EDGE RESONANCE AT VIBRATION AND ELASTIC WAVES EXCITATION IN THREE-DIMENTIONAL ANISOTROPIC BODIES OF THE HEXAGONAL SYSTEM

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Summary The results of edge resonance effects theoretical research for the case of axisymmetric vibrations in transversally-anisotropic solid plates and rings and the case of waves excitation in transversally-anisotropic semi-layer and anisotropic semi-cylinder are presented. Numerically-analytical method of rows on base great number of travelling and edge standing normal waves was applied to studied problems. Effects of frequency spectrums and edge resonance shapes transformation are described.

Edge resonances by transversally anisotropic solids and rings axisymmetric vibrations and waves excitation in transversally anisotropic semi-layer and anisotropic semi-cylinder theoretical research results are presented. Numerically-analytical method on base great number of travelling and edge standing normal waves was applied to studied problems.

It was fined the special wave anisotropy rate parameter Δ_m that defines a structure of travelling and edge standing waves dispersion spectrums (Fig. 1, Fig. 2) and edge resonance features in studied bodies. This parameter is determine by ratio $\Delta_m = (1-4\alpha_1\delta_1)/\beta_1^2$, where $\alpha_1 = s_1^2\mu_2$, $\delta_1 = s_1^2(\mu_1+1)$, $\beta_1 = s_1^4 + \mu_2(\mu_1+1) - \mu_3^2$, $s_1^2 = 2c_{44}/(c_{11}-c_{12})$, $\mu_1 = (c_{11}+c_{12})/(c_{11}-c_{12})$, $\mu_2 = 2c_{33}/(c_{11}-c_{12})$, $\mu_3 = 2(c_{13}+c_{44})/(c_{11}-c_{12})$, c_{ij} - elasticity constants of hexagonal system anisotropic material.

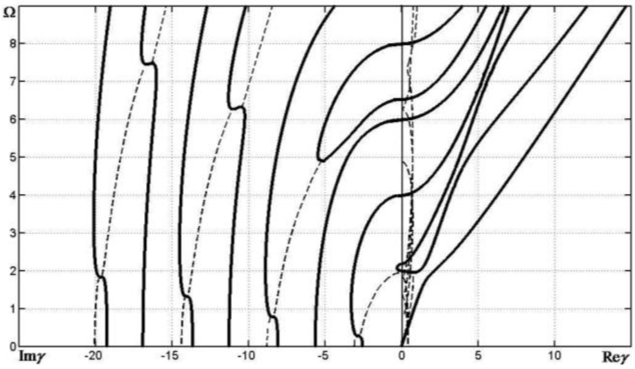


Fig. 1 Dispersion spectrum of *Co* crystal plate $\Delta_m = 0.64$

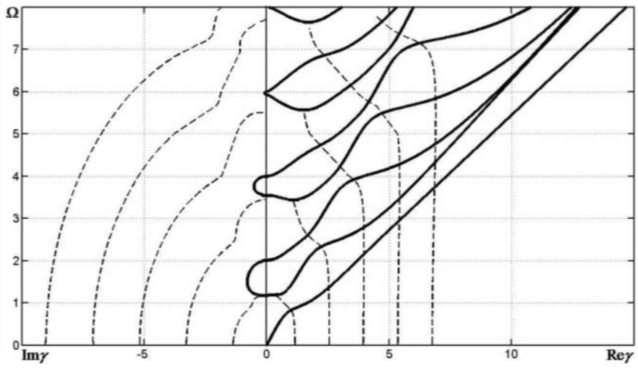


Fig. 2 Dispersion spectrum of *Zn* crystal plate $\Delta_m = -10.2$

Amplitude-frequency and frequency-phase dependences for disk plates and rings dynamical characteristics was obtained and analyzed applied to some real ceramic and crystal materials with different values of generalized wave anisotropy parameter Δ_m. Dependences of resonance frequencies from studied bodies' geometric characteristics are obtained. Theoretical method of edge resonance frequencies Ω_e finding and vibration shapes on these frequencies building was developed. High match level of obtained by this method and presented in the paper [1] results for $BaTiO_3$ piezoceramic solid plate was received.

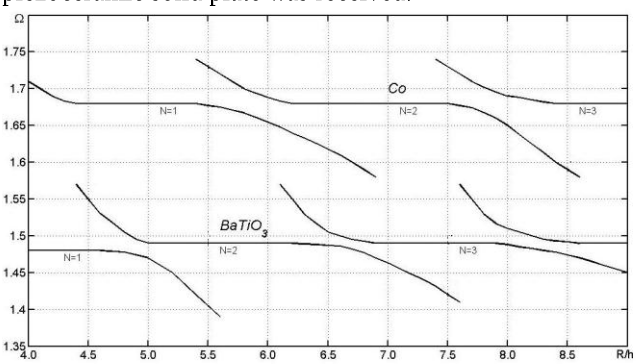


Fig. 3 Edge resonance spectrums for *Co* ($\Delta_m = 0.64$) and $BaTiO_3$ ($\Delta_m = 0.023$) plates

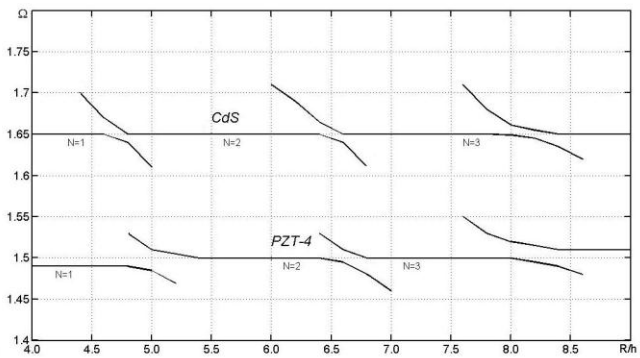


Fig. 4 Edge resonance spectrums for *CdS* ($\Delta_m = 0.4$) and $PZT-4$ ($\Delta_m = 0.055$) plates

The effect of edge resonance frequency Ω_e growth for solid plates with positive growing by module parameter Δ_m was established (Fig. 3, Fig. 4), in particular Ω_e increase on 0.4% for $BaTiO_3$ plates, on 1.15% for $PZT-4$, on 11.82% for CdS, on 13.24% for Co crystal. The effect of Ω_e decrease for solid plates with negative growing by module parameter Δ_m was established, in particular Ω_e decrease on 1.01% for $ZTP-19$ ceramic plates. The absence of edge resonance effect in concerned axisymmetric oscillations frequency range for solid ptales with large-module negative Δ_m was established, in particular for Cd and Zn crystals.

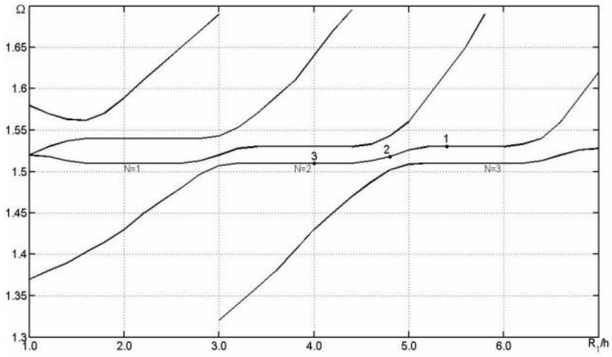
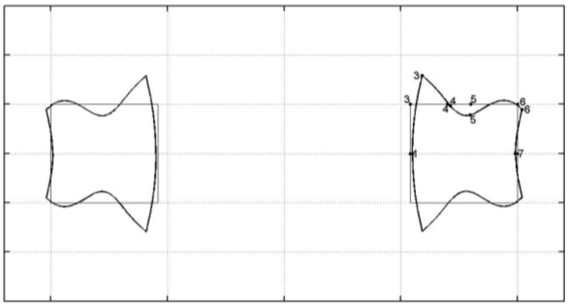
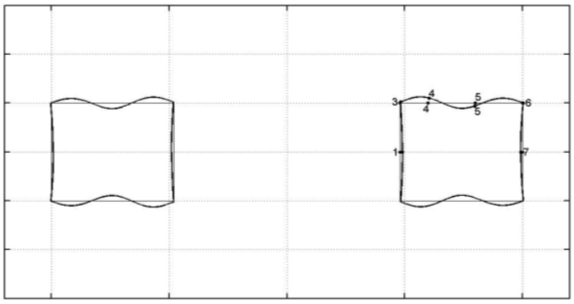


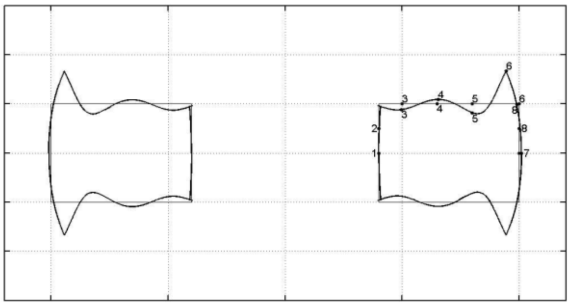
Fig. 5 Edge resonance spectrum for $BaTiO_3$ ring



a) The shape in point 1 on fig. 5



b) The shape in point 2 on fig. 5



c) The shape in point 3 on fig. 5

Fig. 6 Vibration shapes for $BaTiO_3$ ring.

It was showed that more contrast increase of edge standing waves excitation intensity on edge resonance frequencies is inherent for plates with small by module Δ_m values. Frequency dependencies of edge standing waves excitation rates for large-module positive Δ_m plates near Ω_e have more monotonic character and the relational rate of lowest edge standing wave mode in this case is decreasing. In particular the mentioned rate for Co plate is nearly in 54 times less than for $BaTiO_3$ solid plate.

The edge resonance effect also was researched in transversally-anisotropic rings. It was established that plateau-areas in the frequency spectrum have two-level structure conditionally on relations of rings geometrical and mechanical parameters. In particular (Fig. 5) for $BaTiO_3$ ring the changing of resonance frequency value by jumping from the top mesa to the lower is going with the changing of edge resonance type from localized on the inside cylindrical surface (Fig. 6a) to the outside cylindrical surface localized (Fig. 6c). Oscillation localization on the frequency between mesa arrears is absent (Fig. 6b).

In regard to symmetrical waves excitation in transversally-anisotropic semi-layer the empirical regularity of edge resonance frequency Ω_e increase that is characterized by growing positive parameter Δ_m relatively to edge resonance frequency for isotopic semi-layer was obtained. In particular the mentioned growing is 0.7% for $BaTiO_3$ semi-layer, 2.0% for $PZT-4$ semi-layer, 12.1% for CdS and 14.9% for Co semi-layers. The edge resonance effect in transversally-anisotropic semi-layer with large-module negative Δ_m value is not occurring in the mentioned frequency area, in particular for Cd and Zn semi-layers.

The physical law of edge resonance oscillations shapes near the transversally-anisotropic semi-layer border zone was researched. Vertical wave displacements levels in an angular point of semi-layer's section, that are defined mentioned oscillation intensity levels, are decreasing in line with increasing of positive semi-layer material characteristic Δ_m.

The existence of edge resonance effects in transversally-anisotropic semi-cylinder by axisymmetric P-SV waves excitation is established. It was also ascertained that in the researched case of semi-cylinder material isotropy axis orientation a regular dependence between edge resonance frequency values and general wave anisotropy parameter Δ_m is absent.

References

[1] Shaw E.A.G. On the resonant vibration of thing barium titanate disks / E.A.G. Shaw // J. Acoust. Soc. Amer. – 1956. – V. 20, № 1. – P. 38-50.