy increment in comparison with the condition without a domain structure: 1) 90-degree domain walls

$S^{\|}$ and $S^{\perp a}$ types are magnetostrictively charged (i.e. spontaneous magnetostrictive stresses is nonzero in domains), but 90-degree walls $S^{\perp b}$ type and all 180-degree domain walls are magnetostrictively noncharged (i.e. spontaneous magnetostrictive stresses is nonzero into domain walls only); 2) the contribution to an increment of elastic energy is given only by nonuniform internal mechanical stresses; 3) for $S^{\|}$ structures interaction of domain structure with nonuniform internal mechanical stresses can be determined only at the account of an exchange part of magnetoelastic energy.

Conditions of relative energy-advantage of domain structures with a defined type of domain walls further are defined. From the analysis of a full energy of domain structures follows, that at $P = 0$ the presence of internal mechanical stresses can result in energy-advantage of structures with 90-degree magnetostrictively charged walls in comparison with 180-degree magnetostrictively not charged ones. We shall assume, that the internal inhomogeneous mechanical stresses vary under the law

$$\sigma^{in} = -\sigma_0 \sin\frac{\pi x_i}{d} , \qquad (1)$$

where σ_0 and $2d$ denotes the amplitude value and period of nonuniform internal stresses, and x_i – axis that normal to domain walls plane. For this situation the advantage condition of the 90-degree structure in comparison with the 180-degree (at $D = (2n+1)d$) can be rewritten as

$$\sigma_0 > \sigma_{kd},$$

$$\sigma_{kd}^{\perp a} = \pi(2n+1)K_{ms}^{\perp a}\frac{C_{11}+C_{12}+2C_{66}}{4B_{66}}; \qquad (2)$$

Results for wall $S^{\|}$ type qualitatively iterate results for the $S^{\perp a}$-DW. As it's shown at second chapter the most energy-advantageous is the 90-degree structure with the period $L_0 = 2D$ equal to the period of internal mechanical stresses $2d$. This structure becomes more advantageous than the 180-degree domain structure at the smallest value of the amplitude of internal mechanical stresses σ_0 .

Possibility of advantage of formation of multidomain structure with the 90-degree magnetostrictively noncharged walls in comparison with a magnetouniform condition is considered. It is shown, that the fragmentation of the sample with uniform distribution of an antiferromagnetic vector to domain structure with 90-degree walls such as $S^{\perp b}$ will be energy-favorable under following condition:

$$\Delta W = \frac{C_{33}(C_{11}-C_{12})+2C_{13}^2}{8C_{11}\left[C_{33}(C_{11}+C_{12})-2C_{13}^2\right]}\sigma_0^2 - \frac{2d}{\pi D}\frac{B_{66}}{4C_{66}}\sigma_0 + \frac{E_W^{(90)}}{D} < 0 . \qquad (3)$$

Here the second item describes interaction of inhomogeneous mechanical stresses with inhomogeneous magnetostrictive strains caused by inhomogeneous distribution of an antiferromagnetic vector. The discriminant of a square inequality concerning unknown parameter σ_0 will look like:

$$\Delta_\sigma = \left(\frac{2d}{\pi D}\frac{B_{66}}{4C_{66}}\right)^2 - \frac{\sqrt{A\widetilde{K}_4}}{D}\cdot\frac{C_{33}(C_{11}-C_{12})+2C_{13}^2}{2C_{11}\left[C_{33}(C_{11}+C_{12})-2C_{13}^2\right]} \geq 0,$$

where $\widetilde{K}_4$ is constant of 4[th] order of a magnetic crystallographic anisotropy that renormalized with account of the spontaneous magnetostriction, A is a constant of exchange interaction. Further, with assuming $B_{66} \sim 10^6\ \mathrm{J/m^3}$, , $C_{ik} \sim 10^{11}\ \mathrm{J/m^3}$, $\widetilde{K}_4 \sim 10^3\ \mathrm{J/m^3}$ and $d = D$, the ratio for width of the domain and effective width of domain wall is obtained $\pi\delta_0/D < 10^{-2}$. From eq.(3) it appears, that multidomain structure with $S_{90}^{\perp b}$ domain walls at amplitude values $\sigma_1 < \sigma_0 < \sigma_2$ is energetically more advantageous than magnetouniform state, where

$$\sigma_{1,2} = \left(\frac{2d}{\pi D}\frac{B_{66}}{4C_{66}} \pm \sqrt{\Delta_\sigma}\right)\cdot\frac{2C_{11}\left[C_{33}(C_{11}+C_{12})-2C_{13}^2\right]}{C_{33}(C_{11}-C_{12})+2C_{13}^2}. \qquad (4)$$

The estimate for stresses amplitude value $\sigma_i \sim 10^6\ \mathrm{J/m^3}$ is obtained, and it correlates well with experimental data [8, 9].

In contrast to ferromagnets, where fragmentation to domain structure caused by magnetostatics, in antiferromagnets described structures are stabilized due magnetoelastic interaction. In this connection, domain structure that is stabilized due nonuniform stresses we will call *magnetoelastic domain structure*, and domains – *magnetoelastic domains*.

At Third chapter the processes of domain structure reconstruction under influences an external magnetic field and an unidirectional pressure, that impressed along one of antiferromagnetic axes [110], are described. Taking into consideration this processes the magnetization curve of tetragonal antiferromagnets with presence of nonuniform magnetostrictive and mechanical stresses in a crystal is constructed.

The condition of magnetic phases stability with presence of the magnetic field have the form:

$$\widetilde{K}_4 > \pm\left(\frac{1}{4}\chi_\perp H^2 - K_p\right) \tag{5}$$

here the "+" sign corresponds to the phases $\varphi = 0, \pi$, whereas the "–" sign corresponds to the phases $\varphi = \pm\pi/2$. As can be seen from Eq.(5), the stability areas of different magnetic phase overlap. In this case a 90-degree domain structure of the antiferromagnet can exist.

The processes of domain structure reconstruction in the magnetic field is investigated by analyzing following Euler equation

$$A\frac{d^2\varphi}{dx^2} - 2\widetilde{K}_4 \sin 2\varphi \cos 2\varphi = \Phi(x,\varphi)\,. \tag{6}$$

The form of $\widetilde{K}_4$ and function $\Phi(x,\varphi)$ at right part of Eq.(6) is determined by type of domain wall. The solitons perturbation theory is applied for determination of characteristics of domain wall and magnetic field critical values of domain structure reconstruction. Investigation is made with assumption that for all structures take place following condition:

$$K_4 >> \left|K_\sigma\right|, K_{ms}, K_P, \chi_\perp H^2, \tag{7}$$

90-degree domain structure. When condition (7) is met, it can be consider that:

$$\varphi = \varphi_0 + \varphi_1 + \varphi_2 + ..., \qquad q = q_{eq} + q_1 + ...$$

where q is the parameter describing the position of the domain wall centre along the direction of the x axis ; q_{eq} is the value which describes the DW equilibrium position; q_1 describes the deviation of q from q_{eq}; φ_1, φ_2 are small deviations from φ_0. From equation for φ_0 dependence of antiferromagnetic vector rotation angle on parameter q in domain wall is obtained:

$$\cos 2\varphi_0 = \tanh\xi; \quad \sin 2\varphi_0 = \cosh^{-1}\xi, \quad \xi = \frac{x - q_p}{\delta_0}, \quad \delta_0 = \sqrt{\frac{A}{4\widetilde{K}_4}}. \tag{8}$$

From solvability condition of equation for φ_1 it is obtained that in an external magnetic field and unidirectional pressure absent the 90-degree domain walls are placed at the places of reversing signs of internal nonuniform stresses $\sigma^{(in)}(x)$. In the presence of an external magnetic field or unidirectional pressure, the 90-degree domain wall moves from the stable position. Dependence of equilibrium displacement on magnetic field for magnetostrictively charged structures is shown on fig.2

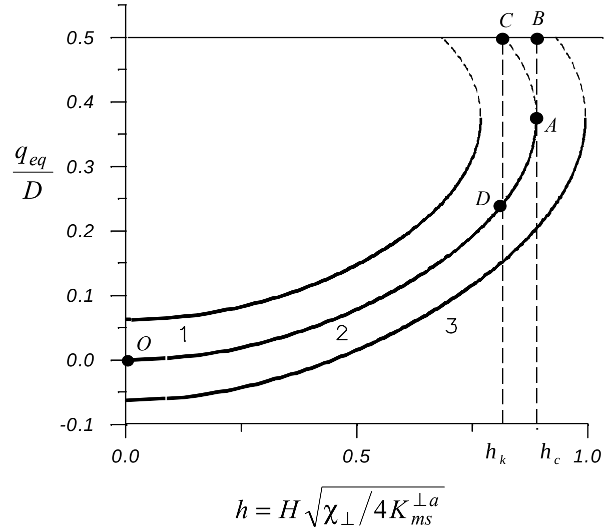

Fig.2 The stable location of the 90-degree DW in an external magnetic field (solid lines correspond to stable DW conditions, whereas dashed ones – to unstable ones), at $\sigma_{kw}/\sigma_0 = 1.2/\pi$; K_p/K_{ms} : 1) – 0.2; 2) 0.0; 3) 0.2; h_c is the detachment field of the 90-degree DW from the potential hole, h_k is the field of stability loss by the 180-degree DW.

From solvability condition of equation for φ_2, critical values of magnetic field H_c and pressure P_c of DW separation from the "defect" is determined for all types of domain walls. For example for structure with domain walls of $S_{90}^{\perp a}$ type the critical parameters has form::

$$H_c^{\perp a} = \frac{2}{\sqrt{\chi_\perp}}\left\{\frac{B_{66}\sigma_0}{C_{11}+C_{12}+2C_{66}}\left[\sqrt{1-\left(\frac{\sigma_{kw}}{\sigma_0}\right)^2} - \frac{\sigma_{kw}}{\sigma_0}\arccos\frac{\sigma_{kw}}{\sigma_0}\right] + \frac{B_{66}P}{4C_{66}}\right\}^{1/2}$$

$$P_c^{\perp a} = -\frac{4\sigma_0 C_{66}}{C_{11}+C_{12}+2C_{66}}\left[\sqrt{1-\left(\frac{\sigma_{kw}}{\sigma_0}\right)^2} - \frac{\sigma_{kw}}{\sigma_0}\arccos\frac{\sigma_{kw}}{\sigma_0}\right]$$

From the analysis of H_c it follows existence of the amplitude value of 90-degree wall stability σ_{kw}, and the following proportion is met: $\sigma_{kd}^{\perp a}/\sigma_{kw}^{\perp a} = \pi^2/8$, at $n = 0$.

180-degree domain structure. As well as in case of 90-degree domain structure the Euler equation is solved by a method of the solitons theory of perturbations. The detailed consideration is written for a wall such as $S_{180}^{\perp a}$. The decision of the equation in a zero approximation looks like:

$$\tan\varphi_0 = -\sqrt{\frac{\kappa_0}{1+\kappa_0}}\sinh\left(\xi\sqrt{1+\kappa_0}\right), \qquad (9)$$

$$\kappa_0 = \frac{1}{K_4^{\perp a}}\left(\frac{1}{4}\chi_\perp H^2 + K_{ms}^{\perp a} - K_P - K_\sigma^{\perp a}\right).$$

At $\kappa_0 \to 0$, there appears on the dependency $\varphi = \varphi(x)$ a long inflection, whereas the DW width tends to infinity. This, as is well known [9], means the 180-degree DW instability to disintegration into two 90-degree ones. Critical value of field has a form:

$$H_k^{\perp a} = \frac{2}{\sqrt{\chi_\perp}}\left(K_\sigma^{\perp a} - K_{ms}^{\perp a} + \frac{B_{66}P}{4C_{66}}\right)^{1/2}.$$

Thereby, with an increasing of value of pressure, at $P > 0$ the magnetic field value of domain wall disintegration $H_k^{\perp a}$ grows, whereas at $P < 0$ – it descends. In last case at $P = P_k^{\perp a}$ value of critical field is zero $H_k^{\perp a}$=0, where

$$P_k^{\perp a} = \frac{4C_{66}}{B_{66}}\left(K_{ms}^{\perp a} - K_\sigma^{\perp a}\right).$$

From expression for $H_k^{\perp a}$ it is seen, that at $P = 0$ stability can be lost only when $K_\sigma^{\perp a} > K_{ms}^{\perp a}$ is met, i.e. at $\sigma_0 > \pi\sigma_{kw}^{\perp a}/2$, where $\sigma_{kw}^{(0)} = \sigma_{kw}$ for $n = 0$.

Reconstruction 90-degree domain wall in 180-degree one for magnetostrictively charged walls occurs as follows: as the strength of the magnetic field gradually increases, the coordinate of the equilibrium position of the 90-degree DW q_{eq} increases, for example, following the curve *ODA* (see Fig. 2) and full energy of the 90-degree domain structure decreases (see Fig.3). In the point *A*, i.e. at $H = H_c$ there will occur a separation of the domain wall from the potential hole, and in a leap it will find itself in the point *B* with the coordinate $q_{eq} = d/2$. In this point the similar-polarity domain walls merge into one 180-degree DW,

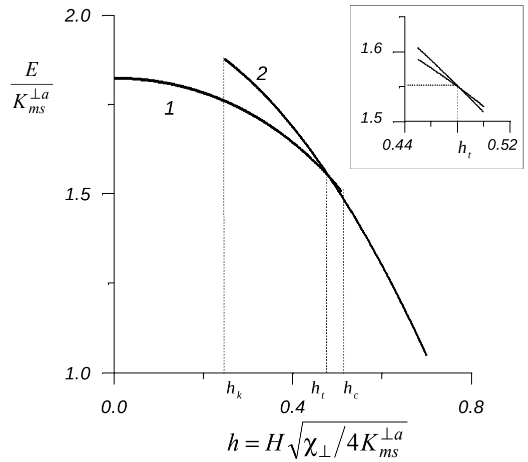

Fig.3. Full energy of the 90- (curve 1) and 180-degree (curve 2) domain structures in an external magnetic field, at $\delta_0/D = 10^{-2}; \sigma_{kw}/\sigma_0 = 0.6; K_p = 0.0$; h_t is the field of the transition of the 90-degree domain structure into the 180-degree one.

whereas the ones of opposite polarities annihilate. If now the field strength is again decreased, the 180-degree DW will remain stable in the same position (line *BC*). Only its thickness will increase until the field strength reaches the critical value H_k of the stability loss of the 180-degree DW structure. Proceeding from last statement the conclusion, that the process of reconstruction has hysteretic character, is made. The fields H_c and H_k determines the metastability boundaries of domain structures with 90-degree and 180-degree DWs, respectively. However, the transition is effected in a leap, as a phase transition of the first kind in the point $H = H_t$, the latter point being determined by the equality condition of the full energies of both of the structures (see Fig.3).

For the case of magnetostrictively noncharged $S_{90}^{\perp b}$ DW, points *A* and *B* are matching, i.e. domain wall shifts to displacement value equal $q_{eq} = D/2$. Thus reconstruction occurs smoothly, without leap.

Further, on the basis of results of an investigation of domain structure reconstruction, magnetization curves were plotted. The experimental and theoretical data are compared. Form of magnetization curve of magnetostrictively

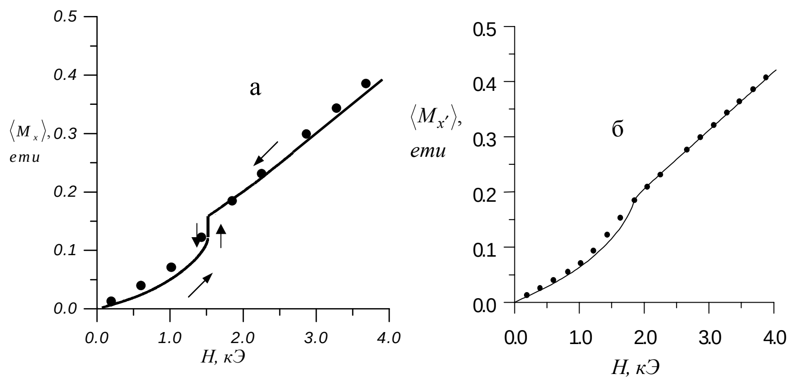

Fig.4. Magnetization curves for magnetostrictively charged (a) and noncharged (b) domain structures at *P=0*. Experimental data that was obtained by Vlasov K.B. and others [8, 9] is marked by points.

charged and noncharged walls is shown on Fig.4. It is seen that for magnetostrictively charged walls at some value of strength of magnetic field, a leap of magnetization takes place. Value of strength of magnetic field at this point corresponds to a stability loss field of 90-degree domain wall. In a case of the magnetostrictively noncharged walls on a magnetization curve there is no leap.

From Fig.4 it's seen, that theoretical curve agree well with experimental data. The most complete conformity can achieve with assumption, that in a sample there are different types of a DW simultaneously.

At Fourth chapter the results of theoretical investigation of translation and pulse domain wall oscillation are stated. It is turned out, that the frequency of translation oscillations is sensitive to characteristics of nonuniform mechanical stresses (like amplitude and period).

Fig.5 presents dependence of frequency of translation oscillations of 90-degree domain wall. It can be seen, that at increase of strength of magnetic field at stretching ($P<0$) and zero pressure there is a monotone reduction of frequency up to zero, and at compressing external pressure ($P>0$) at first there is an increase of frequency, and then same monotone reduction up to zero. It is related with fact, that at chosen geometry of fields and pressures ($\vec{H} \uparrow\uparrow \vec{P} \parallel [110]$) under influence of unidirectional pressure, domain walls moves, and at $P<0$ DW moves in the same direction, as in a case of influence of magnetic field, and at $P>0$ in the opposite one.

The transformation of frequency of translation oscillations into zero means a point of an detachment of 90-degree domain wall from a potential hole.

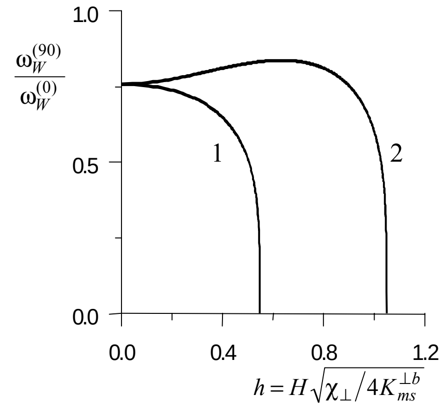

Fig.5 Dependence of frequency of translation oscillations of 90-degree domain wall $S_{90}^{\perp b}$ on external magnetic field at $K_{\sigma_0} / K_{ms}^{\perp b} = 0.7$, 1) $K_p / K_{ms}^{\perp b} = -0.4$; 2) $K_p / K_{ms}^{\perp b} = 0.4$.

Fig.6 presents plots of frequency of translation and pulse oscillations of 180-degree domain walls. It can be seen, that with decrease strength of magnetic field (at $\sigma_0 > \sigma_{kd}$) value of translation oscillations frequency increases and at some point turns to the infinity. This situation is specified by domain wall width's growth, that leads from one hand to reduction of effective mass of domain wall, and from other hand to augmenter of quasi-elastic nexus parameter.

New oscillation mode of 180-degree domain wall, that correspond to domain wall width oscillation is discovered. The oscillations that type is called *pulse oscillations*. With decreasing strength of magnetic field the frequency of the pulse oscillations

$$\omega_p = \frac{2\gamma}{\sqrt{2\chi_\perp}}\left[4\left(K_{ms}^{\perp a} - K_{\sigma_0}^{\perp a} - K_P\right) + \chi_\perp H_0^{\,2}\right]^{1/2}$$

decreases too, and at field value of disintegration of 180-degree wall into two 90-degree ones frequency value is vanished. This fact means that at some critical value of the magnetic field, 180-degree DW becomes unstable relatively to disintegration into two 90-degree ones. In case of domain walls $S^{\parallel}$, and when $\sigma_0 < \sigma_{kd}$ for $S^{\perp}$ structures, with decreasing magnetic field value, the frequency of translation oscillation increases to some finite value, and pulse oscil-

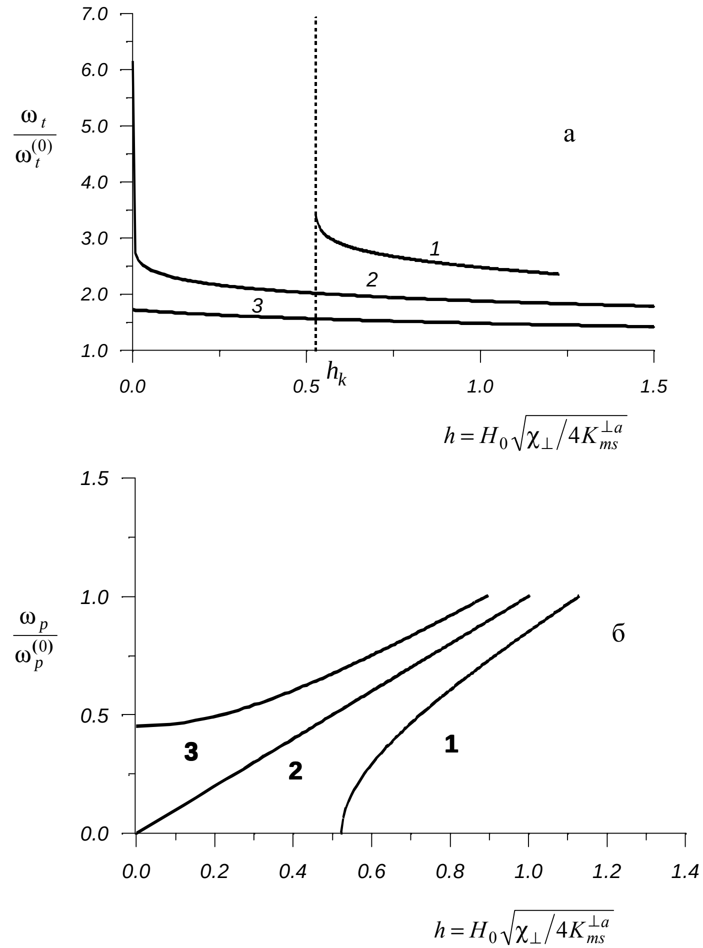

Рис.6. Зависимость частоты трансляционных (а) и пульсационных колебаний 180-градусной доменной границы при $P=0$; σ_k/σ_0: 1 – 0.5; 2 – 0.8; 3 – 2.0.

lation frequency with decreasing does not vanish. So, 180-degree domain structure with domain walls $S^{\parallel}$ type is stable an in magnetic field absent.

It is shown, that critical fields of reconstruction, that are determined from investigations both ground state and domain walls dynamics is matched.

About a point of disintegration 180-degree DW into two 90-degree ones, the giant oscillations of domain wall width can be generated, that at first time is investigated in case of cubic ferromagnets [11]. For ferromagnets a backmoving force is conditioned by magnetostatics. This thesis researches allows to assert that for the case of antiferromagnets the backmoving force is conditioned by magnetostriction.

Giant oscillations of domain wall width may be accompanied by an emission of acoustic waves.

In Conclusion main results of the thesis is formulated:

1) There theory of 90-degree and 180-degree domain structures in easy-plane tetragonal antiferromagnet is developed. It is sequentially taking into account spontaneous magnetostriction, internal nonuniform mechanical stresses, an external magnetic field and unidirectional external pressure. It is shown, that in defined interval of an amplitude of internal nonuniform mechanical stresses energetically more advantageous is the formation of the 90-degree magnetostrictively noncharged domain structure.
2) Existence of the critical values of the internal nonuniform stresses amplitude of stability σ_{kw} and advantage σ_{kd} of the 90-degree magnetostrictively charged structure relatively to 180-degree one is shown. There critical values of an external magnetic field and unidirectional pressure are found, under that 90-degree domain wall separates from a potential hole, that is conditioned by interaction between domain walls and nonuniform mechanical stresses.
3) It is established, that disintegration 180-degree domain walls, that perpendicular to the basal plane, into two 90-degree take place in presence of internal alternating mechanical stresses. Critical values of magnetic field of 180-degree walls disintegration is defined by amplitude of internal nonuniform mechanical stresses and by value of an external unidirectional pressure. The processes of domain structure reconstruction for the magnetostrictively charged walls has hysteretic and for magnetostrictively noncharged – nonhysteretic nature.
4) The magnetization curves for all considered structures are plotted. It is shown, that at critical value of a magnetic field when 90-degree structure is reconstructing into 180-degree one, in the case of magnetostrictively charged walls take place the leap of magnetization, and in the case of magnetostrictively noncharged this leap is absent. Results of theoretical investigations agree well with experimental data.
5) Linear oscillations of domain walls in easy-plane tetragonal antiferromagnets are investigated. It is shown strong influence of internal and external nonuniform mechanical stresses on dependence of the frequency of transla-

tion and pulse oscillations on an external magnetic field. It is established, that at positive magnetostriction an external compressive stresses results in decreasing and vanishing value of the pulse oscillation frequency ω_p , i.e. to instability of 180-degree domain wall concerning to disintegration into two 90-degree. An external stretching stresses vice versa, results in increasing value of the frequency ω_p , and then to stability of the structure with 180-degree domain walls

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