SDNS01 - Model probabilistic nonparametric - parametric of a flexbeam with nonlocalised linearities of Summarized

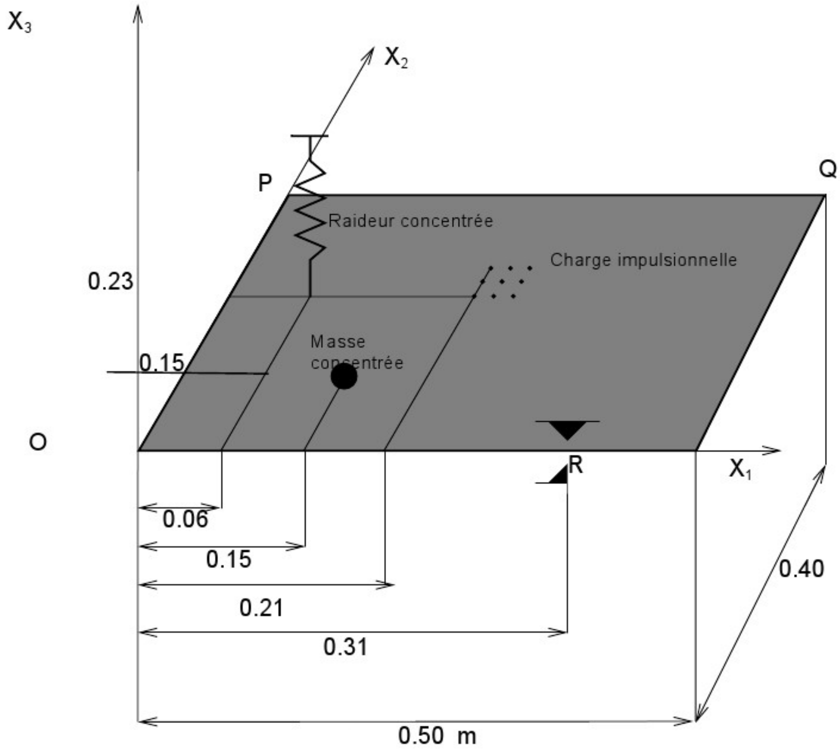
shock:

This benchmark relates to the nonparametric and parametric probabilistic models of uncertainties in linear dynamics with possibly of nonthe localised linearities. The model mechanical used is a rectangular plate with an elastic thrust of shock. The random generators of matrixes and random variables (operators GENE_MATR_ALEA and GENE_VARI_ALEA) are tested and validated in this case test. Statistical postprocessings (CALC_FONCTION) are also tested.

This benchmark has two modelizations. The first uses a proportional damping. The second uses a reduced damping defined by the key word CALC_AMOR_GENE of COMB_MATR_ASSE testing this functionality thus.

1 Problem of reference

1.1 Geometry



Thickness of the plate: $e=0.0004\,m$.
Clearance enters the thrusts : $jeu=\pm 0.002\,m$.

1.2 Material properties

Plates:

Poisson's ratio: 0.3
Young modulus: $2.1\,10^{11}\,N/m^2$
Density: $7800\,kg/m^2$
Concentrated stiffness: $2.388\,10^7\,N/m$
Lumped mass: $4\,kg$
Stiffness of shock: $25000\,N/m$

1.3 Boundary conditions and loadings

the flexbeam is out of simple on 3 edges and free bearing on its fourth edge OR . The blocked degrees of freedom are thus:

- on OP and QR, displacements according to $X_{1,}X_{2,}X_3$ and the rotations according to $X_{1,}X_3$.
- on PQ , displacements according to $X_{1,}X_{2,}X_3$ and the rotations according to $X_{2,}X_3$.

- on OR , displacements according to $X_{1,}X_2$.

The plate is subjected to a vertical impulse load $e(t)$ on 9 nodes of the plate according to the direction X_3 . The loading $e(t)$ is such that, for $t<0$ and $t>2t_1$, $e(t)=0$ and for $0\le t\le 2t_1$:

$$e(t)=(\Delta\omega(t-t_1))^{-1}(\sin((\Omega_c+\Delta\omega/2)(t-t_1))-\sin((\Omega_c-\Delta\omega/2)(t-t_1))) .$$

with $t1=2\pi/\Delta\omega$ $\Delta\omega=2\pi\times 40\,rad/s$ $\Omega_c=2\pi\times 20\,rad/s$.

The energy of the function $e(t)$ is mainly distributed in the frequential tape $[0,60]Hz$, which contains 8 elastic modes of the linearized dynamic system.

1.4 Initial conditions

the dynamic system is initially at rest.

2 Reference solution

2.1 Method of calculating used for the reference solution

We on the structure study the transient response of a nonlinear dynamic system subjected to a deterministic impulse load due to a shock. Nonthe linearity of the system is due to an elastic thrust of high stiffness comprising a certain clearance. The response sprectrums in frequency standardized are used in order to study the transient response of this system. The equations of the dynamics are discretized by the method with the finite elements. The mesh of structure is supposed sufficiently fine to collect all the dynamic phenomena of this mechanical system in term of field of displacement for the impulse loading considered. Random uncertainties of the dynamic system are modelled by means of the model probabilistic nonparametric uncertainties. Consequently, the transient response is a nonsteady stochastic process whose statistical estimates are evaluated.

The results of reference are given in the form of graphs in the article referred below, consultable on `http://www.resonance-pub.com`.

2.2 Bibliographical reference

1.C. SOIZE: Not linear dynamical Systems with Nonparametric Model of Random Uncertainties”, Uncertainties in Engineering Mechanics (2001) 1(1), 1-38, `http://www.resonance –pub.com Modelization`

3 A Characteristic

3.1 of the modelization Modelization

: DKT `The model`

average with the finite elements of the plate consists of a regular rectangular mesh whose step is constant and is worth in 0.01m the directions and X_1 . X_2 There are thus 41 nodes in the width and 51 nodes in the length. Consequently, all the finite elements are identical and each one is an element plates with 4 nodes. This model finite elements layer comprises 2000 finite elements and degrees of freedom $m=6009$, by counting only the translations in and the z rotations according to and X_1). X_2

The eigenfrequencies of the linearized dynamic system (the plate without the thrusts of shock but with the masses and stiffness concentrated) are: .
$f_1=1.94, f_2=10.28, f_3=15.47, \ldots, f_8=53.5, f_9=66{,}1, f10=68.9, \ldots, f_{30}=198.3,$
$f_{31}=206.0, f_{32}=208.9, \ldots, f_{50}=330.9, f_{51}=336.3, \ldots, f_{100}=670.8, f_{120}=817.6\text{Hz}$ Modelization

: DIS_T

the lumped masses and the concentrated stiffness are modelled by elements DIST `_T. Damping`

the damping matrix of $[\underline{D}]$ the model average finite element is defined as being a linear combination of the matrixes finite elements averages of mass and $[\underline{M}]$ stiffness. $[\underline{K}]$ One thus has with $[\underline{D}]=a[\underline{M}]+b[\underline{K}]$ and

$$a=\frac{2\xi\Omega_{max}\Omega_{min}}{\Omega_{max}+\Omega_{min}} \text{ where } b=\frac{2\xi}{\Omega_{max}+\Omega_{min}}$$

, $\xi=0.04$ and $\Omega_{min}=4\pi\, rad/s$. $\Omega_{max}=200\pi\, rad/s$ Scale model

and degree of freedom observed For

this case test, the model finite elements is linearized project on the first 5 elastic modes of structure, which constitutes the data of the average scale model. It should be noted that the first 5 modes are not enough to obtain convergence compared to the number of modes (cf paragraph Comments of the results of the modelizations).

The degree of freedom observed is the degree of freedom corresponding j_{stop} to following displacement in translation of z the node or are the elastic thrusts. It is the node of coordinates. $(0.31, 0, 0)$ The response sprectrum standardized for this degree of freedom is built for a tape of frequential analysis and $J=2\pi[1,100]rad/s$ of which the frequential resolution is of. 0.5Hz Achievements

of the random matrixes of the nonparametric probabilistic model – parametric

the mass matrixes, of stiffness and dissipation of the scale model layers are replaced by achievements of the random matrixes of mass, stiffness and of nonparametric dissipation following the model probabilistic. For that, we use the generator of random matrixes GENE `_MATR_ALEA. During` the first call to this generator, key word INIT `must` take the value " `YES" in order to` initialize the generator of random variable of uniform model of Python. Thereafter, INIT `will be able` to take its default value (INIT= `` `NON') ``. The initialization of the generator of random variable of Python is to be done only one and only once by study, in theory, except if the user explicitly wishes to re-use the same sequence random pseudonym.

The level of dispersion of the random matrixes of the nonparametric probabilistic model is controlled by a parameter of dispersion built-in δ to 20% (). $\delta=0.2$ Key word DELTA `thus` takes value 0.2. Lastly,

for each pulling of the random matrixes of mass, stiffness and dissipation, it is necessary to inform the corresponding average matrix of the model reduces average via key word MATR_MOYEN .

The stiffness of shock is also made random due to uncertainties. To build a realization of the stiffness of shock following a model gamma, we use random generator GENE `_VARI_ALEA with` the key word TYPE = `` `GAMMA'. We `` suppose that possible all the values for the achievements of the random stiffness of shock are the interval, $[0,+\infty[$ that the mean value of all the achievements of the stiffness of shock corresponds to the stiffness of shock of the model finite elements layer. The level of dispersion of the achievements of the stiffness of shock is controlled by a parameter built-in δ to 1% (). $\delta=0.01$ Key word DELTA `thus` takes the value. 0.01 Resolution

of the probabilistic nonlinear dynamic system.

Operator DYNA `_VIBRA` is used to build the transient response of the nonlinear dynamic system for each realization of the random stiffness of random shock and the matrixes of mass, stiffness and dissipation. It should be noted that we carry out for this case test only achievements $n_s=5$ of each random variable (stiffness of shock + matrixes) what corresponds to 5 iteration of the method of computational simulation of Monte Carlo (cf paragraph Comments of the Results of the modelizations).

The temporal interval of the study is, $T=[0,4]s$ with a step of. $5.10^{-5}s$ The diagram of temporal integration selected is EULER . `Construction`

of the statistical estimates. After

each call to DYNA `_VIBRA, we` have a realization of the stochastic process of generalized displacements. It is thus possible to build acceleration with the node of shock following the degree of freedom by the operator j_{stop} RECEIVED `_FONCTION`. The standardized response sprectrum is then built by the operator CALC `_FONCTION. These`

two operations are classically carried out during deterministic studies and give us here a realization of the stochastic process of the standardized response sprectrum. It is then a question of building statistical estimates of the achievements n_s of this last. The estimates under consideration in this case test are the envelopes min and max as well as the average and the moment of order two of the standardized response sprectrums. A each pulling (iteration of Monte Carlo) we build these estimates with the assistance only of operator CALC `_FONCTION and` key words ENVELOPPE , PUISSANCE `and` COMB . `At the end of` the iterations n_s of Monte Carlo, we have the required statistical estimates relating to the stochastic process of the standardized response sprectrum. Finally the norm of $L2$ the average is calculated by the key word NORMALIZES `of` operator CALC `_FONCTION`. The interest to evaluate such a norm is to allow studies of convergence according to the number of modes of the random average scale model and according to the iteration count of the numerical method of Monte Carlo. This norm is calculated here to check that the functionality goes, but convergence is not reached to save the TEMPS CPU. Characteristics

3.2 of the mesh Many

degrees of freedom: 6009 Many

finite elements: 2000 QUA4 and 2 DIS_T Quantities

3.3 tested and results

the initial validity of the case test was established by comparison with bibliographical reference given in [§3.2]. One

tests the following values into non regression (cf comments): Statistics

on the values of the response sprectrum with 50Hz with the degree of freedom observed (cf modelization) Identification	
References	**Estimate**
of the envelope max 4.4433958494950	E+02 Estimate
of the envelope min 1.2534278720661	E+02 Estimate
of the average 3.2330416710925	E+02 Estimate
of the moment of order 2 1.2260792008492	E+02 Estimate
of the Norm of $L2$ the average 2.0657959602609	E+03 Comments

3.4

the various statistical estimates are not converged here. Only 5 simulations of Assembles - Carlo were made. One would have needed 700 at least of them. Moreover, it is necessary to increase the number of modes with 50 to obtain the convergence of the model project in the waveband considered. Computations being then too long for a case test, we preferred to voluntarily degenerate two convergences after validation of those on a complete study. After convergence, the statistical estimates calculated from Aster *correspond* very exactly to the results given by the standard commodity. Modelization

4 B Characteristic

4.1 of the modelization Only

the modelization of damping changes modelization A. Amortissement compared to the

damping matrix of $[\underline{D}]$ the model average finite element is defined as corresponding with a straight line modal reduced damping of 4%. Characteristics

4.2 of the mesh Many

degrees of freedom: 6009 Many
finite elements: 2000 QUA `4 and` 2 DIS_T `Quantities`

4.3 tested and results One

tests the following values into non regression, with: 50Hz Statistics

on the values of the response sprectrum with to 50Hz the degree of freedom observed (cf modelization) Identification

References	Estimate
of the envelope max 2.7570639015302	E+02 Estimate
of the envelope min 9.3629561795277	E+01 Estimate
of the average 1.9641139264813	E+02 Estimate
of the moment of order 2 4.3869049613023	E+04 Estimate
of the Norm of $L2$ the average 1.2384277999571	E+03 Comments

4.4 Same

comments as for modelization A. Synthèse

5 of the results

the got results are completely in conformity with those of bibliographical reference [§2.2] entirely obtained in Matlab.