Investigation of the stress-strain state for the fuel tank separator

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Abstract. The work carried out finite element modeling for the thin-walled shell of revolution loaded uniform pressure with using MSC NASTRAN software. The simulations results allow us to study the stress-strain state of the torus rolling zone for refine the boundaries of plastic deformation. It is determined that the region of plastic deformation does not arise in the entire torus zone. This region is limited by the outer part of the torus along the generatrix edges.

1. Introduction
To ensure proper supply fuel component from the tank to the liquid thruster with pressure feed system must be guaranteed separation of the liquid phase from the gaseous phase. Guaranteed separation is possible only by mechanical separation. Effective is the use of axisymmetric metal eversible separators [1].

Mathematical relationships, compiled on experimentally-based physical model of the plastic deformation for thin-walled shells of arbitrary form, is not accurate enough and do not correspond to the results of experimental data. This can be explained accepted without sufficient justification symmetrical borders for deformation plastic zone and the surface appearance is adopted as torus [2-4]. This approach requires for each form of the shell the procedure identification theoretical and experimental data for specifying coefficients of parameters eversion shell. In the shell, moving along the generatrix of plastic deformation during eversion, the thin-walled condition is not fulfilled and it is necessary to justify a new physical material model.

To reduce the cost of designing shells is necessary to clarify the physical model of plastic deformation for the thin-walled shell in the rolling zone. One of the methods for solving the problem to clarify the boundaries for deformation plastic zone of the torus for the separator can be computer simulation with using advanced finite element packages such as MSC NASTRAN.

2. Research model
Dimensions of the separator and a simulated three-dimensional image of the separator shown in figure 1. The loading scheme and the torus zone are presented in figure 2.

To conduct the study selected MSC NASTRAN computer simulation package. When working in similar software products, the calculation basis is the right application and registration of loads acting on the model, as well as creating high-quality finite element (FE) mesh.
Since posed problem is axisymmetric, it is advisable to use the Axisymmetric FE from section volume finite elements [5-7]. Axisymmetric FE is an annular member with a triangular or quadrangular cross-section. This type of FE is constructed in XZ plane from the base coordinate system, where Z - body rotation axis. For construction needs only half the cross section for the body of revolution. Model should not intersect the Z axis.

For high-quality meshing appropriateness simulate the cross-section of the separator finite elements without creating a geometric model.

The paper investigates two positions of the separator. Initial with a torus zone angle $\varphi = 180^\circ$ and intermediate with a torus zone angle $\varphi = 120^\circ$. Finite-element models are presented in figure 3.

Initial data for modeling:
- Material - aluminum AD-1M ($E = 0.7 \times 10^5$, $\mu = 0.27$, $\sigma_{02} = 50$ MPa, $\sigma = 80$ MPa), isotropic, elastoplastic;
- Load - $p = 0.1$ MPa, distributed on the bottom of the separator;
- Boundary conditions - fixed edge of the outer shell;
3. Results and Discussion
The simulation results for Von Mises stresses are presented in figure 4.

For greater clarity, we have limited the maximum displayed stress to 50 MPa (stress yield point of the material). We get the image in figure 5:

The red zones in figure 5 displays where the stresses exceed the yield strength. Plastic deformations occur in these places. The scaled deformed view is presented in figure 6.
The analysis of stress-deformed state indicates that the plastic stress distributed in torus zone is not symmetrical relative to the minor axis of the torus and not uniformly. Plastic deformation is pronounced at the edges of the torus zone only in the outer layers of the shell (fig. 6). With the development of plastic deformations, the plasticity zones merge and the middle surface of the torus zone deforms at angles $\varphi = 0 \ldots 90^\circ$.

The simulation results confirm that mathematical models of plastic deformation for thin-walled shells with an arbitrary shape of the generatrix, based on the symmetry of the boundaries deformation plastic zone, do not have sufficient accuracy.

4. Conclusion
1. A finite element model of two positions of the stress-strain state of the fuel tank separator in the MSC NASTRAN package based on axisymmetric finite elements has been created.
2. Plastic stress distributed by torus zone is not symmetrical and uniformly.
3. Mathematical models of plastic deformation for thin-walled shells with arbitrary shape of the generatrix, based on the symmetry of boundaries deformation plastic zone, are not accurate enough.

References
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Figure 6. The scaled deformed view: a) in the initial position; b) in intermediate position.