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

**Abstract:**

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

# 1 Problem of reference

## 1.1 of the digital model

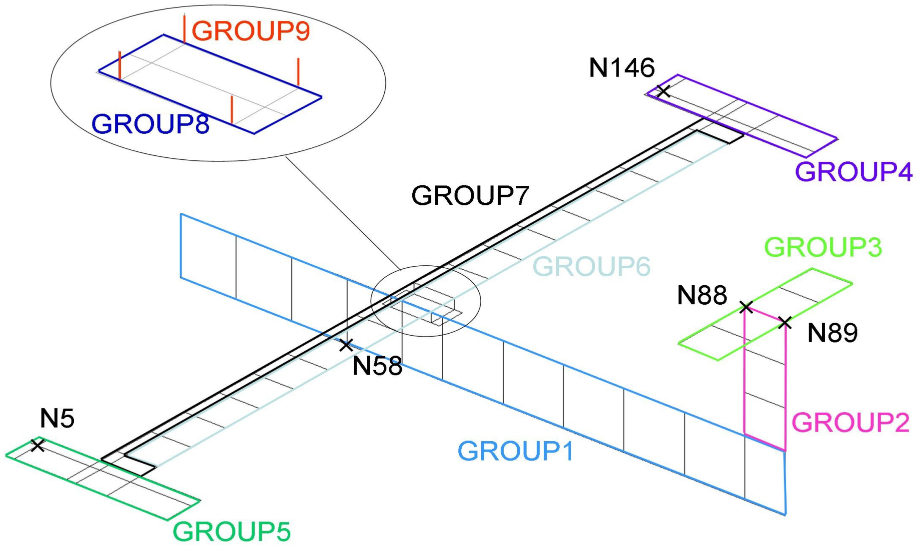



**Figure 1-1: mesh of the model numeriqueGeometry**

- Coordinated 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 $(m)$ :
  - $e1=0.05$ $GROUP1$
  - $e2=0.01$ $GROUP2, GROUP3, GROUP4, GROUP5, GROUP7$
  - $e3=0.011$ $GROUP6$
  - $e4=0.016$ $GROUP8$
- formulate
  - $GROUP10:(N5, N88, N89, N146)$

## 1.2 Properties of the materials

- $GROUP1$ with $GROUP7$
  - $E=7.2\times10^{10} Pa$ Modulus Young
  - $\nu=0.34$ Poisson's ratio
  - $\rho=2700.0\,kg.m^{-3}$ Density
- $GROUP8$
  - $E=2.1\times10^{11} Pa$ Modulus Young
  - $\nu=0.29$ Poisson's ratio
  - $\rho=7800.0\,kg.m^{-3}$ Density

- characteristics for $GROUP9$ :
- Stiffness matrix 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 $GROUP10$ :

  - Mass matrix 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:

  - the node is outside the field of definition with a right profile of the EXCLU type node: $N58 \quad DRX=DRY=DRZ=DX=DY=DZ=0.0$

## 1.4 Geometry of the experimental model

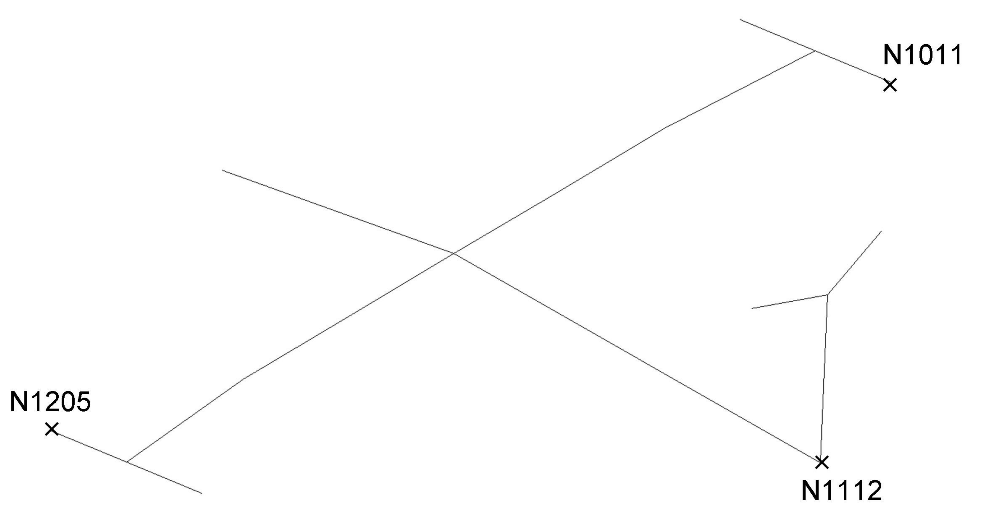



**Figure 1-2: mesh of the experimental model**

Coordinated of the nodes formuleformule $(m)$ :

$N1011 : (0.78 ; 0.98 ; 0.186)$
$N1112 : (0.42 ; -0.98 ; 0.186)$
$N1205 : (1.45 ; -0.025 ; 0.075)$

Group of mesh:

formuleformule $NOEU$ : Together elements segments of the experimental model

## 1.5 Properties of the experimental model

Characteristic for the group of mesh formuleformule $NOEU$ :

- Stiffness matrix K_T_D_N : formuleformule $\begin{bmatrix} 10^{12} & 0. & 0. \\ 0. & 10^{12} & 0. \\ 0. & 0. & 10^{12} \end{bmatrix}$

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

# 2 Purpose of the benchmark, validation

the purpose of the benchmark is to validate the following commands more particularly:

- MAC_MODES : computation 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 deformed shapes.

The benchmark is based on the benchmark of the gartor (www.garteur.eu, group of search in aeronautics European).

The benchmark is commonplace here: the experimental data (FRF and eigen 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 digital

- Model benchmark:
  - Definition and computation of the modal base of the digital model,
  - Extraction of the modes according to their effective mass in the three directions (with EXTR_MODES)
  - Computation of the matrix of correlation between two modal bases with MAC_MODES: this calculation is done to check the orthogonality of base MODESORT.

- Model experimental:
  - Definition of the experimental model: the values of the mechanical characteristics are arbitrary, they only serve to create coherent data structures for the reading as the experimental data,
  - Reading of the experimental harmonic response,
  - Expansion of the experimental response on the model numerical (MACRO_EXPANS),
  - Reading of the experimental modes,
  - Expansion of the experimental modes on the model numerical.

The expansion of the experimental data with MACRO_EXPANS consists of the succession of commands PROJ_MESU_MODAL and REST_GENE_PHYS (and PROJ_CHAMP, for checking). The purpose is to find the best combination of the eigenvectors contained in the numerical base in front of key word BASE which reproduce the behavior of the experimental data correctly. Provided the modelization correctly reflects the physics of measured structure, one the model interpolates the experimental data with the deformed shapes contained in numerical.

- Modelization a: expansion of the FRF defined on the model experimental on a basis made up of the dynamic modes of structure, and expansion of the eigen modes modes identified on the model experimental on the same basis of expansion,
- Modelization b: expansion of the eigen modes identified on the model experimental by means of a basis of expansion made up of static deformed shapes definite on part of the DDL of numerical structure.

## 2.2 Validation of the results

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

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

| | Component | Reference |
|---|---|---|
| Stamps obtained by `MAC_MODES` | `SOMM` | 5.0 |

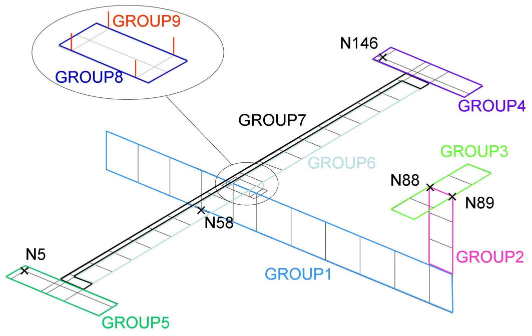
- wide FRF: test of the differences between experimental FRF and FRF wide/reprojetées, on a component of three nodes: the following ratio is calculated:

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

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

# 3 Digital modelization

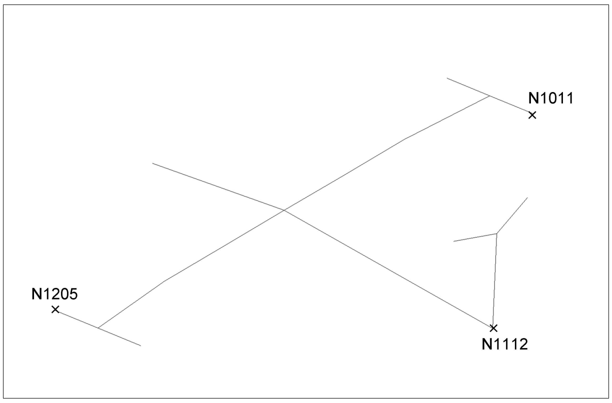
## 3.1 A Model




$GROUP1$ with $GROUP8$ : Modelization DKT
$GROUP9$ : Modelization DIS_TR
formuleformule $GROUP10:(N5, N88, N89, N146)$ : Modelization DIS_T

| | | | | |
|---|---|---|---|---|
| Many nodes | 138 | | | |
| Number of meshes | 86 | Is: | | |
| | | | SEG2 | 4 |
| | | | QUAD4 | 82 |

## 3.2 Models experimental




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

## 3.3 Parameters of the expansion

- Bases expansion: dynamic modes calculated on the model dynamic,

- 21 modes are calculated in the tape $[0.0, 280.0]$,

## 3.4 Quantities tested and results

Stamps numerical 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 structure MODESY).

| | Component | Reference | Tolerance |
|---|---|---|---|
| Stamps obtained by MAC_MODES | $SOMM$ | formuleformule $5.0$ | $10^{-10}$ |

One checks 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 | $N1011$ | $D3$ | $0.0$ | $10^{-2}$ |
| | $N1112$ | $D3$ | $0.0$ | $10^{-2}$ |
| | $N1205$ | $D2$ | $0.0$ | $10^{-2}$ |

One checks that auto--MAC of the extend modes is close to the matrix identity, the extend modes having to be orthogonal. Result must be relatively correct (tolerance of $10^{-2}$ ). Note: for the modelization 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 here better results

| | Component | Reference | Tolerance |
|---|---|---|---|
| Stamps obtained by MAC_MODES | $SOMM$ | $21.0$ | $0.01$ |

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

| | Component | Reference | Tolerance |
|---|---|---|---|
| Stamps obtained by MAC_MODES | $ii, ii$ | $1.0$ | $0.01$ |

# 4 formulates Modelization

## 4.1 Model digital and experimental

the modelizations are identical to the case of modelization A.

## 4.2 Base expansion

the base of expansion is obtained with operator MODE_STATIQUE . It is theoretically necessary to create the deformed shapes 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 model numerical. Two solutions are suggested:

- Nodes list short: for each experimental node, one chose a node of the digital model which is nearest; the correspondence between the nodes of the two models in the ratio of computation of PROJ_MESU_MODAL,
- In the same way, 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 inverse problems: in this case, the inverse problems are badly posed, and it is necessary to regularize it, by means of key words EPS, REGUL and COEF_PONDER in MACRO_EXPANS; by default, that list is in comment.

## 4.3 Quantities tested and results

Some differences are to be noted between the results of the modelization A and B. the base of expansion is the base of the static modes. It should be noted that those are defined (with operator MECA_STATIQUE) on a stiffness matrix for which the degrees of freedom corresponding to the static statements are clamped. It is thus not the same NUME_DDL as for the numerical modes: one cannot thus compare to the extend modes and the numerical 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 |
|---|---|---|---|
| Stamps obtained by MAC_MODES | $SOMM$ | 21.0 | 0.01 |

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

| | Component | Reference | Tolerance |
|---|---|---|---|
| Stamps obtained by MAC_MODES | $ii, ii$ | 1.0 | 0.01 |