

values of forces and coefficient of elongation (shortening) in obtaining of which "internal" instability is respectively implemented under small and large initial strain in the sphere are shown (lines of 2 and 4 of Table 1). It follows from the comparison of results of the second and fourth lines to the results of the third and fifth lines of Table 1 that the buckling of the equilibrium state of elastic homogeneous isotropic sphere on a geometric forming in case of influence of "dead" loads on its surface precedes the "internal" instability. The equilibrium state of the sphere is stable on geometric forming in case of influence of "follower" loads on the surface. Therefore, the "internal" instability occurs without preliminary forming in this case. It should be emphasized that it is clear from the formulae of critical forces and elongation that they don't depend on the geometric parameters of the sphere and buckling mode. An exhaustive explanation is given to this case (Guz 1986a). The boundary surface is one of the coordinate surfaces of the spherical system of coordinates in the considered problems. Eigenvalues should not depend on the geometric parameters of the problem due to the nature of Lamé's Eq. (8) (which includes derivatives of the same order) and the indicated case. The critical loads will depend on the geometric parameters (for example, thin-walled parameters) in case of considering the problems of stability of bodies bounded by several coordinate surfaces. The lack of effects of plastic and viscous properties of the material (Eqs. (14) and (15)) on the value of the critical parameters is related with the fact that inelastic deformation is incompressible due to the adopted laws of state, and inelastic deformation does not occur due to uniform compression in the initial state.

Calculation results implemented on Eqs. (25)-(28) are shown in Table 2. The data relating to the second variant of small initial strain theory is given in the numerator but in denominations - large initial strain theory.

Table 2.

ν	0	0.1	0.2	0.3	0.4	0.41	0.45
K_P^R	$\frac{-1.5}{-2.5}$	$\frac{-1.3182}{-2.1364}$	$\frac{-1.1668}{-1.8333}$	$\frac{-1.0385}{-1.5769}$	$\frac{-0.9286}{-1.3571}$	$\frac{-0.9184}{-1.3369}$	$\frac{-0.8793}{-1.2586}$
	$\frac{-1}{-1.5}$	$\frac{-0.8636}{-1.2273}$	$\frac{-0.75}{-1}$	$\frac{-0.6538}{-0.8077}$	$\frac{-0.5714}{-0.6429}$	$\frac{-0.5638}{-0.6277}$	$\frac{-0.5345}{-0.569}$
K_S^R	$\frac{0.6667}{0.4}$	$\frac{0.8534}{0.5266}$	$\frac{1.1429}{0.7273}$	$\frac{1.6852}{1.1098}$	$\frac{3.2308}{2.2105}$	$\frac{3.5689}{2.4518}$	$\frac{6.2549}{4.3699}$
	$\frac{0.5}{0.3333}$	$\frac{0.5789}{0.4074}$	$\frac{0.6667}{0.5}$	$\frac{0.7647}{0.6190}$	$\frac{0.875}{0.7778}$	$\frac{0.8868}{0.7966}$	$\frac{0.9355}{0.8788}$

The numbers given in lines 4 and 5 of the Table 2 show that if these values are exceeded, the conditions of Eqs. (27) and (28) aren't fulfilled within the considered variants of NLT, i.e. elastic pressure and shear waves can't be propagated in the medium with true velocity accordingly. The subscript in P^l – indicates that these values relate to pressure and S to shear waves. Contrary to that it follows from the data of Fig. 1(a), b that velocities of pressure and shear elastic waves in the sphere are true in PREM in conditions $P \geq 2\mu$. It shows once again that the data on the physical and mechanical, acoustic and density characteristics in the theoretical models should

be distributed in accordance with relevant requirements of the mechanics of deformable media with initial stress considering nonlinear laws of state. The obtained results relate to the data of the inner core. At the same time, they predict that it is necessary to process and interpret the relevant geological and geophysical data on the basis of non-linear (at least within NLT) theories considering preliminary deformation of the medium in solving the problem on the distribution of mantle and lithosphere parameters.

Data on the composition of the inner core material indicate its anisotropy (Fig. 1b) (Litasov and Shatskiy 2016). Naturally, phenomenon of "internal" instability will occur at much lower levels of loads and strain than in the isotropic approximations in the anisotropic medium because of the smallness of the shear stiffness.

It should be noted that the results presented in this article are obtained without considering the influence of temperature, the distribution of which is shown in Fig. 1(a). The consideration of temperature influence on critical values of instability worsens the situation. Buckling process is implemented at significantly lower pressure level under the influence of temperature fields. Therefore, the consideration of temperature will not provide a qualitative impact on the conclusion on the insufficiency of interpretation of geophysical data within the classical theory. The consideration of temperature is necessary to solve specific problems of the local distribution of the considered parameters.

ACKNOWLEDGEMENT

This work has been carried out by the full financial support of the NAS of Azerbaijan within the program "Complex of researches of theoretical and experimental interdisciplinary problems of geomechanics", under the resolution of the Presidium of the NAS of Azerbaijan #5/3 dated on February 11, 2015.

REFERENCES

- Abasov, M.T., Kuliev, G.G. and Dzhevanshir, R.D. (2000), "Development model of the Lithosphere", *Doclady Russian Academy of Sciences*, **70**(2), 129-135.
- Adushkin, V.V., An, V.A., Kvazik, P.B. et al. (2000), "The rotation of the inner core from seismic records of nuclear explosions", *Thesis of reports "The inner core of the Earth. Geophysical data on process in the core"*, IPE RAS, Moscow, Russia.
- Akbarov, S.D. (2013), *Stability Loss and Buckling Delamination: Three-Dimensional Linearized Approach for Elastic and Viscoelastic Composites*, Springer, Berlin, Germany.
- Akbarov, S.D. (2015), *Dynamics of Pre-Strained Bi-Material Elastic Systems: Linearized Three-Dimensional Approach*, Springer, Switzerland.
- Akbarov, S.D., Guliyev, H.H. and Yahnioğlu N. (2016), "Natural vibration of the three-layered solid sphere with middle layer made of FGM: three-dimensional approach". *Structural Engineering and Mechanics An International Journal*, **57**(2), 239-263.
- Anderson, D. (2007), *New Theory of the Earth*, Cambridge University Press, New York, USA.

- Anderson, O.L. (1995), *Equations of State of Solids for Geophysics and Ceramic Science*, Oxford University Press, New York, USA.
- Antonangeli, D. and Ohtani, E. (2015), "Sound velocity of hcp-Fe at high pressure: experimental constraints, extrapolations and comparison with seismic models", *Progress in Earth Planetary Science*, **2**(3), 1-11.
- Avsyuk, Yu.N. (1973), "Motion of the inner core", *Proceedings of the USSR Academy of Sciences*, **212**(5), 1103-1105.
- Avsyuk, Yu.N. (2001), "Extraterrestrial factors affecting tectogenesis", In: *Fundamental Problems of Global Tectonics* (Edited by Pushcharovsky, Yu.M.), Scientific World, Moscow, Russia.
- Badro, J., Côté, A.S. and Brodholt, J.P. (2014), "A seismologically consistent compositional model of Earth's core", *Proceedings of the National Academy of Sciences of USA*, **111**(21), 7542-7545.
- Biot, M.A. (1965), *Mechanics of Incremental Deformation*, Willey, New York, USA.
- Birch, F. (1952), "Elasticity and constitution of the Earth's interior", *Journal of Geophysical Research*, **57**(2), 227-286.
- Bullen, K.E. (1978), *The Density of the Earth*, Mir, Moscow, Russia.
- Chen, B., Li Z., Zhang, D., Liu, J., Hu, M.Y., Zhao, J., Bi, W., Alp, E.E., Xiao, Y. and Chow, P., Li J. (2014), "Hidden carbon in Earth's inner core revealed by shear softening in dense Fe₇C₃", *Proceedings of the National Academy of Sciences of USA*, **111**(50), 17755-17758.
- Decremps, F., Antonangeli, D., Gauthier, M., Ayrinhac, S., Morand, M., Marchand, G.L., Bergame, F. and Phillippe J. (2014), "Sound velocity of iron up to 152 GPa by picosecond in diamond anvil cell", *Geophysical Research Letter*, **41**(5), 1459-1464.
- Deuss, A. (2014), "Heterogeneity and anisotropy of Earth's inner core", *Annual Review of Earth and Planetary Sciences*, **42**, 103-126.
- Dobretsov, N.L. and Shatskiy, A.F. (2012), "Deep carbon cycle and geodynamics: the role of the core and carbonatite melts in the lower mantle", *Russian Geology and Geophysics*, **53**(11), 1117-1132.
- Dziewonski, A.M. and Anderson, D.L. (1981), "Preliminary reference Earth model", *Physics of the Earth and Planetary Interiors*, **25**(4), 297-356.
- Guliyev, H.H. and Askerov, A.D. (2007), "The solution of nonlinear problem on increase of environment density of the Earth depths and its instability", *Proceedings of the NAS of Azerbaijan, Series of Earth Sciences*, (1), 38-50.
- Guliyev, H.H. (2009), "Nonlinear actions of elastic medium and their effect on the propagation velocity of elastic waves", *Proceedings of the NAS of Azerbaijan, Earth Sciences*, (2), 31-39.
- Guliyev, H.H. (2010), "A new theoretical conception concerning the tectonic processes of the Earth", *New Concepts in Global Tectonics Newsletter*, (56), 50-74.
- Guliyev, H.H. (2011), "Fundamental role of deformations in internal dynamics of the Earth", *New Concepts in Global Tectonics Newsletter*, (61), 33-50.
- Guliyev, H.H. (2013), "Deformations, corresponding to processes of consolidation, deconsolidation and phase transitions in internal structures of the Earth", *Geophysical Journal*, **35**(3), 166-176.
- Guz, A.N. (1979), *Stability of Elastic Bodies Under Uniform Compression*, Naukova Dumka, Kyiv, Ukraine.

- Guz, A.N. (1986a), *Fundamentals of Three-Dimensional Theory of Stability of Deformable Bodies*, Vishcha shkola, Head Publishing House, Kyiv, Ukraine.
- Guz, A.N. (1986b), *Elastic Waves in Bodies with Initial Stresses, Propagation Patterns*, (2nd Volume), Naukova Dumka, Kyiv, Ukraine.
- Guz, A.N. (1989), *Fracture Mechanics of Composite Materials Under Compression*, Naukova Dumka, Kyiv, Ukraine.
- Hadji L., Hassaine Daouadji, T. and Adda Bedia, E.A. (2015), "A refined exponential shear deformation theory for free vibration of FGM beam with porosities", *Geomechanics and Engineering An International Journal*, **9(3)**, 361-372.
- Helfrich, G. and Kaneshima, S. (2010), "Outer-core compositional stratification from observed core wave speed profiles", *Nature*, **468(7325)**, 807-810.
- Hirose, K., Labrosse, S. and Hernlund, J. (2013), "Composition and state of the core", *Annual Review of Earth and Planetary Sciences*, **41**, 657-691.
- Kakar, R. and Kakar, Sh. (2016), "Rayleigh wave in an anisotropic heterogeneous crustal layer lying over a gravitational sandy substratum", *Geomechanics and Engineering An International Journal*, **10(2)**, 137-154.
- Kennett, B.L.N. and Engdahl, E.R. (1991), "Traveltimes for global earthquake location and phase identification", *Geophysical Journal International*, **105(2)**, 429-465.
- Kennett, B.L.N., Engdahl, E.R. and Buland, R. (1995), "Constraints on seismic velocities in the Earth from traveltimes", *Geophysical Journal International*, **122(1)**, 108-124.
- Kuliev, G.G. (1988a), "A new approach to calculation of the theoretical ultimate strength of materials", *Strength of Materials*, **20(5)**, 623-629.
- Kuliev, G.G. (1988b), *Fundamentals of the Mathematical Theory of the Stability of Wells*, Elm, Baku, Azerbaijan.
- Kuliev, G.G. and Jabbarov, M.J. (1998), "To elastic waves propagation in strained nonlinear anisotropic media", *Proceedings of the NAS of Azerbaijan, Earth Sciences*, (2), 103-112.
- Kuliev, G.G. and Jabbarov, M.J. (2000), "Amplitude characteristics of elastic waves in stressed medium". *Doclady Russian Academy of Sciences*, **370(4)**, 672-674.
- Kuskov, O.L. and Khitarov, N.I. (1982), *Thermodynamics and Geochemistry of the Core and Mantle of the Earth*, Nauka, Moscow, Russia.
- Levin, B.V. (2001), "The role of the Earth's inner core movements in the tectonic processes", In: *Fundamental Problems of Global Tectonics* (Edited by Pushcharovsky, Yu.M.), Scientific World, Moscow, Russia.
- Li, J. and Fei, Y. (2014), "Experimental constraints on core composition", (3rd Volume), In: *Treatise on geochemistry*, (2nd Volume), (Eited by Holland, H.D. and Turekian, K.K.), Elsevier, Oxford.
- Li, X. and Tao, M. (2015), "The influence of initial stress on wave propagation and dynamic elastic coefficients", *Geomechanics and Engineering An International Journal*, **8(3)**, 377-390.
- Litasov, K.D. and Shatskiy, A.F. (2016), "Composition of the Earth's core: A review", *Russian Geology and Geophysics*, **57(1)**, 22-46.
- Lobkovski, L.I., Nikishin, A.M. and Hain, V.E. (2004), *Modern Problems of Geotectonics and Geodynamics*, Scientific World, Moscow, Russia.
- Lyav, A.I. (1935), *The Mathematical Theory of Elasticity*, ONTI, Moscow, Russia.

- Mao, Z., Lin, J.-F., Liu, J., Alatas, A., Gao, L., Zhao, J. and Mao, H.-K. (2012), "Sound velocities of Fe and Fe-Si alloy in the Earth's core", *Proceedings of the National Academy of Sciences of USA*, **109**(26), 10239-10244.
- Molodensky, M.S. (2001), *The Gravitational Field. The Figure and the Internal Structure of the Earth*, Nauka, Moscow, Russia.
- Molodenskii, S.M. (2010), "Correctives to the scheme of the Earth's structure inferred from new data on nutation, tides, and free oscillations", *Izvestiya, Physics of the Solid Earth*, **46**(7), 555-579.
- Molodenskii, S.M. and Molodenskaya, M.S. (2015), "Attenuation of free spheroidal oscillations of the Earth after the M = 9 Earthquake in Sumatra and the super-deep Earthquake in the Sea of Okhotsk: I. the Admissible Q-factor range for the fundamental mode and overtones of the free spheroidal oscillations", *Izvestiya, Physics of the Solid Earth*, **51**(6), 821-839.
- Molodenskii, S.M. and Molodenskii, M.S. (2015), "Attenuation of free spheroidal oscillations of the Earth after the M = 9 earthquake in Sumatra and super-deep earthquake in the Sea of Okhotsk: II. interpretation of the observed Q-factor", *Izvestiya, Physics of the Solid Earth*, **51**(6), 840-856.
- Morelli, A. and Dziewonski, A.M. (1993), "Body-wave traveltimes and a spherically symmetric P- and S-wave velocity model", *Geophysical Journal International*, **112**(2), 178-194.
- Nimmo, F. (2015), "Energetics of the Core", (8th Volume), In: *Treatise on Geophysics*, (2nd Edition), (Edited by Schubert G.), Elsevier, Oxford.
- Ohtani, E., Shibazaki, Y., Sakai, T., Mibe, K., Fukui, H., Kamada, S., Sakamaki, T., Seto, Y., Tsutsui, S. and Baron A.Q. (2013), "Sound velocity of hexagonal close-packed iron up to core pressures", *Geophysical Research Letter*, **40**(19), 5089-5094.
- Prescher, C., Dubrovinsky, L., Bykova, E., Kuppenko, I., Glazyrin, K., Kantor, A., Vccammon, C., Mookherjee, M., Nakajima, Y. and Miyajima, N. (2015), "High Poisson's ratio of Earth's inner core explained by carbon alloying", *Nature Geoscience*, **8**(3), 220-223.
- Pushcharovsky, Yu.M. and Pushcharovsky, D.Y. (2011), "When, how and why were the Earth's geospheres formed", *Priroda*, (5), 25-31.
- Rabotnov, Y.N. (1988), *Mechanics of Deformable Solids*, Nauka, Moscow, Russia.
- Sadovsky, M.A. and Nikolaev, A.V. (1982), "New methods of seismic exploration. Prospects of development", *Bulletin of the Academy of Sciences of USSR*, **52**(1), 57-64.
- Sedov, L.I. (1970), *Mechanics of the Continuum Medium*, (1st Volume), Nauka, Moscow, Russia.
- Sorokhtin, O.G. and Ushakov, S.A. (2002), *Earth Development*, MGU, Moscow, Russia.
- Souriau, A. and Calvet, M. (2015), "Deep earth structure: The Earth's cores", (1st Volume), In: *Treatise on geophysics*, (2nd Volume), (Eited by Schubert, G.), Elsevier, Oxford.
- Sumita, I. and Bergman, M.I. (2007), "Inner-Core Dynamics", (8th Volume), In: *Treatise on Geophysics*, (Eited by Schubert, G.), Elsevier, Oxford.

- Tao, M., Chen, Z., Li, X., Zhao, H. and Yin, T. (2016), "Theoretical and numerical analysis of the influence of initial stress gradient on wave propagations", *Geomechanics and Engineering An International Journal*, **10**(3), 285-296.
- Teachavorasinskun, S. and Pongvithayapanu, P. (2016), "Shear wave velocity of sands subject to large strain triaxial loading", *Geomechanics and Engineering An International Journal*, **11**(5), 713-723.
- Thurston, R. and Brugger, K. (1964), "Third-order elastic constants and velocity of small amplitude elastic waves in homogeneously stressed media", *Physical Review*, **133**(6A), 1604-1610.
- Truesdell, K. (1975), *Initial Course of Rational Mechanics of Continuum Media*, Nauka, Moscow, Russia.
- Wang, T., Song, X. and Xia, H.H. (2015), "Equatorial anisotropy in the inner part of Earth's inner core from autocorrelation of earthquake coda", *Nature Geoscience*, **8**(3), 224-227.
- Zharkov, V.N. (2012), *Physics of the Earth's interior*, Nauka i obrazovanie, Moscow, Russia.