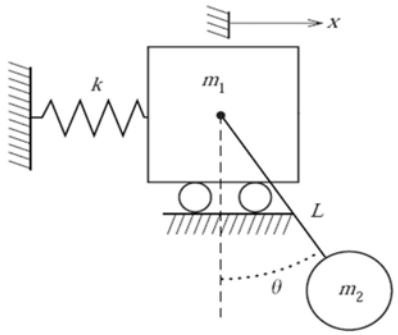

Fig. 1. Mechanical system having the pendulum absorber.

Trajectories of the nonlinear vibration modes in configuration space of the systems are determined by power series. Analysis of the NNMs stability is made by the Hill determinants method and the numerical–analytical method which is a consequence of the classical definition of stability by Lyapunov. Analysis of the modes stability shows that the regions of instability of the localized vibration modes are very narrow for both systems under consideration. So, the localized vibration modes are effective for absorption of elastic vibrations.

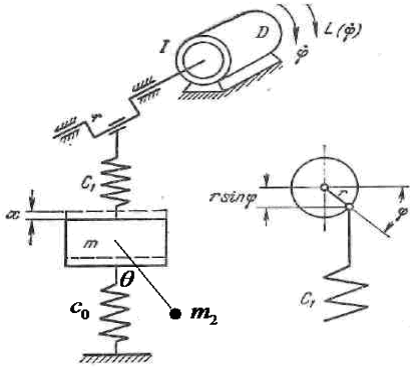

Fig.2. The non-ideal system with pendulum absorber.

Nonlinear normal modes of forced vibrations in the first mechanical system can be obtained by combination of the Kauderer–Rosenberg NNMs approach, and the Rauscher method, modified for n-DOF systems. The modified Rauscher method permits to transform the non-autonomous system to the "pseudo-autonomous" one. In the considered autonomous system the NNMs are constructed. Frequency responses for the NNMs are obtained.

LITERATURE

1. Vakaki A.F., Manevitch L.I., Mikhlin Yu.V., Pilipchuk V.N, Zevin A.A. Normal Modes and Localization in Nonlinear Systems. Wiley Interscience. – New York. – 1996. – 553 p.
2. Mikhlin Yu.V., Avramov K.V. Nonlinear normal modes for vibrating mechanical systems. Review of theoretical developments. // Appl. Mech. Review. – 2010. – 63 (6). – 21 p.
3. Mikhlin Yu. Resonance modes of near-conservative nonlinear systems. // Prikladnaja Matematica i Mekhanica (PMM USSR). – 1974. – 38. – P. 425–429 (in Russian).
1. Klimenko A.A., Mikhlin Y.V., Awrejcewicz J.Nonlinear normal modes in pendulum systems.// Nonlinear Dyn. – 2012. –v.70,N1. – P. 797 – 813.

SINGLE-COMPONENT SURFACE WAVES AND VOLUME VIBRATIONS IN CUBIC CRYSTALS

**Klochko M.S., Feodosyev S.B., Syrkin E.S.*

B. Verkin Institute for Low Temperature Physics and Engineering, Kharkov, Ukraine

Existence of a boundary in a crystal changes significantly the atomic dynamic of the near-surface atoms and makes surface waves to excite. These waves are highly sensitive to surface properties, both for free-surface case and when there is an adsorbed monolayer on the surface. The pure shear surface waves with horizontal polarization (SH-waves) [1,2] show a significant sensitivity comparing with the wide-known Raleigh waves[3].

In the present report taking into account the interactions between the nearest and next-nearest neighbours, dispersion relations of volume and surface vibrations for pure shear waves are carried out in cases of (001), (110) and (111) surface orientations in simple cubic (SC), face-centered cubic (FCC) and body-centered cubic (BCC) free-surface crystals. In addition, we consider an impurity monolayer adsorbed on the crystal surface.

We study both cases when the monolayer consists of lighter atoms than those the crystal has, and having heavier ones. For the lighter atoms, consideration is given to $m_0/m = 1/2$ and $m_0/m = 1/5$; for heavier atoms we study $m_0/m = 2$ and $m_0/m = 5$ (here m_0 is a mass of the each impurity atom in the adsorbed monolayer, m is a mass of the each host atom). In case of interaction only between the nearest neighbours in the SC (001), surface waves do not exist. They appear either when accounting for the interaction with more distant neighbours, or if there is an adsorbed surface monolayer. Surface waves dispersion relation curve splits off the upper boundary of the continuous spectrum in case of heavy impurity atoms and it splits the lower limit in case of light ones. Herein, surface waves amplitude decreases monotonously in case of heavy atoms; in case of light ones amplitude decrease is oscillating (but not monotonous). It is shown that a gap within continuous spectrum and surface waves appear if $m_0/m = 11$. Additionally, we carry out the analysis of surface waves characteristics of a crystal within which long-range interaction is also considered and there is an adsorbed monolayer on its surface.

Finally, we study volume vibration bands when the next-nearest neighbours interaction is taken into account. It is shown that consideration of long-range interaction changes the form of volume vibration band. For SC with (001) orientation surface volume vibration

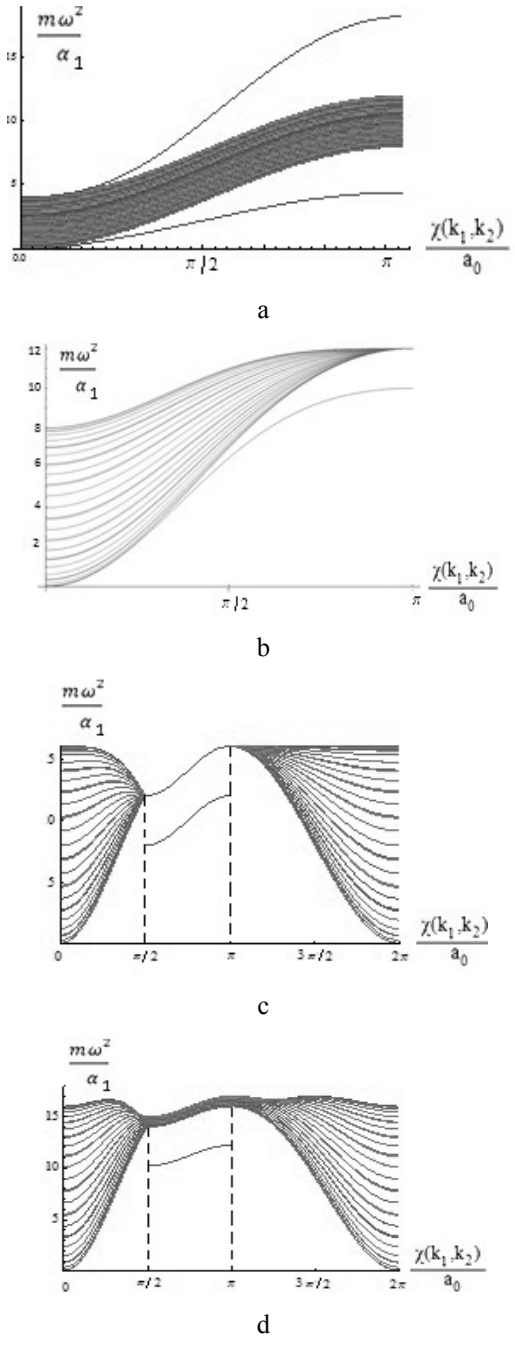

Fig.1. Volume vibration bands and surface waves for:

a) SC (001) crystal having an adsorbed surface monolayer ($m_0 / m = 1/2$ and $m_0 / m = 2$);

b) SC (001) crystal having a free-surface in second neighbors approximation, y=0.25;

Volume vibration bands and surface waves for $k_1+k_2=\pi$ quasi-two-dimensional wave vector region in FCC (001) crystal having a free-surface:

c) in first neighbors approximation;

d) in second neighbors approximation, y=0.25.

band narrows when the two-dimensional quasi-wave vector $\chi(k_1, k_2)$ approaches to π. The narrowing rate depends on *y* value. For example, when $y = 0.25$ volume vibration band degenerates into a line at $\chi(k_1, k_2) = \pi$, which means that vibrations are localized in a single layer within the considered area. As for surface wave in this case, it takes place for SC (001) in the approximation of second neighbours even considering the free-surface crystal. For FCC with (001) surface orientation plane, a volume band occurs within the region where in nearest-neighbours interaction model it degenerates into a single line as there are only vibrations localized in one layer there. The way the volume vibration band changes depending on various values of $y \equiv \alpha_2 / \alpha_1$ is illustrated (here α_1 is an interaction coefficient between nearest neighbours, α_2 is the one for next-nearest neighbours interaction). The results obtained for FCC (001) conform to the research results carried out in [4].

LITERATURE

1. Alldredge G.P.// Phys.Lett. A. – 1972. – v.41,N3. – P.281.
2. Gelfgat I.M.// Fiz.Niz.Temp. – 1977. – v.19. – P.1711.
3. Kosevich Yu.A., Syrkin E.S. // J. Phys.: Condensed Matter. – 1990. – v.2,N22. – P.5047 – 5052.
4. Kovalev A.S., Rysich N.V., Syrkin E.S. // Phys. Low–Dim. Struct. – 2002. – v.104,N3/4. – P.99 – 104.

BUCKLING OF THIN WALLED CYLINDRICAL SHELLS UNDER COMBINED LOADS

*Pupazescu A., *Zaharia M.*

Petroleum-Gas University, Ploiesti, Roumania

Thin walled cylindrical shells are widely used as silos for storing bulk solids. These structures are susceptible to buckling when they are subjected to axially compressive loads that are due to the friction between the bulk material stored and the silo walls, but also to the seismic actions.

Sometimes, for example, under the wind action or during discharge, in addition to axial compression, can also act external pressure, and cylindrical shell is subjected to a combined action. This problem can be studied both with analytical methods and with linear buckling analysis (LBA) based on finite element method.

The analytical method is based on Donnell's equation [1] for the equilibrium of cylindrical shells. After calculation, the final equation that express the critical axial buckling load as a function of the axial half waves number *m*, the circumferential waves number *n* and the external applied pressure *q*, is*:*

$$P = \frac{E \cdot t^3}{12(1-\nu^2)} \frac{\left(\frac{m^2\pi^2}{l^2} + \frac{n^2}{R^2}\right)^2}{\frac{m^2\pi^2}{l^2}} + \frac{E \cdot t}{R^2} \frac{\frac{m^2\pi^2}{l^2}}{\left(\frac{m^2\pi^2}{l^2} + \frac{n^2}{R^2}\right)^2} - qR \frac{\left(\frac{n}{R}\right)^2}{\frac{m^2\pi^2}{l^2}} \quad (1)$$