

# 2. ULUSLARARASI ULUDAĞ BİLİMSEL ARAŞTIRMALAR KONGRESİ

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EDİTÖRLER:

Doç.Dr. Leyla ŞENER

Dr. Gönül GÖKÇAY



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### ORGANIZATION

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### GENERAL COORDINATOR

Yasemin AĞAOĞLU

### COORDINATOR

Dr. Bahar ALTUNOK

### EDITORS

Doç.Dr. Leyla ŞENER

Dr. Gönül GÖKÇAY

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TURKEY TR: +90 342 606 06 75

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E mail: [iksadyayinevi@gmail.com](mailto:iksadyayinevi@gmail.com) [www.iksadyayinevi.com](http://www.iksadyayinevi.com)

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**FREE AND FORCED OSCILLATIONS MODELING OF SHELL STRUCTURES WITH COMPARTMENTS**

**Elena Sierikova, PhD**

National University of Civil Defence of Ukraine, Kharkiv, Ukraine

ORCID: 0000-0003-0354-9720

**Elena Strelnikova, Doctor of Technical Sciences**

A.M. Podgorny Institute for Mechanical Engineering Problems NAS of Ukraine, Kharkiv, Ukraine

ORCID: 0000-0003-0707-7214

**Yury Naumenko**

A.M. Podgorny Institute for Mechanical Engineering Problems NAS of Ukraine, Kharkiv, Ukraine

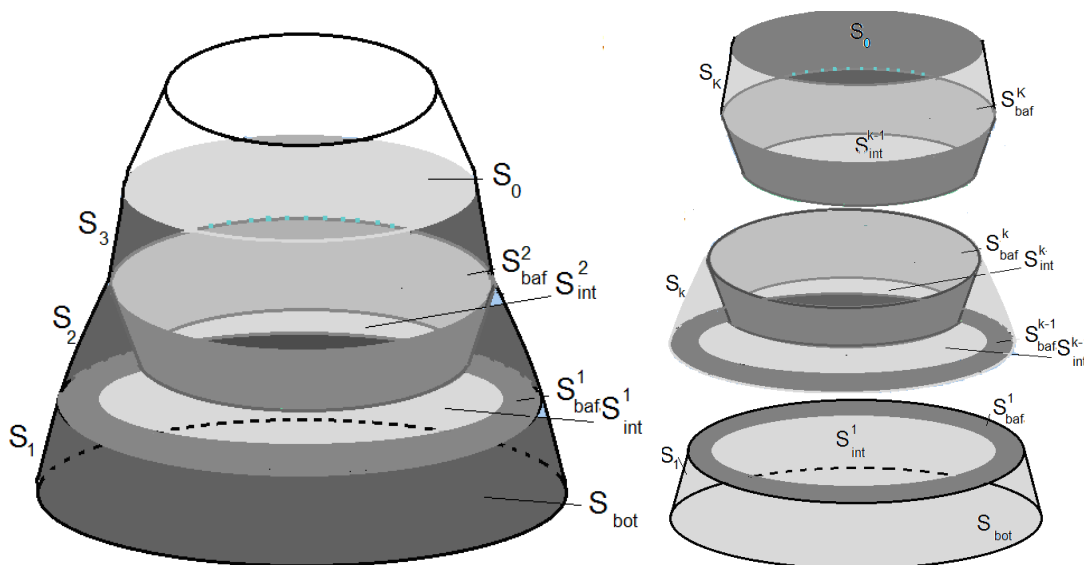
ORCID: 0000-0001-9058-6727

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Storage tanks with oil, flammable and toxic liquids are widely used in various fields of engineering practice, such as aircraft manufacturing, chemical and oil and gas industries, power engineering, and transport. These tanks operate under conditions of increased technological loads and are filled with oil, flammable or toxic substances. As a result of sudden loads caused by earthquakes and other force majeure circumstances, the liquid stored in tanks begins to have intense sloshing.

An analysis of studies devoted to the problems of liquid sloshing in tanks has been presented in the works [1-6]. Let us also note the works devoted to liquid sloshing in cylindrical tanks under the influence of seismic loads [7,8]. Free vibrations of liquid in conical and cylindrical tanks have been considered in [9].

The purpose of this study is to analyze free and forced vibrations of shells of rotation with an arbitrary meridian and internal partitions installed to dampen sloshing [10-12].



**Fig. 1. Shell with internal partitions and superelements diagram**

Let us denote the wetted surface of the shell by  $S_1$ , and the free surface by  $S_0$ . Let also  $S_{baf}$ . is partition surface,  $S_{int}$  is interface surface. Note that there could be several partitions, and, consequently, interface surfaces.

It has been assumed that the Cartesian coordinate system  $Oxyz$  is associated with the shell, the free surface of the liquid  $S_0$  coincides with the  $xOy$  plane at rest. It has been assumed that the fluid is ideal, incompressible, and its motion, starting from a state of rest, is irrotational. Under these conditions, there is a potential fluid velocity  $\Phi$

$$V_x = \frac{\partial \Phi}{\partial x}; V_y = \frac{\partial \Phi}{\partial y}; V_z = \frac{\partial \Phi}{\partial z},$$

satisfying the Laplace equation, since  $\text{div} V = 0$  (incompressibility condition).

The pressure  $p$  on the walls of the shell is determined from the linearized Cauchy-Lagrange integral using the formula

$$p = -\rho_l \left( \frac{\partial \Phi}{\partial t} + gz \right) + p_0 + a_s(t)x,$$

in which  $\Phi$  is the velocity potential,  $g$  is the gravitational acceleration,  $z$  is the coordinate of the fluid point, measured in the vertical direction,  $\rho_l$  is the density of the fluid,  $p_0$  is atmospheric pressure,  $a_s(t)x$  is a function characterizing the external influence (horizontal seismic load or impulse).

The following conditions must be met on the free surface of the liquid:

$$\left. \frac{\partial \Phi}{\partial n} \right|_{S_0} = \frac{\partial \zeta}{\partial t}; \quad p - p_0|_{S_0} = 0,$$

where the function  $\zeta$  describes the shape and position of the free surface.

The first of these conditions is the kinematic condition. It expresses the following fact. The speed of movement of the points of the free surface is equal to the speed of movement of the fluid. This is a kind of condition for the absence of separation of liquid particles from the free surface. The second condition is dynamic - it means that on the free surface the liquid pressure is equal to atmospheric pressure.

Thus, for the velocity potential we have the following boundary value problem

$$\nabla^2 \Phi = 0; \quad \left. \frac{\partial \Phi}{\partial n} \right|_{S_1} = 0; \quad \left. \frac{\partial \Phi}{\partial n} \right|_{S_0} = \frac{\partial \zeta}{\partial t}; \quad p - p_0|_{S_0} = 0; \quad \left. \frac{\partial \Phi}{\partial t} + g\zeta + a_s(t)x \right|_{S_0} = 0.$$

Having determined the velocity potential  $\Phi$  and the function  $\zeta$ , we will establish the height of the rise of the free surface and determine the fluid pressure on the walls of the shell.

**Conclusion**

The developed method allows us to estimate the level of rise of the free surface under the action of a suddenly applied load, which will make it possible to give recommendations on the installation of protective partitions.

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