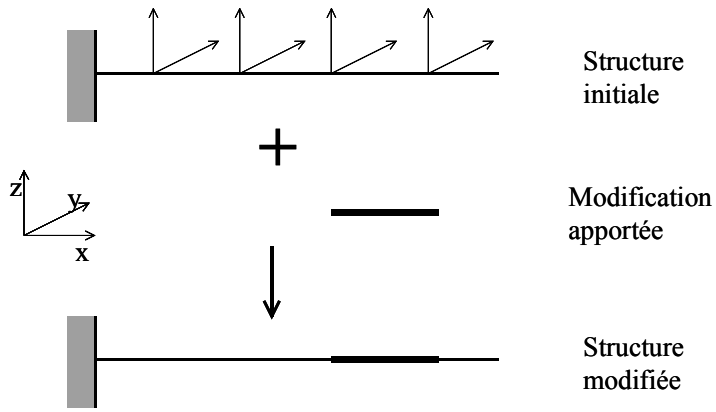
SDLL137 – Structural the purpose of modification of a beam

Summarized

This case test is validating the procedure and the computation of structural modification starting from measured information.
The method of structural modification used is based on the joint operating of measured data and the digital model of the modification made to initial structure. One makes use then of the technique of substructuring for the coupling of the two models.
For this case test, measurement was simulated numerically and the results of reference are obtained by direct computation on the structure supplements.

1 Problem of reference

1.1 Geometry



On the diagram above, the points of measurement on the structure initial are materialized by deflections, of which the point indicates the significant direction of the sensor. These points of measurement are localised with the X-coordinates $0.2\,m$ $0.4\,m$, $0.6\,m$ and $0.8\,m$ according to the directions y and z. Measured information is available only in these points of measurement.

The initial structure is a beam with rectangular section ($9\,mm \times 38\,mm$) length $0.9\,m$.

The modification is an additional beam, with rectangular section ($9\,mm \times 38\,mm$), which one applies between the coordinates $0.6\,m$ and $0.8\,m$.

1.2 Properties of the material

Modulus Young: $E = 2.1\,10^{11}\,N/m^2$
Poisson's ratio: $\nu = 0.3$
Density: $\rho = 7800\,kg/m^3$

1.3 Boundary conditions and loadings

the beam is embedded with the one of its ends (origin of the axes) and free at the other end.

1.4 Initial conditions

Without object.

2 Reference solution

2.1 Method of calculating

It acts here to couple an experimental model representing real structure and a digital model of the modification which one wishes brought to initial structure according to the technique suggested by Mr. Corus [1]. This coupling is done via model “a support” making it possible to condense measurement with the interfaces between real structure and the modification. One by means of assembles then the two models the technique of substructuring. A more detailed description of the procedure of modification used is presented in [U2.07.03]. The extension of this technique on damping structures was studied by B. Groult [2].

The data input of computation are: identified eigen modes of structure initial, the model numerical of the “support” and the model numerical of the “modification”.

One proposes to calculate the variations of the first two eigenfrequencies of the embed-free beam, following the modification made on a portion of the beam.

The model “support” chosen for this case test is a digital model with the finite elements of the embed-free beam described in the preceding paragraph. The first two eigenfrequencies of this beam are: $9.31\,Hz$ and $39.32\,Hz$.

The condensation of the information measured with the interfaces is obtained by carrying out an expansion of measurement via a beforehand selected projection base, defined on this model “support”. The quality of result depends on the choice of this projection base.

Measurement was simulated numerically from a computation resulting from the model support.
The modification was modelled numerically by finite elements.

2.2 Quantities and results of reference

One the model compares the first two eigenfrequencies of structure modified with the eigenfrequencies obtained by a direct computation on complete. The first two eigenfrequencies of modified structure are: $7.78\,Hz$ and $32.85\,Hz$.

One also checks the good progress of the procedure of structural modification by comparing the field obtained with the interfaces of modified structure in two different ways.
The first computation corresponds to the computation of the field to the interfaces on the model coupled.
The second computation corresponds to the computation of the field to the interfaces by static expansion of the field obtained at the points measures modified structure.

The difference between these two fields can be evaluated by the computation of the sum of the terms of the matrix of MAC (Modal Criterion Insurance) between these two fields. A matrix of MAC close to the matrix identity indicates that the two vectors are almost parallel. Criterion IERI is also evaluated (Energy Indicator of Regularity of Interface). This energy criterion tends towards 0 if the two fields are very close.

2.3 Uncertainties

the reference solution on the eigenfrequencies of modified structure is obtained by direct computation on the structure modified.
We consider that the selected discretization led to results very close to the analytical solution.

3 Modelizations has with D

the first 4 modelizations rigorously use the method of structural modification as suggested by Mr. Corus, namely that the basic structure is described under modal shape (a base of eigen modes extended on a simplified digital model) and the modification is described in the form of a physical model. The elements of computations implemented here make it possible to couple the two aspects.
For more details, one will refer to U2.07.03 documentation (section 3).

4 Modelization E

The modelization E implements same computation in the form of a classical computation per substructuring. The principal structure and the modification are described on modal base. The assembly of two substructures is done classically with command DEFI_MODELE_GENE.
For more precise details, one will refer to U2.07.03 documentation (section 4).

4.1 Bibliographical reference

[1] Mr. Corus, Thesis ECP n° 2003-23, Improvement of the methods of structural modification per use of techniques of expansion and reduction of model.
[2] B. Groult, Thesis ECP n° 2008-14, Extension of a method of structural modification for the design of dissipative devices integrating of the viscoelastic materials.

5 Modelization A

5.1 Characteristic of the modelization

The model “support” and the modification were modelled by elements POU_D_E. The projection base chosen for the expansion of measured information, corresponds to the static deformed shapes obtained by application of a loading in each point of measurement according to the significant direction of the sensor. The model “measurement” was built starting from the first five identified modes of initial structure.

5.2 Characteristics of the mesh

Models “support”:
Number and type of mesh: 9 elements of the type SEG2.

Model “modification”:
Number and type of mesh: 2 elements of the type SEG2.

5.3 Features tested

the procedure of structural modification proceeds in several stages. One tests the good progress of this procedure and the following features:
LIRE_RESU, PROJ_MESU_MODAL, MACR_ELEM_STAT, ASSE_MAILLAGE, DEPL_INTERNE.

5.4 Quantities tested and results

One checks the values of the first two eigenfrequencies of modified structure.
One also checks the sum of the terms of the matrix of MAC (Modal Criterion Insurance) obtained between the deformed shapes with the interfaces for the model coupled and the deformed with the interfaces by static expansion of the deformed shapes of the model coupled obtained with the points of measurement. This indicator indicates the relevance of the reconstruction of the field to the interfaces.

Quantity tested	Reference	*Aster*	Difference
$f1$	$7.7807\ Hz$	$7.7852\ Hz$	0.058%
$f2$	$32.852\ Hz$	$32.845\ Hz$	0.022%
MAC (Somme)	2	1.992	0.008

6 Modelization B

6.1 Characteristic of the modelization

It is a modelization identical to the modelization A, but this time, one launches the procedure of modification via macro-command CALC_ESSAI. One uses the method ES (Static Expansion) for computation of the base of expansion.

6.2 Characteristics of the mesh

Models “support”:
Number and type of mesh: 9 elements of the type SEG2.

Model “modification”:
Number and type of mesh: 2 elements of the type SEG2.

6.3 Features tested

the procedure of structural modification proceeds in several stages. One tests the good progress of this procedure and the following features:
LIRE_RESU, PROJ_MESU_MODAL, MACR_ELEM_STAT, ASSE_MAILLAGE, DEPL_INTERNE, MAC_MODES, CALC_ESSAI.

6.4 Quantities tested and results

One checks the values of the first two eigenfrequencies of modified structure.
One also checks the sum of the terms of the matrix of MAC (Modal Criterion Insurance) obtained between the deformed shapes with the interfaces for the model coupled and the deformed with the interfaces by static expansion of the deformed shapes of the model coupled obtained with the points of measurement. This indicator indicates the relevance of the reconstruction of the field to the interfaces.

Quantity tested	Reference	*Aster*	Difference
$f1$	$7.7807\ Hz$	$7.7852\ Hz$	0.058%
$f2$	$32.852\ Hz$	$32.845\ Hz$	0.022%
MAC (Somme)	2	1.99994	$6.\ 10^{-5}$

7 Modelization C

7.1 Characteristic of the modelization

In this modelization, one adds a damping in the model (AMOR_ALPHA = 10-4, AMOR_BETA = 1). One launches the procedure of modification via macro-command CALC_ESSAI. One uses method LMME (Local Model Modeshapes Expansion) for computation of the base of expansion.

7.2 Characteristics of the mesh

Models “support”:
Number and type of mesh: 9 elements of the type SEG2.

Model “modification”:
Number and type of mesh: 2 elements of the type SEG2.

7.3 Features tested

the procedure of structural modification proceeds in several stages. One tests the good progress of this procedure and the following features:
LIRE_RESU, PROJ_MESU_MODAL, MACR_ELEM_STAT, ASSE_MAILLAGE, DEPL_INTERNE, MAC_MODES, CALC_ESSAI.

7.4 Quantities tested and results

One checks the values of the first two eigenfrequencies of modified structure.
One also checks the sum of the terms of the matrix of MAC (Modal Criterion Insurance) obtained between the deformed shapes with the interfaces for the model coupled and the deformed with the interfaces by static expansion of the deformed shapes of the model coupled obtained with the points of measurement. This indicator indicates the relevance of the reconstruction of the field to the interfaces. One calculates also the criterion $IERI$ for the first two modes of structure.

Quantity tested	Reference	*Aster*	Difference
$f1$	$7.7807\,Hz$	7.7842 Hz	0.044%
$f2$	$32.852\,Hz$	32.848 Hz	0.009%
MAC (Somme)	2	1.99994	6. 10^{-5}
$IERI$ stiffness $(1,1)$	0	4.60 10^{-7}	4.60 10^{-7}
$IERI$ mass $(2,2)$	0	3.17 10.-12	3.17 10.-12

8 Modelization D

8.1 Characteristic of the modelization

It acts of the same modelization as the modelization C. This time, one does not call on macro-command CALC_ESSAI.

8.2 Characteristics of the mesh

Models “support”:
Number and type of mesh: 9 elements of the type SEG2.

Model “modification”:
Number and type of mesh: 2 elements of the type SEG2.

8.3 Features tested

the procedure of structural modification proceeds in several stages. One tests the good progress of this procedure and the following features:
LIRE_RESU, PROJ_MESU_MODAL, MACR_ELEM_STAT, ASSE_MAILLAGE, DEPL_INTERNE, MAC_MODES, CALC_ESSAI.

8.4 Quantities tested and results

One checks the values of the first two eigenfrequencies of modified structure.
One also checks the sum of the terms of the matrix of MAC (Modal Criterion Insurance) obtained between the deformed shapes with the interfaces for the model coupled and the deformed with the interfaces by static expansion of the deformed shapes of the model coupled obtained with the points of measurement. This indicator indicates the relevance of the reconstruction of the field to the interfaces. One calculates also the criterion $IERI$ for the first two modes of structure.

Quantity tested	Reference	*Aster*	Difference
$f1$	$7.7807\ Hz$	$7.7835\ Hz$	0.036%
f2	$32.852\ Hz$	$32.848\ Hz$	0.01%
MAC (Somme)	2	1.99994	$6.\ 10^{-5}$
$IERI$ stiffness $(1,1)$	0	$4.92\ 10^{-7}$	$4.92\ 10^{-7}$
$IERI$ mass $(2,2)$	0	3.17 10.-12	3.17 10.-12

9 Summary of the results

the got results depend on measured information and the projection base chosen for the expansion of measurement to the interfaces degrees of freedom. Here, the first five identified eigen modes were exploited and bases it selected expansion being static responses. The got results are correct.

Relative uncertainties on the first two eigenfrequencies obtained by the technique of structural modification used, are lower than $1\ \%$ solution obtained by direct computation.

The fields of displacement to the interfaces of the model coupled and the field with the interfaces obtained by static expansion of the fields at the points of measurement obtained on the structure modified are very close. The associated matrix of MAC is very close to the matrix identity. Criterion IERI is also close to 0 (modelizations C and D).