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DEFINITION OF THE FAILURE REGION OF THE OIL TANK WITH WALL IMPERFECTIONS IN COMBINED LOADING

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Abstract. The stability of an oil reservoir with real imperfections of a wall under the joint action of axial compression and surface pressure is studied using a program complex of finite element analysis. To determine the permissible range of fail-safe operation of the reservoir, irregular imperfections of the middle wall surface are simulated as ratios of the buckling forms with different maximum amplitudes obtained in solving the problem of loss of stability by the Lanczos method. The stability of the shell with real and simulated imperfections of the wall is investigated using the nonlinear static problem by the Newton-Raphson method. Critical ratios of axial compression and surface pressure are determined to ensure overall stability of the reservoir wall. The region of failure on the stability of the oil reservoir with real imperfections is obtained.
Keywords: cylindrical shell, imperfection of shape, stability, combined loading, failure region.

To fully describe the general laws of the stress-strain state of shells with parameters that depend on many factors, the apparatus of linear differential equations turns out to be insufficient, because the most interesting and characteristic features of nonlinear systems do not fit into its framework. They include not only a quantitative change in the parameters of the system in space, related to the magnitude of the initial imperfections and the way the load is applied, but also the qualitative changes that lead to the emergence of critical states, the branching of new solutions and the loss of stable equilibrium.

Mathematical methods that make it possible to investigate nonlinear differential equations are too complicated and laborious to study complex nonlinear systems with multivariant parameters. In those cases when the properties of the shell and the loads acting on it depend on several factors, the shell can have a large number of critical states, the dimension of which is one less than the number of independently varying variables. The problem of constructing such a variety in the general case is extremely complicated, therefore, in the theory of differential equations it is often replaced by the problem of finding only a limited amount of qualitative information concerning the analysis of the quantitative change in the properties of a system when its parameters are varied. The problems of non-linear stability of deformable systems in a number of cases have features that are sensitive to irregularities in shape [2, 6], uneven of the load application, shortcomings in manufacturing technology, and heterogeneity in the physical characteristics of materials.

The presence of small imperfections in the shape of the shell can significantly reduce its critical load. This feature is of great practical importance and therefore

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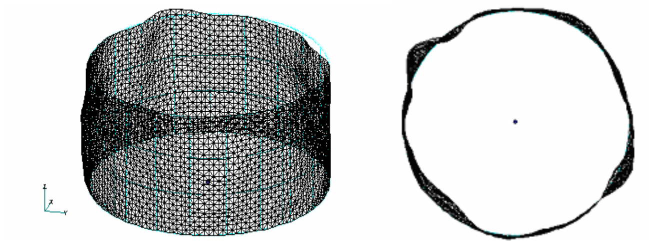
this work is aimed at investigating the influence of initial deflections. One of the approaches of the study proposed by V.T. Coiter [7] is to apply an asymptotic analysis based on the general theory of supercritical behavior. In this case, the sensitivity to imperfections is described as a measure of the initial postcritical behavior and the determination of the first zero coefficient in the power law of the load parameter on the amplitude of stability loss form. Coiter's method has become widely used in computational practice, but its usage imposes a strict limitation on the magnitude of imperfection and its shape. Another approach consists in a direct analysis of the nonlinear deformation of a shell with a curved shape of the middle surface based on one of the grid methods of discretization of the resolving equations. But this method has not received distribution because of the significant expenditure of computer time.

The development of new ideas in the understanding of nonlinear mechanics was greatly aided by the appearance of computers. Their use for nonlinear shell analysis has now reached such a level that it makes it possible to investigate the global behavior of thin-walled systems, including the problems of constructing a load trajectory in a given region of states, establishing buckling points and so on.

At the same time, for practical tasks, it is necessary to analyze various types of imperfections in shells that are characterized not only by the presence of a common continuous initial background of imperfections of limited amplitude but also by specific types of deflections of medium and large amplitudes caused by technological reasons: the manufacture of panels from sheet metal, their welding, mounting by welding to them discrete ribs, which have their imperfections in shape, etc.

1. Taking into account the actual geometry of the reservoir wall in the study of stability

The oil tank is located in the south of Ukraine and is a cylindrical shell with a radius of R_{cp} =19,978 m, height H =17,88 m. The thickness of the shell wall differs in height and acquires a value of 7,63 mm to 15,98 mm. The wall of the tank is made of steel with mechanical characteristics: E =2,06·10^{11} Pa, μ =0,3, ρ =7800 kg/m^3. At the stage of manufacture, transportation and operation in the wall of the reservoir imperfections of form arose. As a result of the theodolite survey, actual radial deviations of the intersection points of generatrixes with horizontal boundaries of the shell belts were obtained. The reservoir calculation model is constructed in a finite element program complex in a cylindrical coordinate system. The initial deviations of the generatrix were added to the corresponding coordinates of the ideal surface and spline curves were constructed from the modified coordinates and then spline surfaces. The shell wall model with imperfect geometry is represented as a triangular finite element grid, and the number of model nodes is greater than the number of initial points of the envelope generators. To visualize the actual imperfections, a special program has been created that allowed the radial deviations of all points of the generatrixes to be represented on a certain scale and turn them into deviations of nodes of the finite element model in the Cartesian coordinate system. In Fig. 1 shows the finite element model of the reservoir in different planes, as an example of visualization of actual wall imperfections in a 1:20 scale.



(a) (b)

Fig. 1. Finite element model of an imperfect shell: side view (a), top view (b)

The problem of stability of the imperfect shell consisted in determining the critical values of axial compression and surface pressure separately for each load and with their combined action. The procedure of solving the non-linear static problem using the modified Newton-Raphson method is applied. Fig. 2 shows the loading curves of the shell surface pressure for three nodes, in which maximum displacements were observed at different loading stages. Surface pressure was supplied in the form $q = \beta q_{cr}^0$, where $q_{cr}^0 = 1257,4\ \text{N/m}^2$ – the critical load value for a shell with an ideal wall shape.

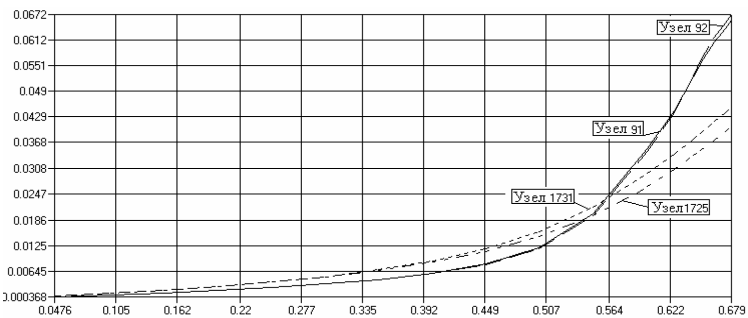
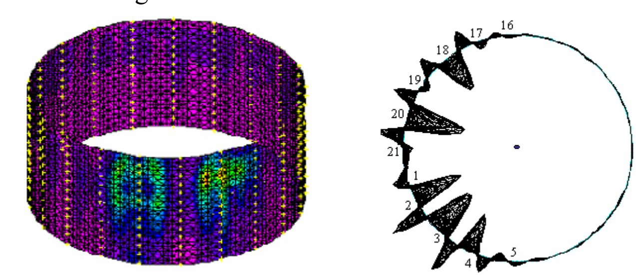


Fig. 2. Load curves for non-linear calculations

The buckling of the shell, taking into account the imperfections of the wall, occurred at $\beta_{cr} = 0,679$. The critical value of the surface pressure was $q_{cr} = 853,77\ \text{N/m}^2$. The stress-strain state of an imperfect shell with loss of stability is shown in Fig. 3.



(a) (b)

Fig. 3. Buckling of the shell under the action of surface pressure:
state of stress (a), form of deformation (b)

The maximum equivalent stress in the wall elements from the outside of the shell (Plate Top VonMises Stress) was 55,235 MPa, which is lower than the design resistance of steel $R_y = 240$ MPa.

The results of an investigation of the stability of the tank imperfect shell under axial compression, which was given in the form $P = \beta P_{cr}^0$, where $P_{cr}^0 = 430597{,}8$ N/m is the critical load value for a shell with an ideal wall shape, are shown in Fig. 4 and 5.

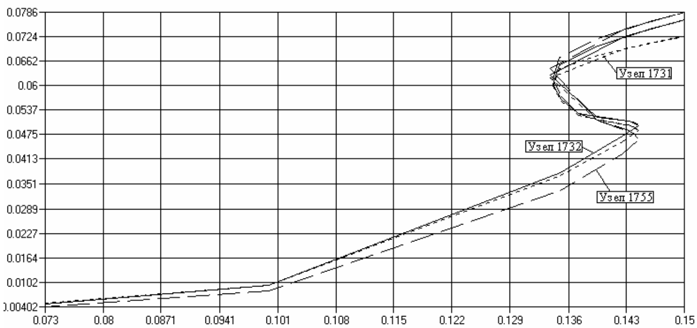
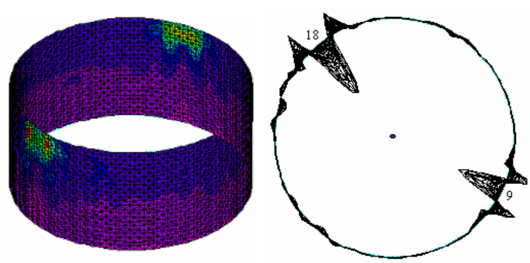


Fig. 4. Load curves of an imperfect shell by axial compression



(a) (b)

Fig. 5. The loss in stability of an imperfect shell under axial compression: state of stress (a), form of deformation (b)

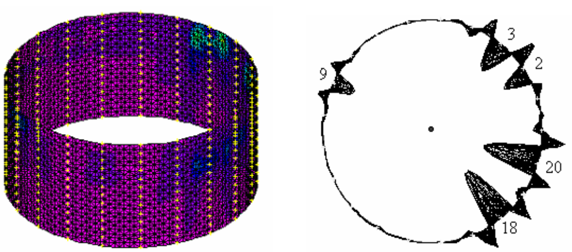
Buckling of the shell taking into account wall imperfections occurred at $\beta_{cr} = 0{,}145$. The critical value of axial compression was $P_{cr} = 62436{,}68$ N/m. The maximum equivalent stresses on the outside of the shell (Plate Top VonMises Stress) for axial compression were 53,732 MPa, which is less than the design resistance of steel $R_y = 240$ MPa.

Investigation of the reservoir stability in the combined action of axial compression and surface pressure is of particular interest. The combined load is given in the form $[\alpha P_{cr}^0; (1-\alpha) q_{cr}^0]$, where $\alpha = [0; 0{,}3; 0{,}5; 0{,}7; 1]$ is the dimensionless combination factor. As a result of solving the nonlinear problem of statics, the coefficients of the critical combined loading β_{cr} are determined, which allowed us to determine the critical values of axial compression and surface pressure when they act together on an imperfect shell by formulas: $\left[P_{cr}; q_{cr}\right] = \left[\beta_{cr} \alpha P_{cr}^0; \beta_{cr}(1-\alpha) q_{cr}^0\right]$. Fig. 6 shows the stress-strain state of a reservoir with real shape imperfections for three critical combinations of loads $0,201\left[0,3P_{cr}^{0};0,7q_{cr}^{0}\right]$, $0,362\left[0,5P_{cr}^{0};0,5q_{cr}^{0}\right]$ and $0,158\left[0,7P_{cr}^{0};0,3q_{cr}^{0}\right]$.

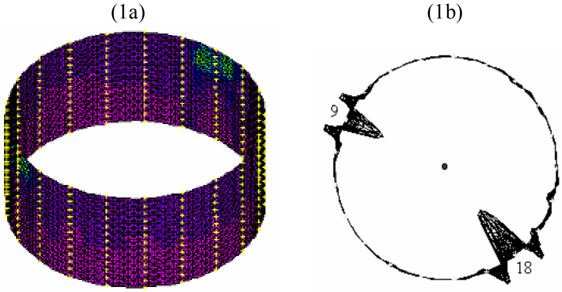
Table 1 illustrates the values of the critical combinations of axial compression and surface pressure $\left[P_{cr};q_{cr}\right]$ for different values of the load combination factor α.

Table 1

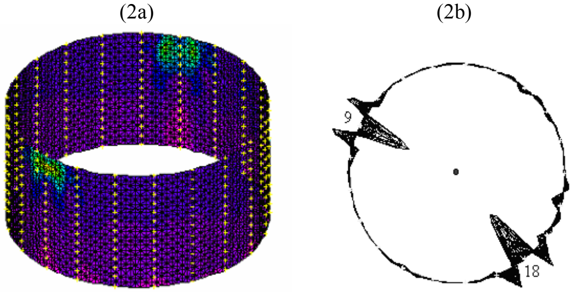
α	$\left[\alpha P_{cr}^{0};(1-\alpha)q_{cr}^{0}\right]$, ($N/m$;$N/m^2$)	β_{cr}	$\left[P_{cr};q_{cr}\right]$, ($N/m$;$N/m^2$)
0	[0; 1257,4]	0,679	[0; 853,77]
0,3	[143517,21; 977,87]	0,362	[51950,36; 353,97]
0,5	[252811,93; 738,24]	0,201	[50711,55; 148,08]
0,7	[362908,42; 454,17]	0,158	[57244,45; 71,64]
1	[430597,8; 0]	0,145	[62436,68; 0]



(1a) (1b)



(2a) (2b)



(3a) (3b)

Fig. 6. The loss in stability of the reservoir with real imperfections in shape under combined loading $0,362[0,3P_{cr}^{0};0,7q_{cr}^{0}]$ (1), $0,201\ [0,5P_{cr}^{0};0,5q_{cr}^{0}]$ (2) and $0,158[0,7P_{cr}^{0};0,3q_{cr}^{0}]$ (3): state of stress (a), form of deformation (b)

The maximum equivalent stresses on the outside of the shell (Plate Top VonMises Stress) for the three critical load combinations $0,362\left[0,3P_{cr}^{0};0,7q_{cr}^{0}\right]$, $0,201\left[0,5P_{cr}^{0};0,5q_{cr}^{0}\right]$ and $0,158\left[0,7P_{cr}^{0};0,3q_{cr}^{0}\right]$ respectively were 75,281 MPa, 99,201 *MPa* and 69.360 MPa, and were less than the design resistance of the steel $R_y = 240$ MPa.

For a tank with real wall shape imperfections, a stability diagram is constructed, load ranges are established, in which the conditions for ensuring general stability are realized under the combined action of axial compression and surface pressure. The region of stability of the shell is bounded by the curve of the equilibrium state and the coordinate axes (Fig. 7).

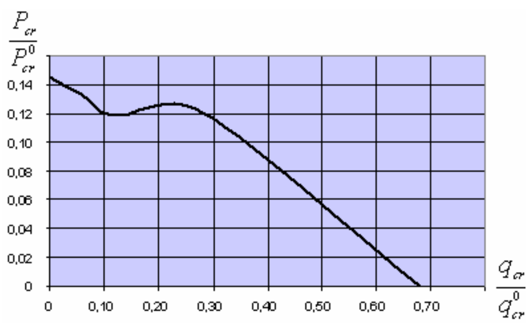


Fig. 7. The region of stability of the reservoir with real imperfections in shape

The reliability of the obtained results is confirmed with the help of theoretical formulas [2] and formulas for practical calculations [14] of the critical stress in the shell, which is caused by the action of uniform compression parallel to the generatrixes and at an external uniform pressure.

2. Stability of the reservoir with simulated irregular imperfections of the shape under the action of a combined load

The use of analytical methods for solving the problem of stability determined the form of imperfections as trigonometric functions [1], which significantly narrowed the range of studies. With a separate action of surface tension or axial compression, the initial imperfection in many cases was adopted as corresponding buckling forms, because such a model of regular imperfections had the greatest influence on the stability of the shell. Under the action of combined loading, the problem of modeling the initial imperfections of the shell is more complicated. But the availability of modern computing systems allows you to specify imperfections of the shell wall in an arbitrary form.

This article propose a numerical approach to the determination of the stability of cylindrical shells with irregular imperfections of the shape under the combined action of axial compression and surface pressure [4]. The approach made it possible to model imperfections in the form of combinations of shell buckling forms, which were obtained a separate action of axial compression and surface tension, to assess the impact of imperfections on the critical values of the combined load and to determine the stability region of the reservoir with variable wall thickness when acting combined loading.

The computational model is formed with the help of a finite element analysis computational complex [17] for a shell segment containing 425 nodes and 768 flat triangular elements. In the nodes of the boundary generators of the segment, displacements along the circle and rotation angles around the radius and generatrix are forbidden. The imperfection of the wall is represented as combinations of a perfect shell buckling forms under the separate action of axial compression and surface pressure: $[\gamma\vec{\Phi}_p;(1-\gamma)\vec{\Phi}_q]$, where $\gamma=[0;0,3;0,5;0,7;1]$ – the dimensionless coefficient, $\vec{\Phi}_P$ and $\vec{\Phi}_q$ – the vectors of the buckling forms of the perfect shell under the action of axial compression and surface pressure, respectively. A program, in which the components of the vectors of the buckling forms are added to the corresponding coordinates of the middle surface of the perfect shell is created in such a way that the maximum amplitude of the initial imperfection takes on the values [0,5t_{min}; t_{min}; 1,5t_{min}; 2t_{min}], where $t_{min}=7{,}63$ mm is the minimum wall thickness. The combined loading (see Section 1) is specified in the form of combinations of axial compression and surface pressure $[\alpha P^0_{cr};(1-\alpha)q^0_{cr}]$, where α – the dimensionless combination factor, acquires a value $[0;0{,}3;0{,}5;0{,}7;1]$.

The solution of the nonlinear equilibrium equations is carried out using the modified Newton-Raphson method. The loss of stability of the shell occurs with a critical combination of axial compression and surface pressure: $[P_{cr};q_{cr}]=\left[\beta_{cr}\alpha P^0_{cr};\beta_{cr}(1-\alpha)q^0_{cr}\right]$, where β_{cr} is the critical load parameter, the value of which is given for a cylindrical shell with imperfections of different shapes and maximum amplitude Δ_{max} in Table 2.

Table 2

Δ_{max}	α	Critical load parameter β_{cr}				
		$\gamma=0$	$\gamma=0,3$	$\gamma=0,5$	$\gamma=0,7$	$\gamma=1$
$0,5t_{min}$	0	0,742	0,795	0,846	0,866	0,934
	0,3	0,485	0,5	0,45	0,45	0,4
	0,5	0,55	0,55	0,5	0,45	0,4
	0,7	0,6	0,6	0,55	0,5	0,45
	1	0,8	0,65	0,6	0,55	0,5
t_{min}	0	0,601	0,626	0,682	0,754	0,9
	0,3	0,375	0,3	0,3	0,269	0,276
	0,5	0,4	0,35	0,3	0,282	0,3
	0,7	0,45	0,35	0,3	0,3	0,3
	1	0,619	0,4	0,35	0,32	0,33
$1,5t_{min}$	0	0,5	0,524	0,6	0,702	0,842
	0,3	0,3	0,25	0,25	0,25	0,25
	0,5	0,3	0,25	0,25	0,25	0,253
	0,7	0,35	0,264	0,278	0,274	0,264
	1	0,5	0,3	0,297	0,289	0,284
$2t_{min}$	0	0,4	0,45	0,486	0,517	0,821
	0,3	0,25	0,2	0,2	0,21	0,243
	0,5	0,25	0,206	0,215	0,25	0,25
	0,7	0,3	0,25	0,25	0,25	0,268
	1	0.3	0.28	0.27	0.27	0.275

It can be seen that the influence of the form of the wall imperfection of a reservoir with variable thickness is not proportional to the corresponding combinations of loads. That is, the critical load parameter is not minimal when the form factor of the imperfection and the load factor coincide, which is typical for cylindrical shells with a constant wall thickness.

To determine the stability region of a reservoir with simulated wall imperfections, critical ratios of axial compression and surface pressure in the form $\left[P_{cr} / P_{cr}^{0}; q_{cr} / q_{cr}^{0}\right]$ are determined. Table 3 presents the results of calculations for a shell with imperfections of various shapes and amplitude $\Delta_{\max}$.

Table 3

$\Delta_{\max}$	α	Combined load critical value $[P_{cr} / P_{cr}^{0}; q_{cr} / q_{cr}^{0}]$				
		$\gamma = 0$	$\gamma = 0,3$	$\gamma = 0,5$	$\gamma = 0,7$	$\gamma = 1$
$0,5t_{\min}$	0	[0;0,742]	[0;0,795]	[0;0,846]	[0;0,866]	[0;0,934]
	0.3	[0,146;0,34]	[0,145;0,35]	[0,135;0,315]	[0,135;0,315]	[0,12;0,28]
	0.5	[0,275;0,275]	[0,275;0,275]	[0,25;0,25]	[0,225;0,225]	[0,2;0,2]
	0.7	[0,42;0,18]	[0,42;0,18]	[0,385;0,165]	[0,35;0,15]	[0,315;0,135]
	1	[0,8;0]	[0,65;0]	[0,6;0]	[0,55;0]	[0,5;0]
$t_{\min}$	0	[0;0,601]	[0;0,626]	[0;0,682]	[0;0,754]	[0;0,9]
	0.3	[0,113;0,263]	[0,09;0,21]	[0,09;0,21]	[0,081;0,188]	[0,083;0,193]
	0.5	[0,2;0,2]	[0,175;0,175]	[0,15;0,15]	[0,141;0,141]	[0,15;0,15]
	0.7	[0,315;0,135]	[0,245;0,105]	[0,21;0,09]	[0,21;0,09]	[0,21;0,09]
	1	[0,619;0]	[0,4;0]	[0,35;0]	[0,32;0]	[0,33;0]
$1,5t_{\min}$	0	[0;0,5]	[0;0,524]	[0;0,6]	[0;0,702]	[0;0,842]
	0.3	[0,09;0,21]	[0,075;0,175]	[0,075;0,175]	[0,075;0,175]	[0,075;0,175]
	0.5	[0,15;0,15]	[0,125;0,125]	[0,125;0,125]	[0,125;0,125]	[0,127;0,127]
	0.7	[0,245;0,105]	[0,185;0,075]	[0,195;0,083]	[0,192;0,082]	[0,185;0,079]
	1	[0,5;0]	[0.3;0]	[0,297;0]	[0,289;0]	[0.284;0]
$2t_{\min}$	0	[0;0,4]	[0;0,45]	[0;0,486]	[0;0,517]	[0;0,821]
	0.3	[0,075;0,175]	[0,06;0,14]	[0,06;0,14]	[0,063;0,125]	[0,073;0,17]
	0.5	[0,125;0,125]	[0,103;0,103]	[0,108;0,108]	[0,125;0,125]	[0,125;0,125]
	0.7	[0,21;0,09]	[0,175;0,075]	[0,175;0,075]	[0,175;0,075]	[0,188;0,08]
	1	[0,3;0]	[0,28;0]	[0,27;0]	[0,27;0]	[0,275;0]

Fig. 8 shows the stability regions of a reservoir with irregular imperfections that lie between the coordinate axes and the equilibrium curves. The effect of imperfections on the stability region is not proportional to the corresponding combinations of loads. It can be seen that the stability regions are different for a shell with various forms of irregular imperfections.

We consider that the stability region of the shell with the corresponding maximum amplitude of imperfection of the wall is the region that lies between the coordinate axes and the curves with the minimum values of the critical loads combinations presented in Table 4 and in Fig. 9.

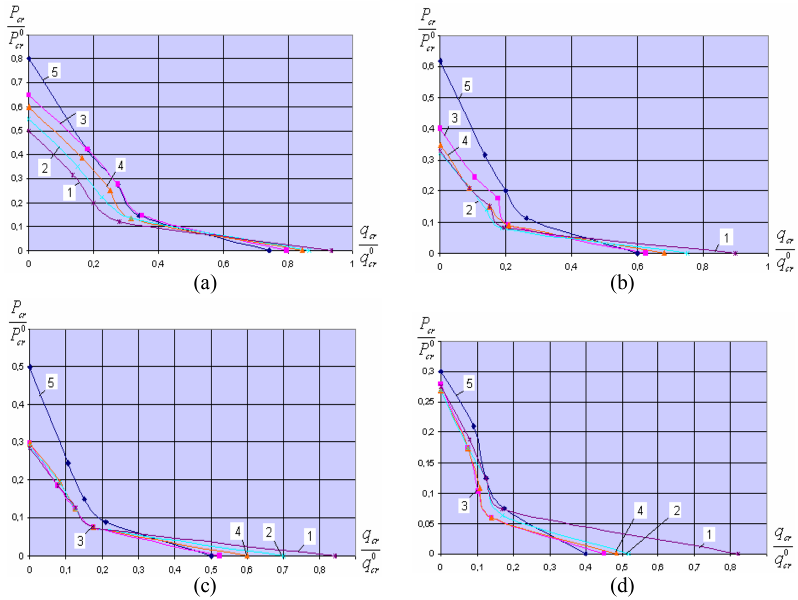


Fig. 8. Diagrams of reservoir stability regions with imperfections of different form:
1 - $\gamma = 0$; 2 - $\gamma = 0,3$; 3 - $\gamma = 0,7$; 4 - $\gamma = 0,5$; 5 - $\gamma = 1$ and different maximum amplitude:
(a) - $0,5t_{\min}$; (b) - $t_{\min}$; (c) - $1,5t_{\min}$; (d) - $2t_{\min}$

Table 4

Minimum combined load critical value $[P_{cr} / P_{cr}^0 ; q_{cr} / q_{cr}^0]_{\min}$			
$0,5t_{\min}$	$t_{\min}$	$1,5t_{\min}$	$2t_{\min}$
[0; 0,742]	[0; 0,601]	[0; 0,5]	[0; 0,4]
[0,12; 0,28]	[0,081; 0,188]	[0,075; 0,175]	[0,06; 0,14]
[0,2; 0,2]	[0,141; 0,141]	[0,125; 0,125]	[0,103; 0,103]
[0,315; 0,135]	[0,21; 0,09]	[0,185; 0,079]	[0,175; 0,075]
[0,5; 0]	[0,32; 0]	[0,284; 0]	[0,27; 0]

Fig. 9(a) shows the curves of the minimum critical ratios of axial compression and surface pressure of the imperfect shell.

It's obvious that an increase in the maximum amplitude of imperfection leads to a decrease in the stability region of the shell.

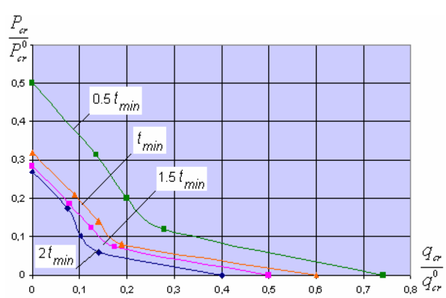


Fig. 9. Curves of critical axial compression and surface pressure ratios of the reservoir with imperfections as combinations of buckling forms

3. Determination of failure region in stability of the reservoir with real wall imperfections

One of the basic concepts of theory of structural reliability is the concept of failure [1, 3]. A failure is a partial or total loss of system quality. In construction mechanics, this notion corresponds to the notion of a limit state. For practical purposes, it is often necessary to assess the probability that the system's response will be in the field of failure-free operation. Then the reliability R of the system is defined as the probability of finding the element of the system reaction vector $S(\tau)$ in the admissible region Ω_0 during the time interval $\left[0 \le \tau \le \text{t}\right]$:

$$R = P_{suc} = \Pr ob\left[S(\tau) \in \Omega_0 ; 0 \le \tau \le \text{t}\right].$$

The probability of failure is a addition to the reliability function:

$$P_{fail}(t) = 1 - P_{suc} .$$

In our case, the failure of the shell in stability is considered, because this type of failure for thin-walled shell structures is more dangerous. For various combinations of axial compression and surface pressure, there is an area that characterizes the ability of the oil reservoir to perceive the combined load and not lose stability. In the work of graphical representation of shell failure-free operation region Ω_0, we can consider the stability region of the reservoir with the maximum permissible amplitude of the imperfection $\Delta_{\max} = 2t_{\min}$ (Fig. 9). Reliability of fail-safe work of building constructions for limit states is $P_{suc} = 99{,}9\ \%$ [1]. It is the probability that the reservoir's reaction vector $S(\tau)$ will stay in the permissible region Ω_0 for a time interval $\left[0 \le \tau \le \text{t}\right]$.

Let's show in Fig. 10 the stability region of the tank with real imperfections of the wall, which is between curve 1 and coordinate axes, and the admissible area of failure-free operation region Ω_0, which is limited by curve 2 and coordinate axes.

Let's show in Fig. 10 the stability region of the tank with real imperfections of the wall, which is between curve 1 and coordinate axes, and the admissible area of failure-free operation, which is limited by curve 2 and coordinate axes. We see that an additional area of failure arose due to the lack of a general stability of the wall in this region. The additional region of failure is 28.2% of the of the failure-free operation region, therefore the reliability of the stability of the tank with real imperfections decreased to $P_{suc} = 71{,}7\ \%$.

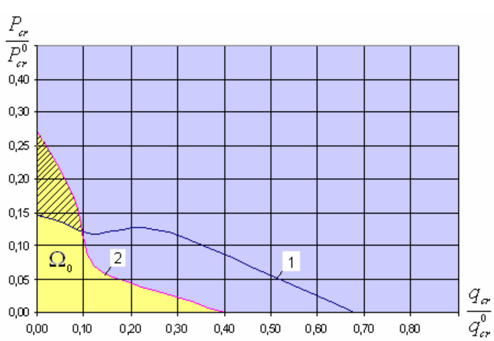


Fig. 10. Curves of critical ratios of axial compression and surface pressure of a tank with imperfections: 1 - real; 2 - modeled as forms of loss of stability

To ensure the overall stability of the tank wall, it is recommended to introduce additional stiffening elements (ribs, rings) into the structure.

Conclusion. The developed numerical technique with application of the program complex of finite element analysis procedures allowed to investigate the stability of the oil reservoir with actually measured imperfections of the wall shape under the joint action of axial compression and surface pressure; get an feasible failure-free operation region of the reservoir with modeled imperfections of the form as relationships of buckling forms; graphically represent the failure region in stability of the reservoir with real imperfections of the wall.

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DEFINITION OF THE FAILURE REGION OF THE OIL TANK WITH WALL IMPERFECTIONS IN COMBINED LOADING

The presence of defects in real oil tanks plays an essential role in their accident-free operation. The majority of theoretical and experimental studies are devoted to the investigation of the effect of defects in the form of initial imperfections of the shape of thin shells on the carrying capacity and stability. Initial imperfections are the main factor that reduces the critical load. The first of the studies of the sensitivity of the critical load to the initial geometric imperfections of the form was performed by L. Donnell. A special role in the development of the theory of stability of imperfect shells was played by the asymptotic method of V.T. Coiter, which is used in J. Hutchinson. I.Arbosh, Ch.Bebkok, J.C.Amazigo and others research. Most of these papers were carried out on the assumption of linear critical behavior of the solution. In the future, for a detailed account of the imperfect geometry of nonlinearly deformed shells under an arbitrary load action, the researchers began to apply the synthesis of the reduction method and the Coiter method. At present, there are modern computational complexes that allow us to introduce initial imperfections directly as geometric parameters of the middle surface of the shells. The solution of the nonlinear problem in such formulation can more fully reflect the influence of the initial imperfections on the decrease of the critical load. However, the problem of determining the permissible failure-free operation region of tanks with real imperfections of the shape under the action of combined loading remains important.

The stability of an oil reservoir with real imperfections of a wall under the joint action of axial compression and surface pressure is studied using a program complex of finite element analysis. To determine the permissible range of fail-safe operation of the reservoir, irregular imperfections of the middle wall surface are simulated as ratios of the buckling forms with different maximum amplitudes obtained in solving the problem of loss of stability by the Lanczos method. The stability of the shell with real and simulated imperfections of the wall is investigated using the nonlinear static problem by the Newton-Raphson method. Critical ratios of axial compression and surface pressure are determined to ensure overall stability of the reservoir wall. The region of failure on the stability of the oil reservoir with real imperfections is obtained.

Key words: cylindrical shell, imperfection of shape, stability, combined loading, failure region.

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ВИЗНАЧЕННЯ ОБЛАСТІ ВІДМОВИ НАФТОВОГО РЕЗЕРВУАРА З НЕДОСКОНАЛОСТЯМИ СТІНКИ ПРИ КОМБІНОВАНОМУ НАВАНТАЖЕННІ

Досліджена стійкість нафтоналивного резервуара з реальними недосконалостями стінки при сумісній дії осьового стиснення і поверхневого тиску. Побудована допустима область безвідмовної роботи резервуара зі змодельованими недосконалостями форми у вигляді сполучень форм втрати стійкості; графічно визначена область відмови за стійкістю резервуара з реальними недосконалостями стінки.

Ключові слова: циліндрична оболонка, недосконалість форми, стабільність, комбіноване навантаження, область відмови.

Баженов В.А., Лукьянченко О.А., Костина Е.В.

ОПРЕДЕЛЕНИЕ ОБЛАСТИ ОТКАЗА НЕФТЯНОГО РЕЗЕРВУАРА С НЕСОВЕРШЕНСТВАМИ СТЕНКИ ПРИ КОМБИНИРОВАННОМ НАГРУЖЕНИИ

Исследована устойчивость нефтяного резервуара с реальными несовершенствами стенки при совместном действии осевого сжатия и поверхностного давления. Построена допустимая область безотказной работы резервуара со смоделированными несовершенствами формы в виде комбинаций форм потери устойчивости; графически определена область отказа по устойчивости резервуара с реальными несовершенствами стенки.

Ключевые слова: цилиндрическая оболочка, несовершенство формы, устойчивость, комбинированная нагрузка, область отказа.

Баженов В.А., Лук'янченко О.О., Костіна О.В. **Визначення області відмови нафтового резервуара з недосконалостями стінки при комбінованому навантаженні** // Опір матеріалів і теорія споруд: наук.-тех. збірн. – К.: КНУБА, 2018. – Вип. 100. – С. 27-39.

Досліджена стійкість нафтоналивного резервуара з реальними недосконалостями стінки при сумісній дії осьового стиснення і поверхневого тиску. Побудована допустима область безвідмовної роботи резервуара зі змодельованими недосконалостями форми у вигляді сполучень форм втрати стійкості; графічно визначена область відмови за стійкістю резервуара з реальними недосконалостями стінки.

Табл. 4. Іл. 10. Бібліогр. 17 назв.

Bazhenov V.A., Lukianchenko O.O., Kostina O.V. **Definition of the failure region of the oil tank with wall imperfections in combined loading** / Strength of materials and theory of structures: Sci.&Tech. Collected Artcl. – K.: KNUBA, 2018. – Issue 100. – P. 27-39.

The stability of an oil reservoir with real imperfections of the wall under the joint action of axial compression and surface pressure is studied. An admissible region of trouble-free operation of the reservoir with modeled imperfections of the form in the form of combinations of forms of stability loss is constructed; graphically determined the area of failure in the stability of the reservoir with real wall imperfections.

Tabl. 4. Fig. 10. Ref. 17.

Баженов В.А., Лукьянченко О.А., Костина Е.В. **Определение области отказа нефтяного резервуара с несовершенствами стенки при комбинированном нагружении** // Сопротивление материалов и теория сооружений: научно-тех. сборн. - К .: КНУСА, 2018. - Вып. 100. - С. 27-39.

Исследована устойчивость нефтяного резервуара с реальными несовершенствами стенки при совместном действии осевого сжатия и поверхностного давления. Построена допустимая область безотказной работы резервуара со смоделированными несовершенствами формы в виде комбинаций форм потери устойчивости; графически определена область отказа по устойчивости резервуара с реальными несовершенствами стенки.

Табл. 4. Ил. 10. Библиог. 17 назв.

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