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The new ROBATEL-NL R79 type B package design for waste transportations

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Abstract

Resulting of years of nuclear activities, the Energy research Centre of the Netherlands (ECN) needs now to evacuate its so called "historical" radioactive wastes that were generated all along its experiments, its material testing activities and its isotope production for medicine and industry. This miscellaneous wastes have to be first transported to Belgium to be reprocessed prior to their interim storage or final disposal.

In support of these operations, ECN is required to acquire a new dedicated and suitable type B package. ROBATEL Industries has been selected by NRG to design and manufacture these casks and their associated equipment.

Therefore, ROBATEL has designed a new cask model, the R79, specifically optimized for its customer's use. The cavity is adapted to the vessel used by NRG to package its wastes, and the shielding thickness (around 155 mm of lead equivalent) ensures the appropriate gamma radiation protection and an optimized weight. Thanks to this weight optimization, two casks can be shipped at a time on one trailer without exceeding the standard road transport load.

The package model is still under certification but it has passed the regulatory drop tests in summer 2015. These drop tests have proven the good performances of the impact limiters made of the ROBATEL's foam FENOSOL™.

This article will lay out in further details the major characteristics of this new design and will highlight some specific points of the safety assessments.

Introduction

This paper deals with one of the latest ROBATEL's package models called the "R79". This model was designed for the Energy research Centre of the Netherlands (ECN) to evacuate its so called "historical" radioactive waste that was generated all along its experiments, its material testing activities and its isotope production for medicine and industry. This package is one of the latest designs made by ROBATEL thanks to its wide experience in the nuclear transportation packages. Indeed, from more than 60 years, ROBATEL has managed the whole process of cask delivery: from the customer technical specification it designs the cask and the operating tools, builds the safety studies, obtains the approval certificate for type B packages, manufactures the casks and tools, performs the qualification tests … The main tasks of this process (design, calculations, drop tests, safety files, cask assembling and testing) are done in-house which ensures a real efficiency and reactivity. ROBATEL has designed the last 30 years almost 80 type B packages and produced over 1000 specimens of packagings (all types and for all kinds of contents: sources, fuel rods, radioactive liquids, activated metal pieces or waste...). This paper first presents the package design with its specificities, then the state of the project and finally it focuses on one aspect of the design: the FENOSOL™ foam used for its shock absorbing capabilities.

Presentation of the R79 package

General description

The R79 package model has a cylindrical shape (see Figure 1). It is used, operated and transported vertically. It is mainly composed of a body, a closure lid, and 2 shock absorbers. The body is made of stainless steel, lead for shielding, and ROBATEL PNT7™ for the thermal protection. The closure lid is made of stainless steel, equipped with EPDM O-rings and attached to the body with stainless steel bolts. The lid is also equipped with a bolted sampling plug to enable access to the containment enclosure. The shock absorbers are composed of a stainless steel casing filled with the ROBATEL FENOSOL™ foams. These impact limiters aim to protect the packaging body in case of a hypothetical accident during transport and thus provide both mechanical and thermal protection

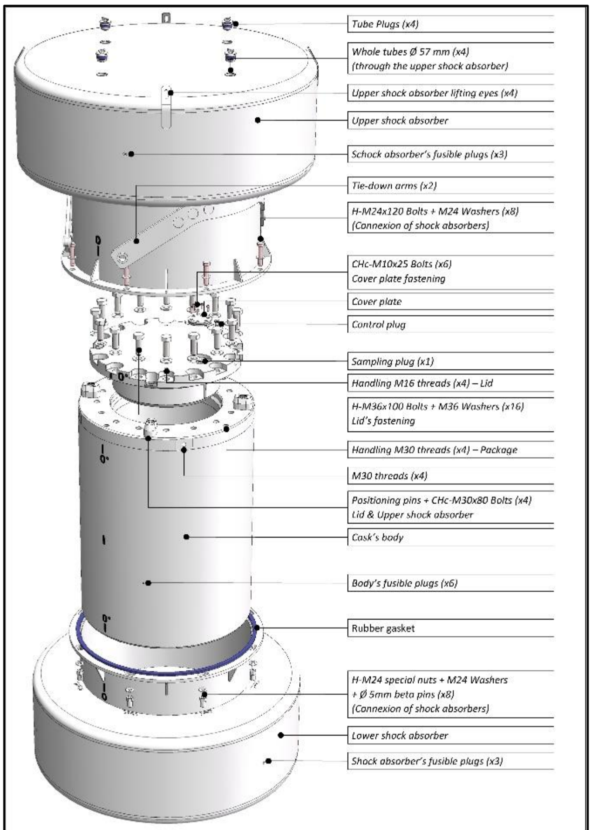
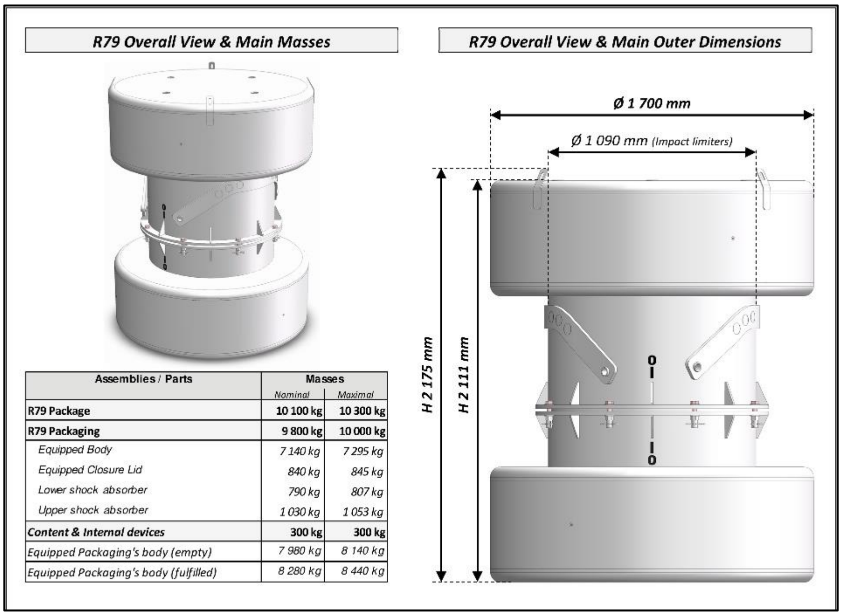


Figure 1 ; cask illustration

to the body and its safety components. In addition, the upper shock absorber is equipped with stowage devices which enable to tie down the package on its conveyances. Figure 2 gives an illustration of the package and its main masses and dimensions.



Assemblies / Parts	Masses	
	Nominal	*Maximal*
R79 Package	**10 100 kg**	**10 300 kg**
R79 Packaging	**9 800 kg**	**10 000 kg**
Equipped Body	*7 140 kg*	*7 295 kg*
Equipped Closure Lid	*840 kg*	*845 kg*
Lower shock absorber	*790 kg*	*807 kg*
Upper shock absorber	*1 030 kg*	*1 053 kg*
Content & Internal devices	**300 kg**	**300 kg**
Equipped Packaging's body (empty)	*7 980 kg*	*8 140 kg*
Equipped Packaging's body (fulfilled)	*8 280 kg*	*8 440 kg*

Figure 2; R79 masses and dimensions

Content description

The content of the R79 package is composed of so called “historical” radioactive waste coming from nuclear facilities, experiments, material testing activities and medical & industrial isotope production, and that belongs to Energy research Centre of the Netherlands (ECN). It comes from activated and/or contaminated components (facilities decommissioning, experiment casings, support for experiments, tools, wires, measurement devices, control elements, reflector elements, absorber elements, fuel assembly boxes, throttle bodies, packaging, cleaning consumables, hot cell consumables, glove box consumables, dried residues, etc.) as well as activated and/or contaminated component parts. It could contain dewatered ion exchange resins, dried concentrates in form of salts, metal oxides, filter masses, sludge and abrasives with metal particles. The waste, after being sorted is loaded in crushable drums that are loaded in the cask. The maximum mass of the content is limited to 300 kg, the maximal total activity of the content shall be below 3 000 A2 and the residual thermal power of the content is limited to 70 W. The allowable source term for the content relative to shielding assessments is defined in an extensive way as both an allowable neutron flux and an allowable spectrum of photons depending on their energy. This limit is defined by the formula:

$$\sum_{i=1}^{9} \frac{a_i}{A_i} + \frac{n}{N} \leq 1$$

where:

a_i : Total photons activity in the energy group i

A_i : Maximal allowable activity limit for the photons of group i

n : Total number of neutrons which are emitted per second

N : Maximal allowable number of neutrons which could be emitted per second.

This type of definition optimizes the allowed content as it takes into account the package shielding efficiency. The orders of magnitudes of the allowed activities resulting from this definition are : 4 TBq of Co60 or 500 TBq of Cs137, or 1.7×10^9 neutrons per second.

The content should not contain significant amount of fissile material. This amount must at least comply with the regulation for the packages to be transported as a type B(U). The content of the R79 package may contain some hydrogenous material that might lead to gas production due to radiolysis phenomena. Depending on the gas production rate, the transport duration may be limited. In such a case, the package should be transported under the B(M) certificate.

R79 specificities

The R79 has been designed to be inexpensive and for a very flexible use.
Its size and weight (10 metric tons) are quite small. This allows the package to be transported by 2 on a truck, and even by 3 if it is used as an IP2 (without its impact limiters) staying below the conventional road weight (see Figure 4). The body itself has no device like trunnions or ears that would have increase its size and cost. For the same reasons, the handling devices are part of the impact limiters and not part of the cask body.

Validation and manufacturing process

The regulatory drop tests were passed with success in presence of the Dutch and Belgium nuclear safety authorities in July 2015 in the Genas plant of ROBATEL Industries. Seven drop tests were performed on a $^{1}/_{2}$ scale model (4 puncture tests and 3 nine meter drops). The safety file was introduced to Dutch and Belgium authorities in December 2015. The approval is expected by the end 2016. ROBATEL Industries has started the manufacturing of 6 cask units in its Genas plant. The packages should be operational at the beginning of 2017.
The whole process from the contract signature to the casks delivery with their certificate of approval will have last 3.5 years only.

Focus on the ROBATEL - FENOSOL™ Foam

Generalities

ROBATEL Industries with the CEA has recently acquired a new technology: the FENOSOL™ phenolic foam [1]. This technology, which opens innovative possibilities (in terms of design and safety assessment) is implemented by ROBATEL for the first time in the R79 cask.
The FENOSOL™ foam general characteristics are:

- Rigid and lightweight material.
- Excellent thermal insulation properties.
- Fireproof. Produces no black or toxic fumes/smoke.
- No flame propagation.
- A large range of densities to adapt to every situation.
- Casted or molded. Can fill complex shapes and small volumes.
- Low permeability to vapor. High moisture resistance.
- CFC and HCFC free.
- No halogenated compounds.

Foam characterization

As a shock absorber, the main mechanical property of FENOSOL™ is its crush strength. It can be measured on a confined sample using a universal mechanical tester. The crush stress as a function of the compressive strain is obtained by measuring the force at a constant quasi-static compression speed. For a shock absorber material, the stress associated to a sample crush follows a three-part behaviour: after an initial elastic behaviour, a plateau appears that dissipates the shock energy, which finishes by a steep ascend of the stress due to the densification process. The longer the plateau, the more efficient the material is as a shock absorber. As illustrated on Figure 3, FENOSOL™ is one of the most efficient isotropic shock absorbers with a plateau going beyond 65% compression. These crush strength results are used to build multivariate models of the foam behaviour accounting for the effects of temperature or humidity. These models are powerful tools to identify the variant of FENOSOL™ that is the most adapted to a given situation. For example, as a phenolic foam, FENOSOL™ crush strength is only moderately affected by temperature. Dynamic effects are also evaluated by comparing static crush tests with fall experiments performed at our facilities. Using a non-linear transient dynamic finite element analysis software, LS-Dyna, simulations of crush tests and fall experiments are performed to assess the accuracy of our models.

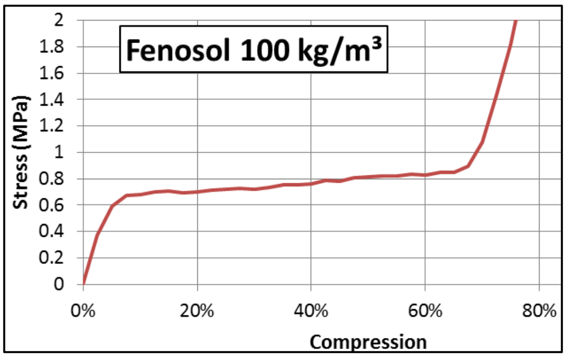


Figure 3; Crush strain sample of FENOSOL™ foam

Drop tests simulations and benchmark

In order to show the ability of the R79 design to resist to normal and accidental conditions of transport, regulatory drop tests have been performed on a R79 half scale model.

At the same time, a finite elements model was developed under LS-DYNA, using the foam behavior coming from the foam crush tests campaign study. This model was developed in order to determine the shock absorbers global deformations and the global deceleration of the package during the impact. The simulations results proved to be in good overall agreement with the actual drop tests as it is shown by the comparisons between the drop tests results and the simulations results in Figure 5 to Figure 7.

Conclusions

The R79 model is the first model of a new family of packages designed to transport drums of waste. Its small mass and shape make it very flexible to use. It can be transported 2 at a time in type B configuration or 3 at a time as industrial packages in a single truck shipment. This design takes advantage of the new ROBATEL FENOSOL™ shock absorbing foam.

References

[1] N MAT NTE 15 EN; Commercial datasheet FENOSOL™

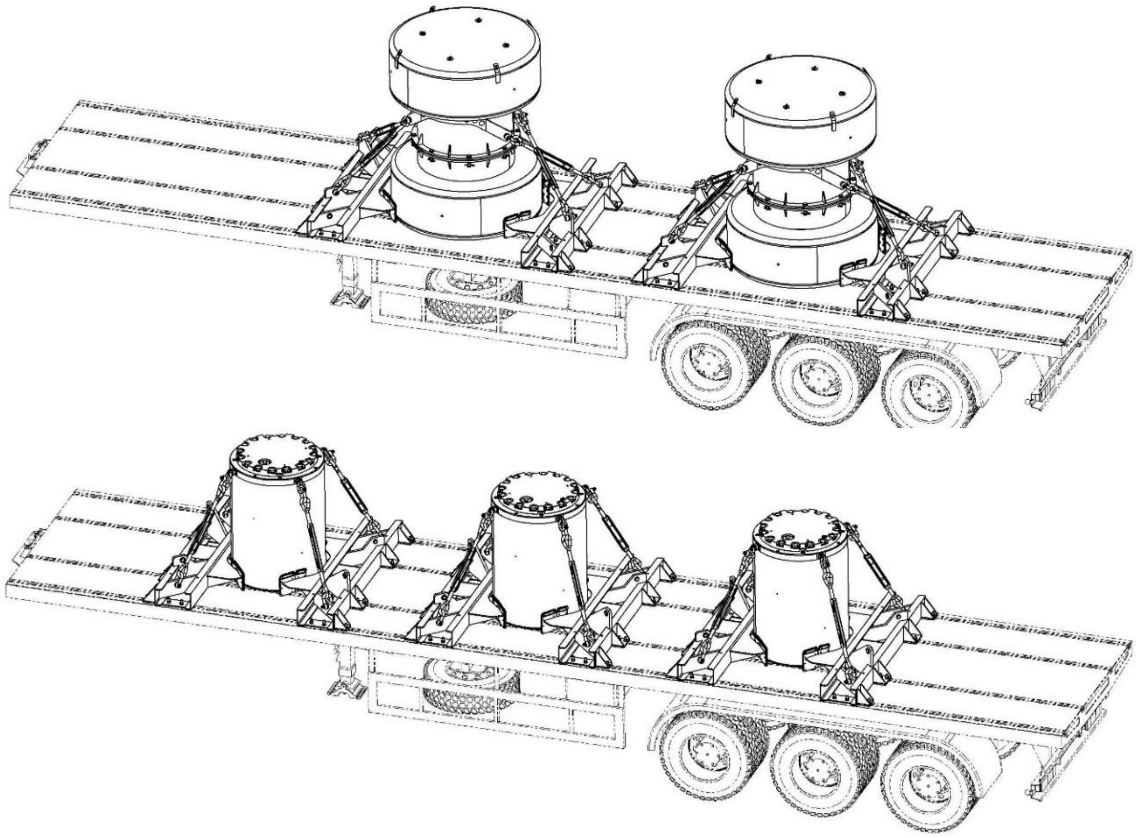


Figure 4; transport configurations (two type B packages or three IP2 packages)

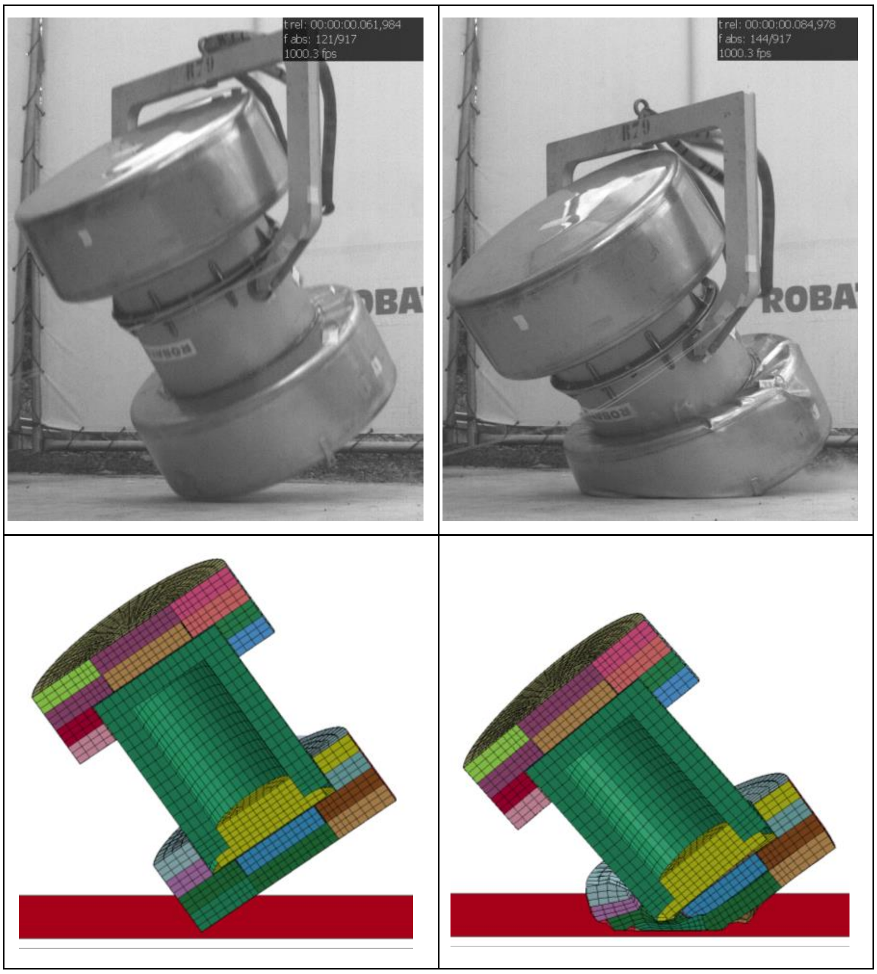


Figure 5 ; Deformation of the shock absorber during an angle drop test

Left: situation at the beginning of the impact. Right: situation at the end of the impact. Top: extracts from the slow motion movie. Bottom: extracts of the LS-dyna simulation.

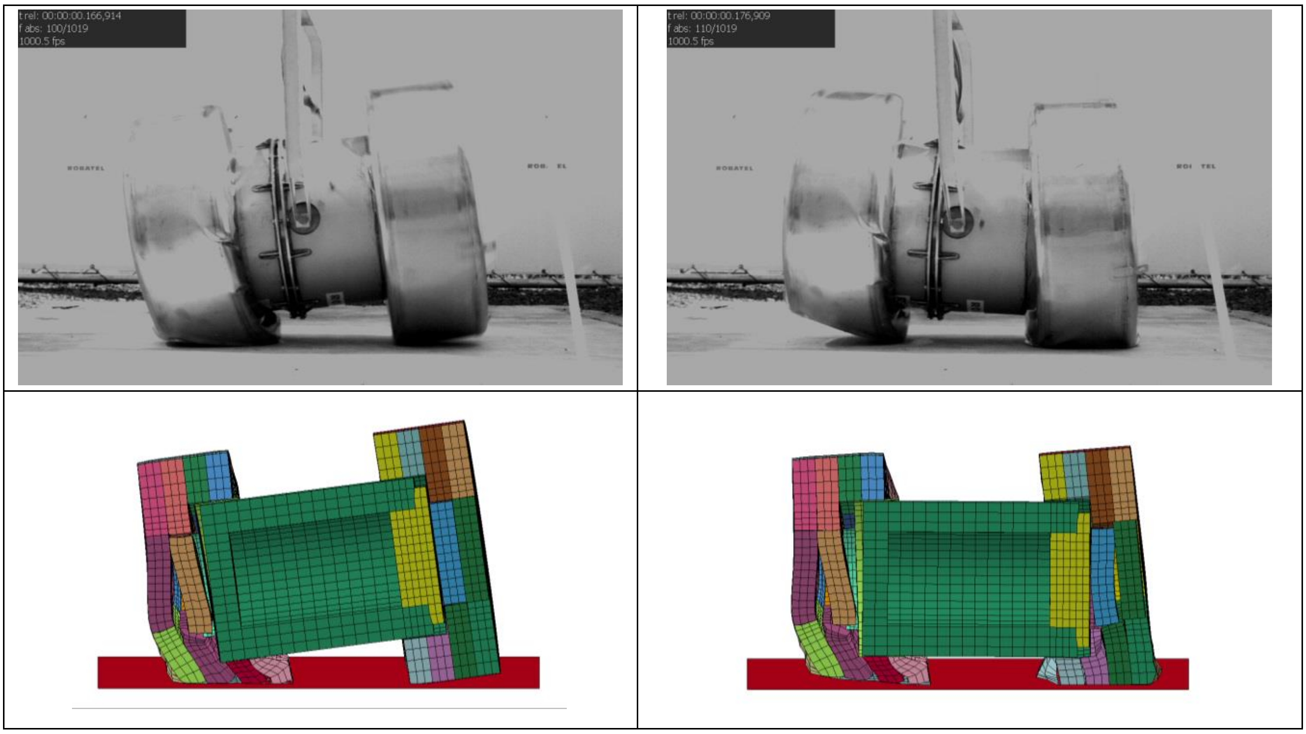


Figure 6: Deformation of the shock absorber during the secondary impact of a slap down drop test. Left: situation at the beginning of the impact. Right: situation at the end of the impact. Top: extracts from the slow motion movie. Bottom: extracts of the LS-dyna simulation.

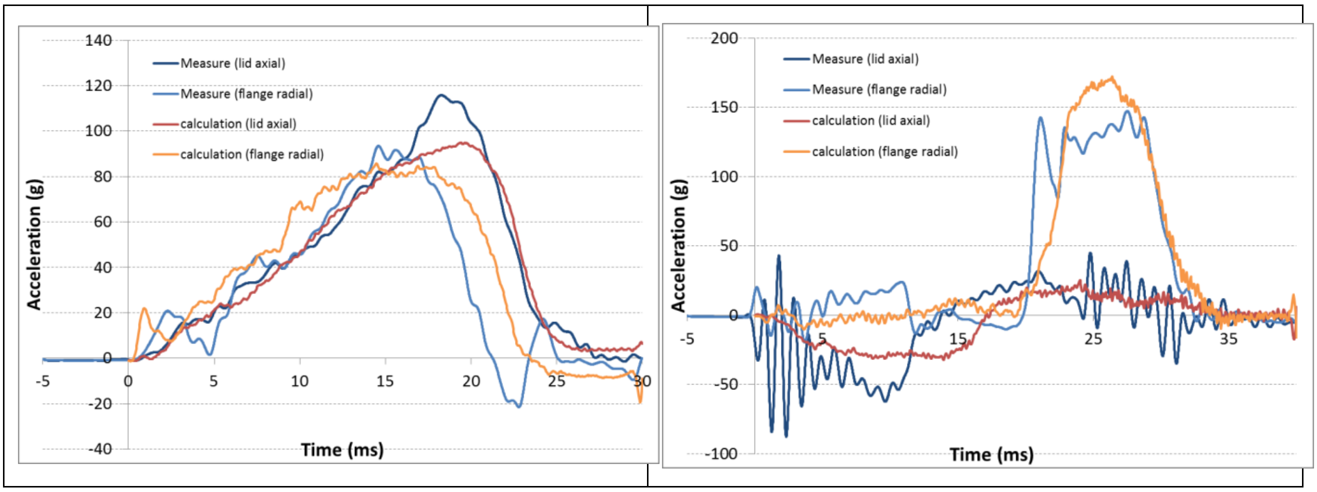


Figure 7: Accelerations during an angle drop (left) and a slap down drop (right) simulation results and drop test measurements