Experimentální Analýza Napětí 2010
Experimental Stress Analysis

Possibilities of experimental verification of containers for radioactive materials transport

František Trebuňa,[1] František Šimčák,[2] Jozef Bocko,[3] Zdenko Bobovský[4]

Abstract: The containers for transport of radioactive materials have to fulfill demands of criterion given for normal and critical conditions of transportation. For the demonstration of criterion accomplishment demanded by relevant regulations are used analytical, numerical and experimental methods of mechanics. After realization of analytical and numerical computations that simulated test according to regulations will be accomplished experimental verification of container safety. In the paper are presented possibilities of experimental methods of evaluation of containers with emphasis to drop test.

Keywords: Container, Finite element method, Drop test

1. Introduction

For the approval process of packages (containers, casks) that are determined for transport of radioactive materials is necessary to realize analyses affirming that transport package fulfill demands of regulation UJD SR No.57/2006 Z.z. [1]. For the safety assessment is possible to use analytical and numerical computations as well as experimental treatments that manifest fulfillment of demands for packages in accordance to addendum No. 4 of above-mentioned regulation.

On the workplace of authors was recently realized computational verification of particular types of packages in accordance with regulation [2]. During the verification process were employed procedures of analytical and numerical modeling in accordance with international standards [3,4]. The computations demonstrated fulfillment of defined demand. In further reference to computational verification of packages was recommended to realize experimental verification of

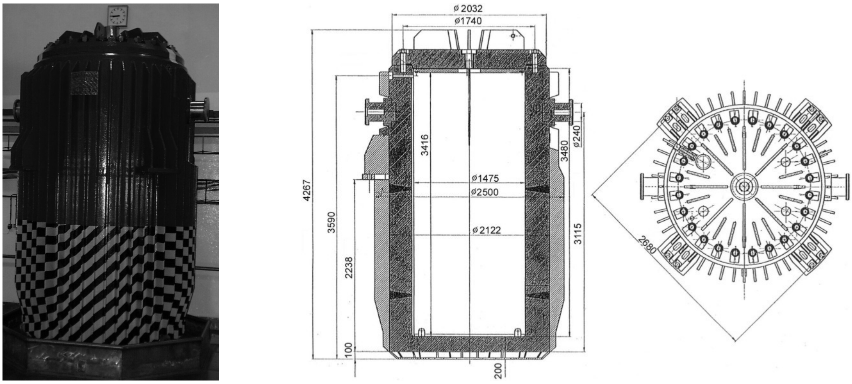
[1] *Dr.h.c mult. prof. Ing. František Trebuňa, CSc.; Department of mechanics and mechatronics at Faculty of mechanical engineering at Technical University of Košice; Letná 9, 042 00 Košice, Slovak republic; frantisek.trebuna@tuke.sk*
[2] *prof. Ing. František Šimčák, CSc.; Department of mechanics and mechatronics at Faculty of mechanical engineering at Technical University of Košice; Letná 9, 042 00 Košice, Slovak republic; frantisek.simcak@tuke.sk*
[3] *doc. Ing. Jozef Bocko, CSc.; Department of mechanics and mechatronics at Faculty of mechanical engineering at Technical University of Košice; Letná 9, 042 00 Košice, Slovak republic; jozef.bocko@tuke.sk*
[4] *Ing. Zdenko Bobovský, PhD; Department of mechanics and mechatronics at Faculty of mechanical engineering at Technical University of Košice; Letná 9, 042 00 Košice, Slovak republic; zdenko.bobovsky@tuke.sk*

Experimentální analýza napětí 2010, Petr Šmíd, Pavel Horváth, Miroslav Hrabovský, eds.,
May 31 - June 3 2010, Velké Losiny, Czech Republic (Palacky University, Olomouc; Olomouc; 2010).

cask safety by performing test on real objects or on models that reflect their properties. In the paper are represented possibilities of experimental verification of state of packages determined for transport of radioactive materials according to regulations with emphasis to drop tests.

2. Computational verification of containers according to regulation UJD SR

Object of investigation by numerical and experimental analysis was spent fuel (Fig.1a) with basic dimensions according to Fig.1b.



a) view on container b) basic dimensions of container

Fig. 1. Container for transportation of spent radioactive fuel.

The cask contains holder of cassettes that are transported to intermediate stock of spent fuel. Transportation is realized by special wagon in which is a frame for positioning of cask. The main parts of containers are:

- body of container made as thick-walled steel vessel with outer ribs,
- lid of container with ribs. The lid is fastened to the body of cask by stud bolts and hermetically sealed by viton washers,
- two supporting journals for manipulation with container,
- four tighten consoles for joining to special wagon,
- holder, spent fuel cells.

The whole container weight together with transported shipment is approximately 85 000 kg.

In accordance to regulation UJD SR No.57/2006 Z.z., the packages for spent fuel transportation have to fulfill criteria established for normal and emergency conditions of transportation i.e. they have to, with sufficient safety, demonstrate resistance to mechanical and thermal influences given by regulation. The packages have to resist during normal transport conditions the following influences

1. free drop from height 0.3 m with further thermal loading by sun,

2. pressure loading (internal pressure 700 kPa, outer underpressure 40 kPa) with further thermal loading by sun,
3. impact of a bar of diameter 32 mm and mass 6 kg with rounded end on container and further thermal loading by sun.

Emergency conditions of transportations are defined by the following influences

1. Cumulative action of various variant of impact, thermal and pressure influence with the worst combination of drop (variant I., II. and III.), thermal loading by flame with temperature 800° C during 30 min and plunging into water to deep 15 m during 8 hours. Possible variants of drop are I – drop of container from height 9 m on the target, II – drop of container from height 1 m on steel bar of prescribed shape and dimensions, fastened perpendicular to the target, III- drop of steel plate of dimensions 1m x 1m, mass 500 kg from height 9 m to container positioned on the target. The most frequently the target comprises thick steel plate located on massive concrete base.
2. Plunging into water to deep 200 m during 1 hour.

Further common conditions for packages concern safety of lifting and fastening parts of the cask, resistance of containment to temperatures scale –40 °C to 70 °C, as well as resistance to whatever accelerations and vibrations that can occur for conditions that are possible during transportation. For all above-mentioned conditions has to be preserved integrity of container and tightness of particular closures.

In order to illustrate the results of numerical analysis we present some load simulations of the cask. In Fig.2 is a model of particular prt of container for computation by the finite element method.

In Fig.3 is the field of equivalent stresses in the container during loading by internal pressure 740 kPa. In Fig.4 is the field of equivalent stresses in the journal of container during simulation of lifting with a crane by hooks positioned on journals.

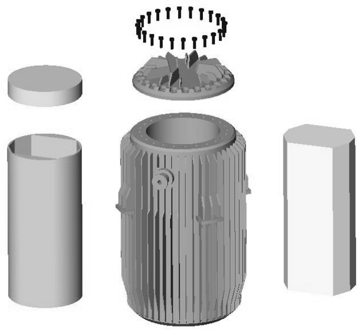


Fig. 2. Model of individual parts of container for computation by FEM.

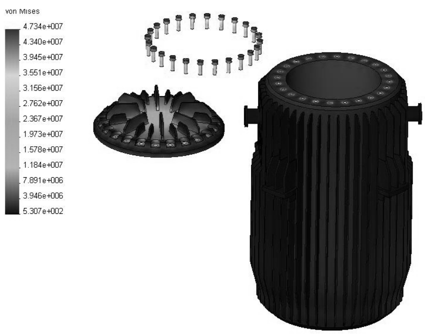


Fig. 3. The field of equivalent stresses in container with internal pressure 740 kPa.

As results from Fig.3 and Fig.4, the values of equivalent stresses reach tens of MPa, which ensure safe operation of container. All further realized computations demonstrated demanded safety of cask.

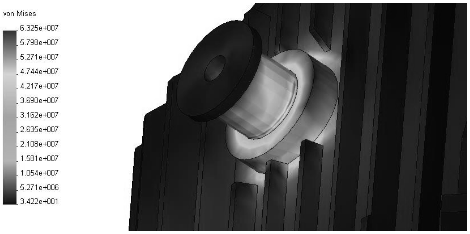


Fig. 4. The field of equivalent stresses in a journal of container during its lifting by crane with the hooks fastened on journals

3. Experimental verification of container safety by the drop test

For the verification of package safety is used in general combination of computational and experimental methods [3]. Combination of numerical and experimental methods has proved to be effective mainly in case of drop tests, where numerical computation allows gain operative results, but the precision of a model is problematic and simulation of impact. From this reason are the drop test accomplished on real containers or their models all around the world [5].

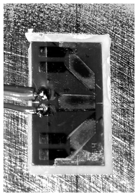
State Institute for Research and Development of Materials (BAM-Bundesanstalt fűr Materialforschung und – prűfung) has realized from 1970 all drop tests of containers designed and approved in Germany [6]. During the drop tests are fulfill the rules of IAEA for safe operation with radioactive materials [4]. Most often are the test accomplished out of regulation frames. From the literature is know drop test from height 200 m (in Fig.5 is container after impact from this height), there were made also drop test from height 800 m [7]. Such tests are realized by drop of cask from helicopter on defined target.

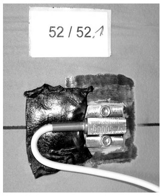
Fig. 5. Container after landing on concrete block from high 200 m [7].

Fig. 6. BAM facility for realization of drop tests [6].

The aim of such tests is to assess resistance of cask body to impact i.e. it is checked the level of damage, break of container integrity and its tightness after drop. For the drop tests from low heights are used drop towers. In Fig.6 is drop tower in BAM for realization of drop tests of containers for maximal mass 200 tons and maximal drop height 30 m [6].

During the drop tests from low heights (according to regulations) is realized measurement of strains and accelerations in defined locations of container. Time-dependent charts of kinematical quantities and strains during drop form a base for validation of results gained from numerical simulations of impact. For the measurement are used appropriate types of resistance strain-gages and sensors of acceleration. In Fig.7 is a view to cask body with installed sensors as well as detail of view on strain-gage and sensor of acceleration [8].





a) **b), c)**

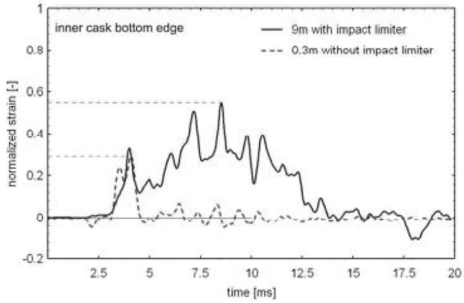
Fig. 7. a) body of container with installed strain-gages, b) strain-gage, c) sensor of acceleration [8].

For decreasing of impact influences during drop of container are used so-called impact limiters located in underside and top of cask (Fig.8) [6].

Fig. 8. Container with impact shock limiter [6].

Influence of impact limiters is obvious from charts of time-dependent strains in Fig.9b at the same location of cask for the drop of container with limiter from height 9 m (Fig.9a) and for drop of container without limiter from height 0.3 m [3].

a)



b)

Fig. 9. a) falling of container on the underside with shock limiter, b) normalized strains during impact test with and without shock limiter [3].

Very often are for the drop tests used diminished models. In that case must be taken into account that the diminished model can manifested other behaviour than real cask. It has to be ensured certain equivalency between impact on the model and real container. It is necessary to have geometrical and material similarity with energetically equivalence of impact processes [5].

4. Methodology for experimental verification of container safety

Experimental verification of safety of spent fuel packages (Fig.1) will be realized by several stages and it will consist following parts [9-11].

a) Identification of geometrical deviations of packages from designed values,
b) determination of material lost as a consequence of wearing or corrosion,
c) identification of eventual enduring deformations of individual package parts,
d) experimental verification of inappropriate connections (lifting and fastening) or their blocation,
e) determination of residual stresses in packages resulting from previous overloading due to operation, residual stresses initiated during manufacturing or residual stresses due to radiation and thermal influences,
f) identification of loading in operational conditions that are defined by regulation [1].
g) realization of experiments that correspond to prescribed tests (e.g. the drop tests in various positions, penetration tests and so on),
h) accomplishing experimental modal analysis of cackages including transport means,
i) providing test under water.

Experimental verification in parts a) to f), h) will be realized on real packages. For realization of real tests in parts g) and i) will be manufactured model in scale 1:8 according to Fig.10.

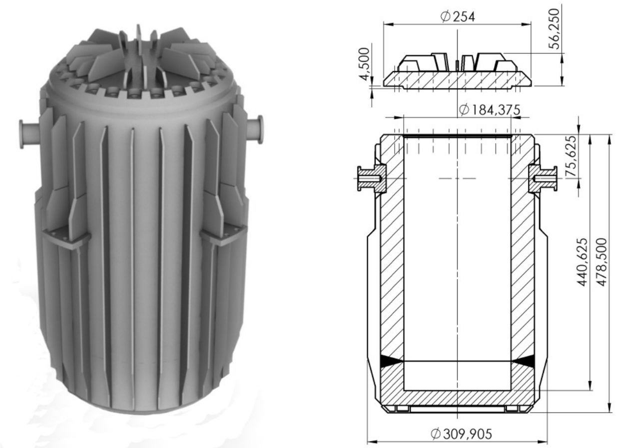


Fig. 10. Model of container for drop and pressure tests.

It must be stressed that the casks that will be experimentally verified belong to category of packages with integrated hard shock limiters. Hard shock limiters are equipped with cooling ribs on the cylindrical part and on upper side of a lid and with small compact rings for limitation of impact that are placed in the bottom of cask. It results that during test of these types of packages are not used removable impact limiters.

5. Conclusions

For verification of safety of containers designated for transport of radioactive materials is suitable to use combination of computational and experimental methods.

On the workplace of authors was realized computational verification of container according to Regulation of UJD SR No.57/2006 Z.z.. The analytical and numerical computations showed prescribed safety, but in accordance with foreign opinions it is suitable to verify the cask safety by experimental methods. In the paper are described some possibilities of experimental verification of package safety with emphasis to drop test, as well as the methodology of experiments that are prepared on the workplace of authors.

Acknowledgement

This work was supported by project VEGA 1/0004/08.

References

[1] Slovenská republika. “Vyhláška č.57/2006, Z.z., UJD SR ktorou sa ustanovujú podrobnosti o požiadavkách pri preprave rádioaktívnych materiálov,” in *Zbierka zákonov č. 57/2006*, Čiastka 25 (12.1.2006), s. 522-559.

[2] Trebuňa F. a kol., *Výpočtové overenie kontajnera C30 typu B(u) v súlade s vyhláškou ÚJD SR č. 57/2006 Z.z (§ 7)*. Záverečná správa, (SjF TU Košice, Košice, 2008).

[3] Vőlzke H., Wolff D., Qiao L., Feutlinske K., Zencker J. and Musolff A., “Topical BAM cask design evaluation using drop tests and numerical calculations: accidental cask drop without impact limiters onto a storage building foundation,” in *15th Int. Symposium – PATRAM 2007*, Miami, Florida, USA, October 2007.

[4] IAEA Safety Standard Series No. TS-R-1. *Regulations for the Safe Transport of Radiactive Material* (International Atomic Energy Agency, Vienna, 2005). ISBN 92–0–103005–3.

[5] Wille F., Ballheimer V. and Droste, B., “Suggestons for correct performance of IAEA 1 m puncture bar drop test with reduced – scale packages cousidering similarity thcory aspects,” in *15th Int. Symposium – PATRAM 2007*, Miami, Florida, USA, October 2007.

[6] Droste B. and Műller K., “Test installations for the examination of Castor casks at the BAM test centre technical safety,” in *5th Int. Seminar – RADWAP 2008*, Wűrzburg, Germany, October 2008.

[7] Droste B., “Testing of type B packages in Germany to Enviroments Beyond regulatory test standards,” *Packaging*, *Transport, Storage & Security of Radioactive Materials*, **18**(2), pp. 73-85 (2007). ISSN 1746-5095.

[8] Quercetti T. and Műller K., “Importance of Strain and acceleration measurements during drop tests for safety analysis and package desing optimization” (Federal Institute of Material Research and – Testing (BAM), D-12200 Berlin, Germany). *Available from:* http://www.tes.bam.de/ram/pics/PATRAM2004_full%20paper%20222.doc *Accessed:* 2010-04-13.

[9] Trebuňa F. a kol., *Metodika na vykonanie experimentálnych meraní a skúšok prepravného kontajnera na vyhoreté jadrové palivo C-30*. Záverečná správa (SjF TU Košice, Košice, 2008).

[10] Trebuňa F. a kol., *Metodika experimentálneho overenia stavu prepravného kontajnera na vyhoreté jadrové palivo C-30*. Záverečná správa (SjF TU Košice, Košice, 2008).

[11] Trebuňa F. and Šimčák F., *Príručka experimentálnej mechaniky*. (TypoPress, Košice, 2007).