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Dynamic calculation of the TN 28 VT package during 9 meter drop

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1. ABSTRACT

International regulations require that a packaging for the transport of radioactive material has to withstand a 9-meter drop onto an unyielding target. It has to be shown that the containment of the radioactive contents is guaranteed.

For some packagings the trunnions are not only used during handling and transport but serve also to absorb the energy of the shock during a 9-meter drop. An LS-DYNA3D model of an angular sector of a trunnion has been developed taking into account the rupture of the structure. The finite element analysis has been validated by successfully calibrating it with an actual drop test.

The cask consists of a main cylindrical steel body equipped with thermal fins and additional neutron shielding encased in an external thin steel shell. During transport, two shock absorbers made of wood in a steel shell are attached to the top and the bottom of the main body. There are two pairs of trunnions to allow fixing and handling of the packaging.

A comparative view of the actual and the simulated deformed structure shows that the residual deformation of the finite element analysis coincides almost perfectly with the one observed after the test.

Comparing the acceleration, as a function of time, measured at the top and the bottom between the reduced scale model and the finite element model some differences are observed although the general shape of the signals is similar.

2. INTRODUCTION

The 9 meter drop test of a packaging for the transport of vitrified residues is studied (see figure 1). It has to be shown that at all time, the confinement of the contents is guaranteed during and after this test case. The structure needs to remain globally intact and the drop test serves as a regulatory demonstration.

In one particular configuration the first impacted part of the packaging is the trunnion, as shown in figure 1. The main purpose of this part is to enable the handling and tie-down of the package. In this case however, it is the part of the package that absorbs most of the drop energy.

In order to simulate correctly the behaviour of the packaging it is a key issue to correctly simulate the fractures that occur when the trunnion is crushed.

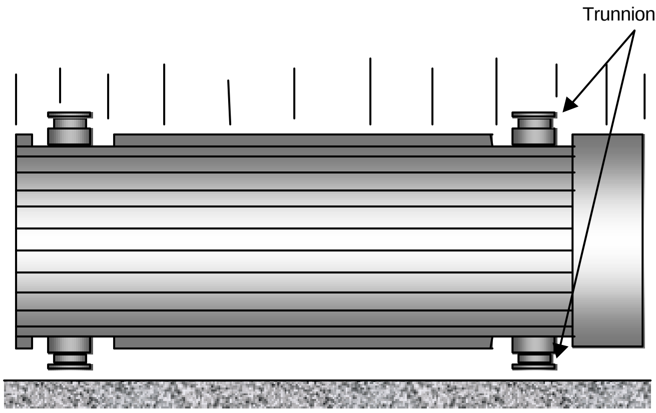

Fig. 1. View of the transport container and the drop test configuration

3. ASSUMPTIONS

- The third-scale model used during the drop test is perfectly representative of the package.
- The main body is modelled with its mass, rigidly connected to the base of the trunnion to simulate the fixing of the trunnion on the forged steel body.
- The model takes into account only ductile fracture; thermal effects or other phenomena that could be involved in the characterisation of the fracture are neglected because of the low strain rate.
- In the test and after observation of the deformed trunnion, it appears that during the test it had penetrated into the wall. Therefore, the wall has been modelled in the simulation.

4. MODEL DESCRIPTION

4.1 Geometry

The packaging (figure 1) consists mainly of a cylindrical steel body, surrounded by a shielding resin encased in a steel shell. During transport, two shock absorbers made of wood in a steel shell are attached to the top and the bottom of the main body. These are not explicitly modelled; their deformation is negligible and neglected. There are two pairs of trunnions to allow handling and tie-down of the packaging.

4.2 Meshing

The mesh, shown in figure 2, is created for a representative sector of the trunnion. It consists of standard brick elements (8 nodes, 3 degrees of freedom per node, 8 integration points).

In the meshing three fracture zones have been modelled (see figure 2); these zones are similar to those observed after the test.

4.3 Materials

The table below summarises the materials of the main components:

Component	Material	Type LS-DYNA : MAT_…	N° type
Trunnion	Stainless steel	PIECEWISE_LINEAR_PLASTICITY	24
Wall	Steel	PIECEWISE_LINEAR_PLASTICITY	24

The material law of the trunnion has been calibrated using a tensile test. A model that simulates this test establishes an effective plastic strain vs stress curve and the plastic strain to failure so as to characterise the material in LS-DYNA3D.

For the wall material law a tangent modulus is used to characterise the plastic domain.

4.4 Boundary Conditions

As the model corresponds to an angular sector of the entire trunnion, symmetry boundary conditions are applied to each side of the sector.

An initial velocity corresponding to a 9 meter drop is applied to the trunnion and the mass rigidly connected to the base of it to simulate its fixation on the forged steel body of the packaging.

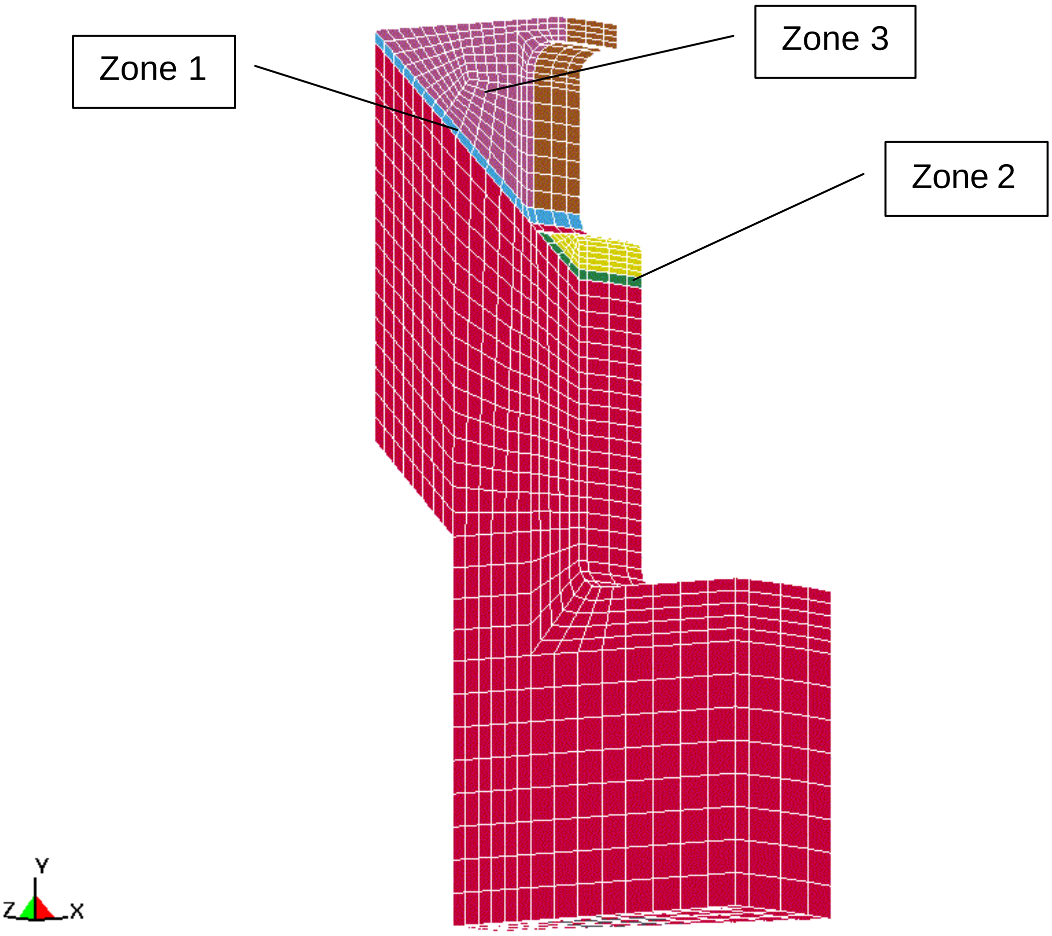

Fig. 2. Finite Element Mesh

5 RESULTS

The kinematics of the crush is presented in figure 4.

It can be seen that when the first fracture zone slides on the top of the trunnion it generated high stresses on the external fillet (in yellow on figure 4) which in turn causes the fracture on zone 2. The last fracture (zone 3) happens on the circumference at the tip of the trunnion and allows a piece of the trunnion to be free of constraints.

A comparative view of the actual and the simulated deformed structure is shown in figure 5. The residual deformation of the finite element analysis coincides almost perfectly with the one observed after the test.

The acceleration obtained from the simulation (see figure 6) does not match closely to the one of the test but the general shape of the signals is similar. The two measurement points of the test correspond to the top and bottom end trunnions.

The instant of time when the fracture happens, just after 2 ms, appears clearly. It can be noticed that the simulation ended before the test. This difference can be explained by the way the fracture is modelled : in the simulation the propagation of the fracture is almost instantaneous.

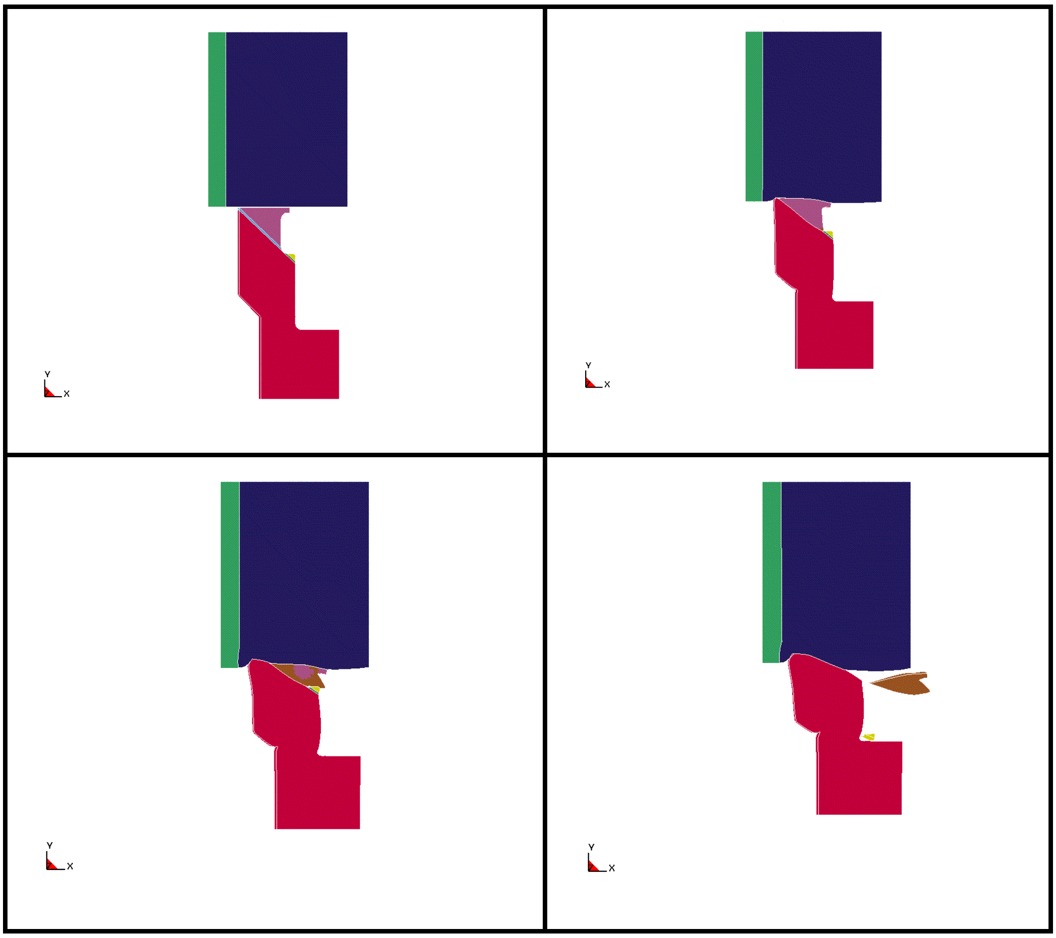

Fig. 4. Kinematics of the crush

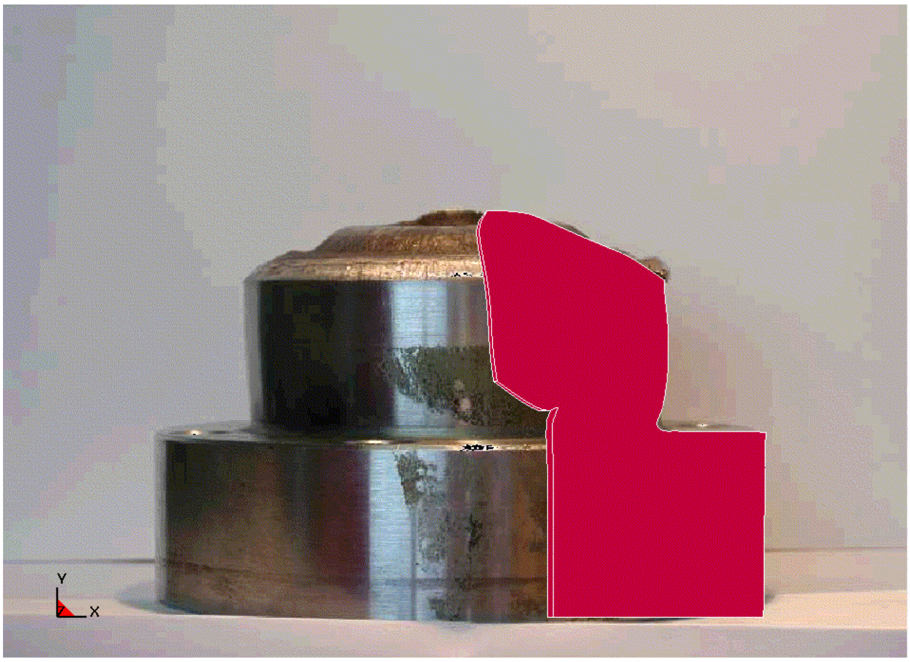

Fig. 5. Residual Deformations

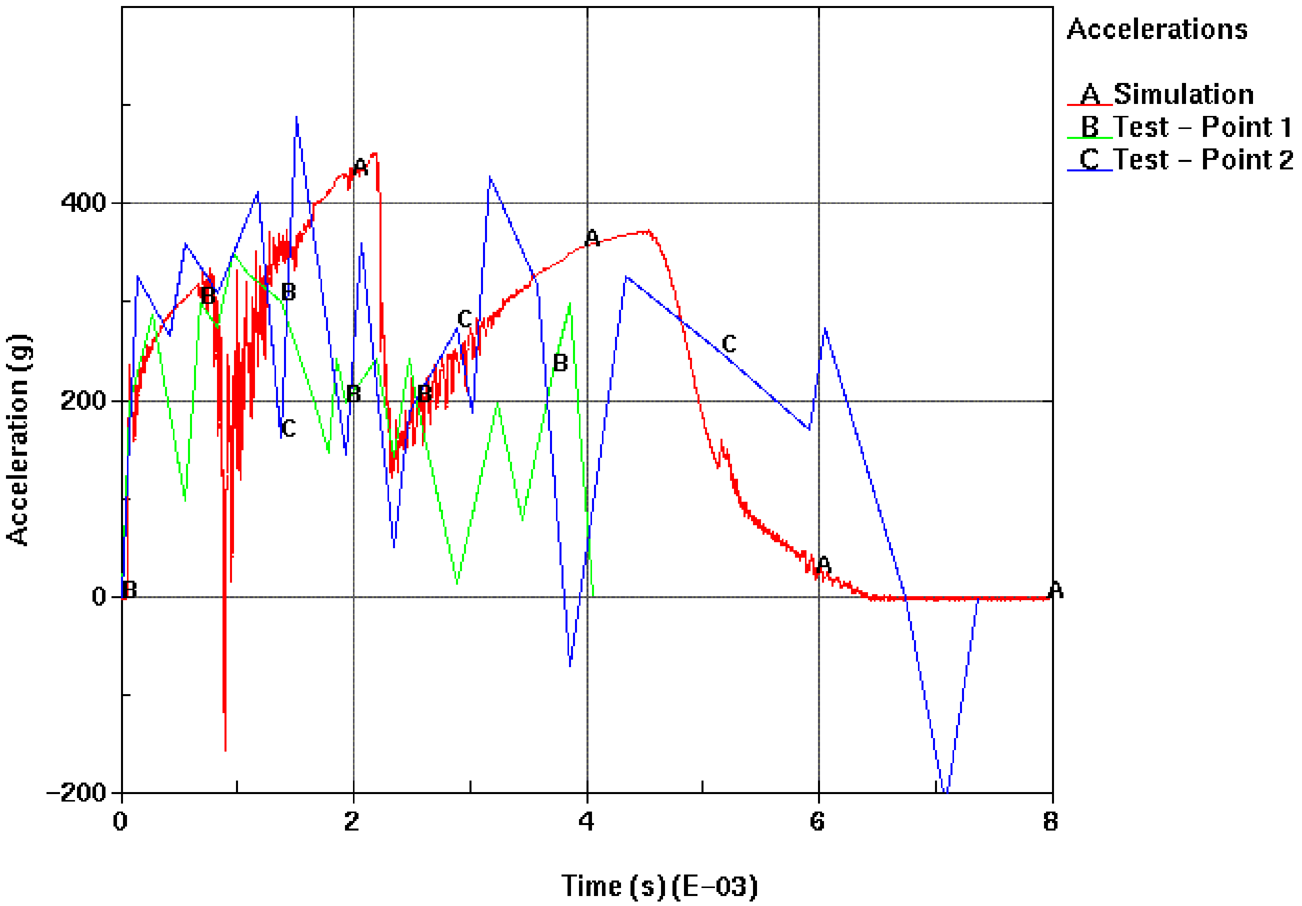

Figure 6 Comparison of accelerations

6 CONCLUSIONS

The LS-DYNA3D model correlates well with the drop test in terms of deformation and fracture modes. Accelerations are not easy to compare because the entire package is not modelled in the simulation. The calibrated model allows to establish a force vs. displacement law which represents correctly the mechanical behaviour of the trunnion in a full scale model of the package.