Macro-command IMPR_DIAG_CAMPBELL

1 Drank

Compute and to plot the diagram of Campbell, the approach is based on that already developed in ROTORINSA. The diagram of Campbell is a chart of the natural frequencies of a system in rotation according to its rotational speed. The natural frequencies and the modes of a system turning are obtained by the resolution of the dynamic balance 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 mass matrix of the system, $C(\Omega)$ is an asymmetric matrix, function rotational speed Ω, including the gyroscopic effect (skew-symmetric), and the characteristic of damping of the bearings, and K is the stiffness matrix of the system.

The data necessary for the layout of the Diagram of Campbell are thus the natural frequencies, like their corresponding modes, according to rotational speed.

This macro-command classifies the modes of bending, torsion and tension compression. It normalizes the modes, determines the meaning of precession of the modes in bending, sort the frequencies according to various methods of follow-up of modes, then trace the diagram of Campbell.

This macro-command makes it possible to plot the diagram of Campbell, the frequencies f into cubes Hz each mode according to the rotational speed of the shaft N in tr/mn, the meaning 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 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 (

# Mesh of the system turning
                    ♦ MAILLAGE = my                          [mesh]


# List modes corresponding to the list velocities
                    ♦ MODES =    l_mode                      [l_mode_meca_c]


# Lists rotational speeds
                    ♦ VITE_ROTA =   l_vit  [l_R]

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

# Choice of the type of computation of the precession
                     ◊ TYP_PREC =/1       #PREC_MOY   [I]   [DEFAULT]
                                /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      [DEFAULT]

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


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


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


# Definition of the logical unit with format XMGRACE , for the diagram of
#Campbell in bending
                    ♦ 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]


# S Lists slopes lines to trace
                    ◊ L_S =   /l_s,                          [l_R]
                              /1.                            [DEFAULT]
```

3 Operands

3.1 Operand MAILLAGE

♦ `MAILLAGE = my,`

Name of the mesh of the revolving system which one wants to extract the nodes. These nodes are used in Classification of the modes in bending, torsion and tension/compression and computation the meaning of precession for a mode at a given rotational speed.

3.2 Operand MODES

♦ `MODES = l_mode`

a list containing the definite `concepts` mode_meca_c for each rotational speed.
The macro `MODE_EN_ROTATION` calculates the frequencies and the modes of the system according to rotational speeds. The search of the frequencies and modes on the complete system led in search of values and eigenvectors of:

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

A : damping matrix of the complete system
C : stamp of Coriolis of the complete system.

Note:
The number of calculated `modes` NVES must be identical for all rotational speeds.

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

3.3 Operand VITE_ROTA

♦ `VITE_ROTA = l_vit`

List rotational speeds Ω which is the same list which was used during the computation of the modes of the system in rotation by the macro `MODE_EN_ROTATION`. For better following the modes, this list presents the beach velocities:

Initial rotational speed: $Omega_{min}$
Final rotational speed : $Omega_{max}$
No rotational speed: $Delta_{omega}$

The 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 the number of frequencies `NFREQ_CAMP` in the diagram of Campbell.
At least `NVES= NFREQ_CAMP+4`.

Notice

Attention built-in minimum NVES= NFREQ_CAMP+4 is not always sufficient. It is necessary to check the numbers of frequencies calculated by type (bending, torsion, tension/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 computation of the precession.

The computation meaning of direct or opposite precession for the modes in bending at each rotational speed is made in two ways different according to the choice from type of computation 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          [DEFAULT]
```

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

- If the type of follow-up of the modes is PAS_TRI , 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. sort of the frequencies gradually according to the meaning of the precession.
- If the type of follow-up of the modes is TRI_FORM_MOD, i.e. sort by the form of the modes. The sort of the frequencies according to the form of the modes requires the computation of the matrix of MAC correlation of the modes.

3.7 Operands of the logical units

In output of this macro, four diagrams of Campbell are generated:

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

3.7.1 Operand UNIT_FLE

♦ UNIT_FLE = unit_fle

Makes it possible to choose on which logical unit one prints the diagram of Campbell for the modes in bending. The value of unit_fle must be the same one as in the Astk interface.

3.7.2 Operand UNIT_TOR

♦ UNIT_TOR = unit_tor

Makes it possible to choose on which logical unit one prints the diagram of Campbell for the modes of torsion. The value of `unit_fle` must be the same one as in the Astk `interface`.

3.7.3 Operand UNIT_LON

♦ UNIT_LON = unit_lon

Makes it possible to choose on which logical unit one prints the diagram of Campbell for the modes in tension/compression. The value of `unit_fle` must be the same one as in the Astk `interface`.

3.8 Operand of the logical units

the points of intersection of the rights of slope S with the diagram of Campbell are saved in a textual file.

♦ UNIT_INT = unit_int ,

Makes it possible to choose on which logical unit will be saved these points of intersection (rotational speed, frequency). The value of `unit_int` must be the same one as in the Astk `interface`, 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.                    [DEFAULT]
```

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

The line of slope $S=1$ makes it possible 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.

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

4 Results file

4.1 results

In the results file, one displays:

Number of values clean detected
Many frequencies requested for the layout

Many total frequencies
Many frequencies in bending
Many frequencies in torsion
Many frequencies in tension/compression

frequencies and the reduced dampings
the MAC matrixes in the case of the method of follow-up of 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 rotational speed, with the meanings of precession. Instability is indicated.

The straight lines of slopes S are plotted. The straight line of slope $1.$ is always plotted.
A file contains the points of intersection of the rights with the diagram of Campbell.

4.2 Code color of the layout

By the codes of colors of the layouts, one specifies the meaning of precession for the modes in bending.

	Direct precession	opposite Precession
Stable	Green, Blue continuous	feature, 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 tension/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.];

DIAGRAM_CAMPBELL (MAILLAGE   =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:

```
Number of values clean detected Many
frequencies required for layout 11 are  20
```

	calculated	Traced
Many total frequencies	20	11
Many frequencies in bending	16	8
Many frequencies in torsion	2	2
Many frequencies in tension/compression	2	1

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

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

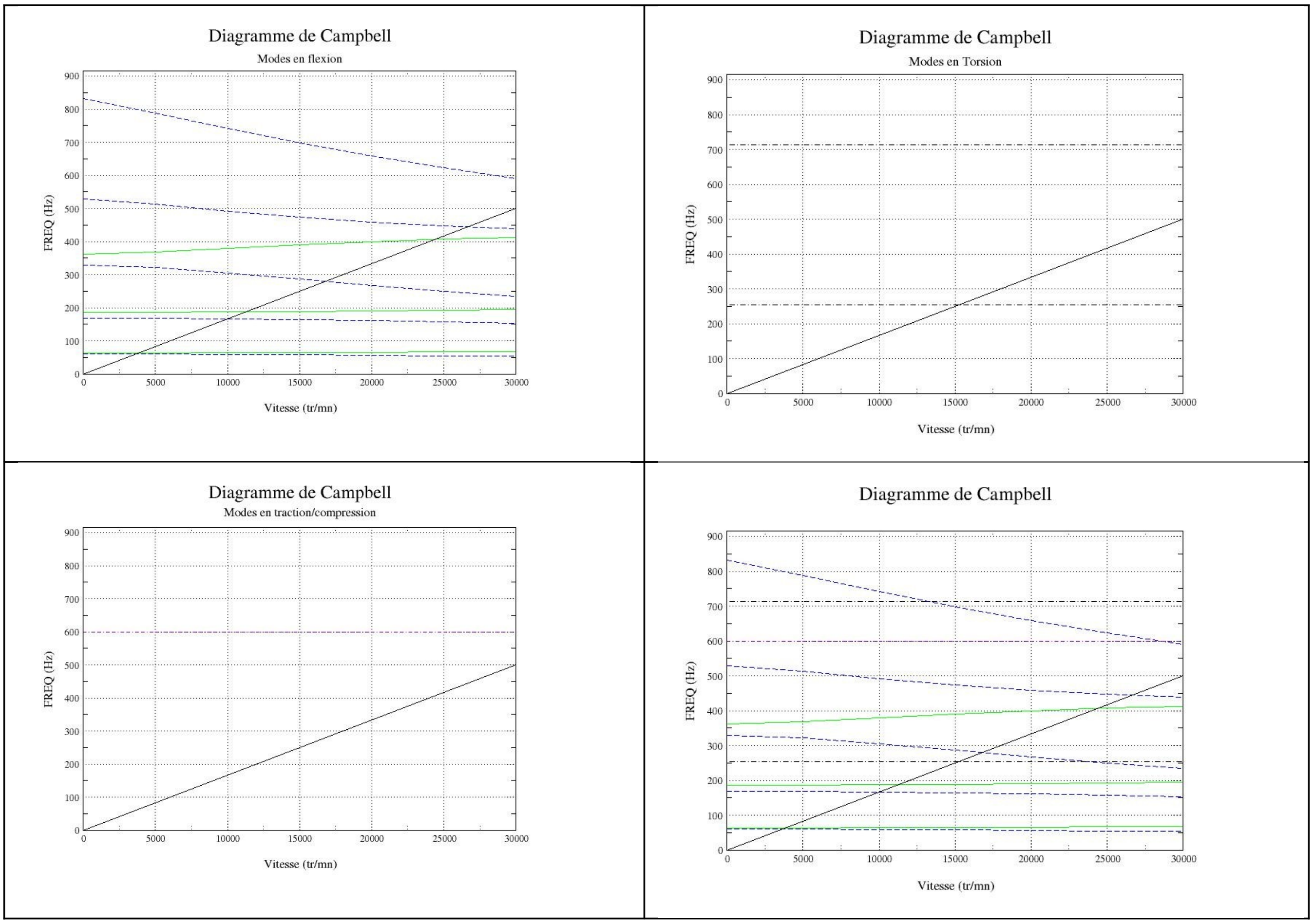

Figure 5-a : Diagrams of Campbell in bending, torsion and tension/compression

the file fort.25 contains the points of intersection.

```
Mode in bending
Points D intersection with lines Y=SX
S =        1.00
Velocity   =    3615.86 rpm
Frequency =      60.26 HZ
Velocity   =    3802.16 rpm
Frequency =      63.37 HZ
Velocity   =   10018.17 rpm
Frequency =     166.97 HZ
Velocity   =   11282.42 rpm
Frequency =     188.04 HZ
Velocity   =   16773.01 rpm
Frequency =     279.55 HZ
Velocity   =   24399.86 rpm
Frequency =     406.66 HZ
Velocity   =   26635.07 rpm
Frequency =     443.92 HZ
----------------------------
Mode in Torsion
Points D intersection with lines Y=SX
S =        1.00
Velocity   =   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 bending, LaMCoS UMR5259, INSA-Lyon.