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RESULTS OF COMPARATIVE ANALYSIS OF THE STATE OF TYPE C PACKAGE (TUK-145/C) FOR SNF SHIPMENT BY AIR AFTER IMPACT ONTO A TARGET AND REAL GROUND AT VELOCITY OF NO LESS THAN 90 M/SEC

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ABSTRACT

The paper describes the results of the designed analysis of TUK-145/C state after the package impact onto a target that is a "soft" ground medium at velocity of 90m/sec. The package is designed for SNF air shipments. The comparative analysis of the package state after the impact onto "soft" grounds and a rigid target was performed. The efficiency of the protective damping casing (PDC) of TUK-145/C package to reduce impact load at the SKODA container after the package impact onto the ground in case of an air crush was studied.

INTRODUCTION

In 2012 a unique package of type C – TUK-145/C was developed in Russia that is intended for SNF and high-level radioactive materials air shipments. Leading specialists from CAE MSS developed the package and performed designed validation of its safety.

Nuclear and radiation safety of the package after the air crush was verified during the testing for the package model impact (scale 1:2.5) onto a target at velocity of ~95m/sec. The testing was performed in accordance with the IAEA regulations.

Certificates- authorizations of the Russian State authorization body were issued for the package design and the first air shipment of spent fuel assemblies from the Vietnamese research reactor.

Taking into account the package huge weight and dimensions, unique design as well as high radiological hazard in case of an air crush, the IAEA experts have recommended conducting a comparative designed analysis of the package state after its impact onto a rigid target and real grounds.

SELECTION OF REPRESENTATIVE TYPES OF "SOFT" GROUNDS TO COMPUTE IMPACTS ONTO A MASSIVE BODY AT VELOCITY UP TO 100M/SEC

The specific analysis of different ground types structural compositions and dynamic features was performed based on the published data. Three ground types were identified, that includes all the possible "soft" targets classified by degree of "rigidity" impact (pressure value in the contact area, calculated in plane approximation) at the TUK-145/C package:

- sand, with density of 1.68g/cm^3 – the "softest" ground target;
- clay sand with density of 2g/cm^3 and 14% humidity – the "medium" target;
- loam with density of 1.97g/cm^3 – the "most rigid" ground target.

The scope of physical mechanical properties of the representative types of "soft" grounds was identified to describe dynamic deformation after an impact with TUK-145/C package at velocity of 90m/sec. The deformation was described using an equation model of the ground state in the form of Soil and Foam which is used in the LS-DYNA application package.

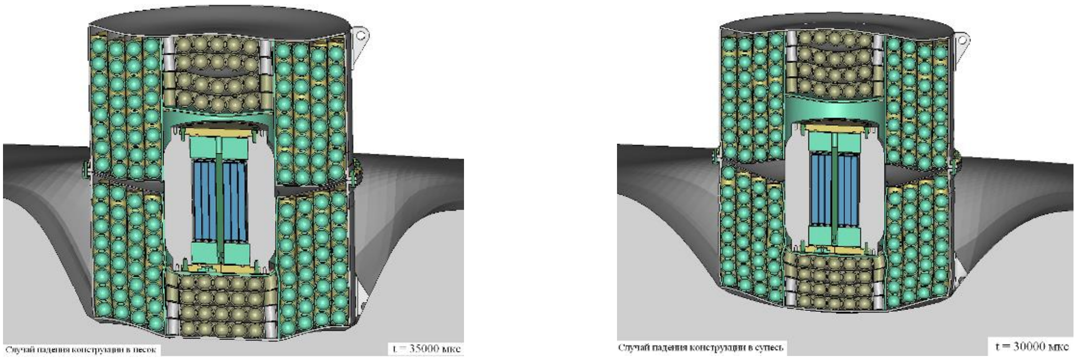
The following factors were taking into consideration while choosing the model of the ground state description:

1) adequacy of the material state description i.e. how accurately the computation results obtained using this model are corresponded to the test data (by amplitude – time characteristics);
2) availability of methods to determine constants- constituents of the state equation;

3) model simplicity that results in building simple algorithms under numerical implementation.

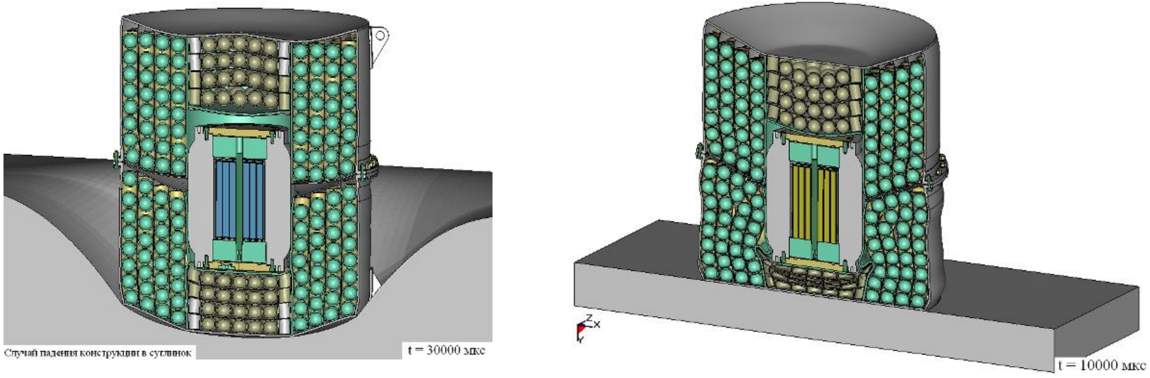
COMPARATIVE ANALYSIS OF COMPUTATIONAL RESULTS OF TUK-145/C PACKAGE DEFORMATION DYNAMICS AFTER IMPACT ONTO SOFT GROUNDS AND RIGID TARGET AT VELOCITY OF 90M/SEC.

Pictures 1, 2 and 3 show TUK-145/C states for axial, lateral and angular impacts of the structure with different targets at the moment when maximal overloading, stresses and deformations have achieved at the main components of the package, while the velocity at the container body has reduced nearly to zero.



Sand

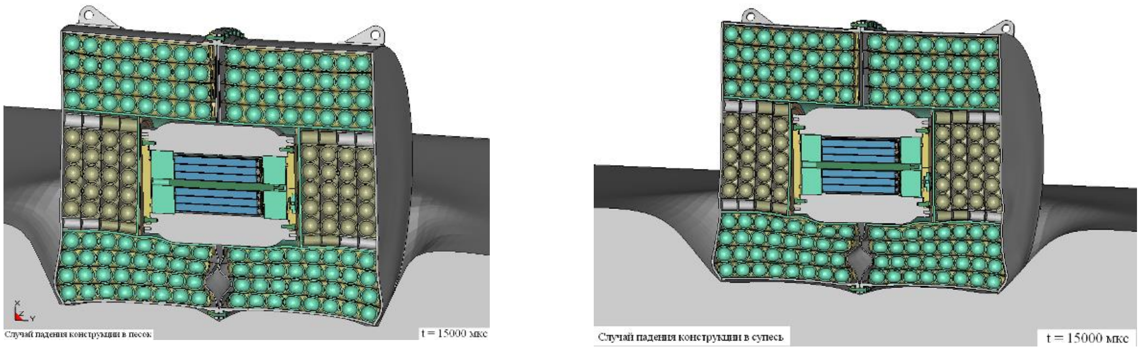
Clay sand



Loam

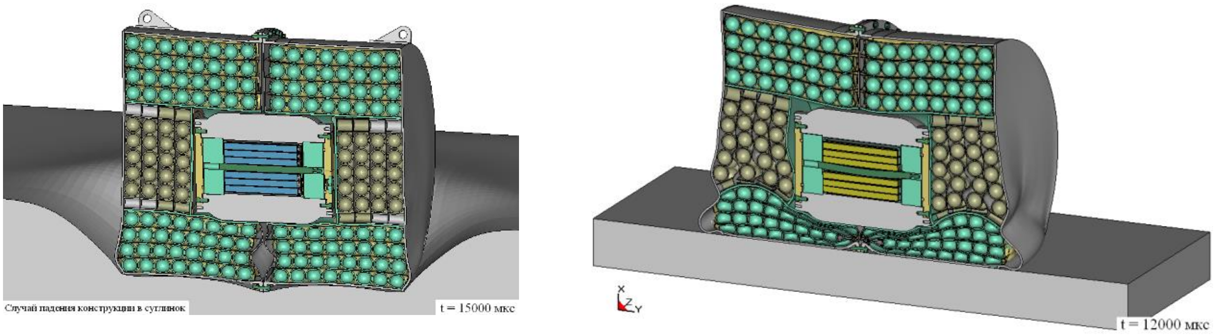
Rigid target

Figure 1. TUK-145/C state after axial impact onto a target (longitudinal axis of the structure is directed by normal to the target surface, PDC contacts with the target surface by bottom).



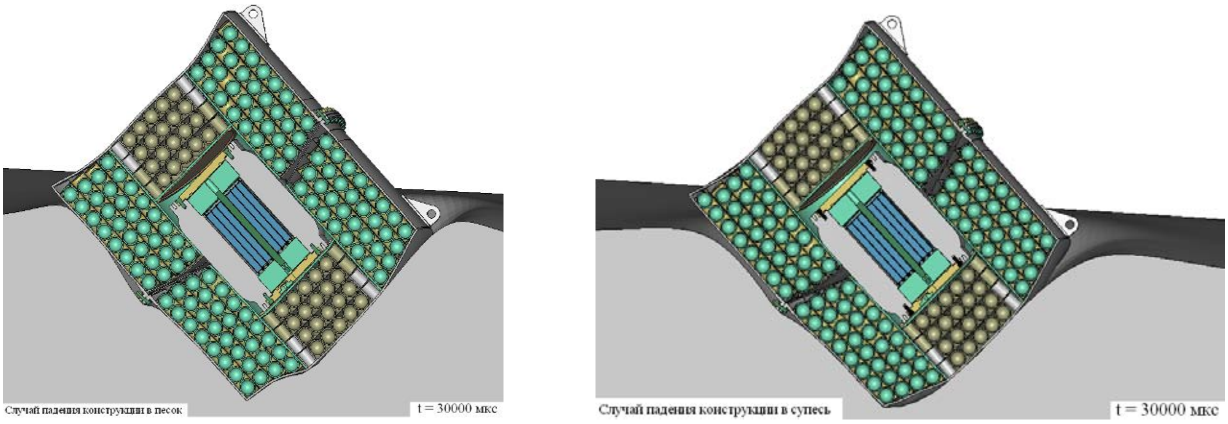
Sand

Clay sand

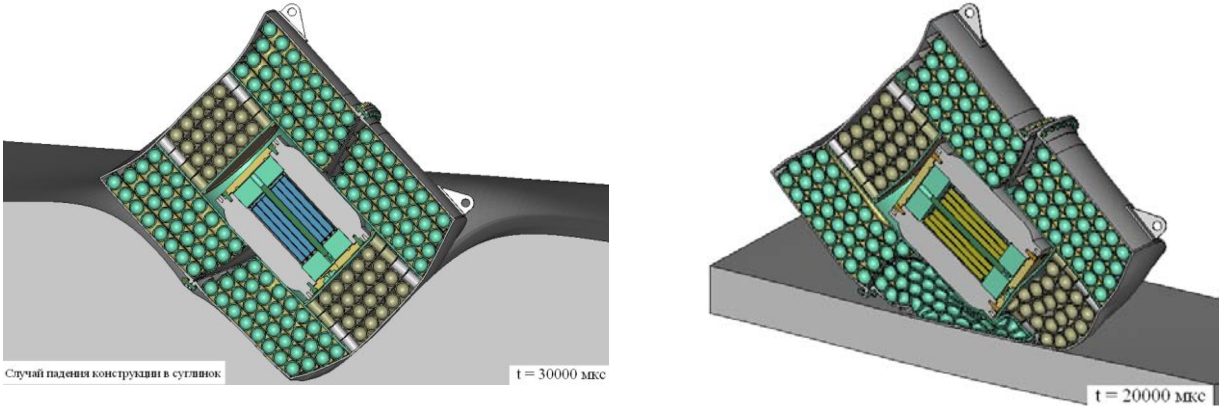


Loam Rigid target

Figure 2. TUK-145/C state after lateral impact onto a target (longitudinal axis of the structure is parallel to the target surface).



Sand Clay sand



Loam Rigid target

Figure 3. TUK-145/C state after angular impact onto a target (the package contacts with the ground surface by the edge of its low end area; the structure's mass center lays on the normal to the ground surface; the angle of TUK-145/C longitudinal axis against the ground surface is ~42º).

The damping system PDC provides the reduction of impact loading at the SKODA VPVR/M container up to the level, when the container keeps its integrity and sealing in all computed events of TUK-145/C impacts onto "soft" grounds as well as onto a rigid target.

It should be noted that in spite of visual similarity of the final deformed configuration of TUK-145/C structure in the pictures showing the package state after impacts onto various types of "soft" grounds, the process of TUK deformation during penetration into different types of grounds goes in different manner. Some differences can be observed in deformation of the PDC part, which is directly in the package contact area with the ground medium. One can see the difference in the grounds behavior as well as the difference in cavities generation under the package penetration into the ground surface and it the depth of penetration.

Though there are some differences in the process of TUK deformation after impact onto various types of grounds, the general similar regularity can be revealed in the structure's stress state fields generation and distribution. The areas with the highest levels of stresses and deformations are produced almost in one and the same areas of the PDC structure and the container. The difference can be found in maximum levels of stresses and deformations obtained at such parts of the structures and in relative dimensions of these parts.

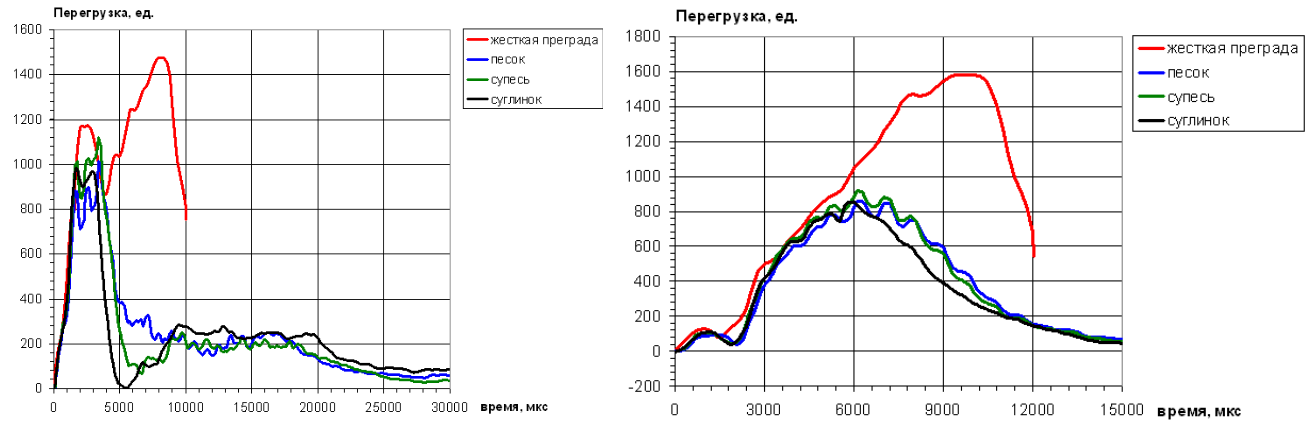
Figure 4 shows the graphs of overloading time changes at the SKODA VPVR/M container body for axial, lateral and angular impacts onto “soft” grounds and a rigid target. It is obvious that the level of overloading at the SKODA VPVR/M container elements after the package impact onto “soft” grounds is much lower than at the container after the package impact onto a rigid target.

The following maximum overloading at the SKODA VPVR/M container body was measured after the impact onto sand, clay sand and loam respectively:

- axial impact – 1000 units, 1100 units, 950 units (1500 units for the rigid target)
- lateral impact - 850 units, 900 units, 880 units (1600 units for the rigid target)
- angular impact 400 units, 420 units, 360 units (1000 units for the rigid target).

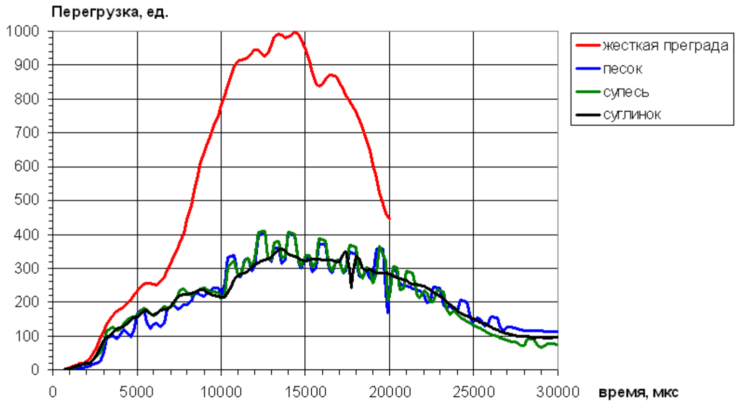
The following maximum damper movement (value of the PDC damping system crushing in the impact direction) was measured after the impact onto sand, clay sand and loam respectively:

- axial impact – 110 mm, 140 mm, 136 mm (460mm for the rigid target)
- lateral impact – 190 mm, 220mm, 180 mm (650mm for the rigid target)
- angular impact – 220 mm, 275 mm, 270 mm (1100mm for the rigid target)



Axial impact

Lateral impact



Angular impact

Figure 4. Graphs of overloading time changes at the SKODA VPVR/M container body after PDC impact onto a rigid target and grounds

Based on comparison of the overloading level at the SKODA VPVR/M container body and the PDC damper movement after the package impact onto grounds and a rigid target we can draw a conclusion that the effect mode of the package orientation angle relative to the target to the PDC damping system movement is not changed (maximum movements of the damper are obtained after angular impacts, lower values are obtained after lateral impacts and the lowest values are obtained after axial impacts). As opposed to the TUK package impact onto a rigid target the maximum overloading at the container body after the package impact onto grounds is distributed in another way. In case of ground impact the maximum overloading was measured in axial impacts, lower values were obtained after lateral impacts and the lowest values were gotten after angular impacts. As for the impact onto a rigid target the maximum overloading was obtained after the package lateral impact, then the axial impact and the lowest value was obtained after the angular impact.

Based on the comparison of initial values of the PDC damping system in axial, side and angular directions (axial direction – 767mm, lateral direction – 888mm, angular direction – 1169mm) with the damper movement values obtained after accidental impacts of the package in the correspondent direction on the discussed grounds we can draw a conclusion that the PDC construction provides sufficiently high resource of damping characteristics after penetration into the ground.

It should be stressed that the design of the TUK damping systems intended for air shipments should take into consideration the possible impacts not only onto a rigid target, but onto “soft” real grounds, those are the most likely during the air crush. The reasonability of such an approach is resulted from significant difference in the absorption processes of the damping system (after impacts onto a rigid or “soft” targets), which operating parameters are identified in terms of impacts onto a rigid target. Therefore in order to provide optimal efficiency of the TUK damping system its design should include a combination of damping components, some of them should be effective under less intense loading that can be applied during the impact with the most likely real target – “soft” grounds.

CONCLUSION

Computational investigations on evaluation of the efficiency of TUK-145/C damping system PDC to reduce impact loading for the SKODA VPVR/M container after the package impact onto a “soft” ground target at velocity of 90 m/sec were performed. Three types of grounds were considered that cover all the possible “soft” targets to be impacted by the package during the air crush (dry sand, clay sand, loam).

The computations prove that the PDC structure keeps its integrity during the package impact onto the ground and provides reduction of impact loading for the SKODA VPVR/M container up to the level, when the cask keeps its strength and sealing. The PDC damping system provides high resource of damping characteristics after the package impact onto “soft” grounds.