SDNL111 - Impact of two beams

Summarized:

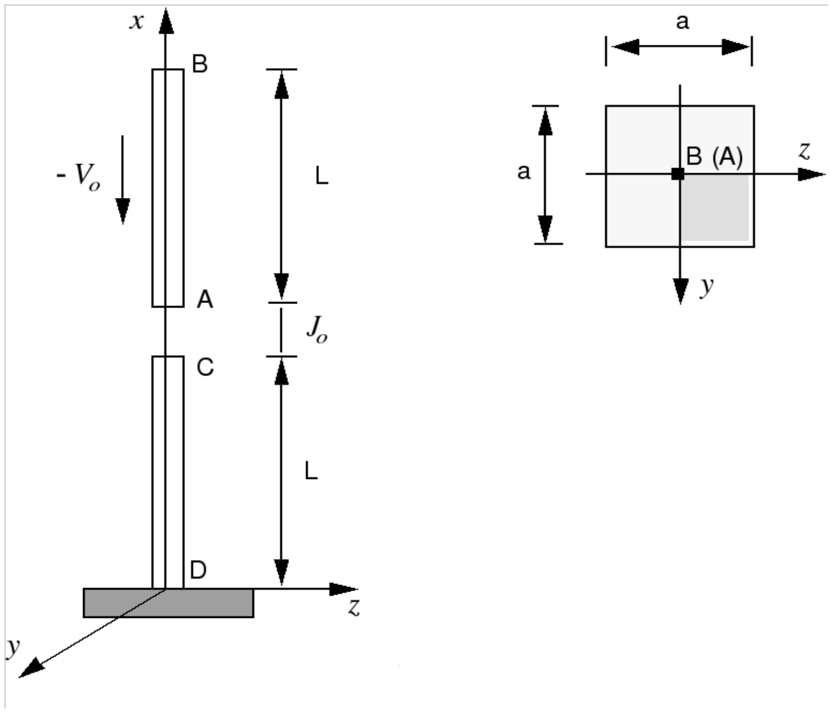
This problem is a problem of impact of two beams in traction and compression. A first free beam is animated an initial velocity parallel with the axis of the two beams and comes to run up against one second embedded against its base. Non-linearity comes from the conditions of contact between two structures. This test comprises an analytical solution of reference.

Initially, one uses a transient analysis by modal recombination of a nonlinear structure system made up of beams (modelizations A and B).
The beams are discretized by of the finite elements type `POU_D_T`. Operators `DEFI_OBSTACLE` [U4.44.21] and `DYNA_TRAN_MODAL` [U4.53.21] are tested. The variations with the values of reference do not exceed 4.5%.

In the second time, one does a direct calculation on physical base, with elements 3D (modelizations C, D, E and F). The operators tested are: `DYNA_NON_LINE`, `DEFI_CONTACT` with the methods `FORCED`, `LAGRANGE` and `CONTINUE`.

1 Problem of reference

1.1 Geometry



Length of the beams: $L=1\text{m}$
Side of the section of the beams: $a=2\text{cm}$

1.2 Material properties

Beam:

Young modulus	$E=2.10^{11}\,Pa$
Poisson's ratio	$\nu=0$ for the modelization 1D and 0.3 the modelization 3D
Density	$\rho=7800\,kg/m^3$

1.3 Boundary conditions and loadings

the problem is one-way according to x .
The beam CD is embedded in D , the beam AB is completely free in translation according to x .

1.4 Initial conditions

With all the nodes of the beam AB are imposed according to the axis x :

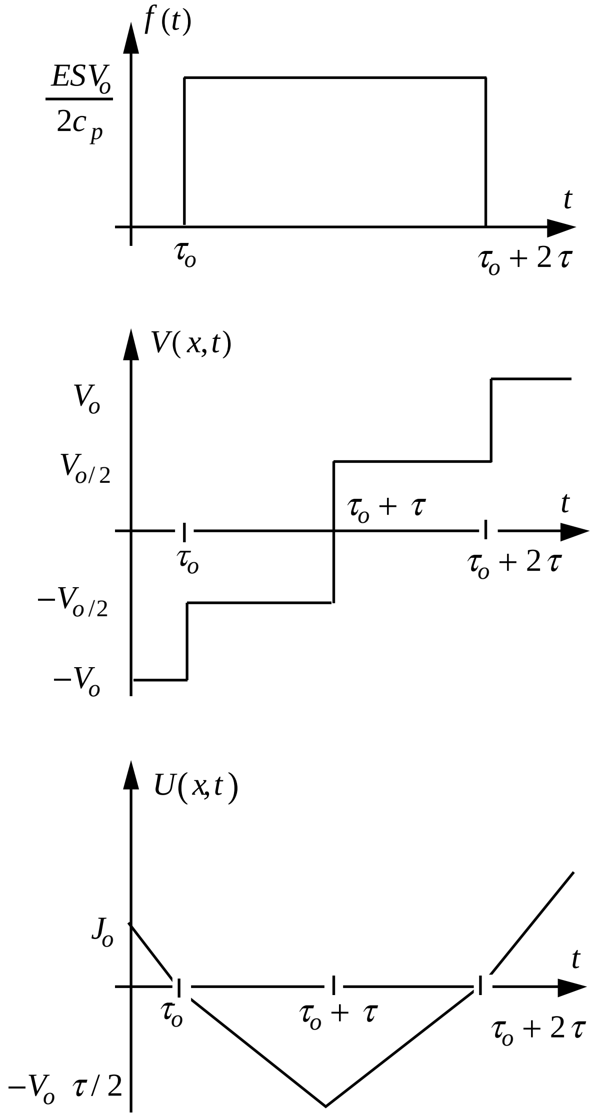
- an initial velocity: $v_0=-1\,m/s$

The nodes of the beam CD have a velocity and an initial displacement no one.
The points A and C are separated from a very weak J_0 initial clearance: $J_0=10^{-5}m$.

2 Reference solution

2.1 Method of calculating

Drawn from [bib1].



$f(t)$: force de contact en A ;

$V(x,t)$: vitesse ;

$U(x,t)$: déplacement ;

$$\tau_o = \frac{J_o}{V_o} ;$$

$$\tau = \frac{2L}{c_p} \text{ Durée de choc} = 2 \cdot \tau ;$$

$$c_p = \sqrt{\frac{E(1-\nu)}{\rho(1+\nu)(1-2\nu)}} ;$$

$S = a^2$ section.

······ pour point A

2.2 Uncertainty on the solution

No (analytical solution).

2.3 Bibliographical reference

1) Algorithms of fast dynamics theoretical Description and examples of applications. Ratio EDF/ DER HP-61/93.115

3 Modelization A

3.1 Characteristic of the modelization

Discretization of the two beams by meshes SEG2 (50 each one) and of the finite elements of type POU_D_T.

A modal base of 40 eigen modes (20 by beams) is used for the modal superposition.
A contractual reduced modal damping of 0.1% is applied to each eigen mode.

The conditions initial velocities are imposed by building a field on the nodes of displacement and by projecting this field on the nodes on modal base.
The vector generalized thus calculated can be introduced into command DYNA_TRAN_MODAL behind the key word VITE_INIT_GENE.

The parameters of modelization of the model of shock used are:

- Stiffness of shock: RIGI_NOR $5.10^9 \, N/m$
- Damping of shock: AMOR_NOR $2.10^4 \, Ns/m$

the First computation:

- the norm with the plane of the shock is selected according to Z : NORM_OBST= (0. 0. 1.)
- an obstacle of the type BI_PLAN_Z is selected

the Second computation:

- the norm with the plane of the shock is selected according to Y : NORM_OBST= (0. 1. 0.)
- an obstacle of the type BI_PLAN_Y is selected

the Third computation:

- the norm with the plane of the shock is selected according to Y: NORM_OBST= (0. 1. 0.)
- an obstacle of the type BI_CERCLE is selected

the values of DIST_1 and DIST_2 which are fictitious here and only to model the contact are selected equal to DIST_1=DIST_2= $J_o/2$ so that there is contact at the beginning of computation.

Temporal integration is carried out with the algorithm of Eulerian and time step of $10^{-6} \, s$.

3.2 Characteristics of the mesh

Many nodes: 102

Number of meshes and types: 100 SEG2

3.3 Quantities tested and results

the First computation

Identification	Standard Value of reference	of reference	Tolerance
DX to the point A t=2.0e-4 S	– 1.E-4	"ANALYTIQUE"	1,0%
DX at the point A t=4.0e-4 S	– 2.E-4	"ANALYTIQUE"	3,5%
DX at the point A t=6.0e-4 S	– 1.E-4	"ANALYTIQUE"	5,0%
DX at the point A t=8.0e-4 S	-1.E-9	"ANALYTIQUE"	1,0E-5
DX at the point A t=1.0e-3 S	2.E-4	"ANALYTIQUE"	3,5%

the Second computation

Identification	Standard Value of reference	of reference	Tolerance
DX to the point A t=2.0e-4 S	– 1.E-4	"ANALYTIQUE"	1,0%
DX at the point A t=4.0e-4 S	– 2.E-4	"ANALYTIQUE"	3,5%
DX at the point A t=6.0e-4 S	– 1.E-4	"ANALYTIQUE"	5,0%
DX at the point A t=8.0e-4 S	-1.E-9	"ANALYTIQUE"	1,0E-5
DX at the point A t=1.0e-3 S	2.E-4	"ANALYTIQUE"	3,5%

the Third computation

Identification	Standard Value of reference	of reference	Tolerance
DX to the point A t=2.0e-4 S	– 1.E-4	"ANALYTIQUE"	1,0%
DX at the point A t=4.0e-4 S	– 2.E-4	"ANALYTIQUE"	3,5%
DX at the point A t=6.0e-4 S	– 1.E-4	"ANALYTIQUE"	5,0%
DX at the point A t=8.0e-4 S	-1.E-9	"ANALYTIQUE"	1,0E-5
DX at the point A t=1.0e-3 S	2.E-4	"ANALYTIQUE"	3,5%

4 Modelization B

4.1 Characteristic of the modelization

Discretization of the two beams by meshes SEG2 (50 each one) and of the finite elements of type POU_D_T.

A modal base of 40 eigen modes (20 by beams) is used for the modal superposition.
A contractual reduced modal damping of 0.1% is applied to each eigen mode.

The conditions initial velocities are imposed by building an initial velocity field applied to the beams $poutre1$ and $poutre2$.

The parameters of modelization of the model of shock used are:

- the norm with the plane of the shock is selected according to Z : NORM_OBST: (0. 1. 0.)
- an obstacle of the type BI_CERC_INT is selected
- Stiffness of shock: RIGI_NOR $5.10^9 N/m$
- Damping of shock: AMOR_NOR $2.10^4 Ns/m$

temporal integration is carried out with the algorithm of Eulerian and time step of $10^{-6} s$.

4.2 Characteristics of the mesh

Many nodes: 102

Number of meshes and types: 100 SEG2

4.3 Quantities tested and results

Identification	Standard Value of reference	of reference	Tolerance
DX at the point A t=2.0e-4 S	– 1.E-4	"ANALYTIQUE"	1,0%
DX at the point A t=4.0e-4 S	– 2.E-4	"ANALYTIQUE"	3,5%
DX at the point A t=6.0e-4 S	– 1.E-4	"ANALYTIQUE"	5,0%
DX at the point A t=8.0e-4 S	-1.E-9	"ANALYTIQUE"	1,0E-5
DX at the point A t=1.0e-3 S	1.E-4	"ANALYTIQUE"	7,0%
DX at the point A t=1.2e-3 S	2.E-4	"ANALYTIQUE"	5,0%
DX at the point A t=1.4e-3 S	1.E-4	"ANALYTIQUE"	7,0%
DX at the point A t=1.6e-3 S	-1.E-9	"ANALYTIQUE"	1,0E-5

5 Modelization C

5.1 Characteristic of the modelization

the two beams are modelled with meshes HEXA8 (50 by beam) and of the finite elements 3D.
The behavior is elastic.

The conditions initial velocities are imposed by building a velocity field initial applied to the two beams: DZ = -1.0 for POU1 and DZ = 0.0 for POU2.

The shock is modelled by a condition of contact. The method used IS FORCED.

Temporal integration is carried out with the method of modified average acceleration (key word HHT with $\alpha=-0,1$) and time step of $10^{-6}s$.

One tests then another algorithm of temporal integration: α - method (key word HHT with $\alpha=-0,3$ and MODI_EQUI=' OUI') and time step unchanged of $10^{-6}s$.

5.2 Characteristics of the mesh

Many nodes: 408

Number of meshes and types: 100 HEXA8

5.3 Quantities tested and results

the First computation

Identification	Standard Value of reference	of reference	Tolerance
DZ to the point A t=2.0e-4 S	– 1.050E-4	"ANALYTIQUE"	5,0%
DZ at the point A t=4.0e-4 S	– 1.550E-4	"ANALYTIQUE"	5,0%
DZ not A t=6.0e-4 S	– 5.540E-5	"ANALYTIQUE"	5,0%
DZ not A t=8.0e-4 S	9.920E-5	"ANALYTIQUE"	5,0%
DZ at the point A t=1.0e-3 S	2.990E-4	"ANALYTIQUE"	5,0%

the Second computation

Identification	Standard Value of reference	of reference	Tolerance
DZ not A t=2.0e-4 S	– 1.050E-4	"ANALYTIQUE"	5,0%
DZ not A t=4.0e-4 S	– 1.550E-4	"ANALYTIQUE"	5,0%
DZ at the point A t=6.0e-4 S	– 5.540E-5	"ANALYTIQUE"	5,0%
DZ not A t=8.0e-4 S	9.920E-5	"ANALYTIQUE"	5,0%
DZ not A t=1.0e-3 S	2.990E-4	"ANALYTIQUE"	5,0%

6 Modelization D

6.1 Characteristic of the modelization

the two beams are modelled with meshes HEXA8 (50 by beam) and of the finite elements 3D.
The behavior is elastic.

The conditions initial velocities are imposed by building a velocity field initial applied to the two beams: DZ = -1.0 for POU1 and DZ = 0.0 for POU2.

The shock is modelled by a condition of contact. The method used is LAGRANGE.

Temporal integration is carried out with method HHT ($\alpha=-0.1$) and time step of $10^{-6}s$.

6.2 Characteristics of the mesh

Many nodes: 408

Number of meshes and types: 100 HEXA8

6.3 Quantities tested and results

Identification	Standard Value of reference	of reference	Tolerance
DZ to the point A t=2.0e-4 S	– 1.050E-4	"ANALYTIQUE"	5,0%
DZ at the point A t=4.0e-4 S	– 1.550E-4	"ANALYTIQUE"	5,0%
DZ at the point A t=6.0e-4 S	– 5.540E-5	"ANALYTIQUE"	5,0%
DZ at the point A t=8.0e-4 S	9.920E-5	"ANALYTIQUE"	5,0%
DZ at the point A t=1.0e-3 S	2.990E-4	"ANALYTIQUE"	5,0%

7 Modelization E

7.1 Characteristic of the modelization

the two beams are modelled with meshes HEXA8 (50 by beam) and of the finite elements 3D.
The behavior is elastic.

The conditions initial velocities are imposed by building a velocity field initial applied to the two beams: DZ = -1.0 for POU1 and DZ = 0.0 for POU2.

The shock is modelled by a condition of contact. The formulation used is CONTINUE.

Temporal integration is carried out with method HHT ($\alpha=-0.1$) and time step of $10^{-6} s$.

7.2 Characteristics of the mesh

Many nodes: 408

Number of meshes and types: 100 HEXA8

7.3 Quantities tested and results

Identification	Standard Value of reference	of reference	Tolerance
DZ not A t=2.0e-4 S	– 1.050E-4	"ANALYTIQUE"	0,01%
DZ not A t=4.0e-4 S	– 1.550E-4	"ANALYTIQUE"	0,03%
DZ at the point A t=6.0e-4 S	– 5.540E-5	"ANALYTIQUE"	0,2%
DZ not A t=8.0e-4 S	9.920E-5	"ANALYTIQUE"	6,0%
DZ not A t=1.0e-3 S	2.990E-4	"ANALYTIQUE"	2,0%

8 Modelization F

8.1 Characteristic of the modelization

the two beams are modelled with meshes HEXA8 (50 by beam) and of the finite elements 3D.
The behavior is elastic.

The conditions initial velocities are imposed by building a velocity field initial applied to the two beams: DZ = -1.0 for POU1 and DZ = +1.0 for POU2.

The shock is modelled by a condition of contact. The formulation used is CONTINUE.

Temporal integration is carried out with diagram THETA_METHODE ($\theta=0,7$, formulation in displacement) and time step of $5,0\times10^{-6}s$.

8.2 Characteristics of the mesh

Many nodes: 408

Number of meshes and types: 100 HEXA8

8.3 Quantities tested and results

Identification	Standard Value of reference	of reference	Tolerance
DZ not A t=0.5e-5 S	-0.5E-5	"ANALYTIQUE"	0,1%
DZ not A t=1.5e-5 S	-1.0E-5	"ANALYTIQUE"	0,1%
DZ at the point A t=2.5e-4 S	-1.0E-5	"ANALYTIQUE"	0,1%
DZ not A t=3.4e-4 S	-1.0E-5	"ANALYTIQUE"	0,1%
DZ not A t=5.0e-4 S	1.0	"ANALYTIQUE"	0,1%

9 Summary of the results

For the modelizations A and B (with DYNA_TRAN_MODAL):
The accuracy of computation is relatively average what is due to the choice of the coefficients of penalization used to model the contact. The increase in the stiffness of contact improves considerably the field of displacement but generates important oscillations of the velocity field around the analytical solution.

For the modelizations C, D and E (with DYNA_NON_LINE):
The accuracy of computation is very good (4% of maximum change). In this case, the three methods used give results of comparable quality.

Moreover, for the modelization C, one also tested two types of diagrams of integration in implicit times: modified average acceleration (key word HHT with option MODI_EQUI=' NON' : default option) and HHT “complete” (key word HHT with option MODI_EQUI=' OUI').
With “complete” diagram HHT, the maximum variation observed with the reference solution drops slightly: 2,15% compared with 3,73% with the modified average acceleration. The other values tested are impacted very little, with the choice of values of the parameter α of the diagrams employed in this benchmark ($\alpha=0.1$ for the modified average acceleration and $\alpha=0.3$ HHT).