Rotor 36

- Français
- English

Downloadable files
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Open access

Git project

About

Rotor 36 is part of a research program to study a advanced-core compressor design with a high compression ratio (20:1). It is therefore the second stage rotor of this eight stage transonic compressor. Of these eight stages, the first four have been designed and tested : rotors 35, 36, 37 and 38. For more information, here is a link to a report from NASA.

- Original technical report [(cite:reid1982design>Reid L., Moore R. D. «Performance of single-stage axial-flow transonic compressor with rotor and stator aspect ratios of 1.63 and 1.78, respectively, and with design pressure ratio of 1.82 » 1982. pdf)]:

```
@TechReport{reid1982design,
  author           = {Reid, L. and Moore, R. D.},
  date             = {1982},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
  title            = {Performance of single-stage axial-flow transonic
compressor with rotor and stator aspect ratios of 1.63 and 1.78,
respectively, and with design pressure ratio of 1.82},
  number           = {NASA-TP-1974},
  url              = {https://ntrs.nasa.gov/citations/19820011348},
}
```

- Pictures :



Fig. 1 https://catalog.archives.gov/id/17467913



Fig. 2 https://catalog.archives.gov/id/17467884

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  @Misc{huebler1977records,
  author   = {Huebler, D.},
  title    = {Rotor 36 assembly and stator 36 casing half. {R}ecords of the
  {N}ational {A}eronautics and {S}pace {A}dministration, 1903 - 2006.
  {P}hotographs relating to agency activities, facilities and personnel,
  1973 - 2013},
  note     =
  {\href{https://catalog.archives.gov/id/17467913}{https://catalog.archives.
  gov/id/17467913}, 1977 }, % for Fig. 1}
  note     =
  {\href{https://catalog.archives.gov/id/17467884}{https://catalog.archives.
  ```
  ```

```
gov/id/17467884}, 1977 }, % for Fig. 2}
```

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. open source code)] 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:reid1982design)]. Corresponding models are computed with the open-source code OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

Geometry

The geometry of rotor 36 is described in the original NASA report by the following tables. The length are in centimeters and the angles in degrees.

(a) Rotor 36

RP	PERCENT SPAN	RADII RI	RADII RO	BLADE ANGLES KIC	BLADE ANGLES KTC	BLADE ANGLES KOC	DELTA INC	CONE ANGLE
TIP	0.	25.291	24.778	62.68	64.29	57.83	2.39	-15.305
1	5.	24.983	24.465	62.03	63.32	56.46	2.69	-14.857
2	10.	24.636	24.153	61.29	62.26	55.19	2.99	-13.420
3	15.	24.286	23.840	60.54	61.24	54.13	3.23	-11.979
4	30.	23.212	22.903	58.52	58.56	50.95	3.64	-7.659
5	50.	21.747	21.653	56.54	55.05	46.11	4.38	-2.125
6	70.	20.229	20.404	54.21	51.54	40.31	5.64	3.616
7	85.	19.020	19.467	52.48	48.18	34.05	6.65	8.615
8	90.	18.594	19.154	52.20	47.38	31.43	6.92	10.573
9	95.	18.149	18.842	52.38	47.05	28.45	7.23	12.817
HUB	100.	17.780	18.529	52.63	46.88	25.40	7.48	13.676

RP	BLADE THICKNESSES TI	BLADE THICKNESSES TM	BLADE THICKNESSES TO	AXIAL DIMENSIONS ZI	AXIAL DIMENSIONS ZMC	AXIAL DIMENSIONS ZTC	AXIAL DIMENSIONS ZO
TIP	.021	.149	.021	.470	1.727	1.705	2.345
1	.022	.157	.022	.445	1.705	1.693	2.395
2	.023	.166	.023	.415	1.681	1.673	2.442
3	.023	.175	.023	.384	1.655	1.638	2.484
4	.025	.202	.026	.288	1.605	1.506	2.585
5	.029	.239	.030	.189	1.568	1.394	2.719
6	.032	.279	.033	.103	1.507	1.292	2.862
7	.036	.311	.036	.035	1.477	1.271	2.981
8	.037	.323	.037	.019	1.463	1.223	3.021
9	.038	.335	.038	.008	1.441	1.172	3.051
HUB	.039	.346	.039	.000	1.421	1.127	3.079

Aerodynamic design

	unit	value
pressure ratio	[-]	1.82
mass flow	[kg/s]	20.2
tip speed	[m/s]	455
tip solidity	[-]	1.3
aspect ratio	[-]	1.63
number of blades	[-]	48
nominal rotation speed ω_n	[rad/s]	1800

Material properties

Rotor 36 is made of a 200-grade maraging steel[(cite:reid1978designandoverall>Reid. «Design and overall performance of four highly loaded, high-speed inlet stages for and advanced high-pressure-ratio core compressor» 1978. pdf)], but the exact material properties are not provided in the NASA report. The following properties are considered:

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

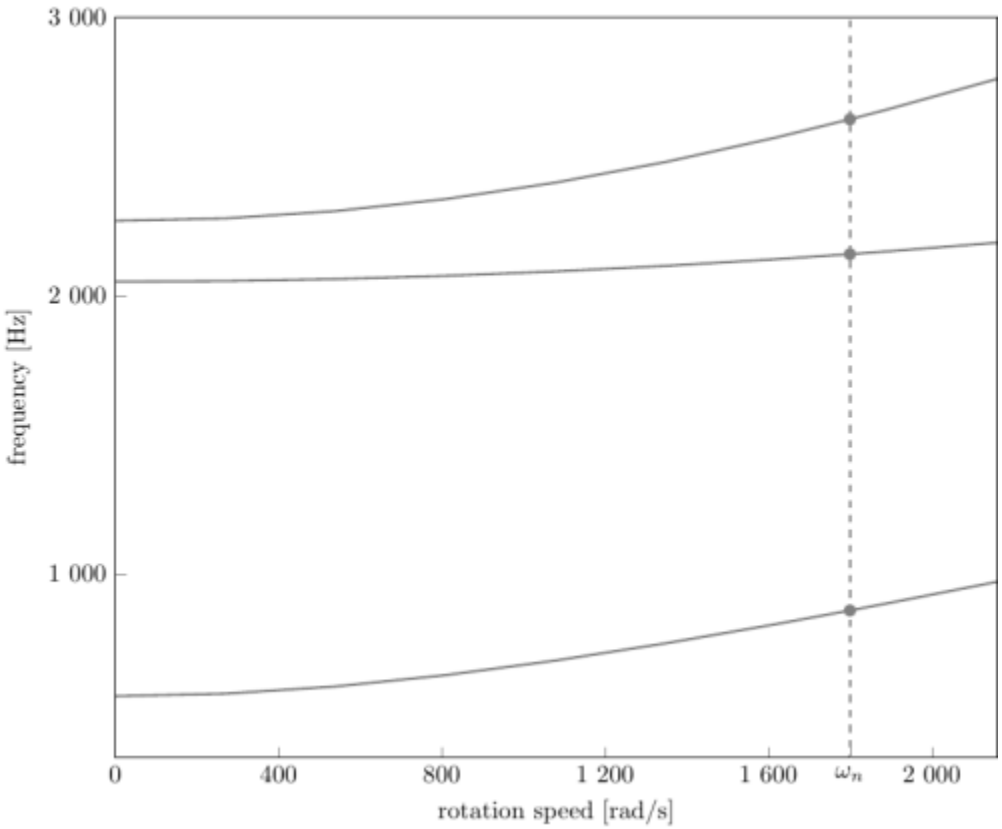
Natural frequencies

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	3525.61	561.119
2	1T	12882.23	2050.27
3	2B	14256.42	2268.98

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 ω_n = 1 800 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	3538.38	563.15
2	1T	12965.60	2063.54
3	2B	14395.72	2291.15

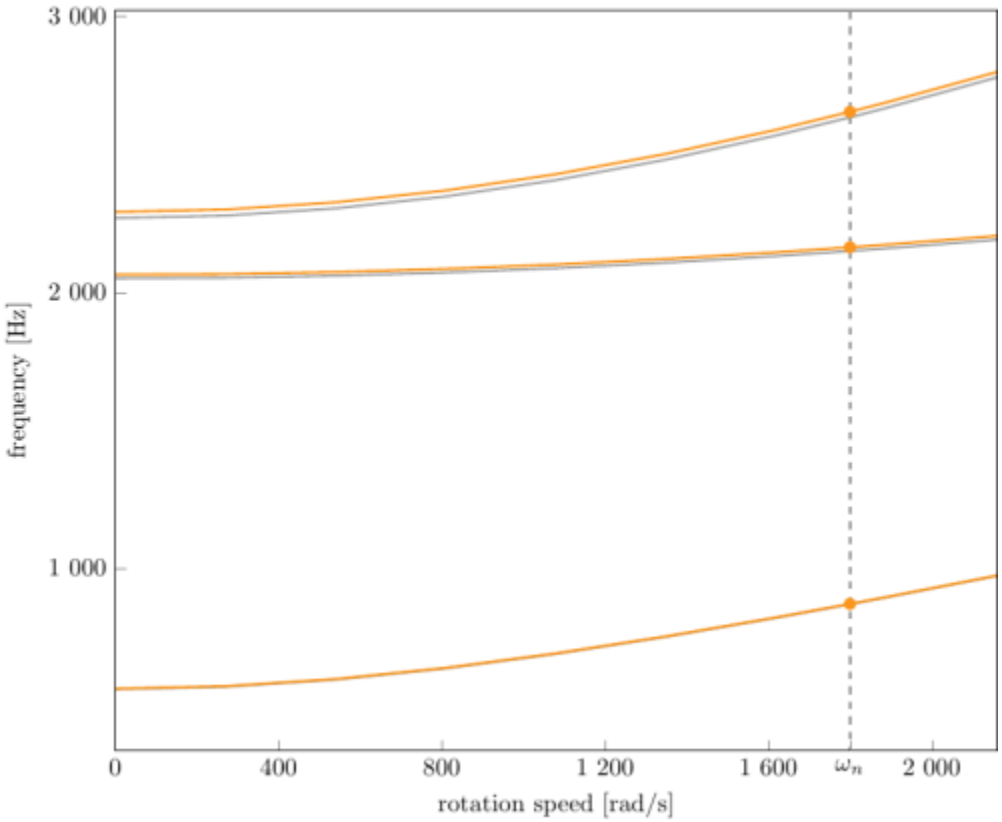
- from the reduced order model:

Mode	Type	Natural angular frequency (rad/sec)	Natural frequency (Hz)
1	1B	3538.56	563.18

Mode	Type	Natural angular frequency (rad/sec)	Natural frequency (Hz)
2	1T	12969.75	2064.2
3	2B	14407,6	2293.04

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 ω_n = 1 800 rad/s),

initial blade (orange), reference blade (gray)

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

Fichiers téléchargeables
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Libre accès

lien vers le projet Git

À propos

Le rotor 36 appartient à un programme de recherche visant à étudier une conception de compresseur possédant un grand taux de compression (20:1). Il est donc le rotor du deuxième étage de ce compresseur transsonique de huit étages. Parmi ces huit étages, les quatre premiers ont été conçus et testés, ils correspondent aux rotors 35, 36, 37 et 38. Pour plus d'information, voici un lien vers un rapport de la NASA.

- Rapport technique original [(cite:reid1982design>)]:

```
@TechReport{reid1982design,
  author           = {Reid, L. and Moore, R. D.},
  date             = {1982},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
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}
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- Photographies :



Fig. 1 https://catalog.archives.gov/id/17467913

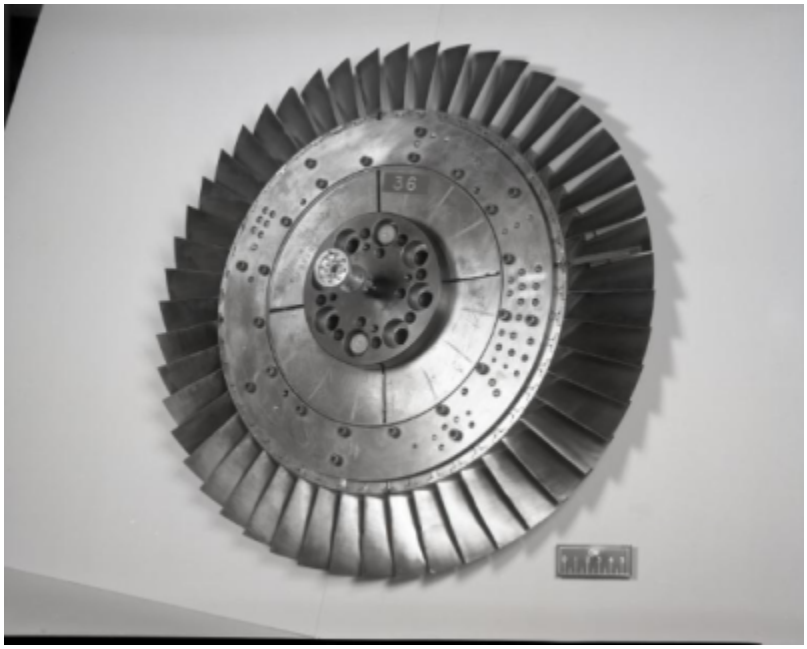


Fig. 2 https://catalog.archives.gov/id/17467884

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  title    = {Rotor 36 assembly and stator 36 casing half. {R}ecords of the
  {N}ational {A}eronautics and {S}pace {A}dministration, 1903 - 2006.
  {P}hotographs relating to agency activities, facilities and personnel,
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  {\href{https://catalog.archives.gov/id/17467913}{https://catalog.archives.
  gov/id/17467913}, 1977 }, % pour Fig. 1
  note     =
  {\href{https://catalog.archives.gov/id/17467884}{https://catalog.archives.
  gov/id/17467884}, 1977 }, % pour Fig. 2}
  ```

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>)] 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:reid1982design)]. Les modèles associés sont obtenus avec le code en libre accès OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

Géométrie

La géométrie du rotor 36 est décrite dans le rapport d'origine de la NASA par les tableaux suivants. Les grandeurs sont en centimètres et en degrés.

(a) Rotor 36

	PERCENT	RADII		BLADE ANGLES			DELTA	CONE
RP	SPAN	RI	RO	KIC	KTC	KOC	INC	ANGLE
TIP	0.	25.291	24.778	62.68	64.29	57.83	2.39	-15.305
1	5.	24.983	24.465	62.03	63.32	56.46	2.69	-14.857
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3	15.	24.286	23.840	60.54	61.24	54.13	3.23	-11.979
4	30.	23.212	22.903	58.52	58.56	50.95	3.64	-7.659
5	50.	21.747	21.653	56.54	55.05	46.11	4.38	-2.125
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7	85.	19.020	19.467	52.48	48.18	34.05	6.65	8.615
8	90.	18.594	19.154	52.20	47.38	31.43	6.92	10.573
9	95.	18.149	18.842	52.38	47.05	28.45	7.23	12.817
HUB	100.	17.780	18.529	52.63	46.88	25.40	7.48	13.676

	BLADE THICKNESSES			AXIAL DIMENSIONS			
RP	TI	TM	TO	ZI	ZMC	ZTC	ZO
TIP	.021	.149	.021	.470	1.727	1.705	2.345
1	.022	.157	.022	.445	1.705	1.693	2.395
2	.023	.166	.023	.415	1.681	1.673	2.442
3	.023	.175	.023	.384	1.655	1.638	2.484
4	.025	.202	.026	.288	1.605	1.506	2.585
5	.029	.239	.030	.189	1.568	1.394	2.719
6	.032	.279	.033	.103	1.507	1.292	2.862
7	.036	.311	.036	.035	1.477	1.271	2.981
8	.037	.323	.037	.019	1.463	1.223	3.021
9	.038	.335	.038	.008	1.441	1.172	3.051
HUB	.039	.346	.039	.000	1.421	1.127	3.079

Caractéristiques aérodynamiques

	unités	**valeurs**
taux de compression	[-]	1,82
débit massique	[kg/s]	20,2
vitesse en tête	[m/s]	455
solidité en tête	[-]	1,3
allongement	[-]	1,63
nombre d'aubes	[-]	48
vitesse de rotation ω_n	[rad/s]	1800

Propriétés matériau

Le matériau du rotor 36 est un alliage à base de nickel : un acier maraging de grade

200[(cite:reid1978designandoverall>Reid. «Design and overall performance of four highly loaded, high-speed inlet stages for and advanced high-pressure-ratio core compressor» 1978. pdf)], mais ses caractéristiques ne sont pas fournies dans le raport de la NASA. Les propriétés considérées sont :

	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	3525,61	561,12
2	1T	12882,23	2050,27
3	2F	14256,42	2268,98

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)]:

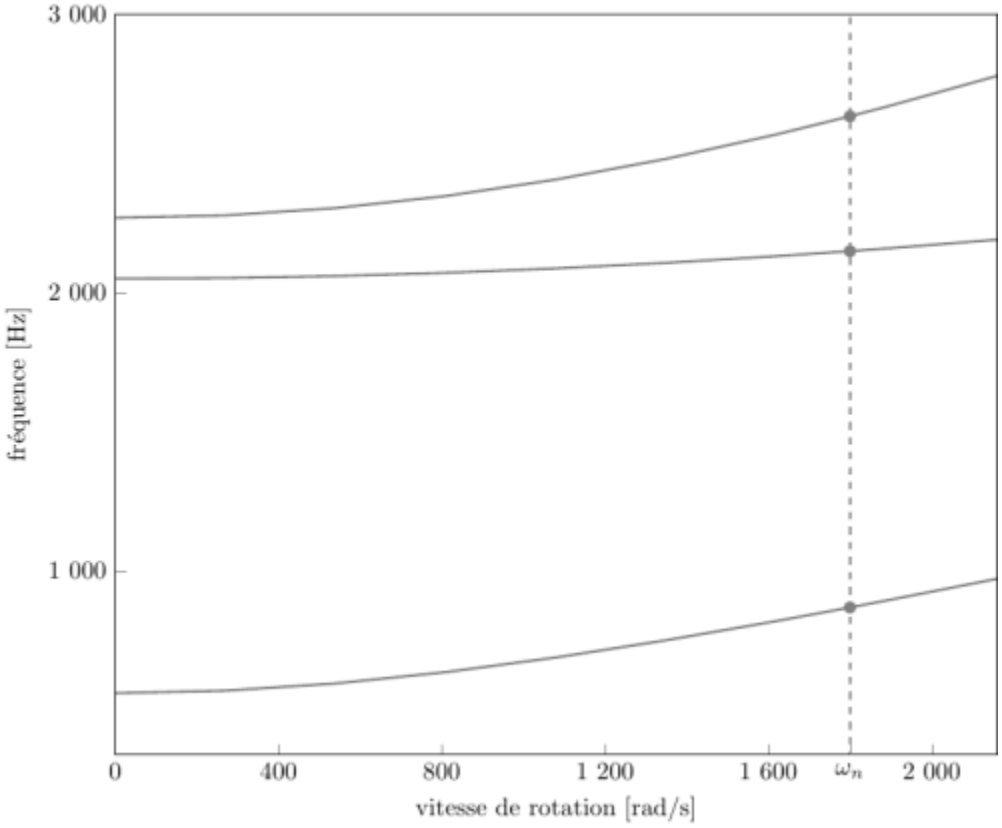


diagramme de Campbell calculé avec une précharge centrifuge linéaire, noeuds du pied d'aube encastrés (vitesse nominale ω_n = 1 800 rad/s)

- 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	3538,38	563,15
2	1T	12965,60	2063,54
3	2F	14395,72	2291,15

- pour le modèle réduit :

Mode	Type	Pulsation propre (rad/sec)	Fréquence propre (Hz)
1	1F	3538,56	563,18
2	1T	12969,75	2064,2
3	2F	14407,6	2293,04

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:

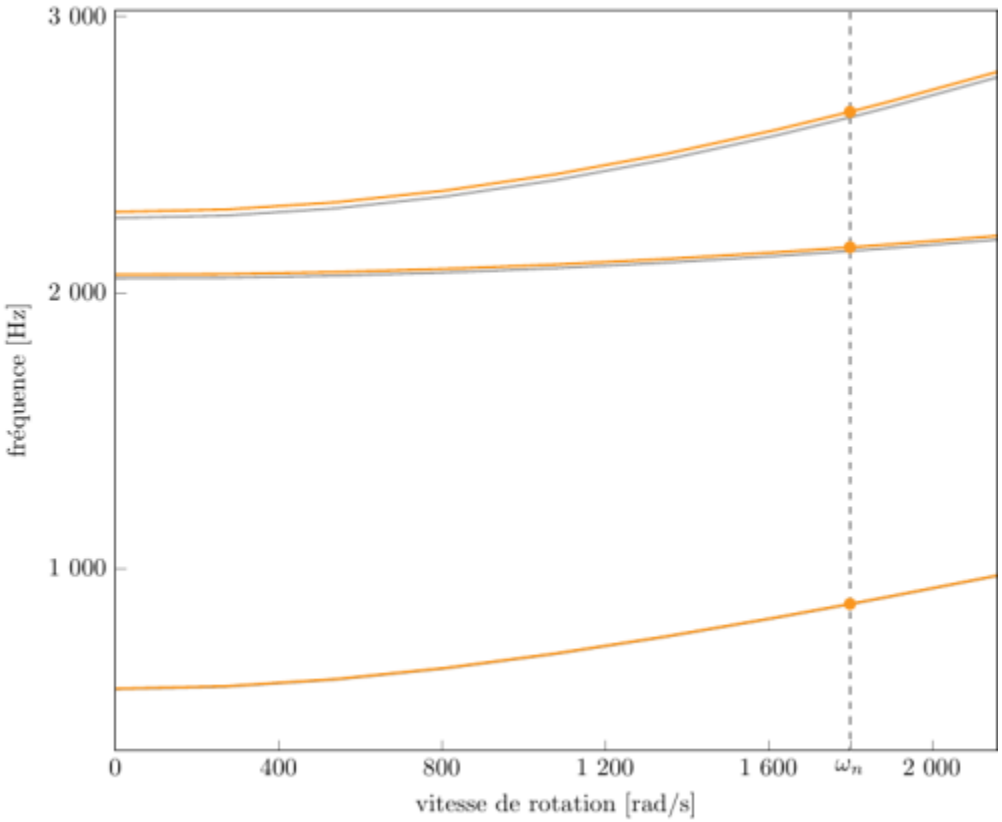


diagramme de Campbell calculé avec une précharge centrifuge linéaire, noeuds du pied d'aube encastrés (vitesse nominale ω_n = 1 800 rad/s),

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_36/accueil?rev=1723064250

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