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Institute of Biomechanics
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PROGRAMME

Edited by:

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10:35	*Extension of Koiter's Linear Shell Theory to Materials Exhibiting Arbitrary Symmetry* **David J. Steigmann**
10:55	*A One-Field Formulation of Elasto-Plastic Shells with Fracture Applications* Gauthier Becker, **Ludovic Noels**
11:15	*Deformations of Transversely Accreted Plates* **Sergey Alexandrovich Lychev**
11:35	*A Vekua-Type Thick Shells' Theory* **Sergey Igorevich Zhavoronok**
11:55	*C1 Continuous Finite Element Approximation for Modeling Finite Deformations of Kirchhoff-Love Shells as Material* **Yury M. Vetyukov**

MS-36.3 Refined Theories of Plates and Shells — Thursday, 14:15 - 15:45
Casineum — Chair: H. Altenbach, E. Ivanova

14:15	*A Modified Energy Method for the Buckling of Thin Plates in Tension* Xiang Liu, **Ciprian Coman**
14:33	*Effect of 'Static Resonance' in Cylindrical Shells with Periodical Geometrical Imperfections* **Maksym Kolesnikov**, Vasily L. Krasovsky, Ruediger Schmidt
14:51	*On the Unsymmetrical Wrinkling of Heterogeneous Circular and Annular Plates* **Eva Voronkova**, Svetlana Bauer, Anders Eriksson
15:09	*On the Stability of the Cylindrical Shell under the Axial Compression with Use of Non-Classical Theories of Shells* **Andrei Ermakov**
15:27	*Theory of Micropolar Orthotropic Elastic Thin Shells* A.J. Farmanyan, **Samvel Hovhannes Sargsyan**

MS-36.4 Refined Theories of Plates and Shells — Thursday, 16:00 - 18:00
Casineum — Chair: G. Dhondt, E. Pruchnicki

16:00	*Efficient High-Fidelity Multiphysics Modeling of Composite Plates Using the Variational Asymptotic Method* (Keynote) **Wenbin Yu**, Chang-Yong Lee, Dewey H. Hodges
16:35	*Automatic Expansion of Shell Elements into 3D by Use of Expandable Rigid Bodies* **Guido Dominique Dhondt**
16:52	*Nonlinear Stability Analysis of Functionally Graded Shells Using the Invariant-Based Triangular Finite Element* **Stanislav Levyakov**, V.V. Kuznetsov
17:09	*Enhanced FGM Shell Finite Elements* **Stephan Kugler**, Peter Fotiu, Justin Murin

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On the stability of the cylindrical shell under the axial compression with use of nonclassical theories of shells

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ABSTRACT

The problem of stability of the cylindrical shell under the axial compression by means of new nonclassical shell theories is studied. To solve it the local approach [1] is used. According to it the buckling deflection is sought in the form of a doubly periodic function of curvilinear coordinates. The comparison of well-known solutions obtained with the use of classical shell theories of Kirchhoff-Love (KL) and Timoshenko-Reissner (TR) with the results of improved nonclassical shell theories of Rodionova-Titaev-Chernykh (RTCH) [3] and Paliy-Spiro (PS)[4] is done.

The improved iterative RTCH theory is based on the following hypotheses: 1) transverse tangential and normal stresses are distributed on shell's thickness according to quadratic and cubic laws respectively; 2) tangential and normal components of the displacement vector are distributed on the shell thickness according to quadratic and cubic laws respectively. This theory allows taking into account turns of fibers, their deviation and change of their length.

The Paliy-Spiro shells theory is a theory of shells of moderate thickness which assumes the following hypotheses: 1) straight fibers of the shell which are perpendicular to its middle surface before deformation remain also straight after deformation; 2) cosine of the slope angle of these fibers to the middle surface of the deformed shell is equal to the averaged angle of transverse shear.

For the PS and RTCH theory of anisotropic shells of moderate thickness the stability equations were developed with linearization of nonlinear equilibrium equations.

Thus the results obtained with the use of PS theory are similar to the TR theory results. This is only the factor of the second coefficient of asymptotical expansion by small parameter h/R makes the results different. And the results which were obtained with the use of RTCH theory include the members of asymptotical expansion of higher order.

$$\sigma_{\mathrm{KL}} = -\frac{E}{\sqrt{3(1-\nu^2)}}\left(\frac{h}{R}\right), \tag{1}$$

$$\sigma_{\mathrm{TR}} = -\frac{E}{\sqrt{3(1-\nu^2)}}\left(\frac{h}{R}\right) + \frac{E^2}{10G(1-\nu^2)}\left(\frac{h}{R}\right)^2, \tag{2}$$

$$\sigma_{\mathrm{PS}} = -\frac{E}{\sqrt{3(1-\nu^2)}}\left(\frac{h}{R}\right) + \frac{E^2}{12G(1-\nu^2)}\left(\frac{h}{R}\right)^2, \tag{3}$$

$$\sigma_{\mathrm{RTCH}} = -\frac{E}{\sqrt{3(1-\nu^2)}}\sqrt{1 - \frac{E^2}{60G^2(1-\nu^2)}\left(\frac{h}{R}\right)^2}\left(\frac{h}{R}\right) + \frac{E^2}{15G(1-\nu^2)}\left(\frac{h}{R}\right)^2. \tag{4}$$

The comparison of analytical results with numerical results which were obtained with the use of three–dimensional theory by the FEM code Ansys 11 is also done. As an example, the model of a steel tube under the influence of the axial compression is studied. The three–dimensional 20–nodes elements Solid186 were used. During mesh contraction the splitting of the thickness which consisted of five elements was applied. The value of critical load for tubes studied which length ranged from 1.5 to 3 diameters of medial surface was practically consistent. The modulus of cross section shear was equal to $G = E/(2(1+\nu))$.

h/R	0.025	0.05	0.1	0.133	0.162
KL	0.01532	0.03103	0.0637	0.08069	0.09814
TR	0.01513	0.03028	0.06054	0.07561	0.09063
PS	0.01516	0.03041	0.06107	0.07646	0.09188
RTCH	0.01519	0.03053	0.06155	0.07722	0.09297
Ansys	0.01445	0.02875	0.055	0.0595	0.0635

Table 1: Specified coefficients for the elasticity tensors of some materials in a decoupled form.

Table 1 shows dimensionless values of critical load σ_0/E for different ratios of tube thickness to the radius of its medial surface. As one can see in the table, as shell thickness increases the values if critical load obtained with the use of shell theories differ more from the results of three-dimensional theory.

References

[1] P.E. Tovstik, Stability of a transversally isotropic cylindrical shell under axial compression. *J. Mechanics of Solids* 44:552-564, 2009.

[2] S. A. Ambarcumian, *The Theory of Anisotropy Shells*. The state publishing of physics and mathematics literature, Moscow, 1961 (in Russian) 446p

[3] V.A. Rodionova, B.F. Titaev and K.F. Chernykh, *Applied Theory of Anisotropic Plates and Shells*. St. Peterburg University Press, St. Petersburg, 1996. (in Russian).

[4] O.M. Paliy and V.E. Spiro, *Anisotropic Shells in Shipbuilding. Theory and Analysis*. Sudostroenie, Leningrad, 1977. (in Russian).