Some NONSAP Impact Simulations

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INTRODUCTION

In the design of casks for radioactive materials transportation, computer simulation plays an important role. Radiological shielding and thermal simulations are very well understood and using them it is posible, in some cases, to reach final design. On the other hand, impact cask simulations (e.g. 9 m free fall test) are not yet accepted and testing of models is currently requiered to achieve a final design. The main reason for this state is that there is not enough evidence that the existing impact codes can simulate the behaviour of a real cask, with complex geometry and different materials, under impact.

The first impact analysis were of the kind energetic balance-dynamic pressure flow. Wilkins and Guinan (1973) published an experimental and numerical study of impact of cylinders on a rigid boundary that can be used as a benchmark. More recently, and analysing this same cylinder impact problem, a study sponsored by the Japan Society of Mechanical Engineers by Yagawa et al. (1984) was published, with the purpose of identifying suitable techniques to analyze impact problems. Another paper by Key (1985) complements this study.

In this paper we present cylinder impact simulations using NONSAP (1974). Firstly we define a problem for comparison with Wilkins-Guinan work, secondly we select problems to compare with Yagawa et al. and Key works.

PROBLEM DEFINITIONS

Wilkins-Guinan work

In their work, Wilkins and Guinan study an experimental and numerical procedure to determine the dynamic yield point of different metals (1090 steel, tantalum, 6061-T6 aluminum,uranium and magnesium) using the computer program HEMP.

The experiments involve on shooting cylinders of different aspect ratios onto a perpendicular rigid target. The velocity is varied between 50 and 500 m/sec. In this velocity range it is observed that: the final length of the cylinder does not depend on the relation length/diameter in a range 1 to 15, and depends on the initial velocity, mass density and dynamic yield point; the time required to bring the cylinder to rest is proportional to the initial length; the strain velocity depends linearly with the initial velocity and the dynamic yiel point and is practically independent of the impact velocity.

They obtain the following formula that agrees very well with their data.

$$\frac{L_f}{L_0} = 0.88 \ \exp(-\rho \, U^2/2 \, \sigma_y) + 0.12$$

L_f = final length
L_0 = inicial length
ρ = inicial density
U = impact velocity
s_y = dynamic yield strength

The dynamic yield point found for 1090 steel is 12000 kg/cm^2.

We evaluated the global deformation of a 20 cm long, 4 cm diameter, 1090 steel cylinder with a 50 m/seg initial impact velocity.

We used an elastic-perfectly plastic material model with an elasticity modulus of 2.1E6 kg/cm^2, a dynamic yield stress of 12000 kg/cm^2, a Poisson modulus of 0.33 and a density of 7.8 gr/cm^3.

Figure 1 presents the grid used to compare our calculations with this correlation.

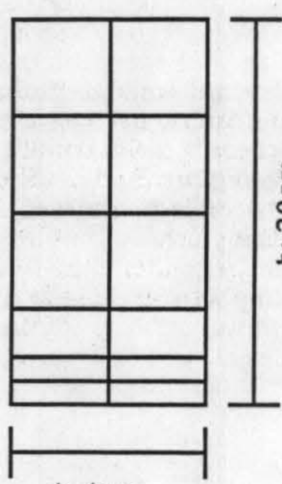

fig 1: Grid used in the 1090 steel cylinder simulation

Yagawa et al.- Samuel Key work

These papers present results obtained with eleven different computer codes (ANSYS, STEALTH-2D, MARC, NASTRAN, PISCES, ABAQUS, ADINA, NEUTDC-01, DYNAX, DYNA-3D and HONDO III).

The problem definition was inspired in an experimental work carried out by Counts and Payne (1979).

It consists of two benchmark problem definitions. Benchmark problem 1 represents a bare lead cylinder of 91.4 cm length and 30.5 cm diameter in an axisymetric collision from height of 9.0 m. Benchmark problem 2 represents a lead cylinder with the same dimensions as benchmark 1 with a 0.635 cm thick steel clad. Two different boundary conditions between lead and steel were simulated: rigidly bonded and frictionless slip.

Figures 2 and 3 represent the grids used in the benchmarks.

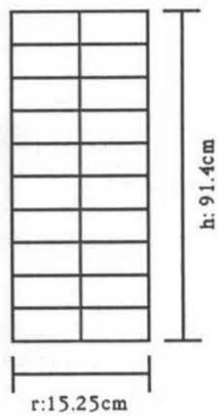

fig 2: Grid used in benchmark problem 1

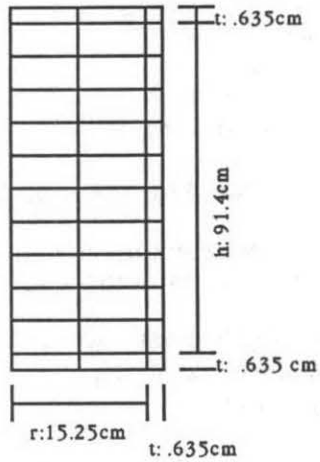

fig 3: Grid used in non slip benchmark problem 2

NONSAP has no direct possibility to simulate slip, it has not gap elements or any possibility to specify contact without friction. Truss elements with convenient material properties were used to represent a slip condition between lead and steel. This model is represented in figure 4. Figure 5 shows the truss behaviour. With this truss configuration the distance between lead and steel is nearly constant during the impact, allowing slip but retaining the pressure that lead exerts on the steel clad. In this model the steel clad radius is 3 cm greater than reference model dimensions in order to place truss elements. The gap between lead and steel clad is also allowed to vary in 0.025 cm.

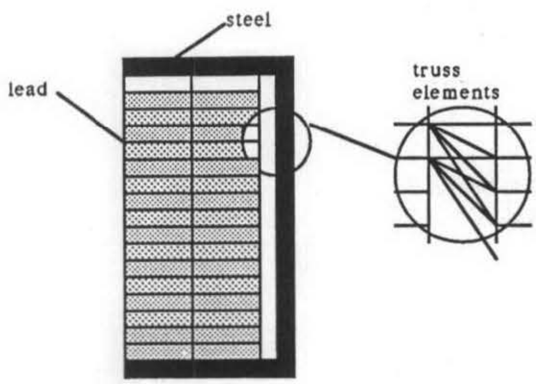

fig 4: grid for benchmark 2, slip condition

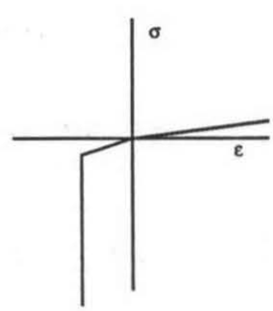

fig 5: truss material properties

Table 1 presents the materials properties used in these calculations.

Table 1: Benchmark material properties

Property	Lead	Stainles Steel
Young Modulus	19.5 Kg/mm^2	19600 Kg/mm^2
Poisson Ratio	0.42	0.33
Yield Stress	3.02 Kg/mm^2	31.6 Kg/mm^2
Hardening Modulus	1.85 Kg/mm^2	195 Kg/mm^2
Mass Density	11.3 g/cm^3	8.0 g/cm^3

Benchmark 2 requires important computational efforts because of the different sections, interface conditions between lead and steel and material properties considered in the model.

The authors cited find good agreement among results obtained with the different codes. However some of the results exhibit oscillations that seem to have a numerical rather than a physical origin.

RESULTS

Wilkins-Guinan work

The final contraction predicted by Wilkins-Guinan formula is 0.142 cm. The head displacement of the steel cylinder versus time is shown in figure 6. The final cylinder contraction predicted by NONSAP is calculated from the mean of the extreme values of figure 6. This contraction is 0.144 cm (a difference of 1.5 %). This difference remains nearly constant for other initial impact velocity and materials.

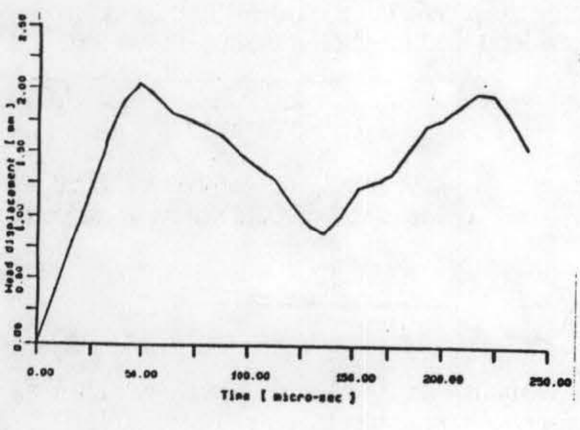

fig 6: Head settlement of the 1090 steel cylinder

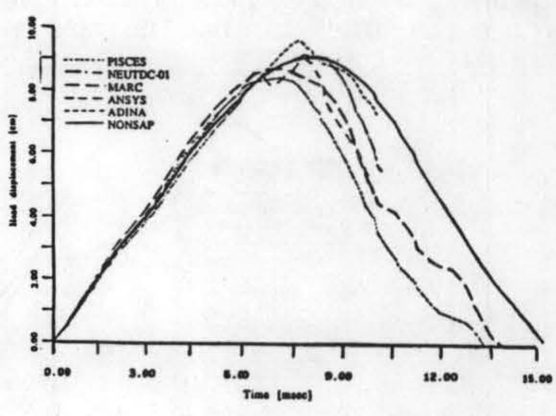

Fig 7: Head settlement of the benchmark problem 1

Yagawa et al-Key work

Benchmark problem 1

This is a very simple benchmark and its simplicity is usefull to compare results obtained with different codes.

The study is carried out giving the entire lead cylinder an initial downward velocity of 13.33 m/sec (corresponding to a 9 m free fall). The axial displacements of the base nodes are forbidden, and no rebounding is allowed. Figure 7 shows NONSAP results of head displacement versus time. The head displacement obtained with ADINA, ANSYS, MARC, NEUTDC and
HONDO III from Yagawa et al.- Key references are also presented.

The motion reverses its direction at 7-8 msec and rebounding occurs at 13-15 msec.

In figure 8 the calculated axial head velocity is presented. Up to 6 msec the head velocity is practically the initial velocity. NONSAP has good agreement with other codes. Some of these codes develop high frequency oscillations at early stages.

Axial stress along centerline at 10 msec is presented in figure 9. At this time all the stress is in the elastic range, and high frequency oscillations are present in the cylinder, so, it is difficult to find good agreement between code results here.

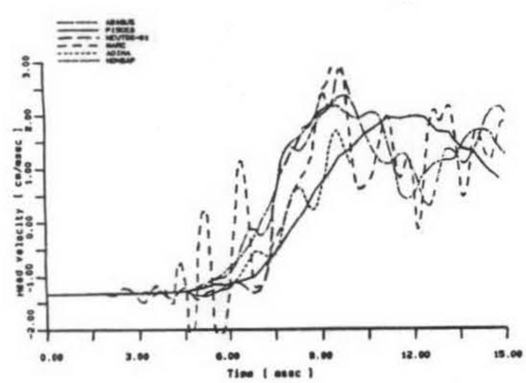

fig 8: Benchmark problem 1
head velocity vs time .

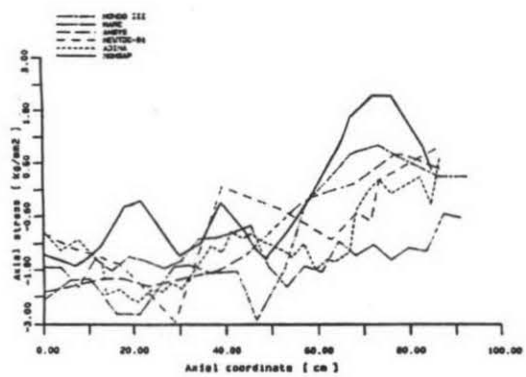

fig 9: Benchmark problem 1, axial distribution of axial stress at 10 msec.

Benchmark Problem 2:

This benchmark is a very interesting case. It incorporates steel and lead, which are materials of common use in radioactive material container design, but retains enough geometrical simplicity to allow direct comparison of impact code.

Two different interface conditions between lead and steel are treated in the original papers: no slip condition and slip condition.

Figure 10 presents the comparison between NONSAP, PISCES and HONDO III for head settlement versus time, with no slip condition. A good agreement is observed among results. The shear stress between lead and steel plays an important role in this simulation and has a strong contribution to the maximun head settlement observed.

Figure 10 shows the head settlement of the cylinder calculated with NONSAP, MARC, ANSYS, ABAQUS and HONDO III with frictionless slip condition. A good agreement is observed among these results, taking into account the differences introduced to the model used in NONSAP calculations.

With this interface condition, the bending of the steel clad near the base is the dominant feature, regarding head settlement.

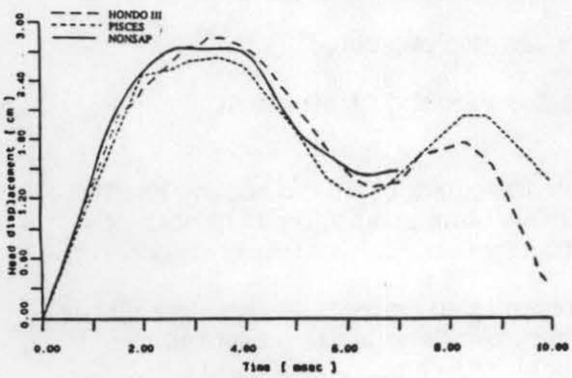

fig 10: head settlement of benchmark 2, no slip condition

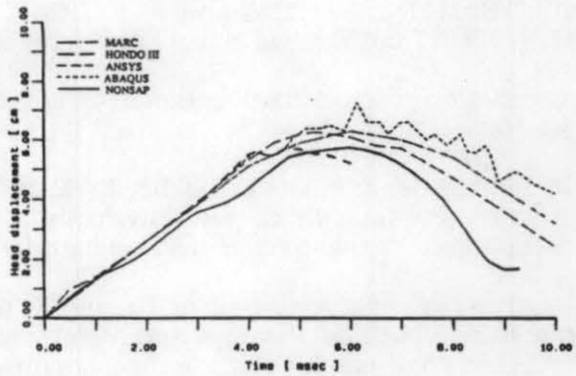

fig 11: head settlement of benchmark 2, slip condition.

DISCUSION:

NONSAP results agree very well with Wilkins-Guinan's work.

The results obtained with NONSAP are within the variation range of those presented by Yagawa et al. and Key.

NONSAP is a suitable tool for container impact analysis but, in general, due to the actual containers geometric complexity and to the dispersion of the results obtained with different codes, nine meters free fall test simulation results cannot be assured without any experimental validation.

For benchmark purposes, it will be preferable to use more realistic lead material properties. In the benchmarks the material properties used induce that the amount of plastic deformation is lower that can be expected.

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