Macro-order `IMPR_DIAG_CAMPBELL`

1 Goal

The goal of this operator is to calculate and plot the diagram of Campbell. The approach is based on that already developed in ROTORINSA. **For a correct use of this operator, the user must obligatorily define axis Z as being the axis of rotation.**

The diagram of Campbell is a chart of the natural frequencies of a system in rotation according to its number of revolutions. The natural frequencies and the modes of a system turning are obtained by the resolution of the dynamic equilibrium equation of a system of rotating shafts, without second member and including the effects due to damping.

$$M\ddot{\delta}+C(\Omega)\dot{\delta}+K\delta=0$$

Where M is the matrix of mass of the system, $C(\Omega)$ is a nonsymmetrical matrix, function number of revolutions Ω , including the gyroscopic effect (antisymétriquE), and characteristics of damping of the stages, and K is the matrix of stiffness of the system.

The data necessary for the layout of the Diagram of Campbell are thus the natural frequencies as well as depreciation and the associated modal deformations, according to the number of revolutions.

This macro-order classifies the modes of inflection, torsion and traction compression. It normalizes the modes, determines the direction of precession of the modes in inflection, sorting the frequencies according to various methods of follow-up of modes, then trace the diagram of Campbell.

This macro-order makes it possible to plot the diagram of Campbell, the frequencies f in Hz of each mode according to the number of revolutions of the tree N in tr/mn , the direction of the direct precession (Forward Whirl) or opposite precession (Backward Whirl). It also indicates if there is an instability. One can plot straight lines of slope S, $f = S \times N/60$ and to determine the points of intersection of these lines with the diagram of Campbell. Among these points of intersection some correspond to critical velocities.

Contents

2 Syntax

```
IMPR_DIAG_CAMPBELL (

# Grid revolving system
                    ♦ GRID =  my                         [grid]


# Lists modes corresponding to the list speeds
                    ♦ MODES =    l_mode                      [l_mode_meca_c]


# Lists number of revolutions
                    ♦ VITE_ROTA =    l_vit  [l_R]

# Many frequencies in the diagram of Campbell
                    ♦ NFREQ_CAMP =  nb_freq_camp            [I]

# Choice of the type of calculation of the precession
                     ◊ TYP_PREC =/1      #PREC_MOY   [I]    [DEFECT]
                                  /2      #PREC_GOR

# Choice of the method of follow-up of the modes
                     ◊ TYP_TRI = /0     #PAS_TRI  [I]
                                 /1     #TRI_PREC_MOD
                                 /2     #TRI_FORMES_MOD     [DEFECT]

# Definition of the logical unit to the format XMGRACE , for the diagram of
#Campbell in inflection
                    ♦ UNIT_FLE =  unit_fle                  [I]


# Definition of the logical unit to the format XMGRACE , for the diagram of
#Campbell in torsion
                    ♦ UNIT_TOR =  unit_tor                  [I]


# Definition of the logical unit to the format XMGRACE , for the diagram of
#Campbell in traction/compression
                    ♦ UNIT_LON =  unit_lon                  [I]


# Definition of the logical unit to the format XMGRACE , for the diagram of
#Campbell in inflection
                    ♦ UNIT_TOT =  unit_tot                  [I]


# Definition of the logical unit to the format textual file, for the points
#d' intersection
                    ♦ UNIT_INT =  unit_int                  [I]


# Lists slopes S of the right-hand sides to be traced
                    ◊ L_S =   /l_s,                         [l_R]
                              /1.                           [DEFECT]
```

3 Operands

3.1 Operand GRID

♦ `GRID = my,`

Name of the grid of the revolving system that one wants to extract the nodes. These nodes are used in Classification of the modes in inflection, torsion and traction/compression and calculation the direction of precession for a mode at a number of revolutions given.

3.2 Operand MODES

♦ `MODES = l_mode`

A list containing the concepts `mode_meca_c` defined for each number of revolutions.
The macro one `CALC_MODE_ROTATION` calculate the frequencies and the modes of the system according to the number of revolutions. The research of the frequencies and modes on the complete system led in search of values and clean vectors of the following system:

$$M\ddot{\delta}+(A+\Omega C)\dot{\delta}+K\delta=0$$

A : matrix of damping of the complete system
C : matrix of gyroscopy of the complete system.

Note:
The number of modes `NVES` calculated must be identical for all the number of revolutions.

To follow the modes on the diagram of Campbell, the number of calculated modes `NVES` must be higher than the number of frequencies `NFREQ_CAMP` in the diagram of Campbell.
At least `NVES= NFREQ_CAMP+4`.

3.3 Operand VITE_ROTA

♦ `VITE_ROTA = l_vit`

List number of revolutions Ω who is the same list which was used during the calculation of the modes of the system in rotation by the macro one `CALC_MODE_ROTATION`. For better following the modes, this list presents the beach speeds:
Number of initial revolutions: $Omega_{min}$
Number of final revolutions : $Omega_{max}$
Pas de number of revolutions: $Delta_{omega}$
L' unit is in rad/s .

3.4 Operand NFREQ_CAMP

♦ `NFREQ_CAMP = nb_freq_camp`

Many frequencies in the diagram of Campbell, it is the number of mode to be followed in the diagram of Campbell.

Even notices that in paragraph 3.2:
To follow the modes on the diagram of Campbell, the number of calculated modes `NVES` must be higher than Nshade of frequencies `NFREQ_CAMP` in the diagram of Campbell.
At least `NVES= NFREQ_CAMP+4`.

Notice

Attention the minimum fixed NVES= NFREQ_CAMP+4 is not always sufficient. It is necessary to check the numbers of frequencies calculated by type (inflection, torsion, traction/compression) and according to these values, to calculate more modes than those requested for the layout of the diagram of Campbell.

3.5 Operand `TYP_PREC`

```
◊ TYP_PREC =  /1       PREC_MOY
              /2       PREC_GOR
```

Choice of the type of calculation of the precession.

Of direction of the direct or opposite precession for the modes in inflection at each number of revolutions is calculated two manners different according to the choice of the type from calculation from the precession:

- `PREC_MOY` : The identification of the precession will be done according to the sign of the sum of the signs of all the orbits.
- `PREC_GOR` : The identification of the precession is according to the sign of the greatest orbit in a mode (Precession direct, opposite Precession).

3.6 Operand `TYP_TRI`

```
◊ TYP_TRI =          /0       #PAS_TRI
                     /1       #TRI_PREC_MOD
                     /2       #TRI_FORMES_MOD          [DEFECT]
```

Choice of the method of follow-up of the modes.

- If the type of follow-up of the modes is `PAS_TRI` , the connection this fact while following the sequence number of the modes.
- If the type of follow-up of the modes is `TRI_PREC_MOD` , i.e. sorting of the frequencies gradually according to the direction of the precession.
- If the type of follow-up of the modes is `TRI_FORM_MOD`, i.e. sorting by the form of the modes. The sorting of the frequencies according to the form of the modes requires the calculation of the matrix of MAC correlation of the modes.

3.7 Operands of the logical units

At exit of this macro, four diagrams of Campbell are generated:

- Diagram of Campbell for modes of inflection,
- Diagram of Campbell for modes of torsion,
- Diagram of Campbell for modes of traction/compression,
- Diagram of Campbell who gathers the three types of modes.

3.7.1 Operand `UNIT_FLE`

♦ `UNIT_FLE = unit_fle`

Allows to choose on which logical unit one prints Diagramme of Campbell for modes in inflection. The value of `unit_fle` must be the same one as in the interface `Astk`.

3.7.2 Operand `UNIT_TOR`

♦ UNIT_TOR = unit_tor

Allows to choose on which logical unit one prints Diagramme of Campbell for modes of torsion. The value of unit_fle must be the same one as in the interface Astk.

3.7.3 Operand UNIT_LON

♦ UNIT_LON = unit_lon

Allows to choose on which logical unit one prints Diagramme of Campbell for modes in traction/compression. The value of unit_fle must be the same one as in the interface Astk.

3.8 Operand of the logical units

The points of intersection of the right-hand sides of slope S with the diagram of Campbell are saved in a textual file.

♦ UNIT_INT = unit_int ,

Allows to choose on which logical unit will be saved these points of intersection (number of revolutions, frequency). The value of unit_int must be the same one as in the interface Astk, of type 'libr' . The name of the file is the concatenation of 'fort.' with the value of unit_int .

3.9 Operand L_S

This macro makes it possible to plot straight lines of slope S and to determine the points of intersection of these lines with the diagram of Campbell.

```
◊ L_S =  /l_s,
         /1.                    [DEFECT]
```

Allows to draw up the list of slopes S lines to be traced.

Line of slope $S=1$ allows to obtain with its intersections with the curves of evolution of the frequencies, the possible critical velocities due to the unbalances or synchronous revolving forces at the speed of the rotor.

Lines of slope $S\neq 1$ allow to obtain with their intersections with the curves of evolution of the frequencies, the possible critical velocities due to asynchronous revolving forces (different speed at the speed of the rotor).

4 Results

4.1 File result

In the file result, one displays:

Many detected eigenvalues
Many frequencies requested for the layout

Many total frequencies
Many frequencies in inflection
Many frequencies in torsion
Many frequencies in traction/compression

Reduced frequencies and depreciation
The MAC matrices in the case of the method of follow-up of the modes TRI_FORM_MOD.
Plugboards.

On, the chart of the diagram of Campbell, are plotted the natural frequencies of a system in rotation according to its number of revolutions, with the directions of precession. Instability is indicated.

Lines of slopes S are traced. Line of slope $1.$ is always traced.
A file contains the points of intersection of the right-hand sides with the diagram of Campbell.

4.2 Code color of the layout

By the codes of colors of the layouts, one specifies the direction of precession for the modes in inflection.

	Direct precession	Opposite precession
Stable	Green, continuous feature	Blue, long indents,
Unstable	Red, continuous feature, marker +	Magenta, indents long, marker □

For the modes of torsion: line color black, style an indent, a dotted line.

For the modes of traction/compression: line color purple, style two indents, a dotted line.

5 Example

Example of diagram of Campbell of a model of rotor with 3 discs of the book *Rotordynamics Prediction in Engineering*.

```
DEBV=0.0;      # rpm
FINV=30000;    # rpm
PASV = 5000.   # rpm
VIT=arange (DEBV, FINV+1, PASV);
nbV=len (LIVES);
L_VITROT= [LIVES [II] *pi/30. for II in arranges (nbV)];

nbF_camp=11;

typ_prec =1
typ_tri=2

unit_fle = 29;
unit_tor = 28;
uniy_lon = 27;
unit_tot = 26;
unit_int = 25;

L_S= [1.];

IMPR_DIAG_CAMPBELL (GRID   =mail,
                 MODES      =MODES,
                 VITE_ROTA   =L_VITROT,
                 NFREQ_camp =nbF_camp,
                 TYP_PREC   =typ_prec,
                 TYP_TRI    =typ_tri,
                 UNIT_FLE   = unit_fle,
                 UNIT_TOR   = unit_tor,
                 UNIT_LON   = uniy_lon,
                 UNIT_TOT   = unit_tot,
                 UNIT_INT   = unit_int,
                 L_S        = L_S,
                );
```

Some results generated in the file *.resu:

```
Many detected eigenvalues are 20
Many frequencies requested for the layout  11
```

	calculated	Layouts
Many total frequencies	20	11
Many frequencies in inflection	16	8
Many frequencies in torsion	2	2
Many frequencies in traction/compression	2	1

Table 5-a: Calculated and traced frequencies (Code_Aster)

The four files thus are obtained that one can visualize in `xmgrace` :

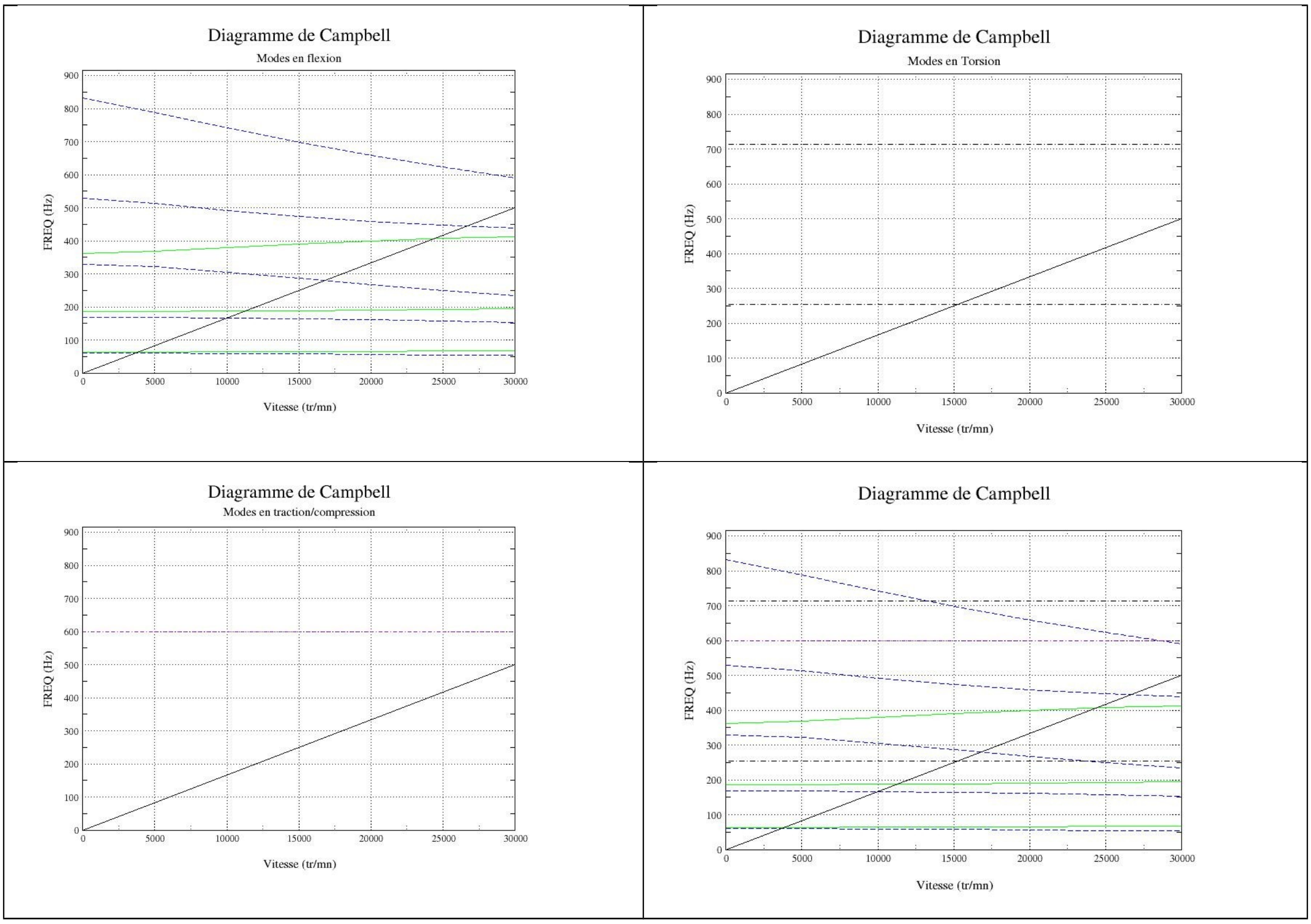

Figure 5-a: Diagrams of Campbell in inflection, torsion and traction/compression

The file fort.25 contains the points of intersection.

```
Mode in inflection
Points D intersection with lines Y=SX
S =       1.00
Speed   =    3615.86 rpm
Frequency =      60.26 HZ
Speed   =    3802.16 rpm
Frequency =      63.37 HZ
Speed   =   10018.17 rpm
Frequency =     166.97 HZ
Speed   =   11282.42 rpm
Frequency =     188.04 HZ
Speed   =   16773.01 rpm
Frequency =     279.55 HZ
Speed   =   24399.86 rpm
Frequency =     406.66 HZ
Speed   =   26635.07 rpm
Frequency =     443.92 HZ
----------------------------
Mode in Torsion
Points D intersection with lines Y=SX
S =       1.00
Speed   =   15240.61 rpm
Frequency =     254.01 HZ
```

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References

•MR. LALANNE, G. FERRARIS, " Rotordynamics Prediction in Engineering ", Second Edition, Wiley, 2001.

•ROTORINSA, software finite elements intended to envisage the dynamic behavior of rotors in inflection, LaMCoS UMR5259, INSA-Lyon.