Operator PROJ_MESU_MODAL

1 Drank

To extrapolate experimental measurements on a digital model in dynamics.

The experimental data can be displacements, velocities, accelerations, strains or stresses. They are defined as a function of time or the frequency, or in the form of list.

It is a question of calculating the model the generalized coordinates of measurement relative to a base of expansion defined on numerical. This base of expansion (deformed, forced or strains) is calculated as a preliminary according to a concept of the mode_meca type. The basic vectors are then restricted with the measured degrees of freedom. Spatial association between the points of measurement and the nodes of the numerical mesh can be carried out manually ou/et automatically. The computation generalized coordinates is carried out by resolution of a problem of minimization of the least squares type, possibly regularized according to the method of Tikhonov.

Is applicable to any type of model (1D, 2D and 3D).

Product a data structure of the tran_gene type, harm_gene or mode_gene.

Contents

2 Syntax

```
repgene [*_gene] = PROJ_MESU_MODAL
   (  ♦MODELE_CALCUL=
            _F (   ♦BASE=     bases
         [mode_meca]
                 ♦ MODELE=    mocalc                         [model]
                   ),
          ♦   MODELE_MESURE =
            _F (   ♦MESURE=       measure
         [dyna_trans]
                                                    /      [dyna_harmo]
                                                    /      [mode_meca]
                                                    /      [mode_meca_c]

                ♦MODELE=      mostru                         [model]
                ◊NOM_CHAM=          |   ' DEPL'
         [DEFAULT]
                              |   ' VITE'
                              |   ' ACCE'
                              |   ' SIEF_NOEU'
                              |   ' EPSI_NOEU'
                   ),
      will ◊NOM_PARA=lpara
[l_Kn]
      ◊CORR_MANU=
            _F (   ♦NOEU_MESURE=     no1                     [node]
                 ♦ NOEU_CALCUL=  no2                     [node]
                   ),
      ◊RESOLUTION=
            _F (    ◊  METHODE=/        "READ"
         [DEFAULT]
                              /   "SVD"
                   SiMETHODE  = "SVD'   then:
                                ◊EPS=/0             .
                                [DEFAULT]
                                          /eps                 [R]
                 ◊  REGUL=/          "NON"
[DEFAULT]
                           /   "NORM_MIN"
                           /   "TIK_RELA"
                   SiREGUL   ! = "NON'  then :
                              ◊/COEF_PONDER=/0             .   [DEFAULT]
                                                    /w      [l_R]
                                /COEF_PONDER_F       =w_f
            [l_fonction]
                   ),
    )
```

```
If measurement = [dyna_trans]      then repgene = [tran_gene]
If measurement = [dyna_harmo]      then repgene = [harm_gene]
If measurement = [mode_meca]          then repgene = [mode_gene]
If measurement = [mode_meca_c]        then repgene = [mode_gene]
```

3 Operands

3.1 Factor key word MODELE_CALCUL

This factor key word gathers the characteristics of the digital model on which one wants to extrapolate measurement. It should not appear qu only once".

3.1.1 MODEL operand

♦**MODELE** = mocalc

Name of the digital model on which is built the base D" expansion.

3.1.2 Operand BASE

♦**BASE** = bases

Name of the base of expansion. This base is of mode_meca type. This concept was possibly enriched, via command CALC_CHAMP, by the strain fields and/or of modal stresses calculated with the nodes.

3.2 Factor key word MODELE_MESURE

This factor key word gathers information on the measured field (observed) that one wishes to extrapolate on the model numerical. It should appear only once.

3.2.1 MODEL operand

♦**MODELE** = mostru

Name of the model associated with the observation.

3.2.2 Operand MESURE

♦**MESURE** = Name

measurement of the measured field.

This key word determines by the operator the type of product concept PROJ_MESU_MODAL. If measurement is of dyna_trans type, the product concept is of tran_gene type. If measurement is of dyna_harmo type, the product concept is of harm_gene type. If measurement is of mode_meca type, or mode_meca_c, the product concept is of mode_gene type.

3.2.3 Operand NOM_CHAM

```
◊NOM_CHAM  = | "DEPL"                                  [DEFAULT]
             | "QUICKLY"
             | "ACCE"
             | "SIEF_NOEU"
             | "EPSI_NOEU"
```

This key word makes it possible to choose fields to read and to extrapolate. The components of the field considered are those which were measured (observed) and were read in `measurement`. For time, one does not affect a weight coefficient on the various components of the field: each component has the same weight during the inversion.

3.3 Operand NOM_PARA

`◊NOM_PARA  will =lpara`

List of symbolic names of the parameters of the measured data which one wishes to transmit to modele generalized.

3.4 Factor key word CORR_MANU

This factor key word makes it possible to the user to manually define (to overload) the correspondence between the node of observation and the similar node of the digital model. This factor key word is optional, but it can appear as many times as necessary. On the other hand, the operands under this factor key word go per pair: `a NOEU_MESURE` must have its `NOEU_CALCUL` associated.
If this factor key word is absent, spatial association between the points of measurement and the nodes of the numerical mesh is automatically by means of carried out the shape function of the element of the digital model to determine the value of the field on the point of measurement.

3.4.1 Operand NOEU_MESURE

♦NOEU_MESURE `= no1`

This key word informs the name of the node of observation which one wishes to associate with the node of the digital model `no2`. In certain cases, mesh file associated with measurement is with the universal format (Ideas format), one cannot thus know a priori the name Aster associated with the node. It is thus necessary, in this case, of reading the mesh resulting from `PRE_IDEAS`, by `LIRE_MAILLAGE` in order to be able to name of the node.

3.4.2 Operand NOEU_CALCUL

♦NOEU_CALCUL `= no2`

This key word informs the name of the node of the digital model which one wishes to associate with the node observation `no1`.

3.5 Factor key word RESOLUTION

One defines the method of resolution here and to use parameters associated with this method.

3.5.1 Operand METHODE

```
◊METHODE   =  "READ"
             /"SVD"
```

One proposes the method READ (decomposition in LU Lower-Upper) and method SVD (decomposition in singular values) for computation of the opposite matrix. For the method SVD, the number of singular values to take into account depends on the value of eps that the user informs under operand EPS. By default, one adopts the method READ.

3.5.2 Operand EPS

This key word is used if method SVD is chosen.

```
◊EPS=/        0.
          /eps
```

This key word gives the value from which a singular value is regarded as null. It determines the number of singular values thus to exploit during the resolution. A eps equal to zero means that all the singular values are to be taken into account. eps equal to 1 means that one considers only the greatest value singular. By default, one chooses EPS = 0.

3.5.3 Operand REGUL

```
◊REGUL=/         "NON"
             /"NORME_MIN"
             /"TIK_RELA"
```

REGUL makes it possible to specify the method of regularization which one wants to use. By default, one does not add a regularization (not additional stress on the solution: REGUL = "NON").
Currently, two types of regularization are available (minimal norm: REGUL = "NORM_MIN" or Tikhonov of order 0 and "relative" Tikhonov: REGUL = "TIK_RELA").
One seeks to minimize, for each sequence number of the measured field, the following functional calculus compared to η :

$$|q_{\exp}-\bar{\Phi}_{num}\eta|^2+\alpha|\eta-\eta_{priori}|^2$$

with:

- η : generalized coordinates relating to the base of expansion $\bar{\Phi}_{num}$.
- $q_{\exp}$: measured field following the degrees of freedom of observation.
- $\bar{\Phi}_{num}$: base expansion restricted with the degrees of freedom of observation.
- α : weight coefficients allowing to specify the affected weight with information a priori on the solution.

According to the method used, the parameters of the preceding functional calculus are declined as follows:

Without regularization: $\alpha=0$

Minimal norm (NORM_MIN): $\eta_{priori}=0$

"Relative" Tikhonov (TIK_RELA): η_{priori} : solution found at the sequence number preceding

It is disadvised using this key word when the measured field (`measurement`) is of mode_meca type.

3.5.4 Operands `COEF_PONDER` and `COEF_PONDER_F`

This key word corresponds to the affected weight with information a priori α . It is used if one applies a regularization to the solution η .

◊/COEF_PONDER= coeff

Lists weight coefficients on the solution a priori (method of regularization of Tikhonov) [bib3].

/COEF_PONDER_F = coef_f

List of the weight functions on the solution a priori (method of regularization of Tikhonov). The variables of these functions are the same ones as those of the measured field (`measurement`). If the number of coefficients or weight functions given is lower than the number of basic vectors used in the base of expansion, the coefficients or weight functions of the additional vectors are taken equal to the last coefficient or the last function of the list.

4 Phase of checking and execution

4.1 Computation of the base of expansion restricted with the degrees of freedom measured

Initially, the mesh of measurement is project on the mesh of the digital model. One determines then the participation of the nodes of the digital model for each node of measurement via the shape function of the element which contains the node of measurement. The correspondence obtained between the nodes is provided in the message file of the study Aster.

The second processing consists in calculating the component of the field (expansion bases) to the node of measurement according to the measured degrees of freedom.

4.2 Computation of the generalized coordinates

the solution of the equation of minimization is given by:

$$\begin{aligned} \eta(0) &= \left[\bar{\Phi}_{num}^{T}\bar{\Phi}_{num}\right]^{-1}\bar{\Phi}_{num}^{T}q_{\exp}(0) \\ \eta(i) &= \left[\bar{\Phi}_{num}^{T}\bar{\Phi}_{num}+\alpha(i)\right]^{-1}\left(\bar{\Phi}_{num}^{T}q_{\exp}(i)+\alpha(i)\eta_{priori}\right) \end{aligned}$$

With:

- $\eta(i)$: generalized coordinates for sequence number I (Ti or fi)
- $q_{\exp}(i)$: measure I at the sequence number
- $\bar{\Phi}_{num}$: base expansion restricted with the degrees of freedom of measurement
- $\alpha(i)$: coefficients allowing to specify the affected weight with information a priori at the sequence number I. These variables or functions are defined by the user in operands `COEF_PONDER` or `COEF_PONDER_F` of factor key word `the RESOLUTION`. They are introduced in the form of a list of realities or functions and correspond, term in the long term, with each vector of the base of expansion selected.

According to the method used, the preceding parameters are declined as follows:

Without regularization: $\alpha=0$

Minimal norm (NORM_MIN): $\eta_{priori}=0$

"Relative" Tikhonov (TIK_RELA): $\eta_{priori}=\eta_{i-1}$

Notice 1:

If a weight coefficient is negative, the processing stops in fatal error.

Notice 2:

If all the weight coefficients are null for a given sequence number and that the number of measurements is strictly lower than the number of basic vectors, an alarm message is transmitted to prevent risk of singular matrix (indeed, in this case, there is not unicity of the solution).

At the conclusion of computation, the identified generalized coordinates are derived in order to calculate the velocities and the corresponding accelerations.

Result of the inversion is a concept of the tran_gene type, harm_gene or mode_gene.

5 Example of use of PROJ_MESU_MODAL

For the examples of use, it is highly advised to refer to the cases tests SDLD104 and SDLV122.

One the model presents in this paragraph the various stages for the expansion of measurement on numerical.

- Reading of the mesh made up of the points of measurement:
  This operation aims of mesh type to read the position of the points of measure to a file. The format of this file must be readable by *the Code_Aster* (format GIBI, universal (I-deas) or soon MED). Meshes connecting the nodes of measurement can have been defined. They do not have obviously any physical meaning but will possibly make it possible to display the results at the time of the phase of postprocessing.
  In the majority of the cases, the mesh is resulting from a code of experimental measurement which provides a file to the universal format (I-deas format). To transform it into Aster format, operator PRE_IDEAS is used.

```
PRE_IDEAS (UNITE_IDEAS = 19, UNITE_MAILLAGE = 21,)
mailmesu = LIRE_MAILLAGE (UNITE = 21,)
```

- Assignment of a mechanical model to mesh:
  This operation aims the model to define support of the nodes of the mesh made up of the points of measurement. Two cases can be considered: assignment of a modelization DIS_T (discrete in translation => 3 degrees of freedom by the node is outside the field of definition with a right profile of the EXCLU type node: DX, DY and DZ) or assignment of a modelization DIS_TR (discrete in translation - rotation => 6 degrees of freedom by the node is outside the field of definition with a right profile of the EXCLU type node: DX, DY, DZ, DRX, DRY and DRZ) if measurements of rotation are carried out.

```
modlmesu = AFFE_MODELE  ( MAILLAGE=  mailmesu,
                           AFFE   = _F (   GROUP_NO   = "noeumesu",
                                        MODELISATION=  "DIS_T",
                                        PHENOMENE  =  "MECHANICAL",),
                         )
```

- Reading of measurement:

Measurement can be read via operator LIRE_RESU. This operator allows to read a file with the universal format (dataset 58). He recovers the component of the field observed and assigns it to the corresponding model

```
measure = LIRE_RESU  ( FORMAT = "IDEAS_DS58",
                       UNITE = 33,
                       MAILLAGE = mailmesu,
                       TYPE_RESU = "DYNA_TRANS",
                       NOM_CHAM = "SIEF_NOEU",)
```

- Definition of the base of expansion:
  The base of expansion must be of the mode_meca type. This concept can result from MODE_ITER_SIMULT or DEFI_BASE_MODALE.
  If one wants to extrapolate a strain field or of stress, the base must be enriched, via command CALC_CHAMP, by the strain fields or of stress calculated with the nodes.

- Computation of the generalized coordinates:
  The computation generalized coordinates relating to the base of expansion is assured by the operator PROJ_MESU_MODAL.

```
repgene = PROJ_MESU_MODAL   (
             MODELE_CALCUL=_F         ( MODELS = modlcalc,
                                      BASE = bases,),
             MODELE_MESURE=_F         ( MODELS = modlmesu,
                                      MESURE = measurement,
                                      NOM_CHAM = "SIEF_NOEU",),
             CORR_MANU=_F             ( NOEU_MESURE = "no1",
                                      NOEU_CALCUL = "no2",),
             RESOLUTION=_F          ( METHODE = "SVD",
                                      EPS = 1.E-4,),
             )
```

- Expansion on the model numerical:
  This expansion consists in calculating nodes of the digital model on all the, the field compatible with the field observed on the measured degrees of freedom. This expansion is carried out by the command REST_GENE_PHYS.

```
response = REST_GENE_PHYS (   RESU_GENE = repgene,
                              TOUT_CHAM = "OUI',)
```

6 Bibliography

1) C. VARE: Extrapolation of results of experimental measurements on a digital model in dynamics – Specification of the developments in *the Code_Aster*. Note EDF/DER HP - 54/98/063/B

2) S. AUDEBERT: Comparative evaluating of various methods of inversion. Note EDF/DER HP-62/93/036

3) A. TIKHONOV, V. ARSENINE: Methods of resolution of badly posed problems. ED. Mir 1976

4) Mr. BONNET: Digital processing of inverse problems of source in linear acoustics. EDF contract – Convention P55L08/1E5240

5) A. TARANTOLA: Opposite problem theory – Methods for dated fitting and model parameter estimate. Elsevier – 1987