SDNL111 - Impact of two beams

Summary:

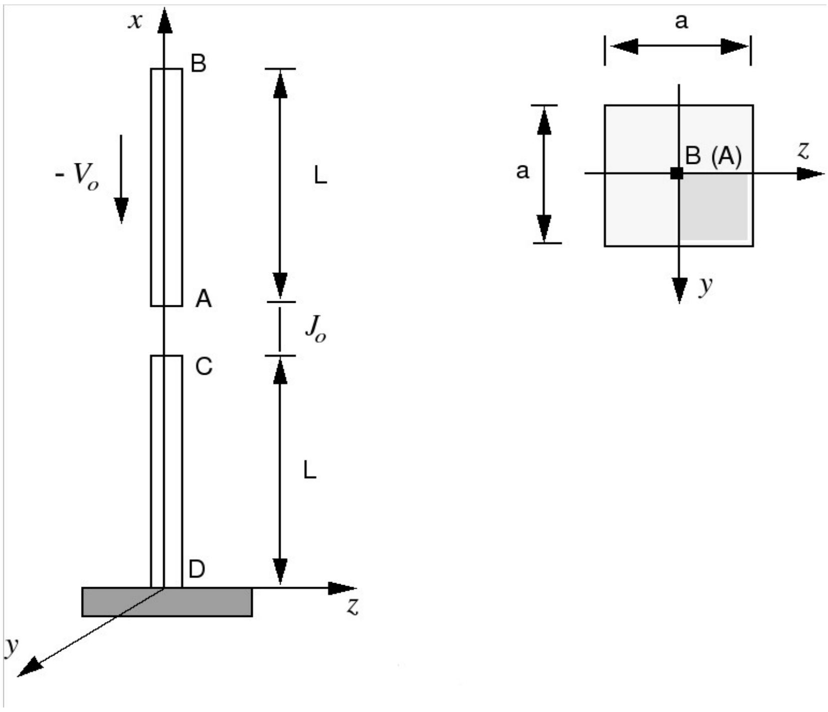
This problem is a problem of impact of two beams in traction and compression. A first free beam is animated an initial speed parallel with the axis of the two beams and comes to run up against one second embedded against its base. Non-linearity comes from the conditions of contact between the two structures.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

Initially, one uses a transitory analysis by modal recombination of a non-linear system made up by structures of beams (modelings A and B).
The beams are discretized by finite elements of 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 basis, with elements 3D (modelings C, D, E and F). The operators tested are: DYNA_NON_LINE, DEFI_CONTACT with the methods CONSTRAINT, LAGRANGE and CONTINUOUS.

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 modeling 1D and 0.3 for modeling 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 :

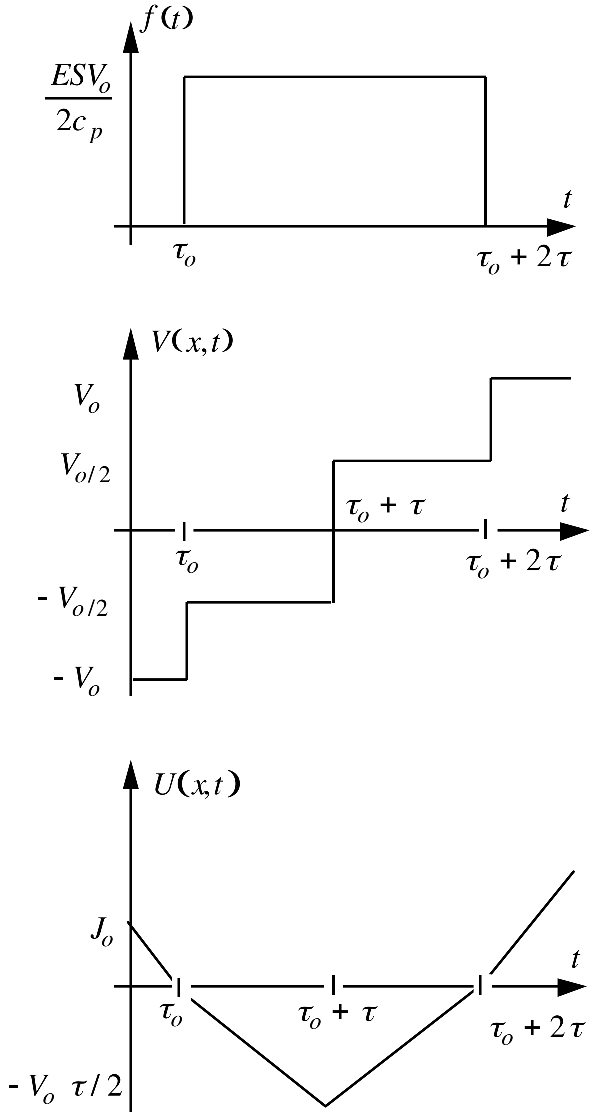
- an initial speed: $v_0=-1\,m/s$

Nodes of the beam CD a speed and an initial displacement have no one.
Points A and C are separated from an initial game J_0 very weak: $J_0=10^{-5}m$.

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 ;

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

$$\tau = \frac{2L}{c_p}$$ 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. Report EDF/DER HP-61/93.115

3 Modeling A

3.1 Characteristics of modeling

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

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

The conditions initial speeds are imposed by building a field on the nodes of displacement and by projecting this field on the nodes on the modal basis.
The vector generalized thus calculated can be introduced into the order DYNA_TRAN_MODAL behind the keyword VITE_INIT_GENE.

The parameters of modeling of the law 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 calculation:

- the normal with the plan 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 calculation:

- the normal with the plan 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 calculation:

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

Values of DIST_1 and DIST_2 who 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 calculation.

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

3.2 Characteristics of the grid

Many nodes: 102

Many meshs and types: 100 SEG2

3.3 Sizes tested and results

The first calculation

Identification	Value of reference	Type of reference	Tolerance
DX at the point A t=2.0e-4 S	– 1.E-4	'ANALYTICAL'	1.0%
DX at the point A t=4.0e-4 S	– 2.E-4	'ANALYTICAL'	3.5%
DX at the point A t=6.0e-4 S	– 1.E-4	'ANALYTICAL'	5.0%
DX at the point A t=8.0e-4 S	-1.E-9	'ANALYTICAL'	1,0E-5
DX at the point A t=1.0e-3 S	2.E-4	'ANALYTICAL'	3.5%

The second calculation

Identification	Value of reference	Type of reference	Tolerance
DX at the point A t=2.0e-4 S	– 1.E-4	'ANALYTICAL'	1.0%
DX at the point A t=4.0e-4 S	– 2.E-4	'ANALYTICAL'	3.5%
DX at the point A t=6.0e-4 S	– 1.E-4	'ANALYTICAL'	5.0%
DX at the point A t=8.0e-4 S	-1.E-9	'ANALYTICAL'	1,0E-5
DX at the point A t=1.0e-3 S	2.E-4	'ANALYTICAL'	3.5%

The third calculation

Identification	Value of reference	Type of reference	Tolerance
DX at the point A t=2.0e-4 S	– 1.E-4	'ANALYTICAL'	1.0%
DX at the point A t=4.0e-4 S	– 2.E-4	'ANALYTICAL'	3.5%
DX at the point A t=6.0e-4 S	– 1.E-4	'ANALYTICAL'	5.0%
DX at the point A t=8.0e-4 S	-1.E-9	'ANALYTICAL'	1,0E-5
DX at the point A t=1.0e-3 S	2.E-4	'ANALYTICAL'	3.5%

4 Modeling B

4.1 Characteristics of modeling

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

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

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

The parameters of modeling of the law of shock used are:

- the normal with the plan 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 Euler and a step of time of $10^{-6}\,s$.

4.2 Characteristics of the grid

Many nodes: 102

Many meshs and types: 100 SEG2

4.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
DX at the point A t=2.0e-4 S	– 1.E-4	'ANALYTICAL'	1.0%
DX at the point A t=4.0e-4 S	– 2.E-4	'ANALYTICAL'	3.5%
DX at the point A t=6.0e-4 S	– 1.E-4	'ANALYTICAL'	5.0%
DX at the point A t=8.0e-4 S	-1.E-9	'ANALYTICAL'	1,0E-5
DX at the point A t=1.0e-3 S	1.E-4	'ANALYTICAL'	7.0%
DX at the point A t=1.2e-3 S	2.E-4	'ANALYTICAL'	5.0%
DX at the point A t=1.4e-3 S	1.E-4	'ANALYTICAL'	7.0%
DX at the point A t=1.6e-3 S	-1.E-9	'ANALYTICAL'	1,0E-5

5 Modeling C

5.1 Characteristics of modeling

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

The conditions initial speeds are imposed by building a field initial speed 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 `CONSTRAINT`.

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

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

5.2 Characteristics of the grid

Many nodes: 408

Many meshs and types: 100 `HEXA8`

5.3 Sizes tested and results

The first calculation

Identification	Value of reference	Type of reference	Tolerance
DZ at the point A t=2.0e-4 S	– 1.050E-4	'ANALYTICAL'	5.0%
DZ at the point A t=4.0e-4 S	– 1.550E-4	'ANALYTICAL'	5.0%
DZ at the point A t=6.0e-4 S	– 5.540E-5	'ANALYTICAL'	5.0%
DZ at the point A t=8.0e-4 S	9.920E-5	'ANALYTICAL'	5.0%
DZ at the point A t=1.0e-3 S	2.990E-4	'ANALYTICAL'	5.0%

The second calculation

Identification	Value of reference	Type of reference	Tolerance
DZ at the point A t=2.0e-4 S	– 1.050E-4	'ANALYTICAL'	5.0%
DZ at the point A t=4.0e-4 S	– 1.550E-4	'ANALYTICAL'	5.0%
DZ at the point A t=6.0e-4 S	– 5.540E-5	'ANALYTICAL'	5.0%
DZ at the point A t=8.0e-4 S	9.920E-5	'ANALYTICAL'	5.0%
DZ at the point A t=1.0e-3 S	2.990E-4	'ANALYTICAL'	5.0%

6 Modeling D

6.1 Characteristics of modeling

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

The conditions initial speeds are imposed by building a field initial speed 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 the method HHT ($\alpha=-0.1$) and a step of time of $10^{-6}s$.

6.2 Characteristics of the grid

Many nodes: 408

Many meshs and types: 100 HEXA8

6.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
DZ at the point A t=2.0e-4 S	– 1.050E-4	'ANALYTICAL'	5.0%
DZ at the point A t=4.0e-4 S	– 1.550E-4	'ANALYTICAL'	5.0%
DZ at the point A t=6.0e-4 S	– 5.540E-5	'ANALYTICAL'	5.0%
DZ at the point A t=8.0e-4 S	9.920E-5	'ANALYTICAL'	5.0%
DZ at the point A t=1.0e-3 S	2.990E-4	'ANALYTICAL'	5.0%

7 Modeling E

7.1 Characteristics of modeling

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

The conditions initial speeds are imposed by building a field initial speed 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 CONTINUOUS.

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

7.2 Characteristics of the grid

Many nodes: 408

Many meshs and types: 100 HEXA8

7.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
DZ at the point A t=2.0e-4 S	– 1.050E-4	'ANALYTICAL'	0.01%
DZ at the point A t=4.0e-4 S	– 1.550E-4	'ANALYTICAL'	0.03%
DZ at the point A t=6.0e-4 S	– 5.540E-5	'ANALYTICAL'	0.2%
DZ at the point A t=8.0e-4 S	9.920E-5	'ANALYTICAL'	6.0%
DZ at the point A t=1.0e-3 S	2.990E-4	'ANALYTICAL'	2.0%

8 Modeling F

8.1 Characteristics of modeling

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

The conditions initial speeds are imposed by building a field initial speed 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 CONTINUOUS.

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

8.2 Characteristics of the grid

Many nodes: 408

Many meshs and types: 100 HEXA8

8.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
DZ at the point A t=0.5e-5 S	-0.5E-5	'ANALYTICAL'	0.1%
DZ at the point A t=1.5e-5 S	-1.0E-5	'ANALYTICAL'	0.1%
DZ at the point A t=2.5e-4 S	-1.0E-5	'ANALYTICAL'	0.1%
DZ at the point A t=3.4e-4 S	-1.0E-5	'ANALYTICAL'	0.1%
DZ at the point A t=5.0e-4 S	1.0	'ANALYTICAL'	0.1%

9 Summary of the results

For modelings A and B (with DYNA_TRAN_MODAL):
The precision of calculation 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 field speed around the analytical solution.

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

Moreover, for modeling C, one also tested two types of diagrams of integration in implicit times: modified average acceleration (keyword HHT with the option MODI_EQUI=' NON' : option by default) and "complete" HHT (keyword HHT with the 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 diagrams employed in this CAS-test ($\alpha=0.1$ for the modified average acceleration and $\alpha=0.3$ for HHT).