Rotor 74A1

- Français
- English

Downloadable files
×

Open access

Git project

About

Compressor 74A is part of a research program to study fans and compressors for advanced airbreathing engines to assess and improve the technology needed for high pressure ratio, good efficiency, and adequate stall margin in as few stages as possible. This compressor consists of inlet guide vanes and five stages, and it is designed for a 9.271 pressure ratio. Rotor 74A1 is the rotor of the first stage of this compressor.

- Original technical report [(cite:steinke1986design>Steinke R.J. «Design of 9.271-Pressure-Ratio Five-Stage Core Compressor and Overall Performance for First Three Stages » 1986. pdf)]:

```
@TechReport{steinke1986design,
  author           = {Steinke, Ronald J.},
  date             = {1986},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
  title            = {Design of 9.271-Pressure-Ratio Five-Stage Core
Compressor and Overall Performance for First Three Stages},
  number           = {NASA-TP-2597},
  url              = {https://ntrs.nasa.gov/citations/19870008266},
}
```

- Picture :

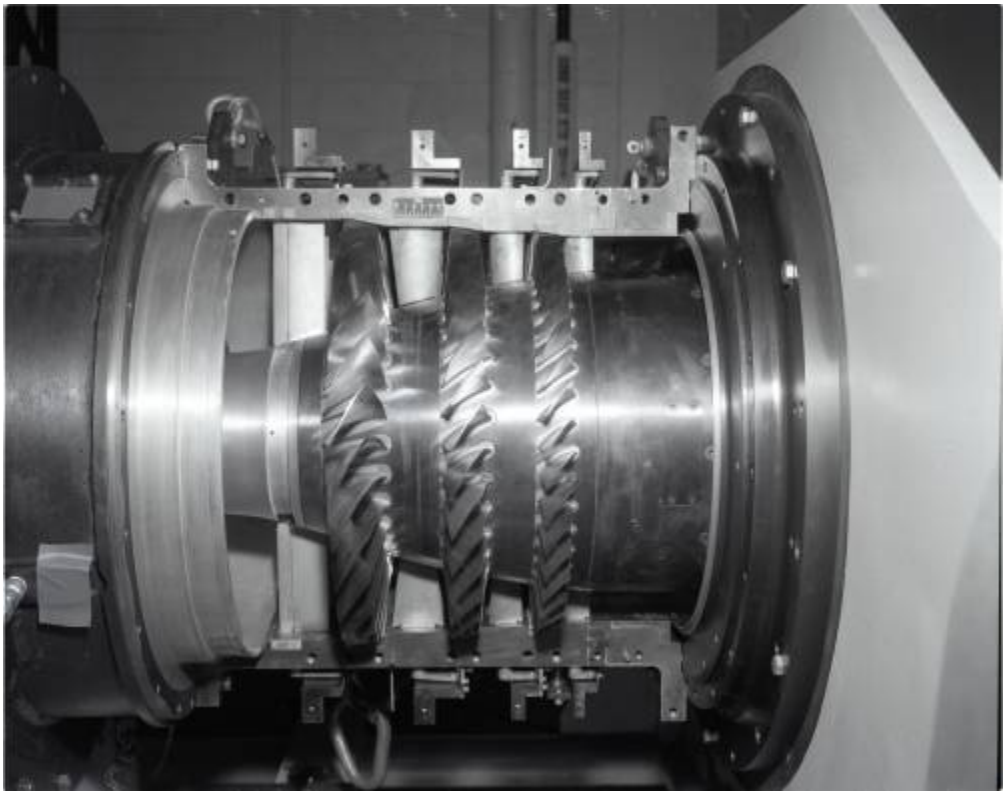


Fig. 1 https://catalog.archives.gov/id/17443470

- ```
  @Misc{Huebler1978records,
  author   = {Huebler, D.},
  title    = {74A Compressor. {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},
  year     = {1978},
  url     = {https://catalog.archives.gov/id/17443470}}
  ```

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:steinke1986design)]. Corresponding models are computed with the open-source code OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

Geometry

The geometry of rotor 74A1 is described in the original NASA report by the following tables. The length are in centimeters and the angles in degrees.

(b) Rotor 1

RP	PERCENT SPAN	RADII RI	RADII RO	BLADE ANGLES KIC	BLADE ANGLES KTC	BLADE ANGLES KOC	DELTA INC	CONE ANGLE
TIP	0.	25.613	24.973	64.13	60.20	49.27	2.97	-9.556
1	5.	25.057	24.468	62.69	58.89	48.63	3.20	-8.420
2	10.	24.444	23.963	61.22	57.51	47.85	3.44	-6.616
3	20.	23.229	22.952	58.73	54.88	45.72	3.93	-3.550
4	30.	22.008	21.941	56.48	51.41	43.25	4.41	-.800
5	40.	20.776	20.931	54.37	48.31	39.85	4.88	1.729
6	50.	19.520	19.920	52.33	45.34	35.29	5.34	4.186
7	60.	18.229	18.909	50.33	42.53	29.34	5.77	6.689
8	70.	16.889	17.899	48.33	39.61	22.00	6.13	9.324
9	80.	15.483	16.888	46.33	36.67	12.99	6.35	12.175
10	90.	13.993	15.877	44.33	33.78	1.70	6.33	15.336
11	95.	13.211	15.372	43.33	32.36	-5.09	6.19	17.060
HUB	100.	12.509	14.867	42.43	31.10	-11.85	6.06	18.117

RP	BLADE THICKNESSES TI	BLADE THICKNESSES TM	BLADE THICKNESSES TO	AXIAL DIMENSIONS ZI	AXIAL DIMENSIONS ZMC	AXIAL DIMENSIONS ZTC	AXIAL DIMENSIONS ZO
TIP	.027	.222	.027	1.877	3.610	4.170	5.679
1	.028	.239	.028	1.778	3.600	4.097	5.755
2	.030	.257	.030	1.677	3.591	4.016	5.829
3	.036	.294	.036	1.506	3.577	3.841	5.974
4	.040	.331	.041	1.326	3.564	3.625	6.137
5	.044	.368	.045	1.159	3.549	3.383	6.293
6	.048	.407	.050	.994	3.529	3.116	6.454
7	.053	.447	.055	.825	3.503	2.814	6.622
8	.059	.490	.060	.642	3.471	2.480	6.793
9	.064	.537	.066	.446	3.436	2.119	6.959
10	.070	.589	.071	.229	3.396	1.719	7.099
11	.074	.618	.074	.108	3.372	1.504	7.151
HUB	.078	.645	.077	-.000	3.350	1.311	7.204

Aerodynamic design

	units	values
pressure ratio	[-]	1.792
mass flow	[kg/s]	29.71
tip speed	[m/s]	430
tip solidity	[-]	1.35
aspect ratio	[-]	1.45
number of blades	[-]	28
nominal rotation speed ω_n	[rad/s]	1680

Material properties

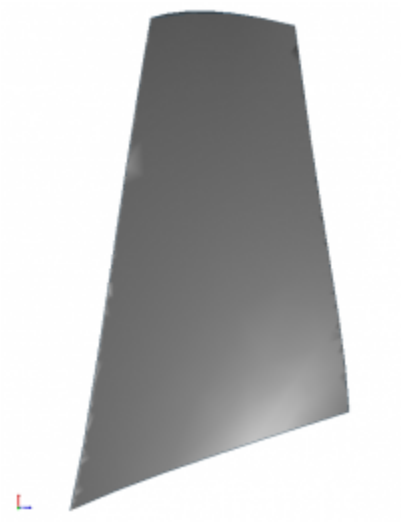
Rotor 74A1 is made of titanium according to the NASA report, but the exact properties are not provided. A generic titanium Ti-6Al-4V is considered:

	units	values
alloy	[-]	Ti-6Al-4V
Young's modulus	[GPa]	108
density	[kg/m3]	4400

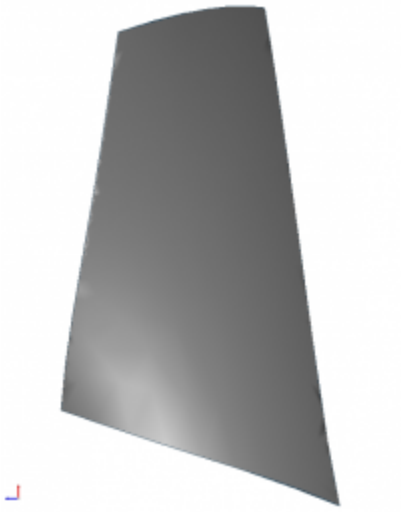
	units	values
Poisson's ratio	[-]	0.34
yield stress	[GPa]	0.824

CAD model

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



pressure side



suction side

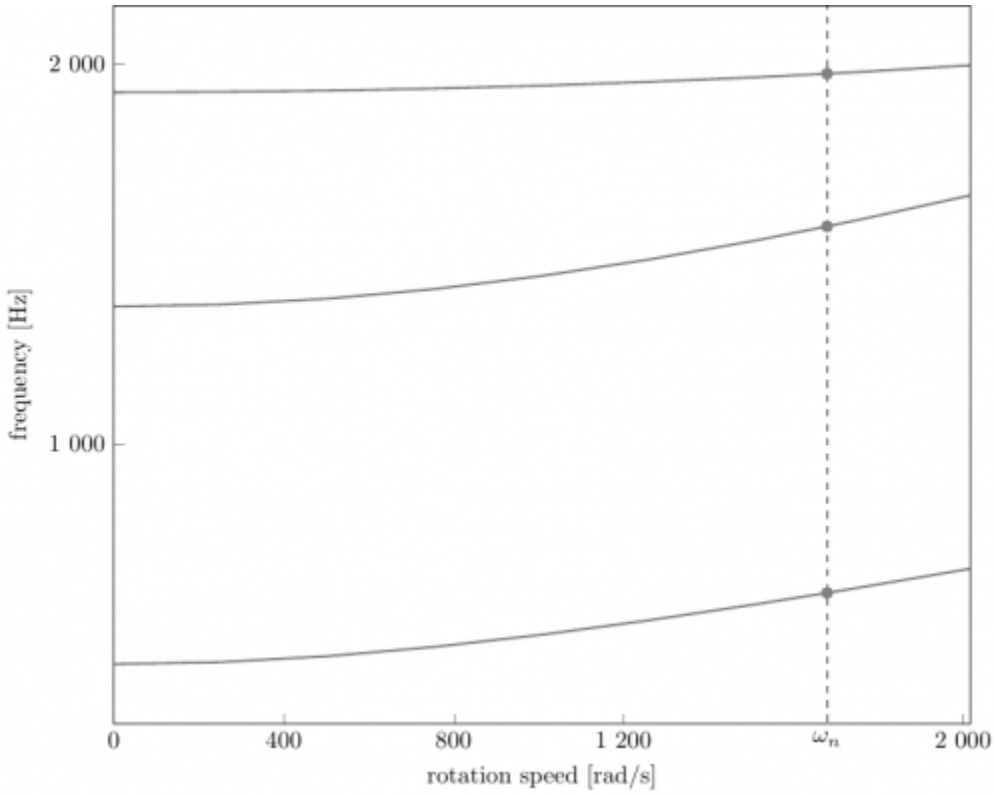
Natural frequencies

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	2641.29	420.38
2	1T	8553.90	1361.40
3	2B	12096.58	1925.23

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 = 1 680 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:

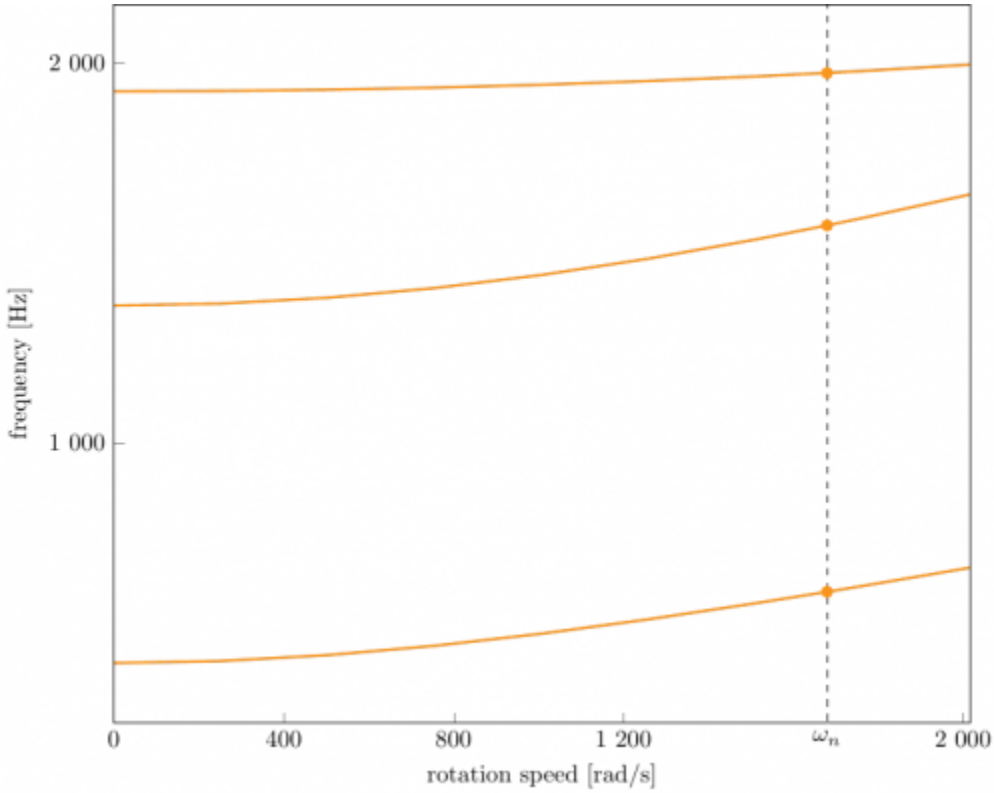
Mode	Type	Natural angular frequency (rad/sec)	Natural frequency (Hz)
1	1B	2643.86	420.78
2	1T	8552.99	1361.25
3	2B	12094.50	1924.90

- from the reduced order model:

Mode	Type	Natural angular frequency (rad/sec)	Natural frequency (Hz)
1	1B	2644.18	420.84
2	1T	8561.84	1362.66
3	2B	12104.24	1926.45

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 = 1 680 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 compresseur 74A fait partie d'un programme de recherche visant à étudier les soufflantes et les compresseurs pour des moteurs à air comprimé afin d'évaluer et d'améliorer les technologies nécessaires pour obtenir un rapport de pression élevé, un bon rendement et une marge de décrochage adéquate avec le moins d'étage possible. Ce compresseur comporte des redresseurs d'admission et cinq étages, et il est conçu pour un rapport de pression de 9,271. Le rotor 74A1 est le rotor du premier étage de ce compresseur.

- Rapport technique original [(cite:steinke1986design>)]:

```
@TechReport{steinke1986design,
  author           = {Steinke, Ronald J.},
  date             = {1986},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
  title            = {Design of 9.271-Pressure-Ratio Five-Stage Core
Compressor and Overall Performance for First Three Stages},
  number           = {NASA-TP-2597},
  url              = {https://ntrs.nasa.gov/citations/19870008266},
}
```

- Photographie :

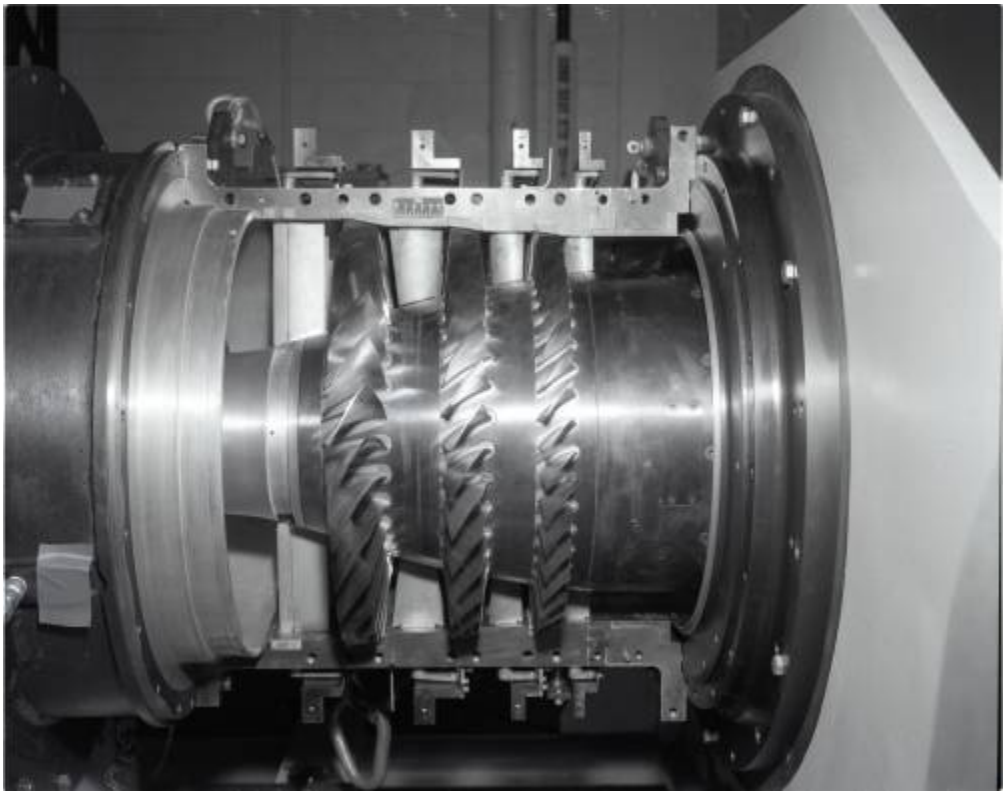


Fig. 1 https://catalog.archives.gov/id/17443470

- ```
  @Misc{Huebler1978records,
  author   = {Huebler, D.},
  title    = {74A Compressor. {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},
  year     = {1978},
  url     = {https://catalog.archives.gov/id/17443470}}
  ```

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:steinke1986design)]. Les modèles associés sont obtenus avec le code en libre accès OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

Géométrie

La géométrie du rotor 74A1 est décrite dans le rapport d'origine de la NASA par les tableaux suivants. Les grandeurs sont en centimètres et en degrés.
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(b) Rotor 1

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3	20.	23.229	22.952	58.73	54.88	45.72	3.93	-3.550
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HUB	100.	12.509	14.867	42.43	31.10	-11.85	6.06	18.117

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TIP	.027	.222	.027	1.877	3.610	4.170	5.679
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2	.030	.257	.030	1.677	3.591	4.016	5.829
3	.036	.294	.036	1.506	3.577	3.841	5.974
4	.040	.331	.041	1.326	3.564	3.625	6.137
5	.044	.368	.045	1.159	3.549	3.383	6.293
6	.048	.407	.050	.994	3.529	3.116	6.454
7	.053	.447	.055	.825	3.503	2.814	6.622
8	.059	.490	.060	.642	3.471	2.480	6.793
9	.064	.537	.066	.446	3.436	2.119	6.959
10	.070	.589	.071	.229	3.396	1.719	7.099
11	.074	.618	.074	.108	3.372	1.504	7.151
HUB	.078	.645	.077	-.000	3.350	1.311	7.204

Caractéristiques aérodynamiques

	unités	valeurs
taux de compression	[-]	1,792
débit massique	[kg/s]	29,71
vitesse en tête	[m/s]	430
solidité en tête	[-]	1,35
allongement	[-]	1,45
nombre d'aubes	[-]	28
vitesse de rotation nominale ω_n	[rad/s]	1680

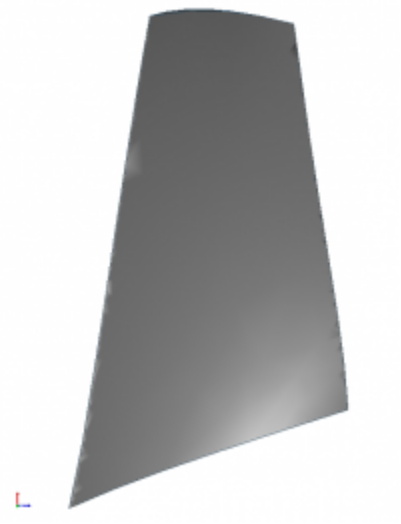
Propriétés matériau

Le matériau du rotor 74A1 est le titane d'après le rapport, mais ses caractéristiques ne sont pas fournies. Un alliage de titane Ti-6Al-4v est considéré :

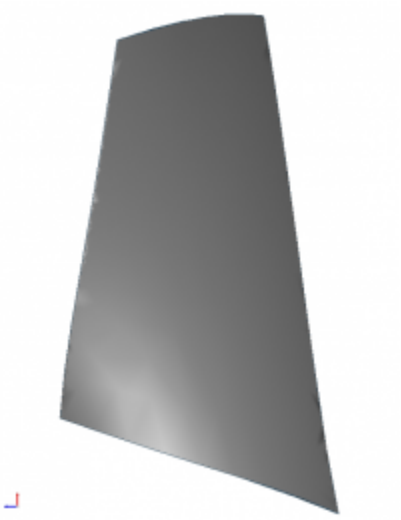
	unités	valeurs
alliage	[-]	Ti-6Al-4V
module d'Young	[GPa]	108
masse volumique	[kg/m3]	4400
coefficient de Poisson	[-]	0,34
limite élastique	[GPa]	0,824

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	2641,29	420,38
2	1T	8553,90	1361,40
3	2F	12096,58	1925,23

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)]:

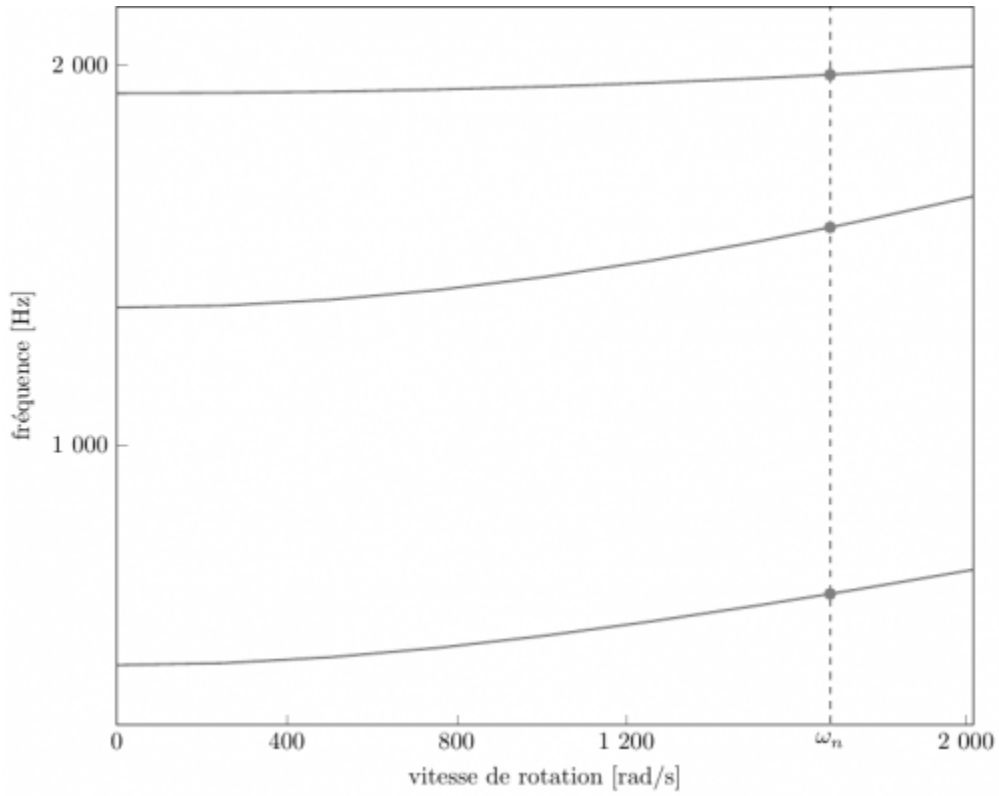


diagramme de Campbell calculé avec une précharge centrifuge linéaire, noeuds du pied d'aube encastrés (vitesse nominale ω_n = 1 680 rad/s)

- 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	2643,86	420,78
2	1T	8552,99	1361,25
3	2F	12094,50	1924,90

- pour le modèle réduit :

Mode	Type	Pulsation propre (rad/sec)	Fréquence propre (Hz)
1	1F	2644,18	420,84
2	1T	8561,84	1362,66
3	2F	12104,24	1926,45

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:

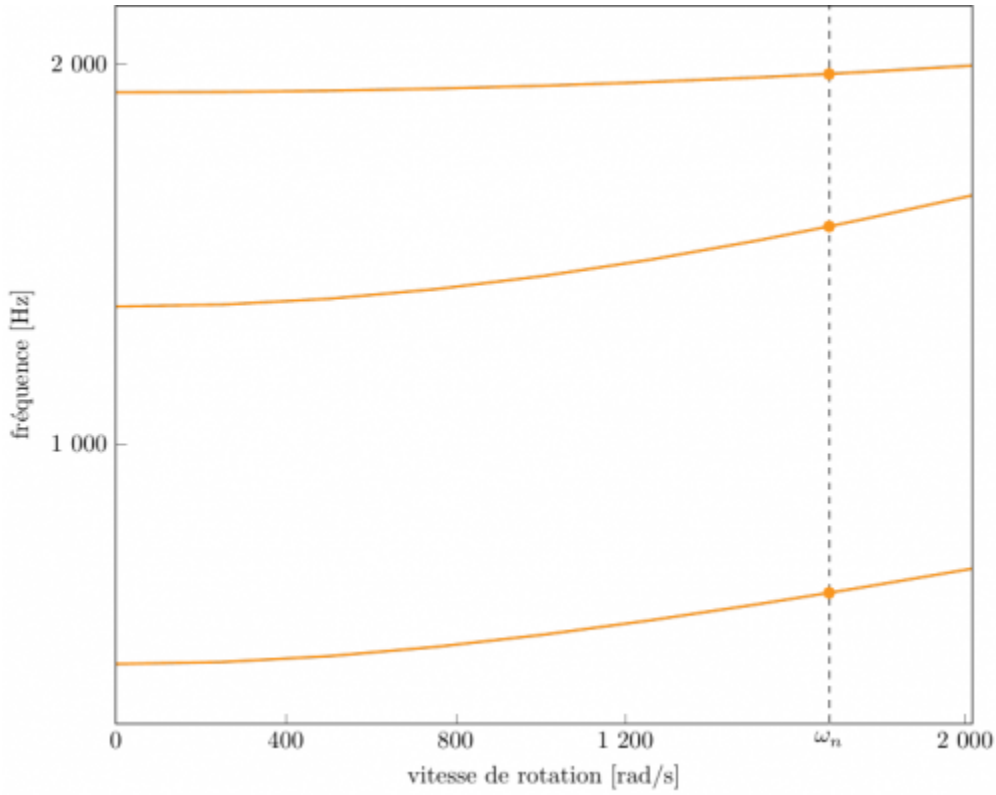


diagramme de Campbell calculé avec une précharge centrifuge linéaire, noeuds du pied d'aube encastrés (vitesse nominale ω_n = 1 680 rad/s),

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_74a1/accueil

Dernière mise à jour: **2024/08/02 10:11**