

SDLS112 - Extrapolation of measurements on a model 2D (test of GARTEUR)

Summary:

This case test makes it possible to validate the extrapolation of measurements obtained by an experimental model on a model 2D digital.

1 Problem of reference

1.1 Geometry of the digital model

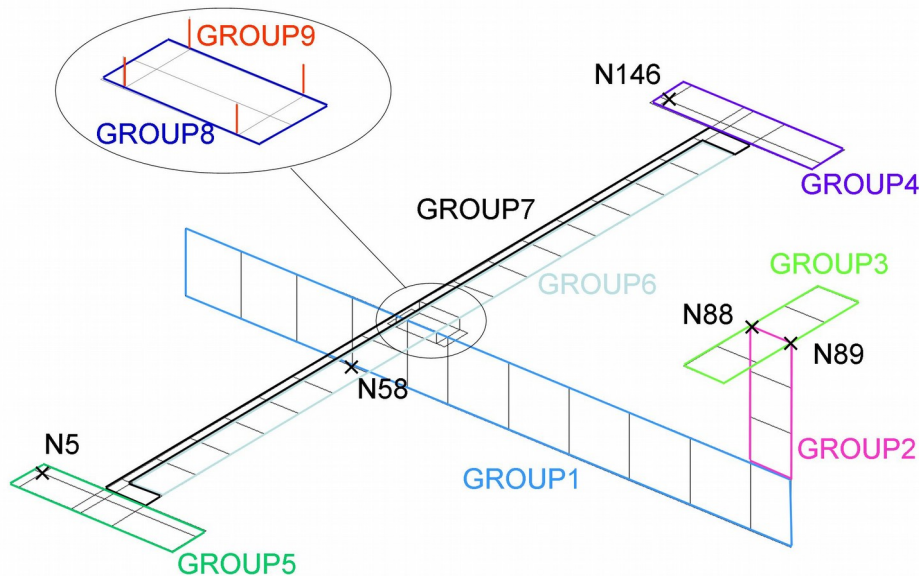


Figure 1-1: grid of the digital model

- Coordinates of the nodes (m) :
 - $N5 : (0.42, -0.93, 0.176)$
 - $N58 : (0.412, 0.0, 0.0)$
 - $N88 : (1.4, 0.0, 0.45)$
 - $N89 : (1.5, 0.0, 0.45)$
 - $N146 : (0.42, 0.93, 0.176)$
- Thickness (m) :
 - $e1=0.05$ GROUP1
 - $e2=0.01$ GROUP2, GROUP3, GROUP4, GROUP5, GROUP7
 - $e3=0.011$ GROUP6
 - $e4=0.016$ GROUP8
- formula
 - $GROUP10 : (N5, N88, N89, N146)$

1.2 Properties of materials

- GROUP1 with GROUP7
 - $E=7.2 \times 10^{10} Pa$ Young modulus
 - $\nu=0.34$ Poisson's ratio
 - $\rho=2700.0 kg.m^{-3}$ Density
- GROUP8
 - $E=2.1 \times 10^{11} Pa$ Young modulus
 - $\nu=0.29$ Poisson's ratio
 - $\rho=7800.0 kg.m^{-3}$ Density

- characteristics for *GROUP9* :

- Matrix of rigidity $K_{TR_D_L}$:

$$\begin{bmatrix} K & -K \\ -K & K \end{bmatrix}$$

with $[K] =$

$$\begin{bmatrix} 10^{12} & 0. & 0. & 0. & 0. & 0. \\ 0. & 10^{12} & 0. & 0. & 0. & 0. \\ 0. & 0. & 10^{12} & 0. & 0. & 0. \\ 0. & 0. & 0. & 10^8 & 0. & 0. \\ 0. & 0. & 0. & 0. & 10^8 & 0. \\ 0. & 0. & 0. & 0. & 0. & 10^8 \end{bmatrix}$$

- characteristics for *GROUP10* :

- Matrix of mass $M_{T_D_N}$: $[M] =$

$$\begin{bmatrix} 0.5 & 0. & 0. \\ 0. & 0.5 & 0. \\ 0. & 0. & 0.5 \end{bmatrix}$$

1.3 Boundary conditions and loadings

- Imposed displacement:

- node *N58* : $DRX = DRY = DRZ = DX = DY = DZ = 0.0$

1.4 Geometry of the experimental model

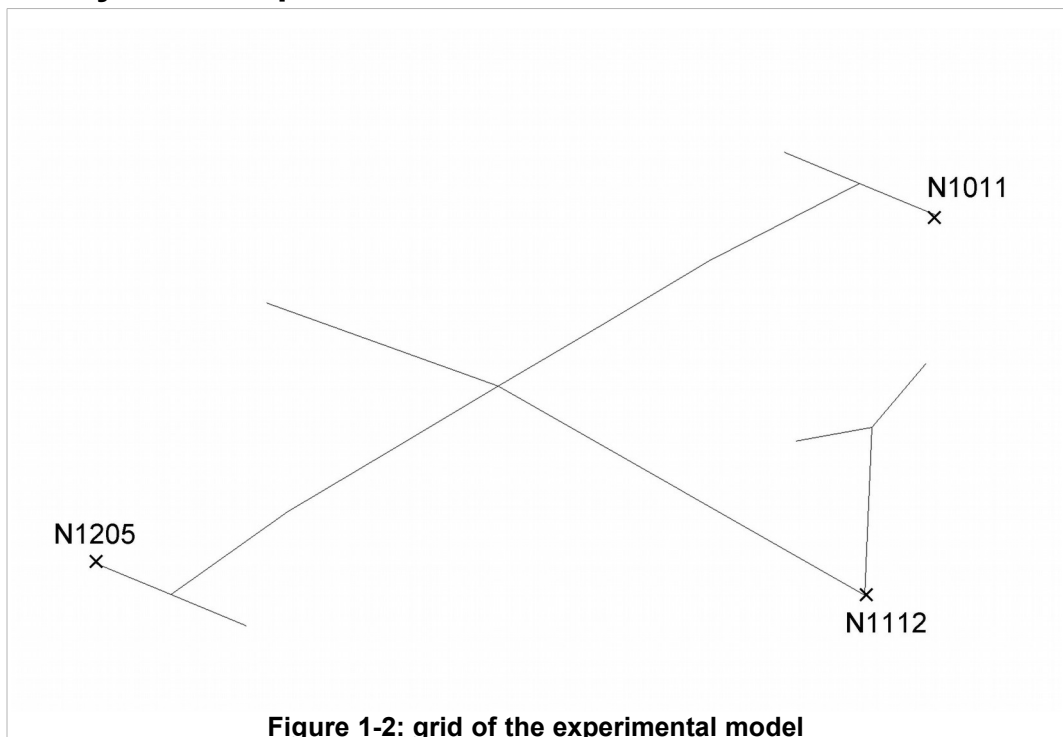


Figure 1-2: grid of the experimental model

Coordinates of the nodes formulates (*m*) :

N1011: (0.78; 0.98; 0.186)

$N1112:(0.42;-0.98;0.186)$
 $N1205:(1.45;-0.025;0.075)$

Group of mesh:

formula *NOEU* : Together elements segments of the experimental model

1.5 Properties of the experimental model

Characteristics for the group of mesh formulates *NOEU* :

- Matrix of rigidity $K_{T_D_N}$: formula
$$\begin{bmatrix} 10^{12} & 0. & 0. \\ 0. & 10^{12} & 0. \\ 0. & 0. & 10^{12} \end{bmatrix}$$

The mechanical characteristics of the experimental model do not have authority to represent the physics of the structure, but to create the structures of data necessary to the reading of the experimental results (the operator *LIRE_RESU* need for the matrices has indeed and *nume_ddl* associated with the structure to create the structure of data *result* associated).

2 Objective of the CAS-test, validation

The objective of the CAS-test is to validate the following orders more particularly:

- `MAC_MODES` : calculation of the matrix of MAC between two modal bases,
- `LIRE_RESU` : reading of experimental data to the format `IDEAS`,
- `MACRO_EXPANS` : expansion of data measured on a digital model made up of a “judicious” base of deformations.

The cas-test is based on the benchmark of the gartor (www.garteur.eu, group of research in aeronautics European).

The cas-test is commonplace here: the experimental data (FRF and clean modes) were initially calculated numerically before being exported with the format `IDEAS`. Their expansion on the same digital model must thus make it possible to find exactly the expected data.

2.1 Course of the CAS-test

- Digital model:
 - Definition and calculation of the modal base of the digital model,
 - Extraction of the modes according to their effective mass in the three directions (with `EXTR_MODES`)
 - Calculation of the matrix of correlation between two modal bases with `MAC_MODES` : this calculation is done to check the orthogonality of the base `MODESORT`.
- Experimental model:
 - Definition of the experimental model: the values of the mechanical characteristics are arbitrary, they are only used to create structures of coherent data for the reading of the experimental data,
 - Reading of the experimental harmonic answer,
 - Expansion of the experimental answer on the digital model (`MACRO_EXPANS`),
 - Reading of the experimental modes,
 - Expansion of the experimental modes on the digital model.

The expansion of the experimental data with `MACRO_EXPANS` consist of the succession of the orders `PROJ_MESU_MODAL` and `REST_GENE_PHYS` (and `PROJ_CHAMP`, for checking). The objective is to find the best combination of the clean vectors contained in the digital base in front of the keyword `BASE` who reproduce the behavior of the experimental data correctly. Provided modeling correctly reflects the physics of the measured structure, one interpolates the experimental data with the deformations contained in the digital model.

- `MODELisation a`: expansion of the FRF defined on the experimental model on a basis made up of the dynamic modes of the structure, and expansion of clean the modes modes identified on the experimental model on the same basis of expansion,
- `Modeling b`: expansion of the clean modes identified on the experimental model by using a base of expansion made up of static deformations definite on part of the DDL of the digital structure.

2.2 Validation of the results

The test of the results is done by expansion/reprojection. No reference external with calculation has thus to be defined. For modeling has, the test following are realized:

- test of the orthogonality of the clean modes extracts MODESY (5 modes): the matrix obtained is the matrix unit,

	Component	Reference
Matrix obtained by MAC_MODES	SOMM	5.0

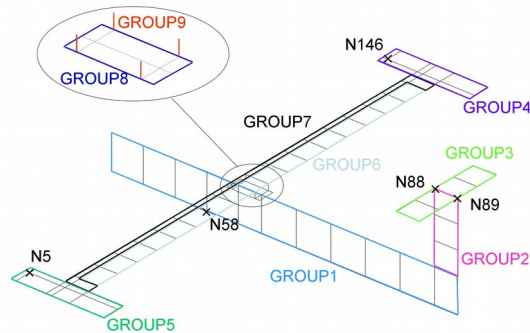
- Wide FRF: test of the differences between experimental FRF and FRF wide/reprojetées, on a component of three nodes: the following ratio is calculated:

$$R = \frac{RMS(|FRF_{exp} - FRF_{et}|)}{RMS(FRF_{exp})}$$

- wide clean modes: test of the orthogonality of the extended base, by making MAC of this one by itself (MAC_ET),
- wide clean modes: test of the diagonal components of the matrix of MAC enters the extend modes modes digital (MAC_ETNX), for modeling A, and between the extend modes/reprojetés and the experimental modes for modeling B (MAC_RDEX).

3 Modeling A

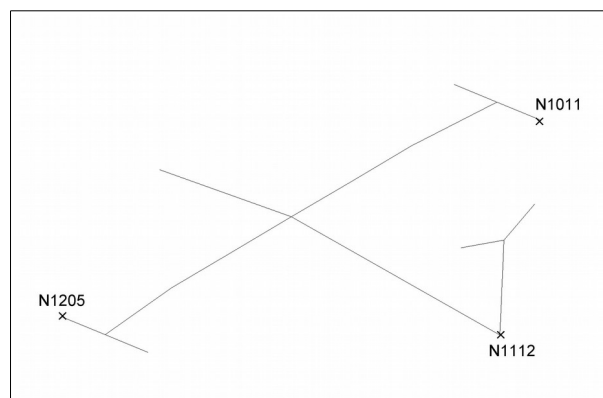
3.1 Digital model



GROUP1 with GROUP8 : Modeling DKT
 GROUP9 : Modeling DIS_TR
 formula GROUP10:(N5 , N88 , N89 , N146) :Modeling DIS_T

Many nodes	138	
Many meshes	86	That is to say:
		SEG2 4
		QUAD4 82

3.2 Experimental model



Modeling DIS_T : the characteristics of the experimental model do not have physical reality, and aim to only be able to affect a classification and matrices which allow the postprocessing of the results. Thus, lira an experimental result (LIRE_RESU), it is necessary before to have defined matrices of mass and stiffness, and to do a calculation of MAC between two bases of experimental modes, it is necessary before to have defined one NUME_DDL.

3.3 Parameters of the expansion

- Base expansion: dynamic modes calculated on the dynamic model,
- 21 modes are calculated in the band $[0.0, 280.0]$,

3.4 Sizes tested and results

Matrix of the digital modes: it must be perfectly orthogonal within the meaning of MAC. The sum of its components must thus be worth 5 (many modes contained in the structure `MODESY`).

	Component	Reference	Tolerance
Matrix obtained by <code>MAC_MODES</code>	<i>SOMM</i>	formula 5.0	10^{-10}

It is checked that the difference between FRF measured and extended/reprojetées is relatively close to zero.

	Node	Component	Reference (m/s^{-2})	Tolerance
Relative variation on acceleration	<i>N1011</i>	<i>D3</i>	0.0	10^{-2}
	<i>N1112</i>	<i>D3</i>	0.0	10^{-2}
	<i>N1205</i>	<i>D2</i>	0.0	10^{-2}

It is checked that auto-MAC of the extend modes is close to the matrix identity, the extend modes having to be orthogonal. The result must be relatively correct (tolerance of 10^{-2}). Note: for modeling B, this test is not carried out, because in this case, the extend modes do not check the condition of orthogonality. The dynamic base of expansion gives better results here

	Component	Reference	Tolerance
Matrix obtained by <code>MAC_MODES</code>	<i>SOMM</i>	21.0	0.01

It is checked that the diagonal of MAC between extend modes and the modes digital are close to 1. For each term of the diagonal (21 modes in all), one carries out the following test:

	Component	Reference	Tolerance
Matrix obtained by <code>MAC_MODES</code>	<i>ii, ii</i>	1.0	0.01

4 Modeling B

4.1 Models digital and experimental

Modelings are identical to the case of modeling A.

4.2 Base expansion

The base of expansion is obtained with the operator `MODE_STATIQUE`. It is theoretically necessary to create the deformations associated with the experimental degrees of freedom, i.e. to choose the nodes placed at the level of the points of measurement.

Here, the points of measurement do not correspond to nodes defined on the digital model. Two solutions are suggested:

- Short list of nodes: for each experimental node, one chose a node of the digital model which is nearest; the correspondence enters the nodes of the two models the report of calculation of `PROJ_MESU_MODAL`,
- Same manner, one defines a long list, which contains all the nodes located near the nodes of measurement; the static modes resulting from this list are however redundant for the resolution of the opposite problem: in this case, the opposite problem is badly posed, and it is necessary to regularize it, by using the keywords `EPS`, `REGUL` and `COEF_PONDER` in `MACRO_EXPANS`; by default, that list is in comment.

4.3 Sizes tested and results

Some differences are to be noted between the results of modeling A and B. the base of expansion is the base of the static modes. It should be noted that those are defined (with the operator `MECA_STATIQUE`) on a matrix of stiffness for which the degrees of freedom corresponding to the static statements are embedded. It is thus not the same one `NUME_DDL` that for the digital modes: one thus cannot to compare the extend modes and the digital modes by criterion of MAC (the latter are thus even not calculated). One thus carries out a comparison of the experimental modes compared to the extend modes/reprojetés.

The static base of expansion is not very good quality, the orthogonality of the extend modes is not carried out. It is not tested here.

	Component	Reference	Tolerance
Matrix obtained by <code>MAC_MODES</code>	<i>SOMM</i>	21.0	0.01

It is checked that the diagonal of MAC between extend modes and the modes digital are close to 1. For each term of the diagonal (21 modes in all), one carries out the following test:

	Component	Reference	Tolerance
Matrix obtained by <code>MAC_MODES</code>	<i>ii, ii</i>	1.0	0.01