Operator DYNA_LINE_HARM

1 Goal

To calculate the dynamic response complexes of a system to a harmonic excitation: direct calculation for a structure in physical space, calculation by harmonic under-structuring for several under structures defined by their modal base in modal coordinates.

This dynamic response can be evaluated in several successive work (réentrant concept).

Product a structure of data of the type dyna_harmo or acou_harmo or harmo_gene.

2 Syntax

```
harm   [*]=  DYNA_LINE_HARM
   (  ◊   reuse                     =  harm,
      ◊   RESULT                 =  harm,     /  [dyna_harmo]
                                                 /  [harm_gene]
      ◊   MODEL                     =  Mo,          [model]
      ◊   CHAM_MATER                =  chmat,       [cham_mater]
      ◊   CARA_ELEM                 =  carac,       [cara_elem]

      ♦   MATR_MASS                 =  m,        /  [matr_asse_DEPL_R]
                                                 /  [matr_asse_PRES_C]
                                                 /  [matr_asse_GENE_R]

      ♦   MATR_RIGI                 =  K,        /  [matr_asse_DEPL_R]
                                                 /  [matr_asse_DEPL_C]
                                                 /  [matr_asse_PRES_C]
                                                 /  [matr_asse_GENE_R]
                                                 /  [matr_asse_GENE_C]

      ◊   MATR_AMOR                 =  C,        /  [matr_asse_DEPL_R]
                                                 /  [matr_asse_PRES_C]
                                                 /  [matr_asse_GENE_R]
      ◊   AMOR_MODAL = _F (
                      /  AMOR_REDUIT  =  Lη ,       [l_R]
                      /  LIST_AMOR    =  Cη ,       [listr8]
                      )
      ◊   MATR_IMPE_PHI             =  imp,      /  [matr_asse_DEPL_R]
                                                 /  [matr_asse_GENE_R]

      ♦   /  FREQ                   =  lf,          [l_R]
          /  LIST_FREQ              =  cf,          [listr8]

      ◊   /  TOUT_CHAM              =  'YES',       [DEFECT]
          /  NOM_CHAM               =  |  'DEPL',
                                       |  'QUICKLY',
                                       |  'ACCE',

      ◊   SOLVEUR                   =  (
                                       . . to see [U4.50.01]….
                                       ),

      ♦   EXCIT  =
          _F (     ♦  /  VECT_ASSE    =  vecti,        [cham_no]
                   /  VECT_ASSE_GENE = vect_gene    [vect_asse_gene]
                   /  LOAD            =  chi,       [char_meca]

                ♦  /  FONC_MULT_C  =  hci,      /  [fonction_C]
                                                 /  [formule_C]
                   /  COEF_MULT_C  =  aci,          [C]
                   /  FONC_MULT    =  hi,       /  [function]
                                                 /  [formula]
                                                 /  [tablecloth]
                   /  COEF_MULT    =  have,            [R]
                ◊  PHAS_DEG        =  /  0. ,          [DEFECT]
                                      /  phi,       [R]
                ◊  PUIS_PULS       =  /  0,         [DEFECT]
                                      /  nor,          [Is]
          ),
```

```
        ◊  EXCIT_RESU   =
           _F (      ♦  RESULT    =  resuforc,     /  [dyna_harmo]
                                                   /  [harm_gene]
                  ♦  COEF_MULT_C  =  aci,             [C]
                               ),

        ◊ TITRE   =  tx,                              [l_Kn]
        ◊ INFORMATION    =  / 1,                             [DEFECT]
                     / 2,
    );


if MATR_RIGI =      [matr_asse_DEPL_R]  then   [*]    dyna_harmo
                    [matr_asse_DEPL_C]                dyna_harmo
                    [matr_asse_PRES_C]                acou_harmo
                    [matr_asse_GENE_R]                harm_gene
                    [matr_asse_GENE_C]                harm_gene
```

3 Recalls

3.1 Equation of dynamic behaviour under harmonic excitation

The damping of the structure can be viscous or hysteretic [U2.06.03] [R5.05.04].

This operator solves the equation:

$$(-j\omega^3 \mathrm{I} - \omega^2 \mathrm{M} + j\omega \mathrm{C} + \mathrm{K})x = \left\{ \sum_{i=1}^{k} h_i(f)\,\omega^{n_i} \mathrm{e}^{j\pi \frac{\varphi_j}{180}} g_i(\mathrm{P}) \right\}$$

Where:

K represent matrix of a real or complex rigidity
M represent a matrix of mass
C represent a matrix of damping
I represent a matrix of acoustic impedance resulting from a formulation in displacement-pressure-potential.
P is a point running of the structure.
$\omega = 2\pi f$: pulsation of excitation
x : complex answer

3.2 Damping hysteretic

$$(\mathrm{K} - \omega^2 \mathrm{M})x = \left\{ \sum_{i=1}^{k} h_i(f)\,\omega^{n_i} \mathrm{e}^{j\pi \frac{\varphi_j}{180}} g_i(\mathrm{P}) \right\}$$

This operator also allows to calculate the harmonic answer of a hysteretic structure with damping.

With K : complex matrix of rigidity.
For detailed examples, one will refer to the document [U2.06.03].
This operator is usable in imposed force and imposed (relative reference frame or absolute).

4 Operands

4.1 Operand RESULT

◊ RESULT = harm

Name of the structure of data result to enrich. This keyword is obligatory if one is in D-entering concept mode (reuse).

4.2 Operand MODEL

◊ MODEL = Mo

Name of the concept defining the model whose elements are the object of harmonic calculation.

4.3 Operand CHAM_MATER

◊ CHAM_MATER = chmat

Name of the concept defining the affected material field on the model Mo.

4.4 Operand CARA_ELEM

◊ CARA_ELEM = carac

Name of the concept defining the characteristics of the elements of beam, hulls, etc…

4.5 Operand MATR_MASS

♦ MATR_MASS = m

Name of the concept stamps assembled corresponding to the matrix of mass of the system.

4.6 Operand MATR_RIGI

♦ MATR_RIGI = K

Name of the concept stamps assembled corresponding to the matrix of rigidity of the system. A hysterical damping is obtained with a complex matrix of rigidity.

4.7 Operand MATR_AMOR

◊ MATR_AMOR = C

Name of the concept stamps assembled corresponding to the matrix of viscous damping of the system.

4.8 Keyword AMOR_MODAL

Keyword factor to inform damping in the shape of lists of damping reduced with operands following.

4.8.1 Operands AMOR_REDUIT / LIST_AMOR

/ AMOR_REDUIT = L η

List of all reduced depreciation: $(\eta_1, \eta_2, \ldots, \eta_n)$.

/ LIST_AMOR = C η

Name of the concept of the type listr8 containing the list of reduced depreciation.

4.9 Operand MATR_IMPE_PHI

◊ MATR_IMPE_PHI = imp

Name of the concept stamps assembled corresponding to the matrix of impedance for a system fluid-structure whose formulation is in displacement-pressure-potential (u, p, φ) [R4.02.02].

4.10 Operands FREQ/LISTE_FREQ

♦ / FREQ = lf

List of all the frequencies of calculation: (f1, f2,…, fn).

/ LIST_FREQ = cf

Name of the concept of the type listr8 containing the list of the frequencies of calculation.

4.11 Operands TOUT_CHAM / NOM_CHAM

```
◊ / TOUT_CHAM  =     'YES'
  / NOM_CHAM   =  |  'DEPL'
                  |  'QUICKLY'
                  |  'ACCE'
```

Choice of the fields to calculate to represent the answer: displacement, speed, acceleration or three.

4.12 Operands SOLVEUR

◊ SOLVEUR

This keyword factor is optional. It makes it possible to define the method of resolution of the system. Syntax is described in the document [U4.50.01].
In the current version, the method MULT_FRONT is not available for the resolution of the systems with generalized matrices.

4.13 Keyword EXCIT

♦ EXCIT

Operand allowing to define several excitations. Either by indicating a vector assembled correspondent to a loading, or of the loads which will lead to the calculation and the assembly of a second member. For each occurrence of the keyword factor, one defines a component of the excitation in the form $(h(f), g(P), \varphi)$.

4.13.1 Operands VECT_ASSE/VECT_ASSE_GENE/CHARGE

Allow to define $g(P)$ space discretization of the loading, in the form of a field with the nodes corresponding to one or more loads of force or imposed movement.

♦ / VECT_ASSE = vecti

Name of the concept produced by:

- the operator ASSE_VECTEUR in imposed force or imposed of displacement in an absolute reference frame. The amplitudes of the excitation can be defined in the concepts of the type charges corresponding. The expected field is a field with the nodes of size DEPL_R, DEPL_C or PRES_C.

/ VECT_ASSE_GENE = vect_gene

Name of the concept produced by:

- the operator `PROJ_VECT_BASE` who allows to project a vector assembled on a modal base or a basis of Ritz.
- the operator `ASSE_VECT_GENE` who allows to project a loading on a basis defined on a model generalized for calculations of dynamic under-structuring.

/ `LOAD = chi`

`chi` name of the concept of loading specified by Ième occurrence of `EXCIT`.
The keyword `MODEL` must be well informed if the keyword is used `LOAD`.

4.13.2 Operands FONC_MULT_C / COEF_MULT_C / FONC_MULT / COEF_MULT

Allow to define $h(f)$ law of evolution, complex or real, of the frequency, applied to all the components of the field to the node associated with this occurrence. Several opportunities are given:

♦ / `FONC_MULT_C = hci`

Name of the concept of the type `fonction_C` or `formule_C` defining a function $h(f)$ complex of the frequency f,

/ `COEF_MULT_C = aci`

Coefficient complexes multiplying loading, independent of the loading,

/ `FONC_MULT = hi`

Concept of the type `function`, `formula` or `tablecloth` defining a function $h(f)$ real of the frequency f,

/ `COEF_MULT = have`

Multiplying real coefficient of the loading, independent of the loading.

4.13.3 Operand PUIS_PULS

◊ `PUIS_PULS = nor`

Allows to define the power of the pulsation when the loading is function of the frequency; by default N_I= 0.

4.13.4 Operand PHAS_DEG

◊ `PHAS_DEG = phi`

Allows to define the phase of each component of the excitation in degrees compared to a single reference of phase; by default $\varphi_i=0$.

4.13.5 Notice

For a problem with imposed movement, one defines the blocked degrees of freedom (conditions kinematics preliminary to the construction of `cham_no`) ; one can then choose an excitation:

- in imposed displacement $n=0$, $\varphi=0$ degree
- in imposed speed $n=1$, $\varphi=90$ degrees
- in imposed acceleration $n=2$, $\varphi=180$ degrees

4.14 Operand EXCIT_RESU

◊ EXCIT_RESU

This keyword factor makes it possible to define several complements of loading in the form of a harmonic evolution of type `dyna_harmo` assembled vectors second members, calculated on the physical basis.

4.14.1 Operand RESULT

This keyword makes it possible to define the seconds members complementary to extract for each frequency from calculation starting from a result already calculated from fields from nodal forces.

♦ RESULT = resuforc

Name of the concept of evolution harmonic of second members produces by the sequence of the operator `CALC_FORC_NONL` [U4.84.21] in order to produce a transitory evolution of second members, and the operator `REST_SPEC_TEMP` [U4.63.34] to transform this transitory evolution into harmonic evolution. An example of use is provided in the case test SDLS119A.

4.14.2 Operand COEF_MULT_C

♦ COEF_MULT_C = aci

Coefficient complexes multiplying vector second member extracted the result `resuforc` for each frequency of calculation.

4.15 Operand TITLE

◊ TITLE = tx

Title attached to the concept produced by this operator [U4.03.01].

4.16 Operand INFORMATION

◊ INFORMATION = inf

Allows to carry out in the file message various intermediate impressions allowing to follow the advance of calculation.

By default, if `INFO=1`, one prints the advance of harmonic calculation with a step which corresponds to the maximum to 5 % of the full number of frequencies. The general rule is systematically to print the first and last frequencies as well as a maximum number of 20 frequencies in the medium.

If `INFO=2`, an impression is carried out for each frequency and makes it possible more precisely to follow the advance of calculation.

5 Example of use in imposed force

```
# ---------------------------------------------------------------
#   REFERENCE: SFM/VPCS SDLD21    ORDERS
# ---------------------------------------------------------------
#   SYSTEM MASSE-RESSORT WITH 8 DEGREES OF FREEDOM WITH DAMPING
#   VISCOUS PROPORTIONAL (HARMONIC ANSWER)
#   9 SPRINGS  8 MASSES  -- K = 1.E+5    M = 10    C = 50--
# ---------------------------------------------------------------
BEGINNING (CODE = _F (NAME = 'SDLD21A'),);
# ---------------------------------------------------------------
MY = LIRE_MAILLAGE ();

MO = AFFE_MODELE (  GRID = MY,
                    AFFE = (   _F (      ALL        = 'YES',
                                    PHENOMENON       = 'MECHANICAL',
                                    MODELING  = 'DIS_T',),
                               _F (      GROUP_NO      = MASS,
                                    MODELING  = 'DIS_T',),
                       ),);

CARELEM = AFFE_CARA_ELEM ( MODEL = MO,
                           DISCRETE =    (   _F (      GROUP_MA  = 'SPRING',
                                                 CARA      = 'K_T_D_L',
                                                 VALE      = (1.E+5,1., 1.),),
                                          _F (      GROUP_NO  = MASS,
                                                 CARA      = 'M_T_D_N',
                                                 VALE      = 10. ,),
                                          _F (      GROUP_MA  = DEADENED,
                                                 CARA      = 'A_T_D_L',
                                                 VALE      = (50. , 1. ,
1.),),
                           ),),);

CH = AFFE_CHAR_MECA (  MODEL = MO,
                       DDL_IMPO =    (   _F (   GROUP_NO = 'A_ET_B',
                                            DX = 0. , DY = 0. , DZ = 0. ,),
                                     _F (   GROUP_NO = 'MASS',
                                            DY = 0. , DZ = 0. ,),),
                       FORCE_NODALE =   _F (   NODE = 'P4', FX = 1. ,),
                       );

MELR = CALC_MATR_ELEM (MODEL = MO, LOAD = CH,
                       OPTION = 'RIGI_MECA',
                       CARA_ELEM = CARELEM,);

MELM = CALC_MATR_ELEM (MODEL = MO, CHARGE= CH,
                       OPTION = 'MASS_MECA',
                       CARA_ELEM = CARELEM,);

MELC = CALC_MATR_ELEM (MODEL = MO, LOAD = CH,
                       OPTION = 'AMOR_MECA',
                       CARA_ELEM = CARELEM,);

VECT = CALC_VECT_ELEM (LOAD = CH, OPTION = 'CHAR_MECA',);
# ---------------------------------------------------------------
NUM = NUME_DDL ( MATR_RIGI = MELR,);
MATASSR = ASSE_MATRICE (MATR_ELEM = MELR, NUME_DDL = NUM,);
```

```
MATASSM = ASSE_MATRICE (MATR_ELEM = MELM, NUME_DDL = NUM,);
MATASSC = ASSE_MATRICE (MATR_ELEM = MELC, NUME_DDL = NUM,);
VECTASS = ASSE_VECTEUR (VECT_ELEM = VECT, NUME_DDL = NUM,);
# ---------------------------------------------------------------
# EXCITATION FORCES SINUSOIDAL AMPLITUDE CRETE FX = 1.N
# AT THE P4 POINT    Waveband 5 Hz - 40 Hz
# (AMPLITUDE INDEPENDENT OF THE FREQUENCY)
LIFREQ = DEFI_LIST_REEL (  BEGINNING = 5. ,
                           INTERVAL =   _F (      JUSQU_A=40.,
                                                  NOMBRE=70,),
                              );

DYNAHARM = DYNA_LINE_HARM( MATR_MASS = MATASSM,
                           MATR_RIGI = MATASSR,
                           MATR_AMOR = MATASSC,
                           LIST_FREQ = LIFREQ,
                           EXCIT     =  _F (      VECT_ASSE = VECTASS,
                                               COEF_MULT = 1. ,) ,
                            );

IMPR_RESU (  MODEL = MO, RESU =  _F (   RESULT = DYNAHARM,),);

END ();
```