Rotor 74A3

- 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 74A3 is the rotor of the third 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 :

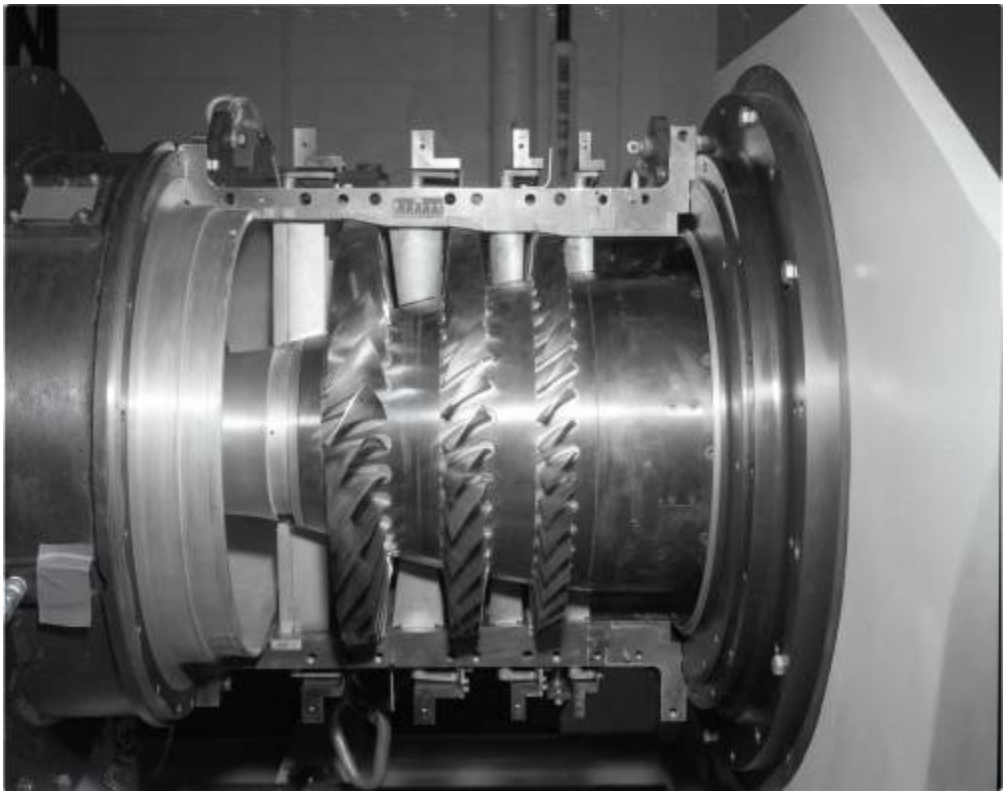


Fig. 1 https://catalog.archives.gov/id/17443470

- ```
  @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 74A3 is described in the original NASA report by the following tables. The length are in centimeters and the angles in degrees.

(f) Rotor 3

RP	PERCENT SPAN	RADII RI	RADII RD	BLADE ANGLES KIC	BLADE ANGLES KTC	BLADE ANGLES KOC	DELTA INC	CONE ANGLE
TIP	0.	24.183	23.769	64.76	49.81	42.83	3.65	-8.673
1	5.	23.772	23.410	62.36	49.41	42.78	4.04	-7.356
2	10.	23.441	23.147	60.59	49.07	42.68	4.34	-5.847
3	20.	22.826	22.640	58.05	48.28	42.10	4.91	-3.579
4	30.	22.240	22.146	56.39	47.29	40.85	5.44	-1.744
5	40.	21.671	21.666	55.04	46.12	39.09	5.96	-.083
6	50.	21.116	21.194	53.80	44.84	37.00	6.45	1.374
7	60.	20.573	20.735	52.68	43.44	34.50	6.93	2.758
8	70.	20.042	20.290	51.67	41.95	31.57	7.39	4.100
9	80.	19.525	19.861	50.78	40.27	27.90	7.82	5.368
10	90.	19.024	19.454	50.06	38.24	22.79	8.20	6.608
11	95.	18.780	19.261	49.78	37.01	19.47	8.37	7.227
HUB	100.	18.420	18.951	49.35	35.24	14.32	8.62	7.721

RP	BLADE THICKNESSES TI	BLADE THICKNESSES TM	BLADE THICKNESSES TD	AXIAL DIMENSIONS ZI	AXIAL DIMENSIONS ZMC	AXIAL DIMENSIONS ZTC	AXIAL DIMENSIONS ZO
TIP	.028	.176	.028	24.234	25.417	25.938	26.948
1	.031	.194	.031	24.170	25.418	25.883	26.975
2	.033	.208	.033	24.124	25.419	25.839	26.995
3	.038	.235	.038	24.057	25.422	25.761	27.032
4	.042	.261	.041	24.008	25.425	25.688	27.075
5	.045	.286	.046	23.964	25.428	25.615	27.126
6	.050	.310	.050	23.919	25.429	25.537	27.177
7	.053	.334	.053	23.877	25.431	25.459	27.235
8	.057	.357	.057	23.833	25.431	25.376	27.294
9	.061	.380	.061	23.784	25.427	25.285	27.359
10	.064	.403	.065	23.724	25.420	25.182	27.437
11	.066	.414	.066	23.687	25.413	25.122	27.480
HUB	.069	.430	.069	23.634	25.403	25.037	27.549

Aerodynamic design

	unit	values
pressure ratio	[-]	1.613
mass flow	[kg/s]	29.71
tip speed	[m/s]	406
tip solidity	[-]	1.21
aspect ratio	[-]	1.04
number of blades	[-]	46
nominal rotation speed ω_n	[rad/s]	1680

Material properties

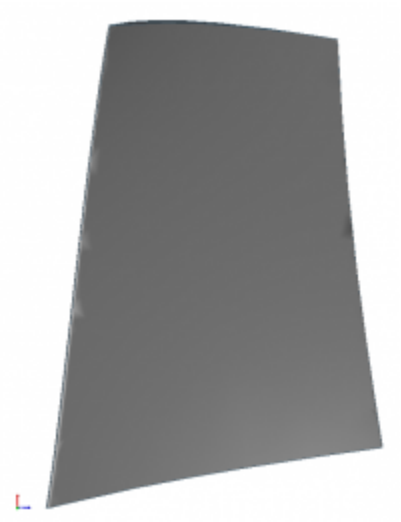
Rotor 74A3 is made of titanium according to the NASA report, but the exact properties are not provided. A generic titanium Ti-6Al-4V is considered:

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

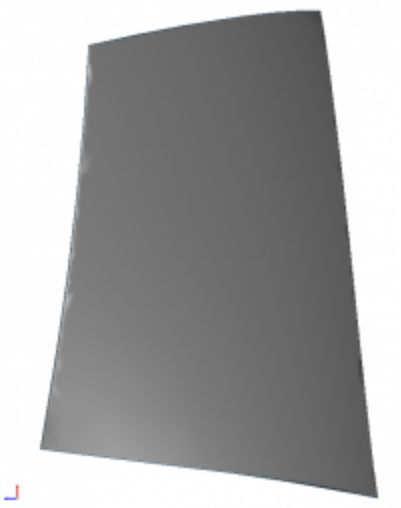
	unité	valeurs
Poisson's ratio	[-]	0.34
yield stress	[GPa]	0.824

CAD model

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



pressure side



suction side

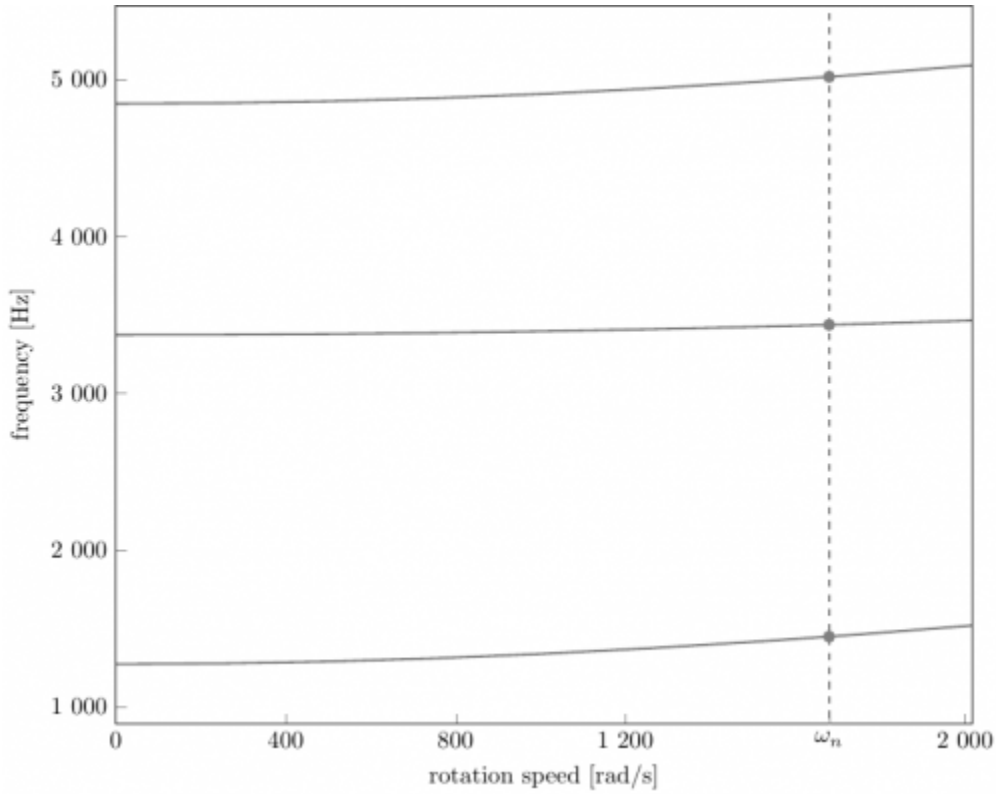
Natural frequencies

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	7993.50	1272.20
2	1T	21194.63	3373.23
3	2B	30465.15	4848.68

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:

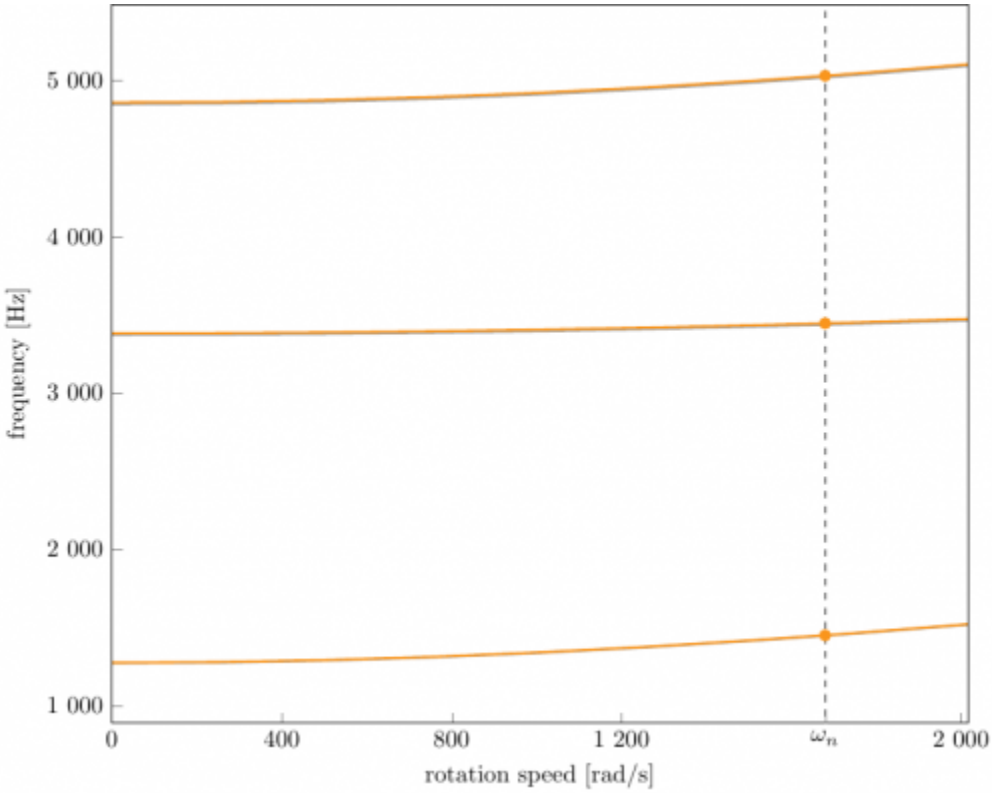
Mode	Type	Natural angular frequency (rad/sec)	Natural frequency (Hz)
1	1B	8010.62	1274.93
2	1T	21254.32	3382.73
3	2T	30532.32	4859.37

- from the reduced order model:

Mode	Type	Natural angular frequency (rad/sec)	Natural frequency (Hz)
1	1B	8011.62	1275.09
2	1T	21266.32	3384.64
3	2B	30581.50	4867.20

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 74A2 appartient au troisième 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 :

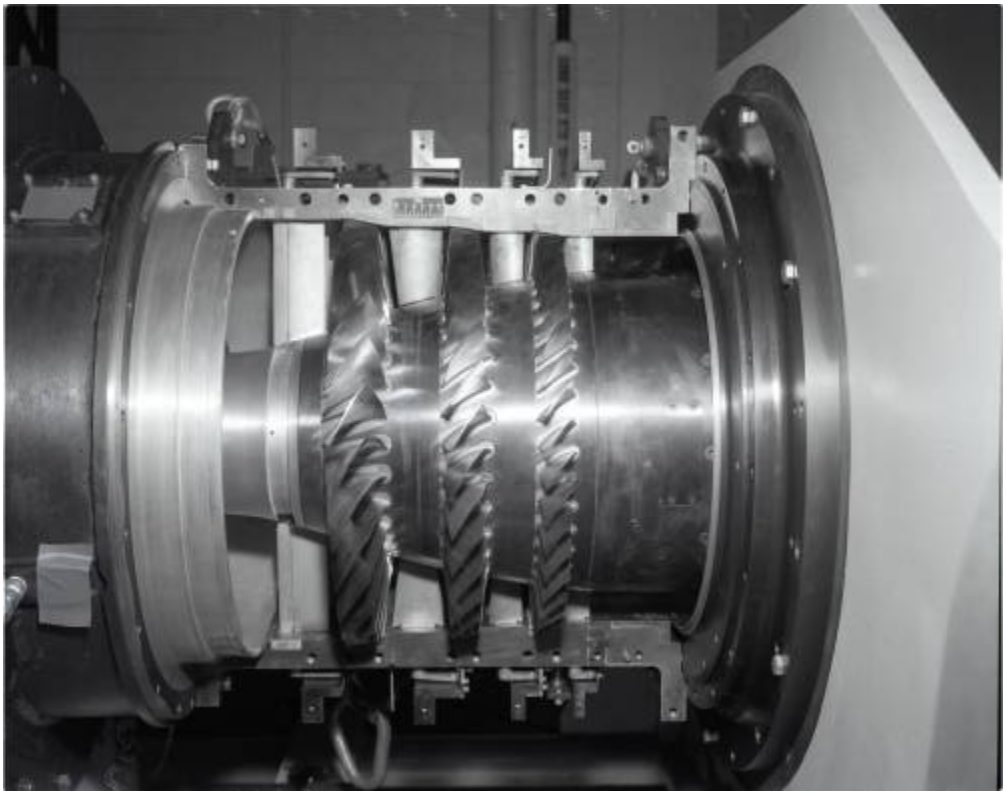


Fig. 1 https://catalog.archives.gov/id/17443470

- ```
  @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 74A3 est décrite dans le rapport d'origine de la NASA par les tableaux suivants. Les grandeurs sont en centimètres et en degrés.
  ```

(f) Rotor 3

RP	PERCENT SPAN	RADII RI	RD	BLADE ANGLES KIC	KTC	KOC	DELTA INC	CONE ANGLE
TIP	0.	24.183	23.769	64.76	49.81	42.83	3.65	-8.673
1	5.	23.772	23.410	62.36	49.41	42.78	4.04	-7.356
2	10.	23.441	23.147	60.59	49.07	42.68	4.34	-5.847
3	20.	22.826	22.640	58.05	48.28	42.10	4.91	-3.579
4	30.	22.240	22.146	56.39	47.29	40.85	5.44	-1.744
5	40.	21.671	21.666	55.04	46.12	39.09	5.96	-.083
6	50.	21.116	21.194	53.80	44.84	37.00	6.45	1.374
7	60.	20.573	20.735	52.68	43.44	34.50	6.93	2.758
8	70.	20.042	20.290	51.67	41.95	31.57	7.39	4.100
9	80.	19.525	19.861	50.78	40.27	27.90	7.82	5.368
10	90.	19.024	19.454	50.06	38.24	22.79	8.20	6.608
11	95.	18.780	19.261	49.78	37.01	19.47	8.37	7.227
HUB	100.	18.420	18.951	49.35	35.24	14.32	8.62	7.721

RP	BLADE THICKNESSES TI	TM	TO	AXIAL DIMENSIONS ZI	ZMC	ZTC	ZO
TIP	.028	.176	.028	24.234	25.417	25.938	26.948
1	.031	.194	.031	24.170	25.418	25.883	26.975
2	.033	.208	.033	24.124	25.419	25.839	26.995
3	.038	.235	.038	24.057	25.422	25.761	27.032
4	.042	.261	.041	24.008	25.425	25.688	27.075
5	.045	.286	.046	23.964	25.428	25.615	27.126
6	.050	.310	.050	23.919	25.429	25.537	27.177
7	.053	.334	.053	23.877	25.431	25.459	27.235
8	.057	.357	.057	23.833	25.431	25.376	27.294
9	.061	.380	.061	23.784	25.427	25.285	27.359
10	.064	.403	.065	23.724	25.420	25.182	27.437
11	.066	.414	.066	23.687	25.413	25.122	27.480
HUB	.069	.430	.069	23.634	25.403	25.037	27.549

Caractéristiques aérodynamiques

	unités	valeurs
taux de compression	[-]	1,613
débit massique	[kg/s]	29,71
vitesse en tête	[m/s]	406
solidité en tête	[-]	1,21
allongement	[-]	1,04
nombre d'aubes	[-]	46
vitesse de rotation nominale ω_n	[rad/s]	1680

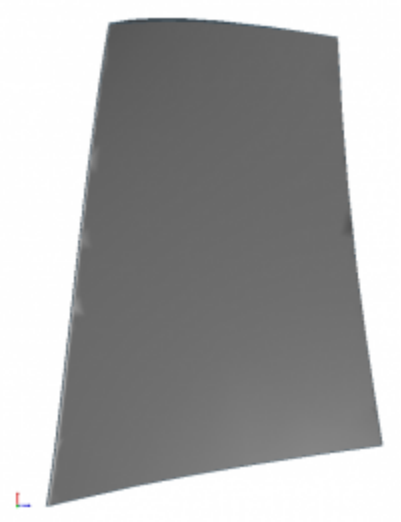
Propriétés matériau

Le matériau du rotor 74A3 est le titane d'après le rapport, mais ses caractéristiques ne sont pas fournies. Un alliage de titane Ti-6Al-4v est considéré :

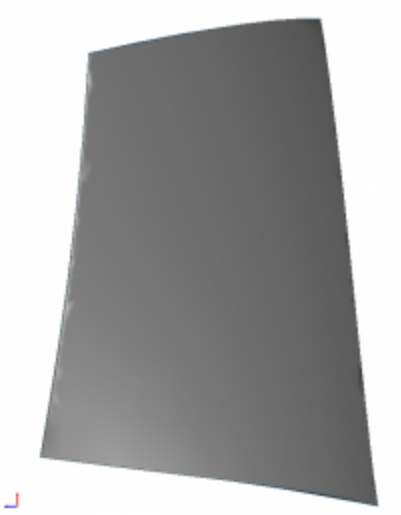
	unités	valeurs
alliage	[-]	Ti-6Al-4V
module d'Young	[GPa]	108
masse volumique	[kg/m3]	4400
coefficient de Poisson	[-]	0,34
limite élastique	[GPa]	0,824

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	7993,50	1272,20
2	1T	21194,63	3373,23
3	2F	30465,15	4848,68

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)]:

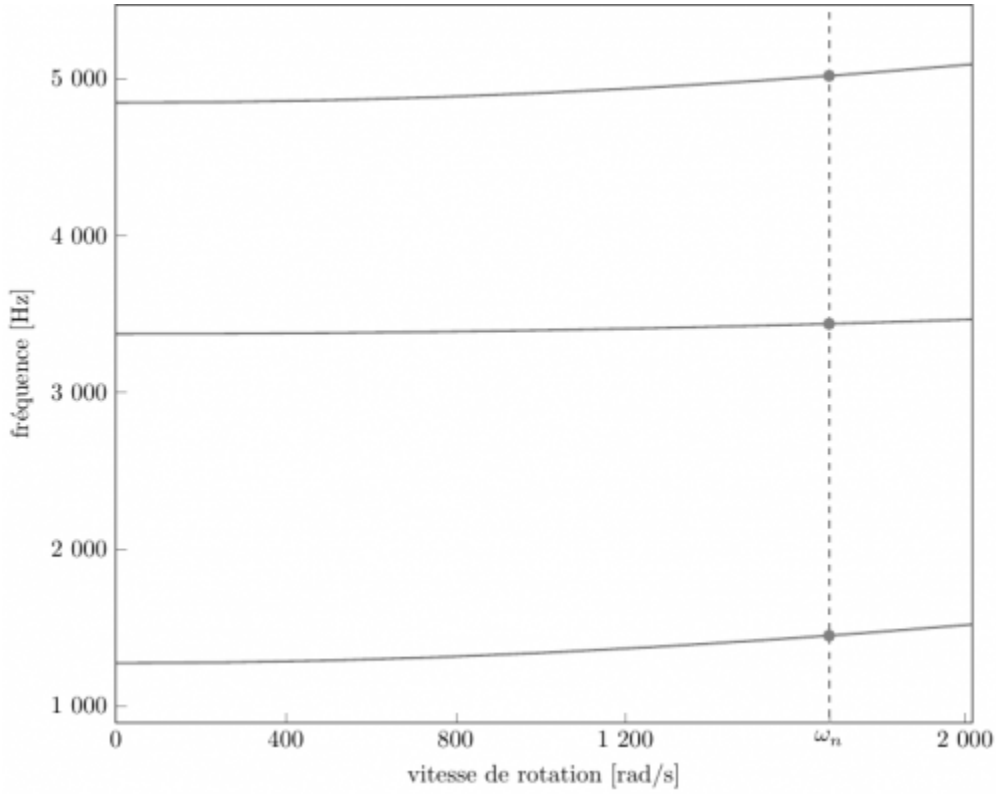


diagramme de Campbell calculé avec une précharge centrifuge linéaire, noeuds du pied d'aube encastrés (vitesse nominale ω_n = 1 680 rad/s)

- 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	8010,62	1274,93
2	1T	21254,32	3382,73
3	2F	30532,32	4859,37

- pour le modèle réduit :

Mode	Type	Pulsation propre (rad/sec)	Fréquence propre (Hz)
1	1F	8011,62	1275,09
2	1T	21266,32	3384,64
3	2F	30581,50	4867,20

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:

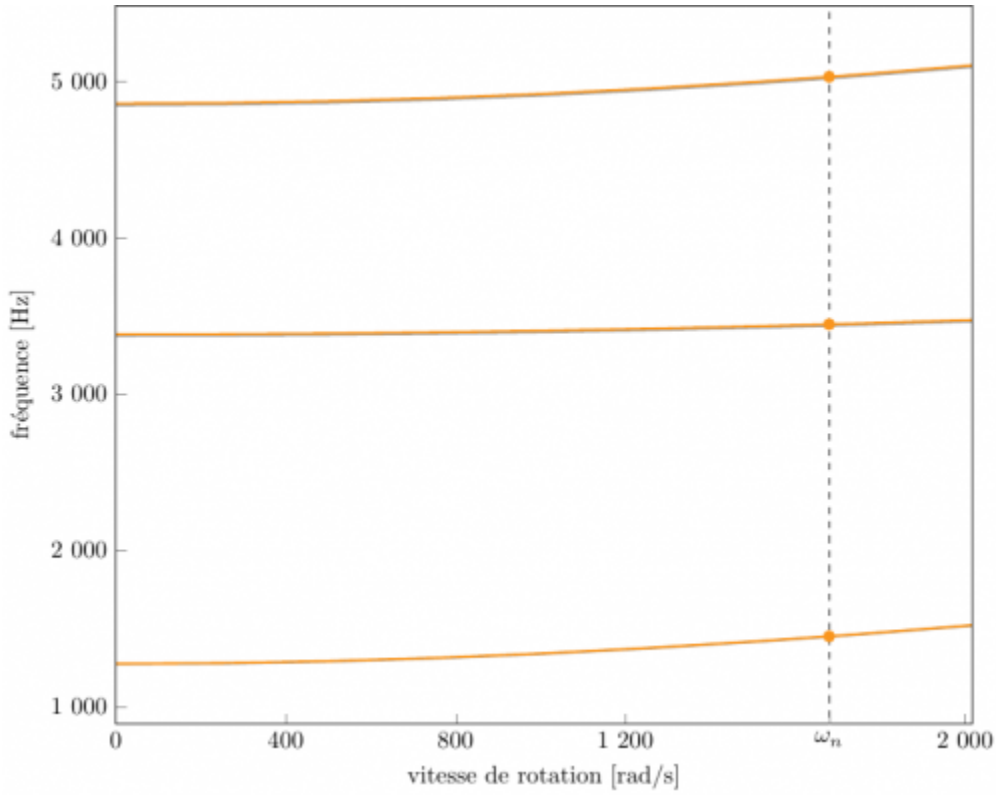


diagramme de Campbell calculé avec une précharge centrifuge linéaire, noeuds du pied d'aube encastrés (vitesse nominale ω_n = 1 680 rad/s),

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_74a3/accueil

Dernière mise à jour: **2024/08/02 10:53**