SMiRT–12 / K. Kussmaul (Editor)
1993 Elsevier Science Publishers B.V.

J04/5

EXPERIMENTAL VERIFICATION OF A DYNAMIC FINITE ELEMENT ANALYSIS FOR A DUCTILE IRON CASK

D. Schreiber[1], T. Quercetti[2] and W. Völzer[1]

[1]Gesellschaft für Nuklear-Service mbH, Essen, Germany
[2]BAM, Bundesanstalt für Materialforschung und -prüfung, Berlin, Germany

Abstract

The paper summerizes the results of an instrumented 9 meter droptest of a Cylindrical Ductile Iron Cask with shock absorbers at the BAM test facility compared to a stress analysis performed with the dynamic finite computer code DYNA 3D (GNS).

The comparison between the results obtained from the experiment and the calculation, which was performed before the droptest, is according to strain and acceleration time history during the impact and the deformation of the shock absorber.

1 Introduction

The DCI cask MOSAIK II-15, a transport and storage package with an lead shilding of 80 mm is already licensed as type (B) package.
For some kind of radioactive materials a lead shilding of 140mm is needed, so that the license must be expand to the higher package weight.
In this context the BAM has performend a 9 meter drop test of the cask with its shock absorbers onto an unyielding target with most dammaging impact orientation (corner of the cask lid) according to the IAEA regulations. The cask was fully instrumentated with strain gauges and accelerometers.
The results of the measurement are then also taken for the aspect of verification of dynamic finite element codes used simulating drop tests.
The GNS has performed a pre-droptest in Duisburg to get information in point of the finit element model of the cask and the shock absorber.
The following explications summerize the results obtained by experiment and calculation with the code DYNA3D in point of the comparisen between them.

2 Drop Test Conditions

The test specimen was a DCI cask type MOSAIK II-15 taken from the serial production of the Siempelkamp foundry, which manifactured these casks for GNS (fig.1).
The cask consists of a cylindrical body with a wall thickness of 160 mm, internal of a leadshielding (thickness 140 mm) and a DCI lid. The lid is bolted with 24 steel bolts and sealed with elastomere gaskets.
The cask is equipped with shock absorbers in the bottom and lid area. The shock absorber is built of a stiffend steel shell with a filling of boards in layers. The fiber direction is orthogonal to the cask axis.
The cask tare weight is 9480 kg, with its loading (for the drop test simulated by peaces of round steel) and the two shock absorbers the gross weight is 11080 kg.
The specimen was instrumentated on the outer surface with strain gauges on the DCI lid, the bottom and the cylindrical body of the cask. Some selected bolts have also been instrumentated by strain gauges.
The acceleration of the DCI cask body and the lead shilding was measured with accelerometers orthogonal over the impact corner.
The signals were recorded by a 30 channel transient recorder (4K words of 8 bit) and parallel by a magnetic type. For data processing, such as filtering, a personal computer was used. The strain gauges were wired in a quarter-bridge configuration with three-wire-circuits and a constant voltage supply.
The droptest was performed from the BAM. According to the IAEA-Regulations the droptest was performed onto an unyielding target with most dammaging impact orientation, wich in this case was the drop on the shock absorber corner respectively the DCI lid corner.
After the impact the damaged shock absorber was divided with a cutting-off wheel to analyse the deformation.

3 Dynamic Stress Analysis

Description of the Dynamic Finite Computer Code

DYNA3D is an explizit finite element code for analyzing the transient dynamic response of threedimensional solids and structures. As an explizit code, DYNA3D is appropriate for problems where high rate dynamics or stress wave propagation effects are important. The code is based on a finite element discretization of the three spatial dimensions and a finite difference discretization of time. The explizit central difference method is used to integrate the equations of motion in time. The central difference method is only conditionally stable, and stability is governed by the Courant limit on the time step dt. For solid elements, this limit is essentially the time required for an elastic stress wave to propagate across the shortest dimension of the smallest element in the mesh. The element formulation available include one-dimensional truss beam elements, two-dimensional quadrilateral and triangular shell elements, and threedimensional continuum elements. The basic continuum finit element is the eight-node solid element. This element optionally use a one-point integration or the constant stress formulation of Flanagan and Belytschko with exact volume integration. Displacements within the element are interpolated using trilinear interpolationfunctions, and the constitutive equations are evaluated once based on the state at the center of the element.

Calculation Model

For the finite element calculations a threedimensional half symmetric element model is used with eight-node brick elements to describe the cask and the boards, shell elements for the steel shell of the absorber and two-node beam elements to describe the bolts (fig.1)
The leadliner and the caskbody are in their contact zone not connected (definition of sliding surfaces) so that their is the possibility of a relative movement between them. The gap between cask and leadliner also between leadliner and leadtop is 2,5 mm.
Contact surfaces are defined between the cask and the top and between the cask and the shock absorber.
The elements describing the boards in layer and the steel shell of the shock absorber are fixed in their contact area, so that there are the same displacements.

Material Behavior

For the DCI and steel components of the cask in the calculation was used a bilinear elastic-plastic model for the material behavior. The stress-strain-behavior of the shock absorber (boards) was obtained by experiments /4/ and used in the calculation.

4 Comparison of Test Results and Calculation

Deformation of the Shock Absorber

The calculated deformation of the shock absorber is shown in figure 2. The lengths charakterizing the deformation were taken from the devided shock absorber and compared with the calculated values in table 1 (see also fig.2). The experiment has shown a crack opening of the welding of the steelshell, which was not simulated by the calculation, so that the impact of the computer simulation is harder. The real damping behavior of the shock absorber was softer as used in the calculation.

position	calculation with DYNA 3D	Experiment
T1	369 mm	369 mm
T2	372 mm	387 mm
T3	391 mm	421 mm
rest thickness of the absorber	110 mm	70 mm

table1: Comparison of Experimental and Calculated Values of Shockabsorber Deformation

Acceleration

The calculated deceleration values show in comparison with the experiment a shorter and harder impact (fig.3). The higher acceleration of the leadshilding in relation to the cask body, a result of the experiment, is simulated by the calculation (fig.3 and fig.4).

Strains

The figures 5 to 11 show the comparison between the results obtained by the computer programm DYNA3D and the experiment : compared are some selected positions on the cask body, the lid and the bottom of the cask.

5 Conclusion

The comparison between the time history of strains and acceleration during impact obtained from experiment and calculation with the code DYNA3D has shown further aspects in point of verification simulating drop tests with finite element codes. The calculated values are mostly higher than those obtained from experiment and in point of time history posterior. The reasons for this effects could be find in the discretisation of the finite element mesh, the used material definition of the shock absorber and the not simulating of the crack opening of the limiter in the calculation.

6 References

/1/ J.O. Hallquist, R.G. Whirley
DYNA3D USERS MANUAL-Nonlinear Dynamic Analysis of Structures in Three Dimensins, Lawrence Livermore National Laboratory, Rev.5,May 1989

/2/ D.W.Stillmann,J.O. Hallquist
INGRID: A three-dimensional Mesh for modeling non linear Systems
Lawrence Livermore national Laboratory, July 1985

/3/ T.Spelce, J.O.Hallquist
TAURUS: An Interactive Post-Processor for the Analysis Codes NIKE3D,DYNA3D, and TOPAZ, May 1991

/4/ Druckproben diverser Holzarten zur Ermittlung von Kennwerten für das Deformationsverhalten
Rheinisch-Westfälischer TÜV e.V
Prüfnummer 451 183/01 - 13.08.1984

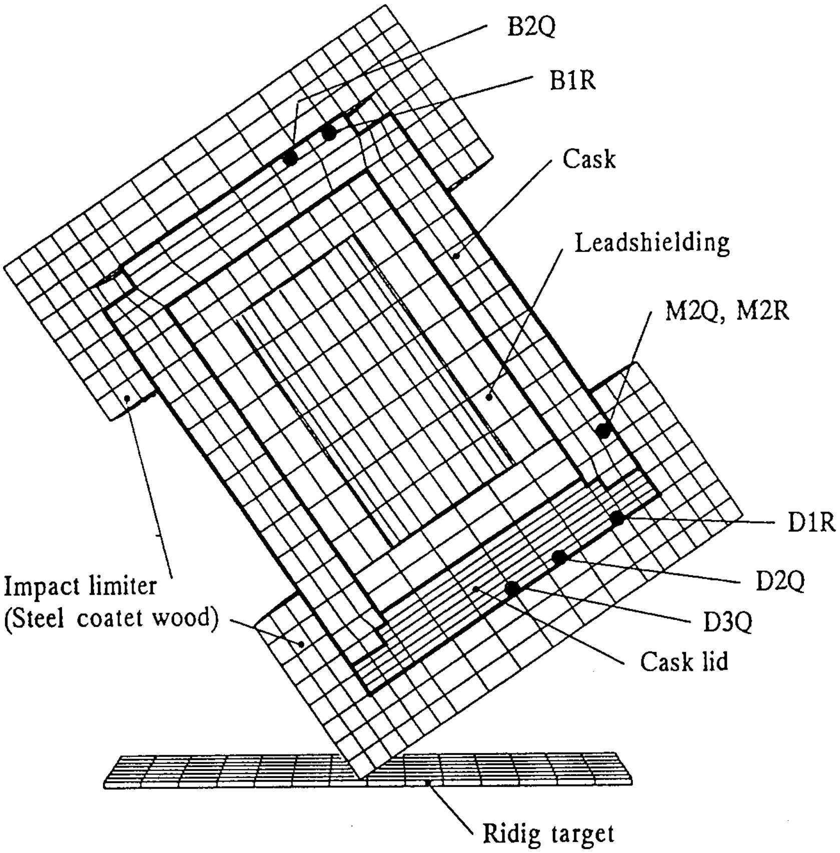

Fig. 1: **Finite Element Model of the Cask and the Shockabsorber. Impact Orientation of the Cask and strain gauge positions, which were selected for the Comparison between Experiment and Calculation.**

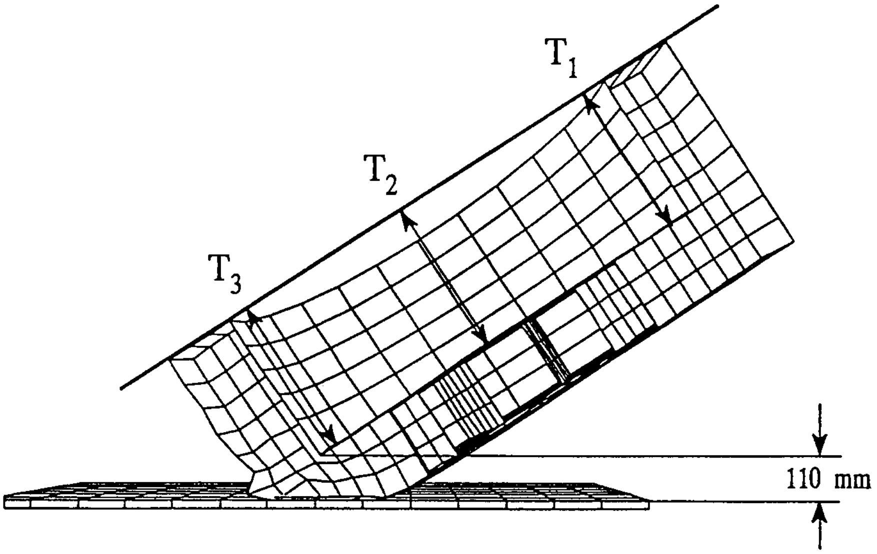

Fig. 2: Deformation of the Shockabsorber after Impact

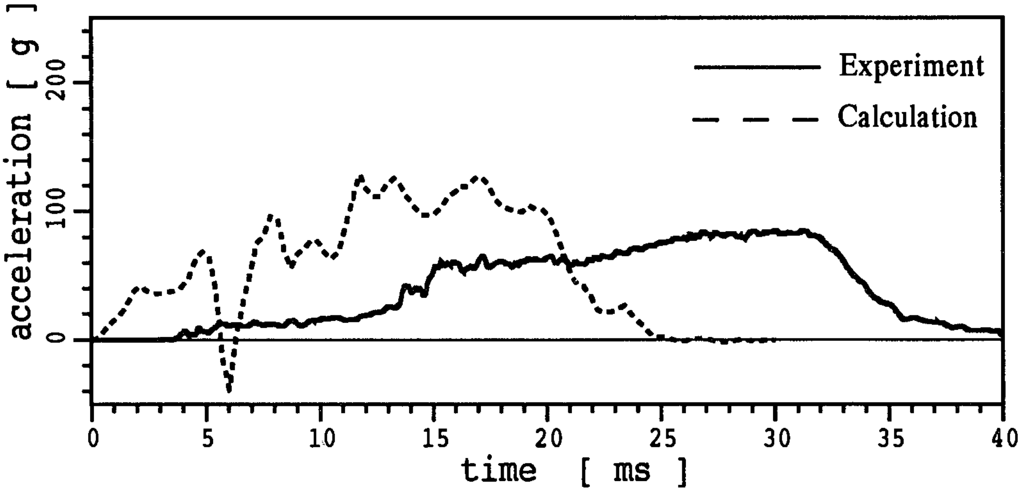

Fig. 3: Rigid body acceleration of the cask

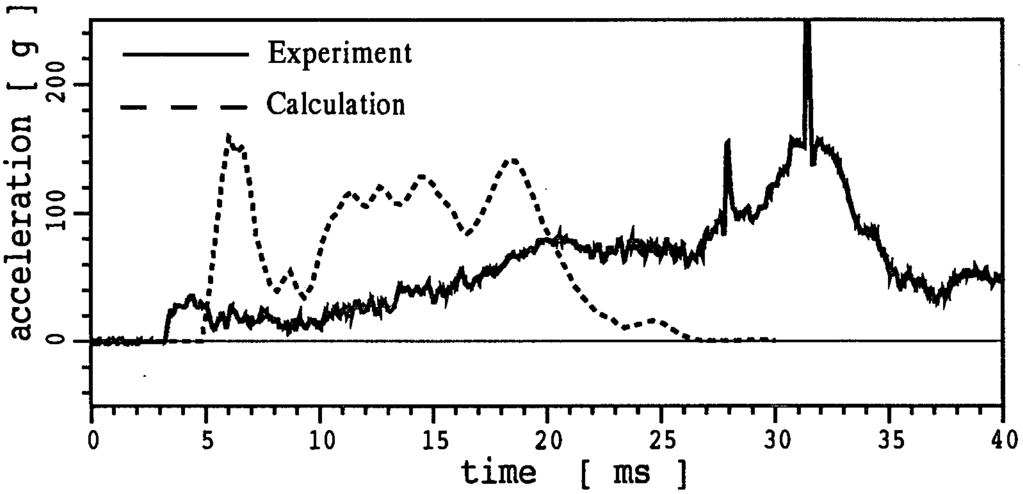

Fig. 4: Rigid body acceleration of the lead shielding

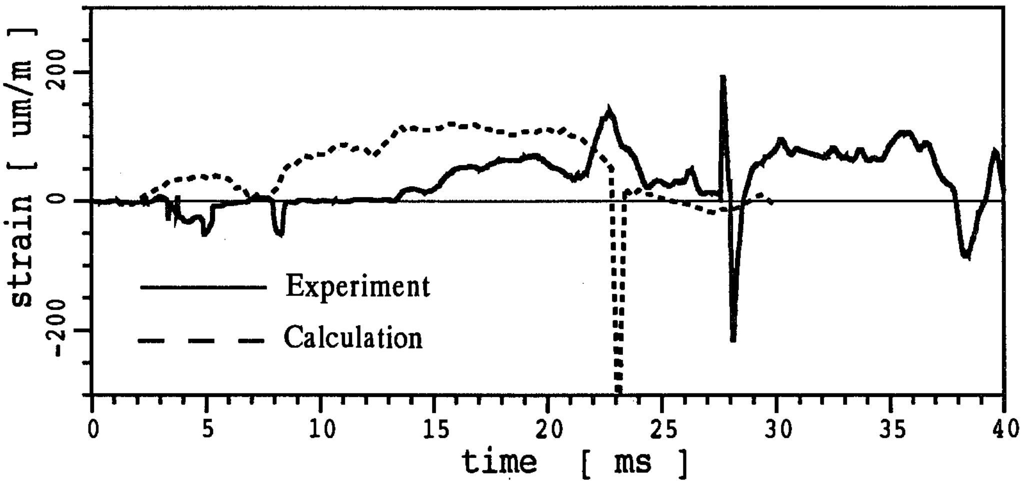

Fig. 5: Strain of the bottom (Pos. B1R)

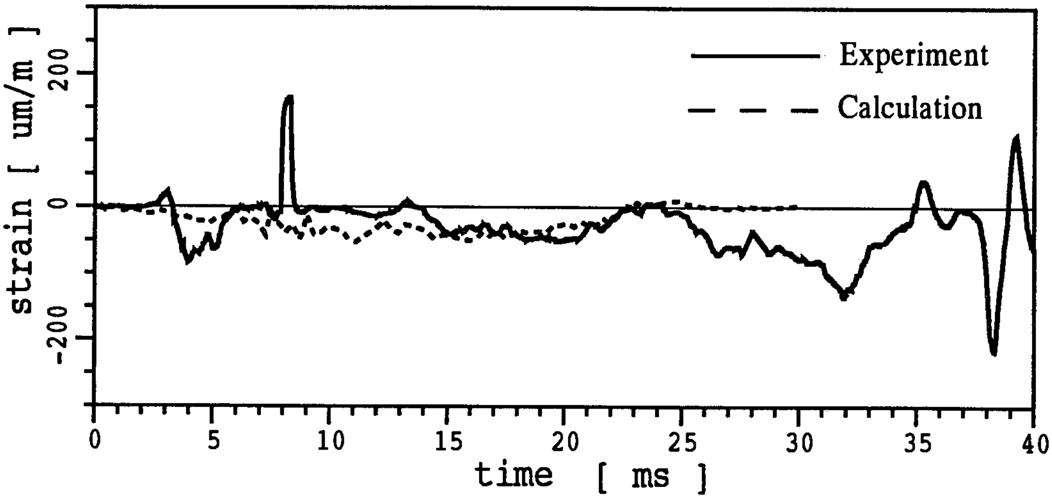

Fig. 6: Strain of the bottom (Pos. B2Q)

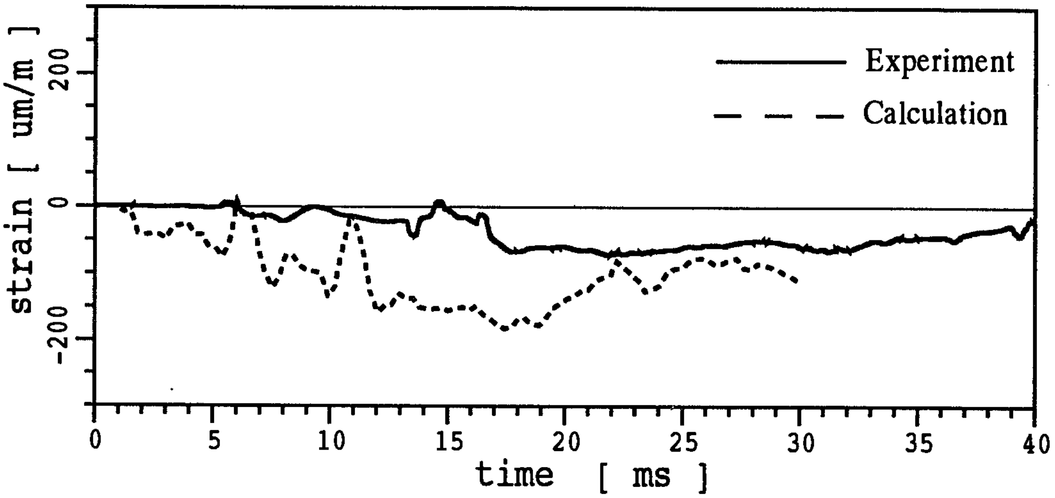

Fig. 7: Strain of the body (Pos. M2R)

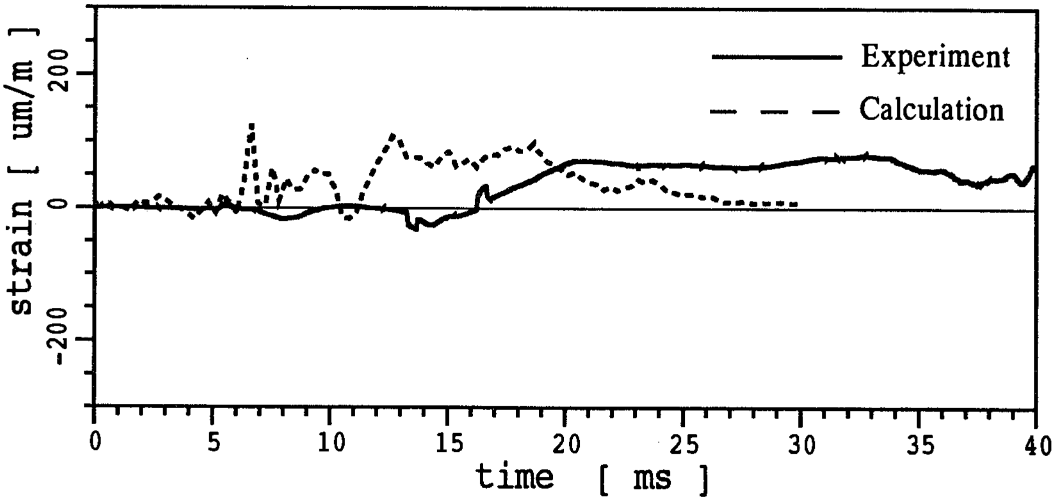

Fig. 8: Strain of the body (Pos. M2Q)

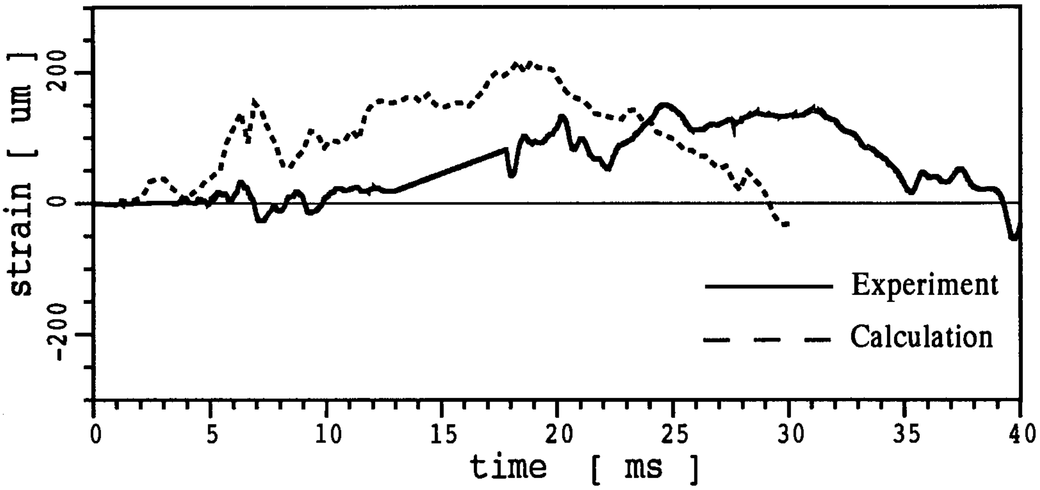

Fig. 9: Strain of the lid (Pos. D1R)

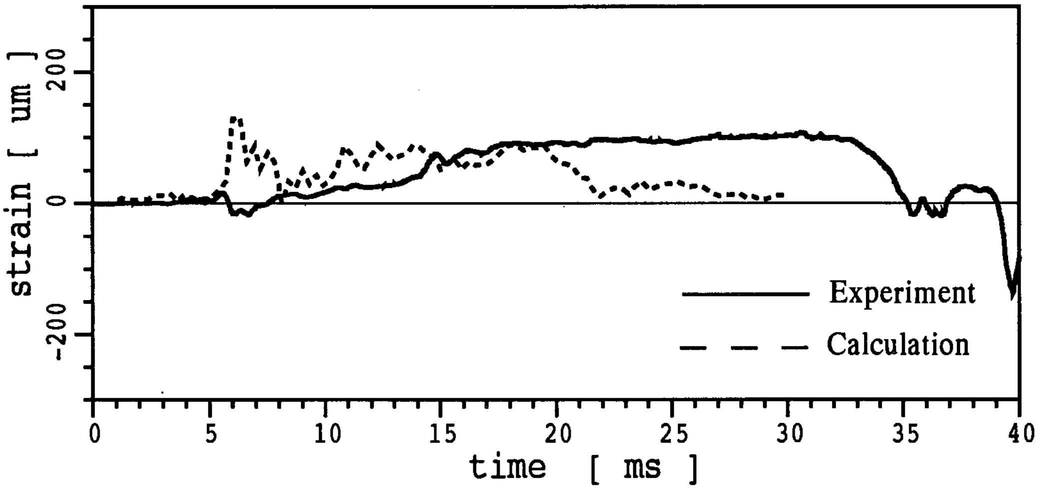

Fig. 10: Strain of the lid (Pos. D2Q)

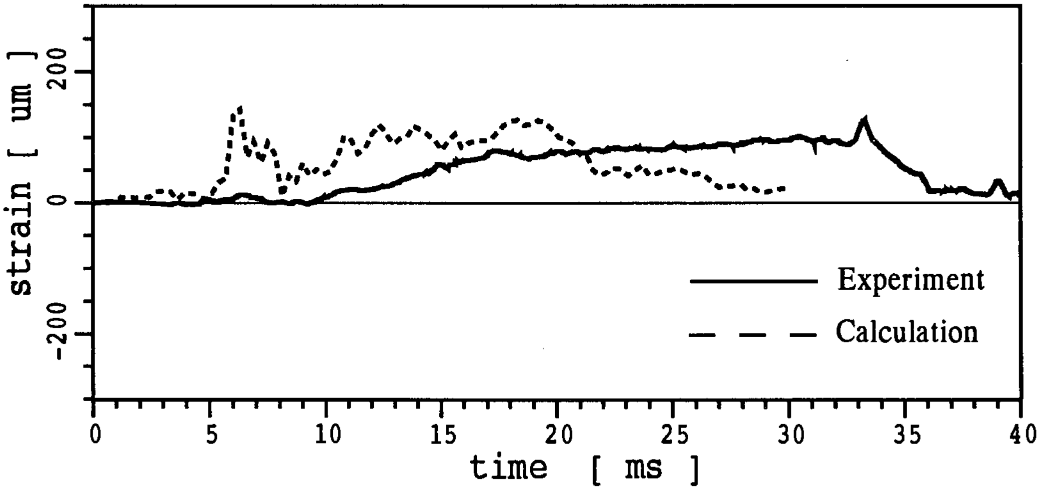

Fig. 11: Strain of the lid (Pos. D3Q)