

# Rotor 28B

- [Français](#)
- [English](#)

Downloadable files

×

**Open access**

[Git project](#)

## About

Rotor 28B is part of a research program to study the effects of aspect ratio, diffusion factor, and solidity on rotors. To do so, experimental studies have been conducted on a series of high-hub-tip-radius-ratio compressor stages representative of the middle and latter stages of axial-flow compressors. In fact, 14 middle stages were tested to assess the effects on performance of varying both diffusion through the rotor and stator blades and blade aspect ratio. Among these 14 stages, there are rotors 23B, 24A, 25A, 26B, 27A and 28B. Both the tip diameter and the hub-tip radius ratio were held constant throughout each stage at 50.8 centimeters and 0.8, respectively.

- Original technical report <sup>[1]</sup>:

```
@TechReport{britsch1979design,  
  author      = {Britsch, Werner R. and Osborn, Walter M. and  
Laessig, Mark R.},  
  date        = {1979},  
  institution = {NASA Lewis Research Center Cleveland, OH, United  
States},  
  title       = {Effects of Diffusion Factor, Aspect Ratio, and  
Solidity on Overall Performance of 14 Compressor Middle Stages},  
  number      = {NASA-TP-1523},  
  url         = {https://ntrs.nasa.gov/citations/19790025039},  
}
```

- Picture :



Fig1. <https://catalog.archives.gov/id/17446213>

- @Misc{brown1975records,  
author = {Brown, M.},  
title = {Rotor 28B - Stator 22. {R}ecords of the {N}ational  
{A}eronautics and {S}pace {A}dministration, 1903 - 2006. {P}hotographs  
relating to agency activities, facilities and personnel, 1975 - 2013},  
url = {<https://catalog.archives.gov/id/17446213>}}

### Useful documents

- [downloadable models](#) (Git project)
  - NASA technical report  
(.pdf)
  - geometrical parameters file  
(.csv), usable as input of OpenMCAD<sup>[2]</sup> to generate reference blade models.

## Reference blade

The **reference blade** is defined with multiple-circular arc profiles<sup>[3]</sup> given in the original NASA report<sup>[1]</sup>. Corresponding models are computed with the open-source code OpenMCAD<sup>[2]</sup>.

## Geometry

The geometry of rotor 28B is described in the original NASA report by the following tables. The length are in centimeters and the angles in degrees.

TABLE 13. - BLADE GEOMETRY FOR ROTOR 28B

| RP  | PERCENT RADII |        |        | BLADE ANGLES |       |       | DELTA<br>'INC | CONE<br>ANGLE |
|-----|---------------|--------|--------|--------------|-------|-------|---------------|---------------|
|     | SPAN          | RI     | RO     | KIC          | KTC   | KOC   |               |               |
| TIP | 0.            | 25.400 | 25.400 | 64.08        | 54.88 | 45.13 | 2.47          | 0.057         |
| 1   | 5.            | 25.191 | 25.146 | 63.64        | 54.10 | 43.52 | 2.63          | -0.606        |
| 2   | 10.           | 24.952 | 24.892 | 63.17        | 53.28 | 41.95 | 2.80          | -0.901        |
| 3   | 15.           | 24.701 | 24.638 | 62.75        | 52.52 | 40.44 | 2.99          | -0.920        |
| 4   | 30.           | 23.905 | 23.876 | 61.79        | 50.77 | 36.55 | 3.56          | -0.401        |
| 5   | 50.           | 22.831 | 22.860 | 60.68        | 48.52 | 30.86 | 4.23          | 0.375         |
| 6   | 70.           | 21.757 | 21.844 | 59.54        | 46.14 | 24.17 | 4.95          | 1.054         |
| 7   | 85.           | 20.971 | 21.082 | 58.68        | 44.18 | 18.04 | 5.39          | 1.282         |
| 8   | 90.           | 20.730 | 20.828 | 58.38        | 43.17 | 14.75 | 5.50          | 1.112         |
| 9   | 95.           | 20.503 | 20.574 | 58.08        | 41.90 | 10.38 | 5.59          | 0.775         |
| HUB | 100.          | 20.320 | 20.320 | 57.82        | 40.76 | 5.60  | 5.66          | 0.057         |

| RP  | BLADE THICKNESSES |       |       | AXIAL DIMENSIONS |       |       |       |
|-----|-------------------|-------|-------|------------------|-------|-------|-------|
|     | TI                | TM    | TO    | ZIC              | ZMC   | ZTC   | ZCC   |
| TIP | 0.051             | 0.188 | 0.051 | 0.702            | 2.319 | 2.253 | 4.362 |
| 1   | 0.051             | 0.197 | 0.051 | 0.669            | 2.320 | 2.224 | 4.419 |
| 2   | 0.051             | 0.207 | 0.051 | 0.634            | 2.320 | 2.191 | 4.473 |
| 3   | 0.051             | 0.217 | 0.051 | 0.599            | 2.320 | 2.157 | 4.523 |
| 4   | 0.051             | 0.250 | 0.051 | 0.515            | 2.316 | 2.055 | 4.645 |
| 5   | 0.051             | 0.292 | 0.051 | 0.402            | 2.309 | 1.909 | 4.808 |
| 6   | 0.051             | 0.332 | 0.051 | 0.279            | 2.303 | 1.744 | 4.983 |
| 7   | 0.051             | 0.360 | 0.051 | 0.172            | 2.297 | 1.603 | 5.125 |
| 8   | 0.051             | 0.369 | 0.051 | 0.120            | 2.296 | 1.541 | 5.192 |
| 9   | 0.051             | 0.377 | 0.051 | 0.057            | 2.295 | 1.468 | 5.278 |
| HUB | 0.051             | 0.383 | 0.051 | -0.000           | 2.294 | 1.404 | 5.370 |

## Aerodynamic design

|                                   | unit    | value  |
|-----------------------------------|---------|--------|
| pressure ratio                    | [-]     | 1.399  |
| mass flow                         | [kg/s]  | 9.46   |
| tip speed                         | [m/s]   | 243.8  |
| tip solidity                      | [-]     | 1.8    |
| aspect ratio                      | [-]     | 0.8    |
| number of blades                  | [-]     | 45     |
| nominal rotation speed $\omega_n$ | [rad/s] | 960.28 |

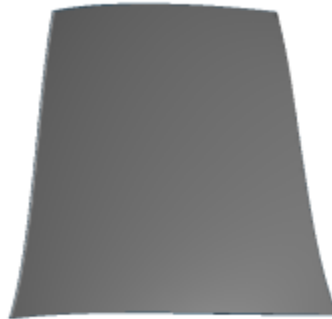
## Material properties

The original material of the rotor 28B is not defined in the NASA report. A 200-grade maraging steel is considered:

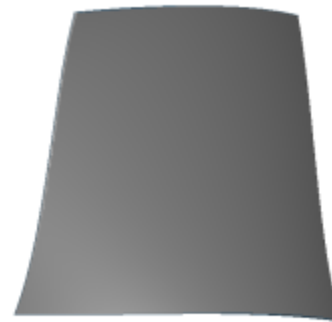
|                 | unit                 | value              |
|-----------------|----------------------|--------------------|
| alloy           | [-]                  | 18-Ni-200-maraging |
| Young's modulus | [GPa]                | 180                |
| density         | [kg/m <sup>3</sup> ] | 8000               |
| Poisson's ratio | [-]                  | 0.3                |
| yield stress    | [GPa]                | 1.38               |

## CAD model

The CAD model is computed with the open source code OpenMCAD<sup>[2]</sup>.



pressure side



suction side



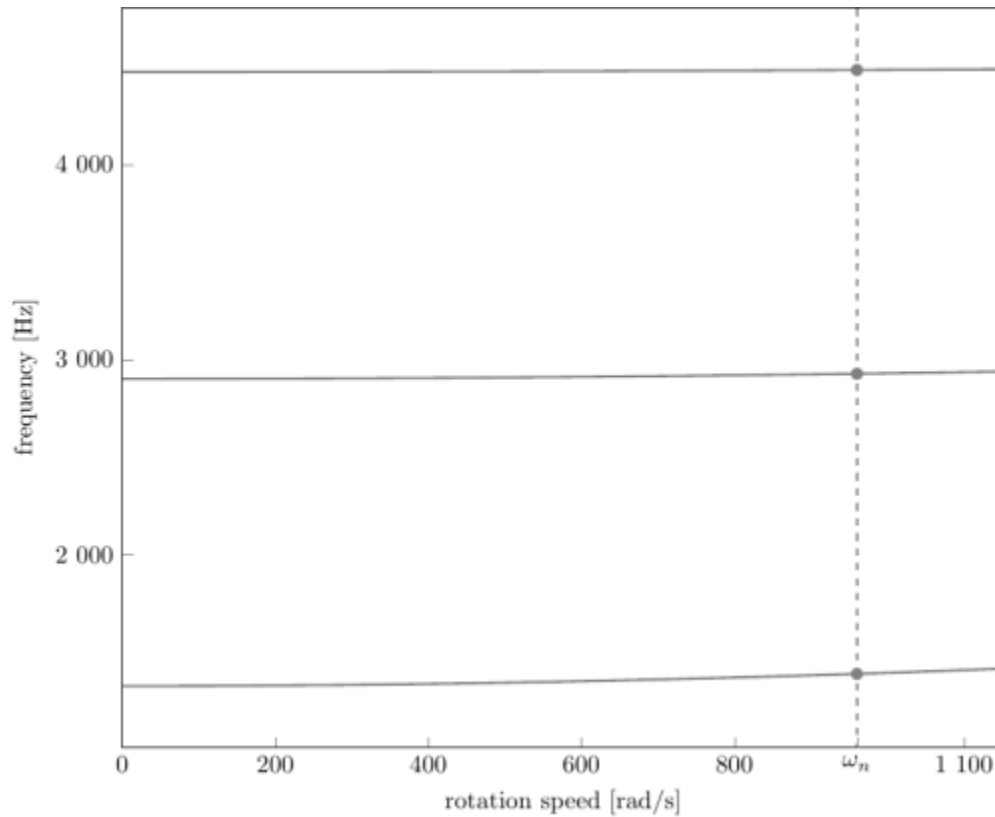
## Natural frequencies

First three natural frequencies (with clamped root) for the mesh computed with OpenMCAD<sup>[2]</sup>:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|------|------|-------------------------------------|------------------------|
| 1    | 1B   | 8345.01                             | 1328.15                |
| 2    | 1T   | 18238.58                            | 2902.76                |
| 3    | 2B   | 28121.40                            | 4475.66                |

## Campbell diagram

Evolution of the natural frequencies of the first 3 vibration modes, as a function of rotation speed, for the mesh computed with OpenMCAD<sup>[2]</sup>:



Campbell diagram computed with a linear centrifugal preload, with clamped root (nominal rotation speed  $\omega_n = 960.28$  rad/s)

- graph (.pdf)
- Campbell data (.csv)

## Initial blade

The **initial blade** is defined with in-house LAVA parameters<sup>[4]</sup> computed from the reference blade CAD model. The initial blade is usually used as starting point for an optimization process. Its geometry is similar to the one of the reference blade.

## Natural frequencies

First three natural frequencies (with clamped root)

- from the whole mesh:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|------|------|-------------------------------------|------------------------|
| 1    | 1B   | 8253.97                             | 1313.66                |
| 2    | 1T   | 18215.39                            | 2899.07                |
| 3    | 2B   | 28231.55                            | 4493.19                |

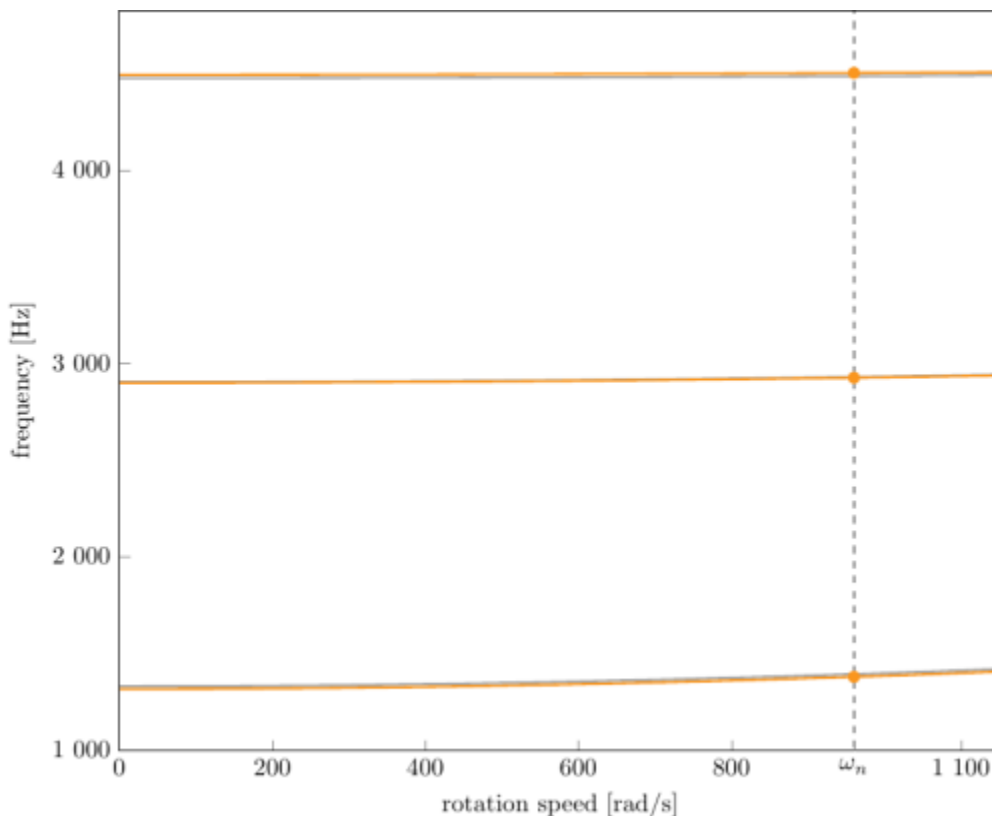
- from the reduced order model:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|------|------|-------------------------------------|------------------------|
| 1    | 1B   | 8255.79                             | 1313.95                |
| 2    | 1T   | 18231.98                            | 2901.71                |

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|------|------|-------------------------------------|------------------------|
| 3    | 2B   | 28284.64                            | 4501.64                |

## Campbell diagram

Comparison of the evolution of the natural frequencies of the first 3 vibration modes, as a function of rotation speed for the initial and the reference blade:



Campbell diagram computed with a linear centrifugal preload, with clamped root (nominal speed  $\omega_n = 960,28$  rad/s),

initial blade (orange), reference blade (gray)

- graph (.pdf)
- Campbell data (.csv)

Fichiers téléchargeables

×

**Libre accès**

[lien vers le projet Git](#)

## À propos

Le rotor 28B fait partie d'un programme de recherche visant à étudier les effets de l'allongement, du

facteur de diffusion et de la solidité des rotors. Pour ce faire, des études expérimentales ont été menées sur une série d'étages de compresseurs à fort rapport entre les rayons du moyeu et de la tête d'aube, représentatifs des étages moyens et avancés des compresseurs à flux axial. En effet, 14 étages intermédiaires ont été testés pour évaluer les effets sur les performances de la variation de la diffusion et de l'allongement des aubes. Parmi ces 14 étages, on trouve les rotors 23B, 24A, 25A, 26B, 27A et 28B. Le diamètre de l'extrémité des aubes et le rapport entre les rayons du moyeu et de la tête d'aube ont été maintenus constants tout au long de chaque étage, respectivement à 50,8 centimètres et 0,8.

- Rapport technique original <sup>[1]</sup>:

```
@TechReport{britsch1979design,  
  author      = {Britsch, Werner R. and Osborn, Walter M. and  
Laessig, Mark R.},  
  date        = {1979},  
  institution  = {NASA Lewis Research Center Cleveland, OH, United  
States},  
  title       = {Effects of Diffusion Factor, Aspect Ratio, and  
Solidity on Overall Performance of 14 Compressor Middle Stages},  
  number      = {NASA-TP-1523},  
  url         = {https://ntrs.nasa.gov/citations/19790025039},  
}
```

- Photographie :



Fig1. <https://catalog.archives.gov/id/17446213>

- @Misc{brown1975records,

```
author = {Brown, M.},
title = {Rotor 28B - Stator 22. {R}ecords of the {N}ational
{A}eronautics and {S}pace {A}dministration, 1903 - 2006. {P}hotographs
relating to agency activities, facilities and personnel, 1975 - 2013},
url = {https://catalog.archives.gov/id/17446213}}
```

## Documents utiles

- [modèles téléchargeables](#) (lien vers projet Git)
  - rapport technique original de la NASA (.pdf)
  - fichier de paramètres géométriques (.csv), utilisable en entrée de OpenMCAD<sup>[2]</sup> pour générer l'aube de référence

## Aube de référence

L'**aube de référence** est définie par des profils de type arcs circulaires multiples<sup>[3]</sup>, donnés dans le rapport technique original de la NASA<sup>[1]</sup>. Les modèles associés sont obtenus avec le code en libre accès OpenMCAD<sup>[2]</sup>.

## Géométrie

La géométrie du rotor 28B est décrite dans le [rapport d'origine de la NASA](#) par les tableaux suivants. Les grandeurs sont en centimètres et en degrés.

TABLE 13. - BLADE GEOMETRY FOR ROTOR 28B

| RP  | PERCENT RADII |        |        | BLADE ANGLES |       |       | DELTA<br>INC | CONE<br>ANGLE |
|-----|---------------|--------|--------|--------------|-------|-------|--------------|---------------|
|     | SPAN          | RI     | RO     | KIC          | KTC   | KOC   |              |               |
| TIP | 0.            | 25.400 | 25.400 | 64.08        | 54.88 | 45.13 | 2.47         | 0.057         |
| 1   | 5.            | 25.191 | 25.146 | 63.64        | 54.10 | 43.52 | 2.63         | -0.606        |
| 2   | 10.           | 24.952 | 24.892 | 63.17        | 53.28 | 41.95 | 2.80         | -0.901        |
| 3   | 15.           | 24.701 | 24.638 | 62.75        | 52.52 | 40.44 | 2.99         | -0.920        |
| 4   | 30.           | 23.905 | 23.876 | 61.79        | 50.77 | 36.53 | 3.56         | -0.401        |
| 5   | 50.           | 22.831 | 22.860 | 60.68        | 48.52 | 30.86 | 4.23         | 0.375         |
| 6   | 70.           | 21.757 | 21.844 | 59.54        | 46.14 | 24.17 | 4.95         | 1.054         |
| 7   | 85.           | 20.971 | 21.082 | 58.68        | 44.18 | 18.04 | 5.59         | 1.282         |
| 8   | 90.           | 20.730 | 20.828 | 58.38        | 43.17 | 14.75 | 5.50         | 1.112         |
| 9   | 95.           | 20.503 | 20.574 | 58.08        | 41.90 | 10.38 | 5.59         | 0.775         |
| HUB | 100.          | 20.320 | 20.320 | 57.82        | 40.76 | 5.60  | 5.66         | 0.057         |

| RP  | BLADE THICKNESSES |       |       | AXIAL DIMENSIONS |       |       |       |
|-----|-------------------|-------|-------|------------------|-------|-------|-------|
|     | TI                | TM    | TO    | ZIC              | ZMC   | ZTC   | ZCC   |
| TIP | 0.051             | 0.188 | 0.051 | 0.702            | 2.319 | 2.255 | 4.362 |
| 1   | 0.051             | 0.197 | 0.051 | 0.669            | 2.320 | 2.224 | 4.419 |
| 2   | 0.051             | 0.207 | 0.051 | 0.634            | 2.320 | 2.191 | 4.473 |
| 3   | 0.051             | 0.217 | 0.051 | 0.599            | 2.320 | 2.157 | 4.523 |
| 4   | 0.051             | 0.250 | 0.051 | 0.515            | 2.316 | 2.055 | 4.645 |
| 5   | 0.051             | 0.292 | 0.051 | 0.402            | 2.309 | 1.909 | 4.808 |
| 6   | 0.051             | 0.332 | 0.051 | 0.279            | 2.303 | 1.744 | 4.983 |
| 7   | 0.051             | 0.360 | 0.051 | 0.172            | 2.297 | 1.603 | 5.125 |
| 8   | 0.051             | 0.369 | 0.051 | 0.120            | 2.296 | 1.541 | 5.192 |
| 9   | 0.051             | 0.377 | 0.051 | 0.057            | 2.295 | 1.468 | 5.278 |
| HUB | 0.051             | 0.383 | 0.051 | -0.000           | 2.294 | 1.404 | 5.370 |

## Caractéristiques aérodynamiques

|   | unités  | valeurs |
|---|---------|---------|
| taux de compression                     | [-]     | 1,399   |
| débit massique                          | [kg/s]  | 9,46    |
| vitesse en tête                         | [m/s]   | 243,8   |
| solidité en tête                        | [-]     | 1,8     |
| allongement                             | [-]     | 0,8     |
| nombre d'aubes                          | [-]     | 45      |
| vitesse de rotation nominale $\omega_n$ | [rad/s] | 960,28  |

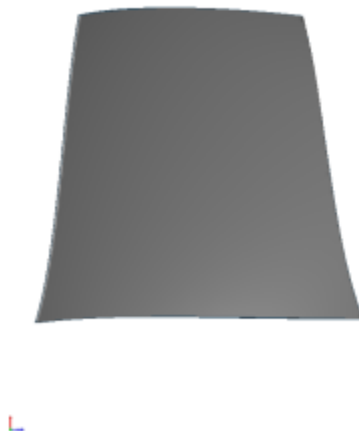
## Propriétés matériau

Le matériau original du rotor 28B n'est pas défini dans le rapport de la NASA. Un acier maraging de grade 200 est considéré :

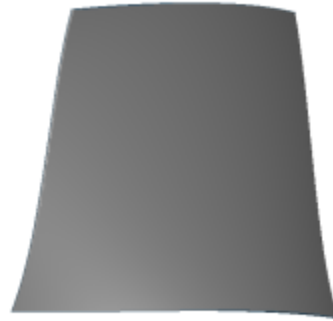
|                        | unité                | valeurs            |
|------------------------|----------------------|--------------------|
| alliage                | [-]                  | 18-Ni-200-maraging |
| module d'Young         | [GPa]                | 180                |
| masse volumique        | [kg/m <sup>3</sup> ] | 8000               |
| coefficient de Poisson | [-]                  | 0,3                |
| limite élastique       | [GPa]                | 1,38               |

## Modèle CAO

Le modèle CAO est obtenu avec OpenMCAD<sup>[2]</sup>.



intrados



extrados

## Fréquences propres

Fréquences des trois premiers modes (noeuds du pied d'aube encastrés) pour le maillage obtenu avec OpenMCAD<sup>[2]</sup> :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|------|------|----------------------------|-----------------------|
| 1    | 1F   | 8345,01                    | 1328,15               |
| 2    | 1T   | 18238,58                   | 2902,76               |
| 3    | 2F   | 28121,40                   | 4475,66               |

## Diagramme de Campbell

Évolution des fréquences propres des 3 premiers modes, en fonction de la vitesse de rotation, pour le maillage obtenu avec OpenMCAD<sup>[2]</sup>:

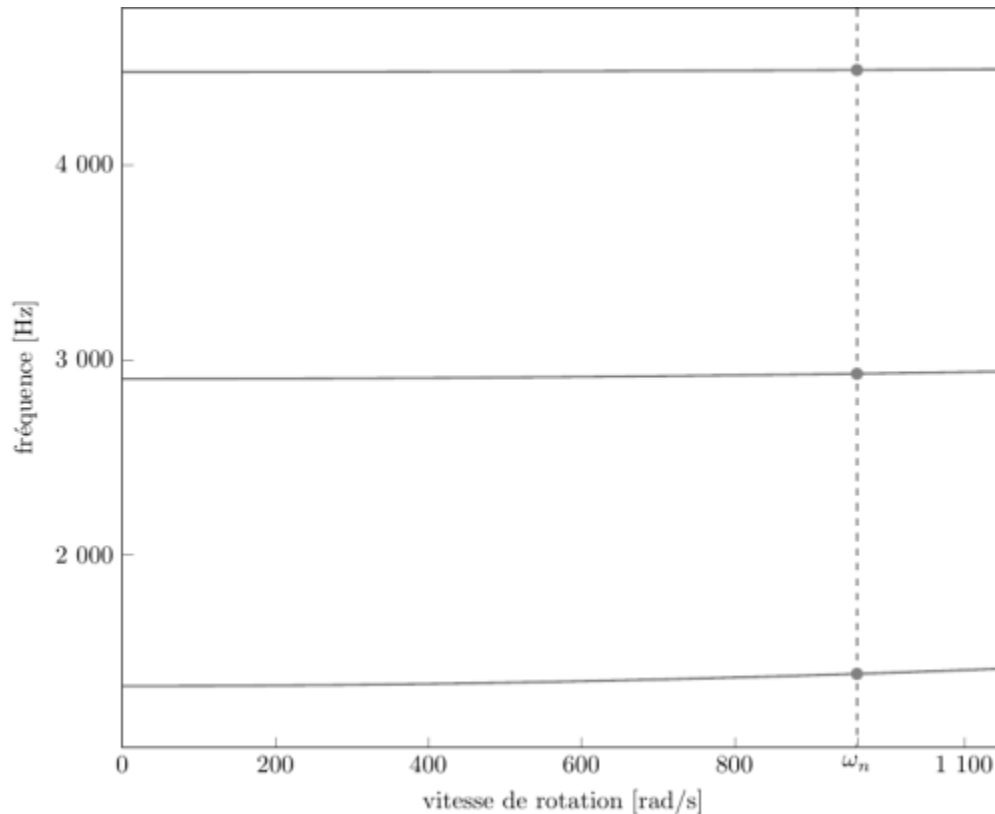


diagramme de Campbell calculé avec une précharge centrifuge linéaire, noeuds du pied d'aube encastrés (vitesse nominale  $\omega_n = 960,28$  rad/s)

- graphique (.pdf)
- données du Campbell (.csv)

## Aube initiale

L'**aube initiale** est définie par des paramètres spécifiques au LAVA<sup>[4]</sup> obtenus à partir du modèle CAO de l'aube de référence. L'aube initiale est classiquement utilisée comme point de départ dans le cadre de procédures d'optimisation; sa géométrie est similaire à celle de l'aube de référence.

## Fréquences propres

Fréquences des trois premiers modes (noeuds du pied d'aube encastrés),

- pour le maillage complet :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|------|------|----------------------------|-----------------------|
| 1    | 1F   | 8253,97                    | 1313,66               |
| 2    | 1T   | 18215,39                   | 2899,07               |
| 3    | 2F   | 28231,55                   | 4493,19               |

- pour le modèle réduit :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|------|------|----------------------------|-----------------------|
| 1    | 1F   | 8255,79                    | 1313,95               |

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|------|------|----------------------------|-----------------------|
| 2    | 1T   | 18231,98                   | 2901,71               |
| 3    | 2F   | 28284,64                   | 4501,64               |

## Diagramme de Campbell

Comparaison de l'évolution des fréquences propres des 3 premiers modes, en fonction de la vitesse de rotation, pour l'aube initiale et de référence:

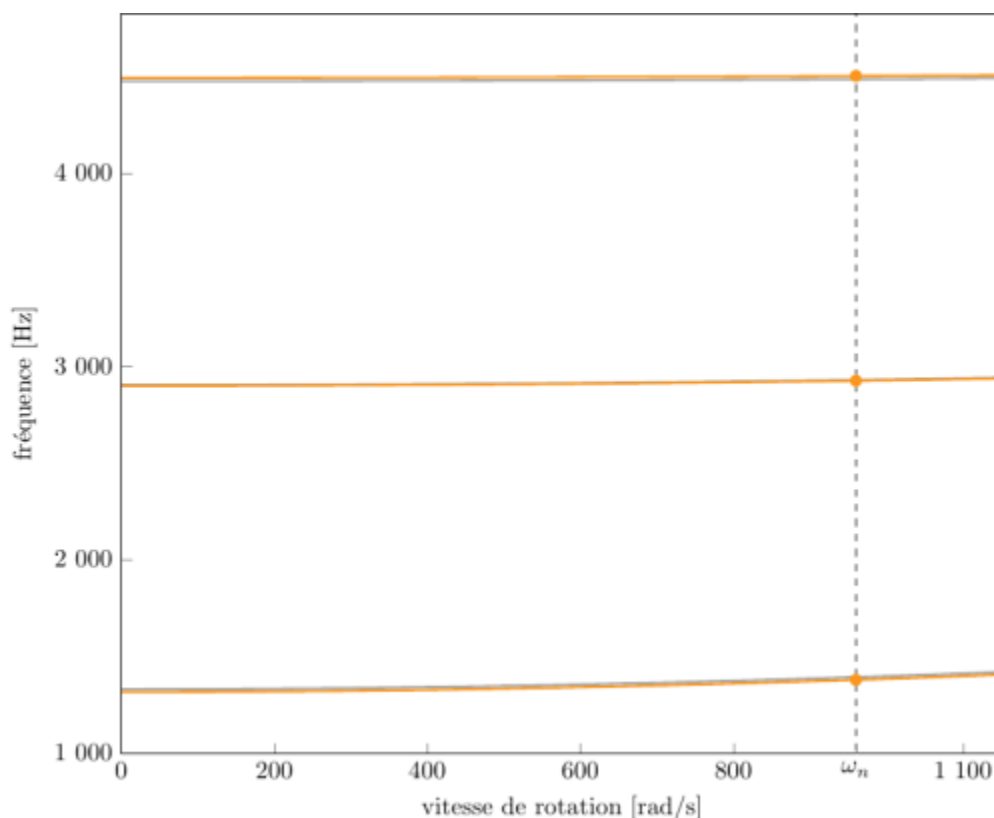


diagramme de Campbell calculé avec une précharge centrifuge linéaire, noeuds du pied d'aube encastrés (vitesse nominale  $\omega_n = 960,28$  rad/s),

aube initiale (orange), aube de référence (grise)

- graphique (.pdf)
- données du Campbell (.csv)

1. <sup>a, b, c, d</sup> Britsch *et al.* «Design and overall performance of four highly loaded, high speed inlet stages for an advanced high-pressure-ratio core compressor » 1979. [pdf](#)
2. <sup>a, b, c, d, e, f, g, h, i, j</sup> Kojtych S., Batailly A. «OpenMCAD, an open blade generator: from Multiple-Circular-Arc profiles to Computer-Aided Design model» 2022. [open source code](#)
3. <sup>a, b</sup> Crouse *et al.* «A computer program for composing compressor blading from simulated circular-arc elements on conical surfaces » 1969. NASA-TN-D-5437. [pdf](#)
4. <sup>a, b</sup> Kojtych S. *et al.* «Methodology for the Redesign of Compressor Blades Undergoing Nonlinear

Structural Interactions: Application to Blade-Tip/Casing Contacts » 2022. Journal of Engineering for Gas Turbines and Power, Vol. 145, No. 5. [pdf](#)

Document issu de la page wiki:

[https://lava-wiki.meca.polymtl.ca/public/modeles/rotor\\_28b/accueil](https://lava-wiki.meca.polymtl.ca/public/modeles/rotor_28b/accueil)

Dernière mise à jour: **2024/07/29 13:35**