Macro-order CALC_ESSAI

1 Goal

Launching of the macro-order CALC_ESSAI, which makes it possible to launch calculations of identification and expansion on telegraphic telegraphic structures and of launching calculations of structural modification:

- expansion of experimental data on basis of digital deformations, by using the macro-order MACRO_EXPANS (which carries out the elementary operations EXTR_MODE, PROJ_MESU_MODAL, REST_GENE_PHYS and PROJ_CHAMP),
- identification of efforts on an unspecified structure, with decomposition of the movement on modal base and localization *a priori* loadings,
- structural modification: to evaluate the effect of a modification knowing the experimental modal model of the initial structure and the model with the finite elements of the made modification

Contents

2 Syntax

```
CALC_ESSAI (
```

1. Expansion of an experimental model on digital basis (MACRO_EXPANS)

```
◊ EXPANSION = _F (♦ CALCULATION = calculation,
[mode_meca]

                  ♦ MEASUREMENT = measurement,            [mode_meca,
dyna_harmo]

                  ♦ NUME_MODE_CALCUL = L_I,                      [L_I]

                  ♦ NUME_MODE_MESURE = L_I,                      [L_I]

                  ◊   RESOLUTION =/'SVD',                     [DEFECT]
                                 /'LU',

                  # If RESOLUTION = 'SVD',
                         ◊ EPS = /0. ,
[DEFECT]
                                 /epsilon,                         [R]
                ),
```

2. Structural modification

```
◊ MODIFSTRUCT  = _F (♦ MEASUREMENT = measurement,
[mode_meca]

                     ♦ MODELE_SUP = model,                     [model]

                     ♦ MODELE_MODIF = model,                   [model]

                     ♦ NUME_MODE_CALCUL = L_I,                   [L_I]

                     ♦ NUME_MODE_MESU = L_I,                     [L_I]

                     ♦ MATR_RIGI = matrix,                 [matr_asse]

                     ◊ RESOLUTION =/'ES',                   [DEFECT]
                                   /'LMME',

                     If RESOLUTION = 'LMME',

                     ♦ MATR_MASS = matrix,                 [matr_asse]

                    ),
```

If MODIFSTRUCT:

```
◊ GROUP_NO_CAPTEURS = _F (♦ GROUP_NO = gr_no,             [mode_meca]

                          ♦ . NOM_CMP = nom_cmp,
[matr_asse]
                         ),

◊ GROUP_NO_EXTERIEUR = _F (♦ GROUP_NO = gr_no,            [mode_meca]
```

```
                         ♦ NOM_CMP = nom_cmp,            [matr_asse]
                        ),

◊ RESU_MODIFSTRU = _F ( ◊ MODE_MECA = mode,
[mode_meca]

                        ◊ MODEL = model,                    [model]

                        ◊ GRID = grid,              [grid]

                        ◊ Digital NUME_DDL=,
[nume_ddl]

                        ◊ MASS_MECA = mass,                [matr_asse]

                        ◊ RIGI_MECA = raid,                 [matr_asse]

                        ◊ AMOR_MECA = amor,                 [matr_asse]

                        ◊ MACR_ELEM = water caltrop,
[macr_elem_stat]

                        ◊ PROJ_MESU = proj,                 [mode_gene]

                       | ◊ BASE_LMME = ba_lmme,             [mode_meca]
                       | ◊ BASE_ES = ba_es,                 [mode_meca]

                        ◊ MODE_STA = modesta          [mode_stat_force]
                      ),
```

5. Identification of efforts with localization a priori

```
◊ IDENTIFICATION = _F (♦ BASE = bases,
[mode_meca]

                        ♦ INTE_SPEC = intsp,           [interspectre]

                        ♦ OBSERVABILITY = mode_obs,         [mode_meca]

                        ♦ COMMANDABILITE = mode_com,        [mode_meca]

                        ◊   EPS = /0. ,
[defect]
                                 /epsilon,                         [R]
                        ◊   ALPHA = /0. ,
[defect]
                                   /alpha,                         [R]

◊  RESU_IDENTIFICATION = _F (♦ TABLE = table,              [function]
                           ),
                        ),
)
```

3 Introduction

3.1 Objectives of the order

The macro-order CALC_ESSAI allows to carry out calculations of identification starting from measured data: expansion of experimental data on digital model, identification of efforts, and structural modification.

4 Use of the modal expansion (EXPANSION)

The mode of use of this option is not very relevant, it is especially useful for the validation. It is preferable, if one wishes to carry out a modal expansion, to use the order directly MACRO_EXPANS, or the sequence PROJ_MESU_MODAL, REST_GENE_PHYS and PROJ_CHAMP.

4.1 Keywords MEASUREMENT and NUME_MODE_MESURE

♦ MEASUREMENT = measurement,

Concept sd_resultat of type mode_meca or dyna_harmo who contains the modes to be extended on the digital model.

♦ NUME_MODE_MESURE = L_I,

Allows to select the sequence numbers of the modes which one wishes to extend.

4.2 Keyword CALCULATION

♦ CALCULATION = calculation,

Concept sd_resultat of the mode_meca type which will be the base of expansion. The choice of the base of expansion is important for the quality of the results.

♦ NUME_MODE_CALCUL = L_I,

Allows to select the sequence numbers of the modes which one wishes to use in the base of expansion. It is more interesting to keep only the modes which “resemble” the deformations to extend, the criterion of resemblance which can be obtained by calculation of MAC.

4.3 Keywords RESOLUTION and EPS

The expansion consists of the resolution of an opposite problem for the determination of the generalized coefficients PROJ_MESU_MODAL. The methods of inversion and coefficients of regularization are detailed in the user's documentation of this operator (cf [U4.73.01]).

5 Structural modification (MODIFSTRUCT)

This technique of structural modification is based on the method of under-structuring. The first substructure corresponds to the initial structure and the second substructure corresponds to the made modification.
The initial structure is modelled starting from in experiments identified clean modes. The second substructure is modelled numerically by finite elements. Except very particular case, the points of measurement are not at the level of the interface between the initial structure and the modification. It

is thus necessary to pass by an intermediate stage which consists in carrying out an expansion measurement on the degrees of freedom interfaces. This expansion is made via the digital model support. The following paragraphs describe the keywords necessary in CALC_ESSAI for this functionality.
More details on the method and the principles of implementation in Code_Aster are given in U2.07.03 documentation.

5.1.1 Keyword MEASUREMENT

♦ MEASUREMENT = measurement [mode_meca]

measurement is the name of the concept which contains the identified clean modes.

5.1.2 Keyword MODELE_SUP

♦ MODELE_SUP = model [model]

Name of the model support on which the base of expansion is built.

5.1.3 Keyword MODELE_MODIF

♦ MODELE_MODIF = model [model]

Name of the model of the modification made to the initial structure.

5.1.4 Keyword MATR_RIGI

♦ MATR_RIGI = matrix, [matr_asse]

Matrix of rigidity defined on the model support, necessary for the calculation of the static modes.

5.1.5 Keyword RESOLUTION

```
♦ RESOLUTION =   /'ES',                [DEFECT]
                 /'LMME'
```

This keyword makes it possible to choose the method used for calculation of the base of expansion. ES corresponds to the static expansion and LMME corresponds to “Room Model Modeshapes Expansion”.

5.1.6 Keyword NUME_MODE_MESU

♦ NUME_MODE_MESU = L_I, [l_I]

This keyword makes it possible to select the numbers of the modes to be exploited among the identified clean modes. By default, one takes into account all the clean modes of the concept measures.

5.1.7 Keyword NUME_MODE_CALCUL

♦ NUME_MODE_CALCUL = L_I, [l_I]

This keyword makes it possible to select the numbers of the modes to be used among the vectors of the base of expansion. By default, one takes into account all the vectors of the base of expansion.

5.1.8 Keyword GROUP_NO_CAPTEURS

```
◊ GROUP_NO_CAPTEURS = _F (♦  GROUP_NO = gr_no,    [mode_meca]
                          ♦  NOM_CMP = nom_cmp,  [matr_asse]
```

This keyword factor makes it possible to select the list of the groups of nodes which will be used for the calculation of the static modes associated with the points of measurement. These groups of nodes are defined on the model support.

5.1.9 Keyword GROUP_NO_EXTERIEUR

```
◊ GROUP_NO_EXTERIEUR = _F (  ♦  GROUP_NO = gr_no,    [mode_meca]
                             ♦  NOM_CMP = nom_cmp,  [matr_asse]
```

This keyword factor makes it possible to define the “external” groups of nodes where will be condensed measured information. These groups of nodes must at least contain the interface between the model support and the model of the modification.

5.2 Produced concepts

The user can specify the names of the concepts produced by the interface by informing the keyword factor RESU_MODIFSTRU. These concepts could then be used for later calculations.

◊ MODE_MECA = mode,   [mode_meca]

mode will be the name of the concept which contains the clean modes of the modified structure.

◊ MODEL = model,   [model]

model will be the name associated with the model with the modified structure.

◊ GRID = grid,   [grid]

grid will be the name of the grid associated with the modified structure.

◊ Digital NUME_DDL=,   [nume_ddl]

digital will be the name of the concept nume_ddl associated with the modified structure.

◊ MASS_MECA = mass,   [matr_asse]

mass will be the name of the concept which contains the matrix of mass assembled of the modified structure.

◊ RIGI_MECA = raid,   [matr_asse]

raid will be the name of the concept which contains the matrix of rigidity assembled of the modified structure.

◊ AMOR_MECA = amor,   [matr_asse]

amor will be the name of the concept which contains the matrix of damping assembled of the modified structure.

◊ MACR_ELEM = macrel,   [macr_elem_stat]

macrel will be the name of the concept which contains the macronutrient where measurement is condensed.

◊ `PROJ_MESU = proj, [mode_gene]`

`proj` will be the name of the concept which contains the generalized coordinates of the identified modes relating to the base of expansion.

◊ `BASE_LMME = balmme, [mode_meca]`

`balmme` will be the name of the base of expansion resulting from method LMME.

◊ `BASE_ES = bases, [mode_meca]`

`base` will be the name of the base of expansion resulting from the static expansion (method ES).

◊ `MODE_STAT = modest, [mode_stat_force]`

`modest` will be the name of the concept which contains the static modes associated with the points with measurement.

6 Identification of localised efforts *a priori* (`IDENTIFICATION`)

6.1 Keyword `INTE_SPEC`

♦ `INTE_SPEC = intsp`

Inter-spectrum which will be used as displacements, to find the associated efforts.

6.2 Keywords `OBSERVABILITY` and `COMMANDABILITE`

♦ `OBSERVABILITY = observ`
♦ `COMMANDABILITE = command`

Concept of the type `mode_meca`. Correspond respectively to the objects $C\Phi$ and $\Phi^T B$ described in the section 6.4. ON can is to choose one `mode_meca` gross, that is to say to manufacture it with the operator `OBSERVATION` (U4.90.03).

6.3 Keywords `ALPHA` and `EPS`

♦ `ALPHA = real`
♦ `EPS = real`
Parameters of regularization. More details section 6.5.

6.4 Recall of the theoretical principles

The identification of the efforts supposes that one can break up the movement of the structure studied on modal basis:

$$y(\omega)=[C\Phi].[Z(\omega)]^{-1.}[\Phi^T B].f(\omega)$$

In the following equations, one will omit the dependence compared to ω . Φ is a base of modal deformations associated with the studied structure. In theory, it is the base of the continuous deformations. In practice, one in general uses a base defined on a digital model with a relatively fine discretization. This base can be calculated numerically, or be the result of a modal expansion. The

operator C allows to project this base of deformations on the subspace of the observable degrees of freedom.
The operator B allows to project the base of deformations on a set of degrees of freedom called actuators: one finds here one of the fundamental assumptions of the identification: **the identified efforts are located on declared degrees of freedom *a priori*** by the user, as one made to declare the degrees of freedom of measurement (use of the operator `OBSERVATION`). The objective is of to decrease to the maximum the number of unknown factors to be determined, which makes it possible to avoid the problems of under-determination of the problem.
To identify the efforts amounts reversing the system above:

$$f=\left[\Phi^T B\right]^{-1.}\left[Z\right].\left[C\Phi\right]^{-1.}y \qquad (8\text{-}1)$$

NB: the base Φ can be different on the right and on the left from Z: it is the case when measurements available are deformations. The equation connecting the effort to measurement is written then:

$$f=\left[\Phi^T B\right]^{-1.}\left[Z\right].\left[C\Psi\right]^{-1.}\epsilon \qquad (8\text{-}2)$$

where the matrix Ψ is the data of the modes in deformation. Attention however: to write this last equation is an abuse language, because the passage of displacements to the deformations should be normally written in the operator of projection (who, let us recall it, is linear in the case of small deformations), and not while replacing Φ by Ψ . But in practice, a base of modes is often imported Ψ directly since the software of measurement.

6.5 Concepts to be used

Observability and commandability:
The calculation of $\left[C\Phi\right]$ is made within the framework "Definition of the concept of observability", in which one gives the base of modes Φ , and an experimental model qu contains the degrees of freedom on which one projects it. One chooses in the degrees of freedom of the experimental model (gathered by groups of node and mesh) the degrees of freedom corresponding to measurement. One can thus choose only one direction if one used during the measurement of the monoaxial sensors. It is in addition possible to carry out a change of reference mark. For more detail, to refer to the documentation of the operator `OBSERVATION` (U4.90.03).

- **It is important that the nodes the components declared in the inter-spectrum are coherent with the degrees of freedom of the concept of observability**. If the inter-spectrum is read by `LIRE_INTE_SPEC` (`FORMAT = 'IDEAS'`), the nodes are defined at the head of each dataset; the table then created by this operator keeps the notations of this file.

The calculation of $\left[\Phi^T B\right]$ is made within the framework "Definition of the concept of commandability". The choice of the degrees of freedom and the changes of potential reference marks are done according to the same rule.
Each mitre has a button of basic choice, which allows, as for equation 8-2, to use two different bases.

Regularization:
The inversion of the transfer transfer function is done in two stages:
- inversion of $\left[C\Phi\right].\left[Z\right]^{-1}$, which makes it possible to calculate the modal efforts,
- inversion of $\left[\Phi^T B\right]$, which makes it possible to calculate the efforts on physical basis.

These two stages are done by SVD (SVD of LinearAlgebra, module of python, which calls on a bookstore lapack_lite, in the package numpy). It is possible to regularize the inversion in three manners:

1) truncation of the SVD (parameter ε),
2) regularization of Tikhonov (parameter α),

3) control of the slope: it is possible to multiply the parameter α by $(\omega-\omega_i)^m$, where ω_i is the own pulsation of the mode and m a parameter to be determined; that allows D to control the slope of the curve obtained for the high frequencies, when the measured signal is strongly made sound effects for out of HF.