# Rotor 1

- Français
- English

Downloadable models
×

**Open access**

**Git project**

## About

Rotor 1 is part of a research program to study aspect ratio because the use of high aspect ratio blading can lead to a decrease in the axial length of compressors and therefore a reduction of their size and weight. To investigate the effects of aspect ratio on compressor range and efficiency, two transonic rotors (rotor 1 and 2) were designed and tested. The variation in aspect ratio was based on a change in aerodynamic chord, and the solidity was kept the same by varying the number of blades.

- Original NASA technical report [(cite:hager1974design>Hager. «Effect of damper on overall and blade-element performance of a compressor rotor having a tip speed of 1151 feet per second and an aspect ratio of 3.6 » 1974. pdf)]:

```
@TechReport{hager1974design,
  author           = {Hager, Roy D. and Lewis, George W.},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
  title            = {Effect of damper on overall and blade-element
performance of a compressor rotor having a tip speed of 1151 feet per
second and an aspect ratio of 3.6},
  year             = {1974},
  number           = {NASA-TM X-3041},
  url              = {https://ntrs.nasa.gov/citations/19740018135},
}
```

- Pictures :

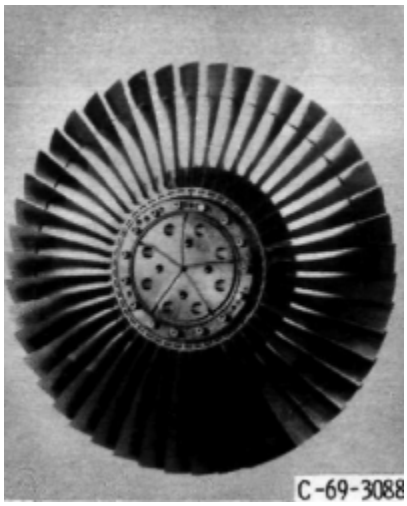



Fig1. https://ntrs.nasa.gov/citations/19740018135 p.68

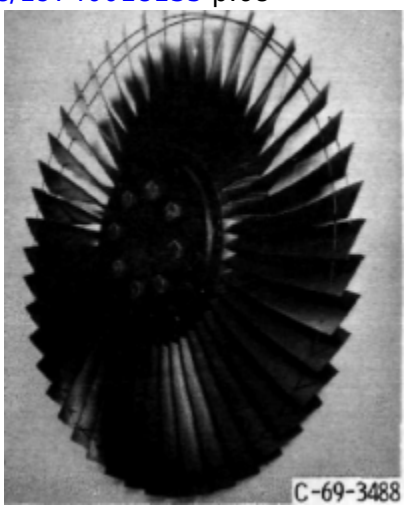



Fig2. https://ntrs.nasa.gov/citations/19740018135 p.68

**Useful documents**

- downloadable models (Git project)
  - NASA technical report (.pdf)
  - geometrical parameters file (.csv), usable as input of OpenMCAD[(cite:Kojtych_2022_gene_aubes>Kojtych S., Batailly A. «OpenMCAD, an open blade generator: from Multiple-Circular-Arc profiles to Computer-Aided Design model» 2022. code en libre accès)] to generate reference blade models.

# Reference blade

The **reference blade** is defined with multiple-circular arc profiles[(cite:Crouse_1969_computer)] given in the original NASA report[(cite:hager1974design)]. Corresponding models are computed with the open-source code OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

## Geometry

The geometry of rotor 1 is described in the original NASA report by the following table. The lenghts are in inches and the angles in degrees.

ROTOR 1 - MOD 1

| RP | PERCENT SPAN | RADII RI | RADII RO | BLADE ANGLES KIC | BLADE ANGLES KTC | BLADE ANGLES KOC | DELTA INC |
|---|---|---|---|---|---|---|---|
| TIP | 0. | 10.000 | 9.900 | 59.46 | 52.90 | 46.35 | 3.21 |
| 1 | 5. | 9.730 | 9.657 | 57.70 | 51.81 | 45.80 | 3.31 |
| 2 | 10. | 9.442 | 9.413 | 56.00 | 50.54 | 45.00 | 3.43 |
| 3 | 20. | 8.883 | 8.927 | 53.05 | 47.75 | 42.30 | 3.64 |
| 4 | 22. | 8.740 | 8.810 | 52.40 | 46.97 | 41.50 | 3.70 |
| 5 | 25. | 8.604 | 8.684 | 51.70 | 46.21 | 40.40 | 3.75 |
| 6 | 28. | 8.460 | 8.560 | 51.20 | 45.37 | 39.00 | 3.80 |
| 7 | 30. | 8.313 | 8.430 | 50.50 | 44.48 | 37.80 | 3.87 |
| 8 | 33. | 8.160 | 8.300 | 49.80 | 43.52 | 36.40 | 3.92 |
| 9 | 50. | 7.193 | 7.467 | 45.70 | 36.53 | 26.30 | 4.33 |
| 10 | 70. | 5.991 | 6.494 | 39.90 | 25.27 | 10.00 | 5.09 |
| 11 | 90. | 4.630 | 5.521 | 33.45 | 10.69 | -10.50 | 6.38 |
| HUB | 100. | 4.000 | 5.050 | 30.78 | 4.42 | -21.94 | 7.07 |

| RP | BLADE THICKNESSES TI | BLADE THICKNESSES TM | BLADE THICKNESSES TO | AXIAL DIMENSIONS ZMC | AXIAL DIMENSIONS ZTC | AXIAL DIMENSIONS ZOC | CONE ANGLE |
|---|---|---|---|---|---|---|---|
| TIP | 0.020 | 0.073 | 0.020 | 0.501 | 0.501 | 1.084 | -3.800 |
| 1 | 0.020 | 0.074 | 0.020 | 0.520 | 0.520 | 1.116 | -2.100 |
| 2 | 0.020 | 0.075 | 0.020 | 0.540 | 0.540 | 1.149 | -0.900 |
| 3 | 0.020 | 0.078 | 0.020 | 0.574 | 0.574 | 1.215 | 1.600 |
| 4 | 0.020 | 0.078 | 0.020 | 0.582 | 0.582 | 1.231 | 2.300 |
| 5 | 0.020 | 0.079 | 0.020 | 0.589 | 0.589 | 1.248 | 2.900 |
| 6 | 0.020 | 0.080 | 0.020 | 0.597 | 0.597 | 1.265 | 3.700 |
| 7 | 0.020 | 0.081 | 0.020 | 0.604 | 0.604 | 1.282 | 4.400 |
| 8 | 0.020 | 0.082 | 0.020 | 0.612 | 0.612 | 1.300 | 5.100 |
| 9 | 0.020 | 0.089 | 0.020 | 0.659 | 0.659 | 1.409 | 10.100 |
| 10 | 0.020 | 0.103 | 0.020 | 0.710 | 0.710 | 1.513 | 16.900 |
| 11 | 0.020 | 0.127 | 0.020 | 0.720 | 0.720 | 1.506 | 29.600 |
| HUB | 0.020 | 0.143 | 0.020 | 0.686 | 0.686 | 1.398 | 36.600 |

## Aerodynamic design

| | unit | value |
|---|---|---|
| **pressure ratio** | [-] | 1.53 |
| **mass flow** | [kg/s] | 33.5 |
| **tip speed** | [m/s] | 350.8 |
| **tip solidity** | [-] | 1.3 |
| **aspect ratio** | [-] | 3.6 |
| **nominal rotation speed $\omega_n$** | [rad/s] | 1381.25 |

## Material properties

The material of rotor 1 is not defined in the original NASA report. A 200-grade maraging steel is considered:

| | unit | value |
|---|---|---|
| **alloy** | [-] | 18-Ni-200-maraging |

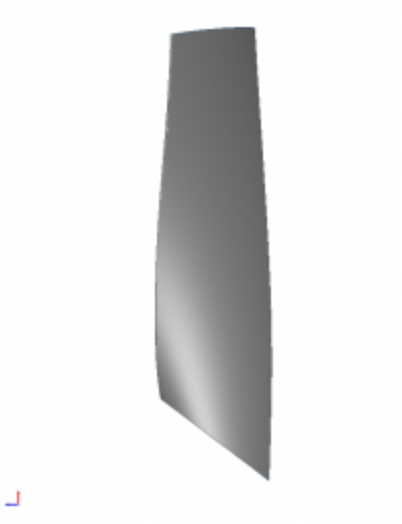
| | unit | value |
|---|---|---|
| **Young's modulus** | [GPa] | 180 |
| **density** | [kg/m3] | 8000 |
| **Poisson's ratio** | [-] | 0.3 |
| **yield stress** | [GPa] | 1.38 |

## CAD model

The CAD model is computed with the open source code OpenMCAD[(cite:Kojtych_2022_gene_aubes)].



pressure side



suction side

## Natural frequencies

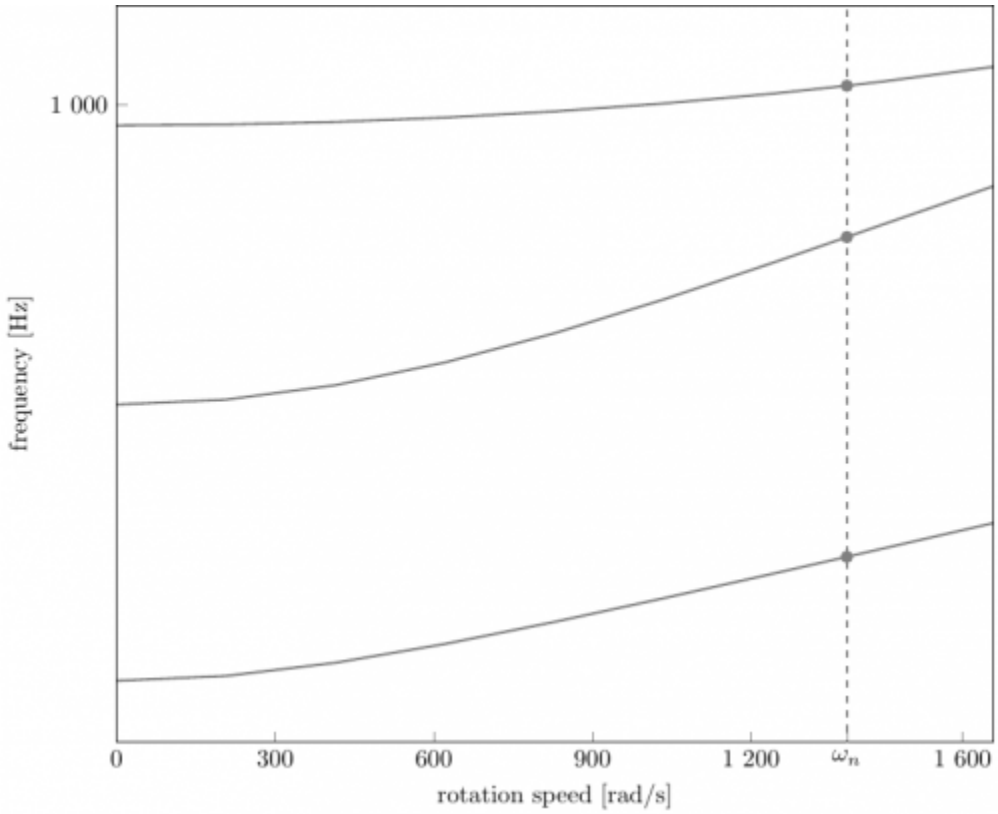
First three natural frequencies (with clamped root) for the mesh computed with OpenMCAD[(cite:Kojtych_2022_gene_aubes)]:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|---|---|---|---|
| 1 | 1B | 1018.5 | 162.1 |

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|---|---|---|---|
| 2 | 1T | 3542.5 | 563.8 |
| 3 | 2B | 6094.7 | 970.0 |

### 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[(cite:Kojtych_2022_gene_aubes)]:




Campbell diagram computed with a linear centrifugal preload, with clamped root (nominal rotation speed $\omega_n$ = 1 381.25 rad/s)

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

# Initial blade

The **initial blade** is defined with in-house LAVA parameters[(cite:Kojtych_2022_Methodology)] 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:

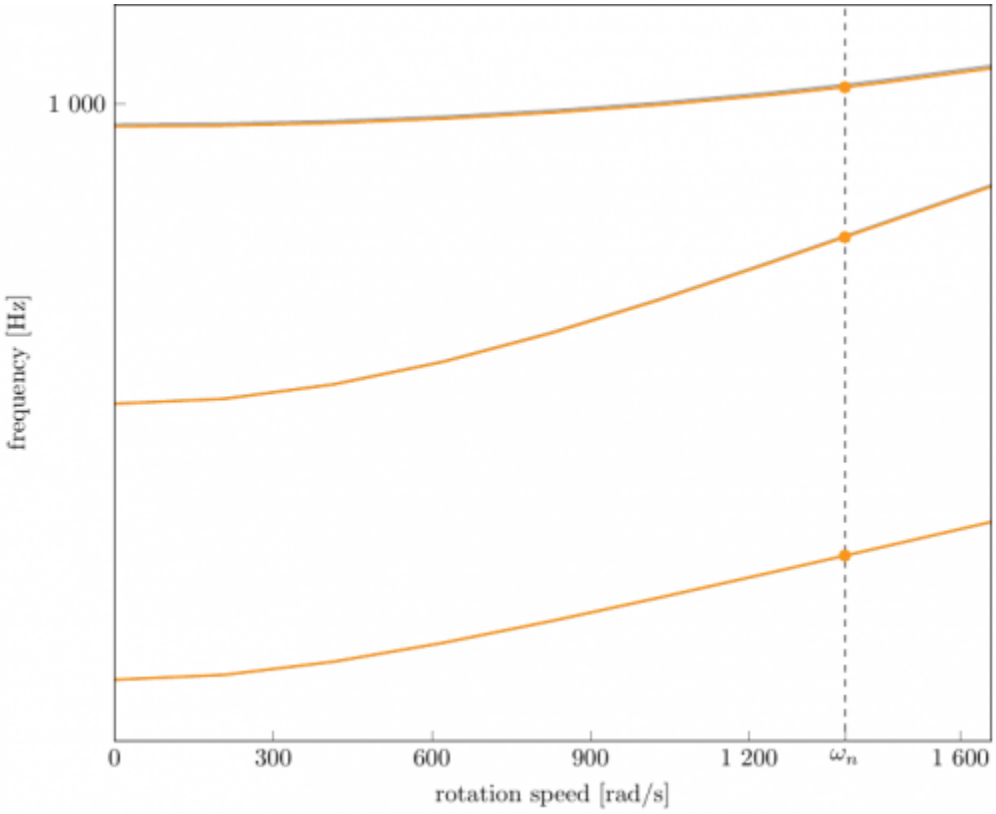
| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|---|---|---|---|
| 1 | 1B | 1019.1 | 162.2 |
| 2 | 1T | 3539.3 | 563.3 |
| 3 | 2B | 6074.0 | 966.7 |

- from the reduced order model:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|---|---|---|---|
| 1 | 1B | 1019.1 | 162.2 |
| 2 | 1T | 3540.8 | 563.5 |
| 3 | 2B | 6075.8 | 967.0 |

## 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 $\omega_n$ = 1 381.25 rad/s),

initial blade (orange), reference blade (gray)

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

Modèles téléchargeables

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**Libre accès**

**lien vers le projet Git**

# À propos

Le rotor 1 fait partie d'un programme de recherche visant à étudier l'allongement des aubes, car l'utilisation d'un fort allongement peut conduire à une diminution de la longueur axiale des compresseurs et donc à une réduction de leur taille et poids. Pour étudier les effets de cet allongement sur les rendements des compresseurs, deux rotors transsoniques (rotor 1 et 2) ont été conçus et testés. La variation d'allongement entre ces deux rotors a été effectuée grâce à une modification de la corde aérodynamique et la solidité a été maintenue identique en faisant varier le nombre d'aubes.

- Rapport technique original [(cite:hager1974design>)]:

```
@TechReport{hager1974design,
  author           = {Hager, Roy D. and Lewis, George W.},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
  title            = {Effect of damper on overall and blade-element
performance of a compressor rotor having a tip speed of 1151 feet per
second and an aspect ratio of 3.6},
  year             = {1974},
  number           = {NASA-TM X-3041},
  url              = {https://ntrs.nasa.gov/citations/19740018135},
}
```

- Photographies :

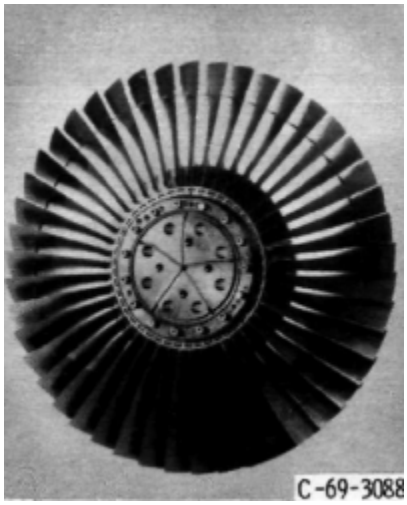



Fig1. https://ntrs.nasa.gov/citations/19740018135 p.68

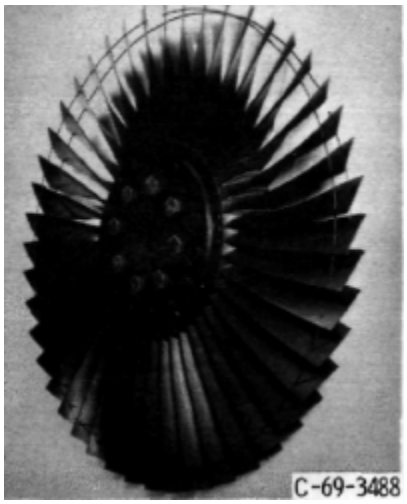



Fig2. https://ntrs.nasa.gov/citations/19740018135 p.68

**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[(cite:Kojtych_2022_gene_aubes>Kojtych S., Batailly A. «OpenMCAD, an open blade generator: from Multiple-Circular-Arc profiles to Computer-Aided Design model» 2022. code en libre accès)] pour générer l'aube de référence

# Aube de référence

L'**aube de référence** est définie par des profils de type arcs circulaires multiples[(cite:Crouse_1969_computer>Crouse *et al*. «A computer program for composing compressor blading from simulated circular-arc elements on conical surfaces » 1969. NASA-TN-D-5437. pdf)], donnés dans le rapport technique original de la NASA[(cite:hager1974design)]. Les modèles associés sont obtenus avec le code en libre accès OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

## Géométrie

La géométrie du rotor 1 est décrite dans le rapport d'origine de la NASA par les tableaux suivants. Les grandeurs sont en pouces et en degrés.

ROTOR 1 - MOD 1

| RP | PERCENT SPAN | RADII RI | RO | BLADE ANGLES KIC | KTC | KOC | DELTA INC |
|---|---|---|---|---|---|---|---|
| TIP | 0. | 10.000 | 9.900 | 59.46 | 52.90 | 46.35 | 3.21 |
| 1 | 5. | 9.730 | 9.657 | 57.70 | 51.81 | 45.80 | 3.31 |
| 2 | 10. | 9.442 | 9.413 | 56.00 | 50.54 | 45.00 | 3.43 |
| 3 | 20. | 8.883 | 8.927 | 53.05 | 47.75 | 42.30 | 3.64 |
| 4 | 22. | 8.740 | 8.810 | 52.40 | 46.97 | 41.50 | 3.70 |
| 5 | 25. | 8.604 | 8.684 | 51.70 | 46.21 | 40.40 | 3.75 |
| 6 | 28. | 8.460 | 8.560 | 51.20 | 45.37 | 39.00 | 3.80 |
| 7 | 30. | 8.313 | 8.430 | 50.50 | 44.48 | 37.80 | 3.87 |
| 8 | 33. | 8.160 | 8.300 | 49.80 | 43.52 | 36.40 | 3.92 |
| 9 | 50. | 7.193 | 7.467 | 45.70 | 36.53 | 26.30 | 4.33 |
| 10 | 70. | 5.991 | 6.494 | 39.90 | 25.27 | 10.00 | 5.09 |
| 11 | 90. | 4.630 | 5.521 | 33.45 | 10.69 | -10.50 | 6.38 |
| HUB | 100. | 4.000 | 5.050 | 30.78 | 4.42 | -21.94 | 7.07 |

| RP | BLADE THICKNESSES TI | TM | TO | AXIAL DIMENSIONS ZMC | ZTC | ZOC | CONE ANGLE |
|---|---|---|---|---|---|---|---|
| TIP | 0.020 | 0.073 | 0.020 | 0.501 | 0.501 | 1.084 | -3.800 |
| 1 | 0.020 | 0.074 | 0.020 | 0.520 | 0.520 | 1.116 | -2.100 |
| 2 | 0.020 | 0.075 | 0.020 | 0.540 | 0.540 | 1.149 | -0.900 |
| 3 | 0.020 | 0.078 | 0.020 | 0.574 | 0.574 | 1.215 | 1.600 |
| 4 | 0.020 | 0.078 | 0.020 | 0.582 | 0.582 | 1.231 | 2.300 |
| 5 | 0.020 | 0.079 | 0.020 | 0.589 | 0.589 | 1.248 | 2.900 |
| 6 | 0.020 | 0.080 | 0.020 | 0.597 | 0.597 | 1.265 | 3.700 |
| 7 | 0.020 | 0.081 | 0.020 | 0.604 | 0.604 | 1.282 | 4.400 |
| 8 | 0.020 | 0.082 | 0.020 | 0.612 | 0.612 | 1.300 | 5.100 |
| 9 | 0.020 | 0.089 | 0.020 | 0.659 | 0.659 | 1.409 | 10.100 |
| 10 | 0.020 | 0.103 | 0.020 | 0.710 | 0.710 | 1.513 | 16.900 |
| 11 | 0.020 | 0.127 | 0.020 | 0.720 | 0.720 | 1.506 | 29.600 |
| HUB | 0.020 | 0.143 | 0.020 | 0.686 | 0.686 | 1.398 | 36.600 |

## Caractéristiques aérodynamiques

| | unité | valeurs |
|---|---|---|
| **taux de compression** | [-] | 1,53 |
| **débit massique** | [kg/s] | 33,5 |
| **vitesse en tête** | [m/s] | 350,8 |
| **solidité en tête** | [-] | 1,3 |
| **allongement** | [-] | 3,6 |
| **vitesse de rotation nominale $\omega_n$** | [rad/s] | 1381,25 |

## Propriétés matériau

Le matériau original du rotor 1 n'est pas défini dans le rapport de la NASA. Un acier maraging de grade 200 est considéré:

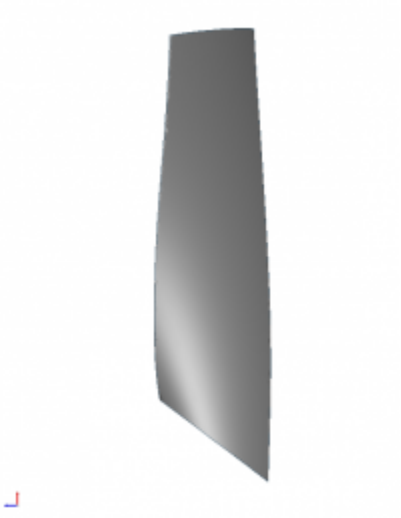
| | unité | valeurs |
|---|---|---|
| **alliage** | [-] | 18-Ni-200-maraging |
| **module d'Young** | [GPa] | 180 |
| **masse volumique** | [kg/m3] | 8000 |
| **coefficient de Poisson** | [-] | 0,3 |
| **limite élastique** | [GPa] | 1,38 |

## Modèle CAO

Le modèle CAO est obtenu avec OpenMCAD[(cite:Kojtych_2022_gene_aubes)].



intrados



extrados

## Fréquences propres

Fréquences des trois premiers modes (noeuds du pied d'aube encastrés) pour le maillage obtenu avec OpenMCAD[(cite:Kojtych_2022_gene_aubes)] :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|---|---|---|---|
| 1 | 1F | 1018,50 | 162,10 |
| 2 | 1T | 3542,50 | 563,80 |
| 3 | 2F | 6094,70 | 970 |

## Diagramme de Campbell

Évolution des fréquences propres des 3 premiers modes, en fonction de la vitesse de rotation, pour le maillage obtenu avec OpenMCAD[(cite:Kojtych_2022_gene_aubes)]:

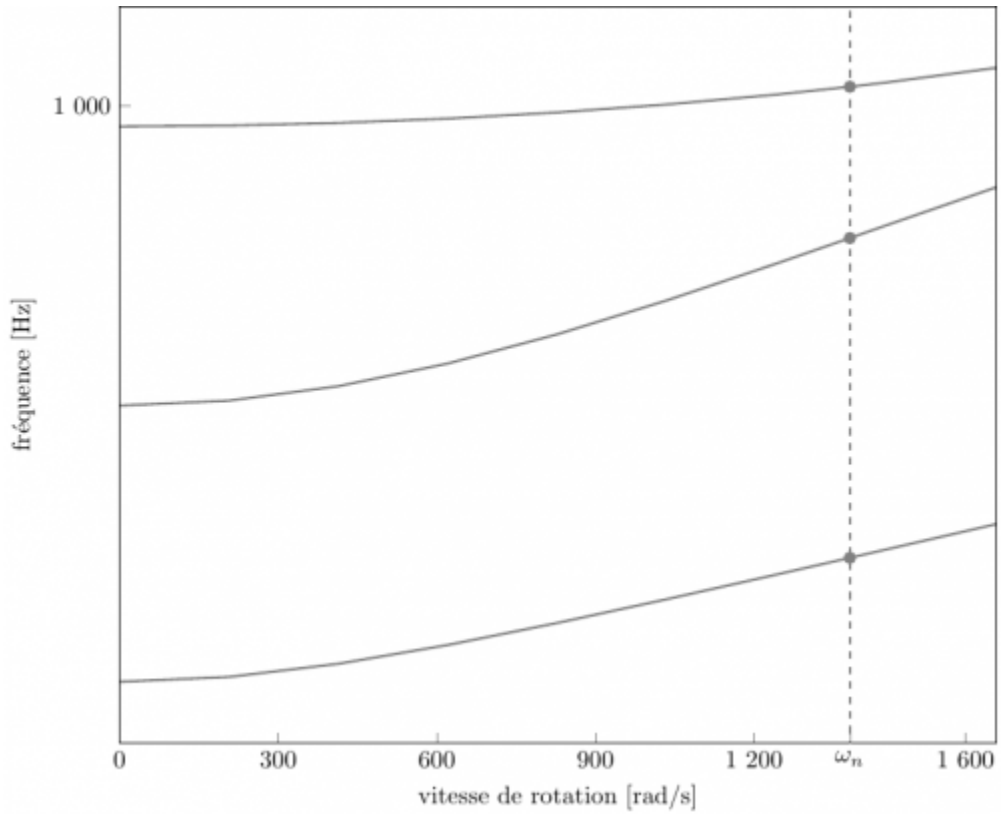



diagramme de Campbell calculé avec une précharge centrifuge linéaire, noeuds du pied d'aube encastrés (vitesse nominale $\omega_n$ = 1 381,25 rad/s)

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

# Aube initiale

L'**aube initiale** est définie par des paramètres spécifiques au LAVA[(cite:Kojtych_2022_Methodology>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)] 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 | 1019,10 | 162,20 |
| 2 | 1T | 3539,30 | 563,30 |
| 3 | 2F | 6074 | 966,70 |

- pour le modèle réduit :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|---|---|---|---|
| 1 | 1F | 1019,10 | 162,20 |
| 2 | 1T | 3540,80 | 563,50 |
| 3 | 2F | 6075,80 | 967 |

## 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:

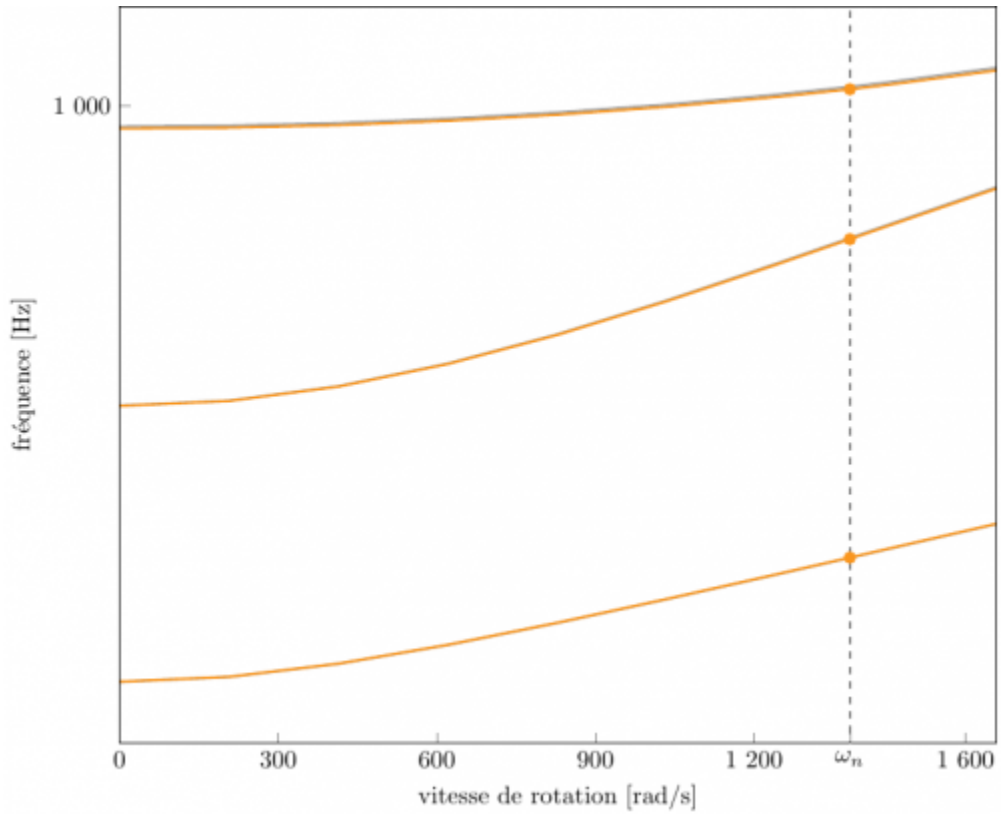



diagramme de Campbell calculé avec une précharge centrifuge linéaire, noeuds du pied d'aube encastrés (vitesse nominale $\omega_n$ = 1 381,25 rad/s),

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

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

Document issu de la page wiki:
**https://wiki.lava.polymtl.ca/public/modeles/rotor_01/accueil?rev=1722886808**

Dernière mise à jour: **2024/08/05 15:40**