Rotor 37

- Français
- English

Downloadable files
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Open access

Git project

About

Rotor 37 is part of a research program to study a advanced-core compressor design with a high compression ratio (20:1). It is therefore the third 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 [1]:

```
@TechReport{moore1980design,
  author           = {Moore, R. D. and Reid, L.},
  date             = {1980},
  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 1.19 and 1.26,
Respectively, and With Design Pressure Ratio of 2.05},
  number           = {NASA-TP-1659},
  url              = {https://ntrs.nasa.gov/citations/19800012840},
  }
```

- Pictures :

Fig. 1 https://catalog.archives.gov/id/17468361

Fig. 2. https://catalog.archives.gov/id/17468389

- ```
  @Misc{huebler1977records,
  author   = {Huebler, D.},
  title    = {Rotor 37 and stator 37 assembly. {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/17468361}{https://catalog.archives.
  gov/id/17468361}, 1977 }, % for Fig. 1
  note     =
  {\href{https://catalog.archives.gov/id/17468389}{https://catalog.archives.
  gov/id/17468389}, 1977 }, % for Fig. 2}
  ```
  ```

Useful documents

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

Reference blade

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

Geometry

The geometry of rotor 37 is described in the original NASA report by the following tables. The length are in centimeters and the angles in degrees.

(a) Rotor 37

	PERCENT	RADII		BLADE ANGLES			DELTA	CONE
RP	SPAN	RI	RO	KIC	KTC	KOC	INC	ANGLE
TIP	0.	25.230	24.506	62.53	62.83	49.98	2.10	-15.233
1	5.	24.935	24.218	61.66	61.86	49.07	2.39	-14.582
2	10.	24.597	23.929	60.76	60.86	48.18	2.69	-13.139
3	15.	24.254	23.641	60.07	60.09	47.34	2.94	-11.768
4	30.	23.211	22.775	58.48	58.09	44.22	3.40	-7.804
5	50.	21.761	21.622	56.53	54.49	38.87	4.19	-2.276
6	70.	20.246	20.468	54.24	50.48	32.37	5.49	3.311
7	85.	19.030	19.603	52.67	47.60	25.28	6.54	8.010
8	90.	18.603	19.314	52.37	46.87	22.68	6.83	9.728
9	95.	18.161	19.026	52.18	46.39	19.75	7.16	11.584
HUB	100.	17.780	18.738	52.04	46.03	16.75	7.44	12.602

	BLADE THICKNESSES			AXIAL DIMENSIONS			
RP	TI	TM	TO	ZI	ZMC	ZTC	ZO
TIP	.025	.175	.025	.713	2.430	2.399	3.372
1	.026	.186	.026	.665	2.390	2.372	3.424
2	.028	.199	.028	.615	2.346	2.334	3.475
3	.029	.211	.029	.574	2.304	2.280	3.520
4	.032	.250	.033	.466	2.225	2.094	3.644
5	.037	.303	.038	.317	2.164	1.928	3.822
6	.042	.360	.043	.176	2.069	1.773	4.015
7	.047	.407	.047	.079	2.010	1.733	4.153
8	.048	.425	.049	.048	1.984	1.660	4.198
9	.050	.443	.050	.021	1.957	1.591	4.241
HUB	.051	.458	.051	.000	1.933	1.530	4.283

Aerodynamic design

	unit	value
pressure ratio	[-]	2.05
mass flow	[kg/s]	20.2
tip speed	[m/s]	455
tip solidity	[-]	1.3
aspect ratio	[-]	1.19
number of blades	[-]	36
nominal rotational speed	[rad/s]	1800

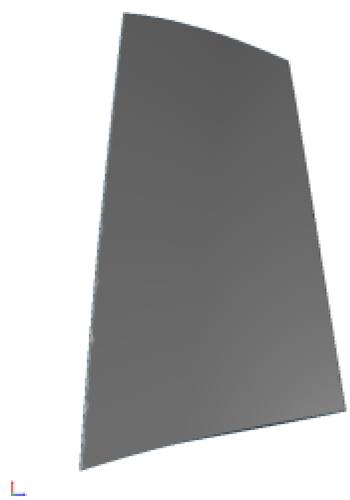
Material properties

Rotor 37 is made of a 200-grade maraging steel[4], but the exact material properties are not provided in the NASA report. The following properties are considered:

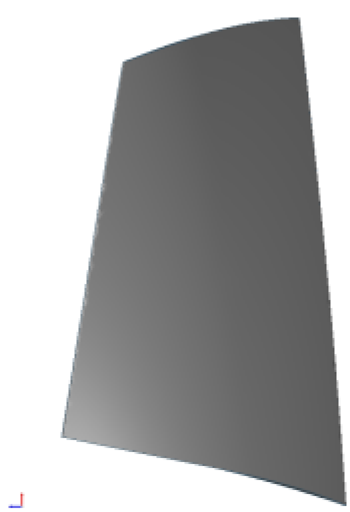
	unit	value
alloy	[-]	18-Ni-200-maraging
Young's modulus	[GPa]	180
density	[kg/m3]	8000
Poisson's ratio	[-]	0.3
yield stress	[GPa]	1.38

CAD model

The CAD model is computed with the open source code OpenMCAD[2].



pressure side



suction side

Natural frequencies

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

Mode	Type	Natural angular frequency (rad/sec)	Natural frequency (Hz)
1	1B	5268.47	838.503
2	1T	15758.10	2507.98
3	2B	19007.70	3025.17

Campbell diagram

Evolution of natural frequencies as a function of rotational speed for the first 3 modes, for the mesh computed with OpenMCAD[2]:

ω_n: Nominal rotational speed

Note: The natural frequencies were found with a linear centrifugal preload

Sources

- Campbell rotor 37 reference blade(.pdf)
- natural frequencies and rotational speeds file (.csv)
- natural frequencies at the nominal rotational speed file (.csv)

Initial blade

The **initial blade** is defined with in-house LAVA parameters[5] 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	5331.54	848.541
2	1T	15903.75	2531.16
3	2B	19317.21	3074.43

- from the reduced order model:

Mode	Type	Natural angular frequency (rad/sec)	Natural frequency (Hz)
1	1B	5332.16	848.64
2	1T	15913.55	2532.72
3	2B	19345.55	3078.94

Campbell diagram

Comparison of the evolution of natural frequencies as a function of rotational speed for the first 3 modes for the initial blade (orange) and the reference blade (gray):

ω_n: Nominal rotational speed

Note: The natural frequencies were found with a linear centrifugal preload

Sources

- Campbell rotor 37 initial blade(.pdf)
- natural frequencies and rotational speeds file (.csv)
- natural frequencies at the nominal rotational speed file (.csv)

Fichiers téléchargeables
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Libre accès

lien vers le projet Git

À propos

Le rotor 37 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 troisième 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 [1]:

```
@TechReport{moore1980design,
  author           = {Moore, R. D. and Reid, L.},
  date             = {1980},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
```

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  title            = {Performance of Single-Stage Axial-Flow Transonic
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- Photographies :

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{A}eronautics and {S}pace {A}dministration, 1903 - 2006. {P}hotographs
relating to agency activities, facilities and personnel, 1973 - 2013},
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gov/id/17468361}, 1977 }, % pour Fig. 1
note     =
{\href{https://catalog.archives.gov/id/17468389}{https://catalog.archives.
gov/id/17468389}, 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[2] pour générer l'aube de référence

Aube de référence

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

Géométrie

La géométrie du rotor 37 est décrite dans le rapport d'origine de la NASA par les tableaux suivants. Les grandeurs sont en centimètres et en degrés.

(a) Rotor 37

RP	PERCENT SPAN	RADII RI	RO	BLADE ANGLES KIC	KTC	KOC	DELTA INC	CONE ANGLE
TIP	0.	25.230	24.506	62.53	62.83	49.98	2.10	-15.233
1	5.	24.935	24.218	61.66	61.86	49.07	2.39	-14.582
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RP	BLADE THICKNESSES TI	TM	TO	AXIAL DIMENSIONS ZI	ZMC	ZTC	ZO
TIP	.025	.175	.025	.713	2.430	2.399	3.372
1	.026	.186	.026	.665	2.390	2.372	3.424
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8	.048	.425	.049	.048	1.984	1.660	4.198
9	.050	.443	.050	.021	1.957	1.591	4.241
HUB	.051	.458	.051	.000	1.933	1.530	4.283

Caractéristiques aérodynamiques

	unités	valeurs
taux de compression	[-]	2,05
débit massique	[kg/s]	20,2
vitesse en tête	[m/s]	455
solidité en tête	[-]	1,3
allongement	[-]	1,19
nombre d'aubes	[-]	36
vitesse de rotation nominale ω_n	[rad/s]	1800

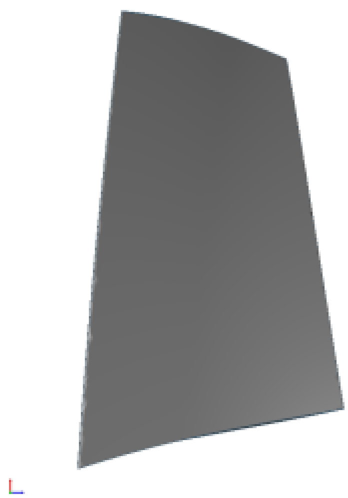
Propriétés matériau

Le matériau du rotor 37 est un alliage à base de nickel : un acier maraging de grade 200[4], mais ses caractéristiques ne sont pas fournies dans le raport de la NASA. Les propriétés considérées sont :

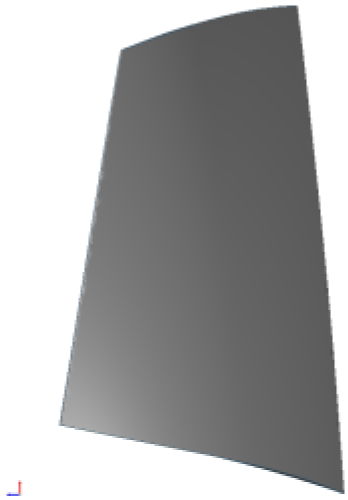
	unité	valeurs
alliage	[-]	18-Ni-200-maraging
module d'Young	[GPa]	180
masse volumique	[kg/m3]	8000
coefficient de Poisson	[-]	0,3
limite élastique	[GPa]	1,38

Modèle CAO

Le modèle CAO est obtenu avec OpenMCAD[2].



intrados



extrados

Fréquences propres

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

Mode	Type	Pulsation propre (rad/sec)	Fréquence propre (Hz)
1	1F	5268,47	838,50
2	1T	15758,10	2507,98
3	2F	19007,70	3025,17

Diagramme de Campbell

Évolution des fréquences propres des 3 premiers modes (noeuds du pied d'aube encastrés), en fonction de la vitesse de rotation, pour le maillage obtenu avec OpenMCAD[2]:

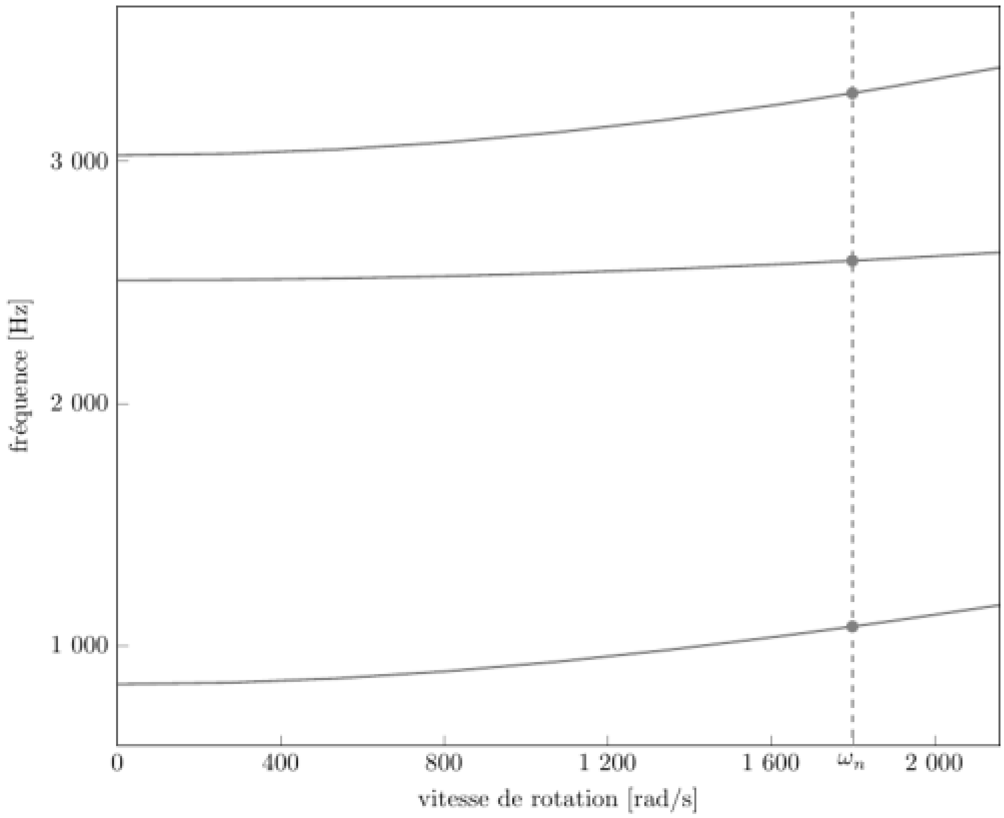


diagramme de Campbell calculé avec une précharge centrifuge linéaire, vitesse nominale ω_n = 1 800 rad/s

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

Aube initiale

L'**aube initiale** est définie par des paramètres spécifiques au LAVA[5] 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	5331,54	848,54
2	1T	15903,75	2531,16
3	2F	19317,21	3074,43

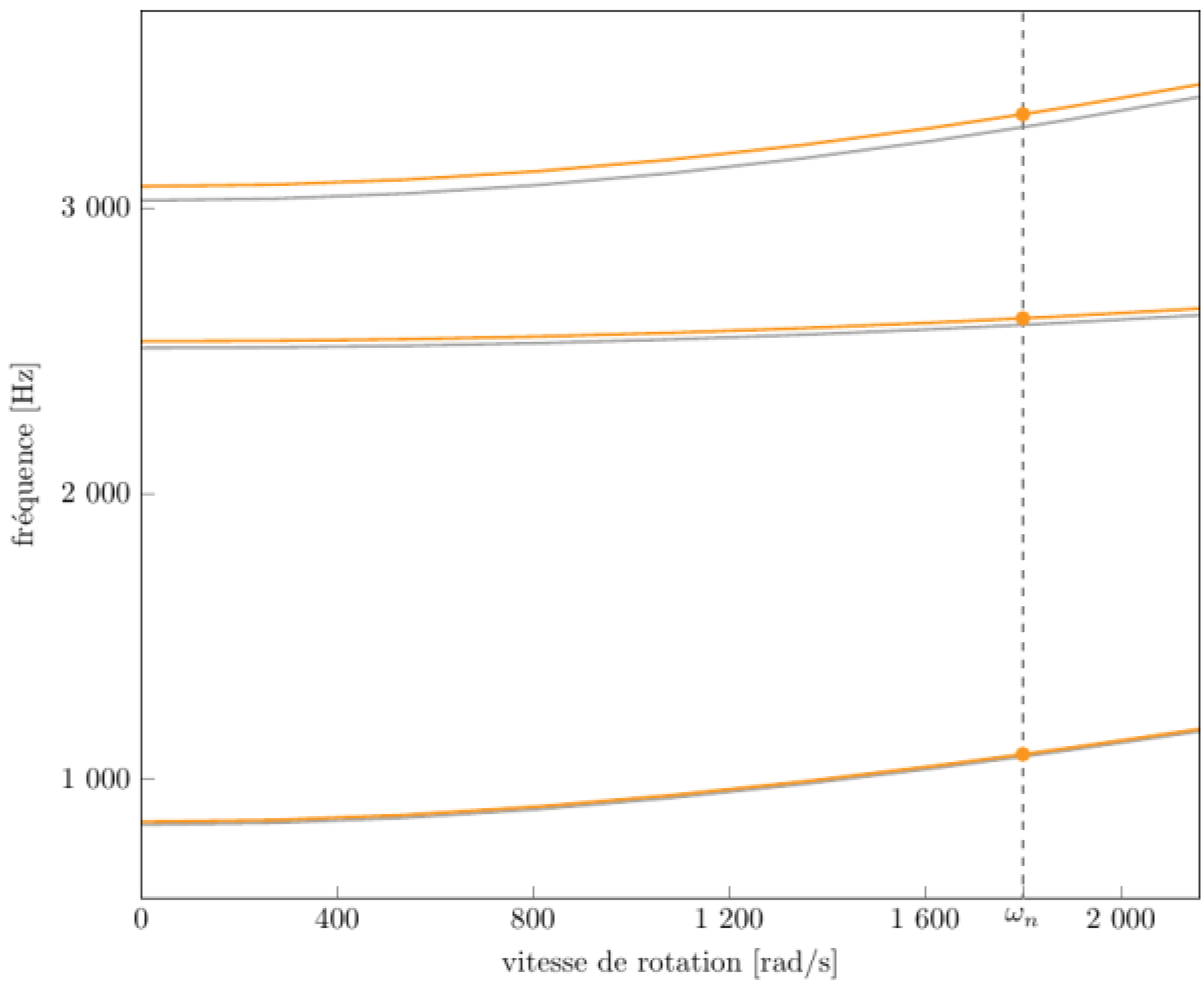
- pour le modèle réduit :

Mode	Type	Pulsation propre (rad/sec)	Fréquence propre (Hz)
1	1F	5332,16	848,64

Mode	Type	Pulsation propre (rad/sec)	Fréquence propre (Hz)
2	1T	15913,55	2532,72
3	2F	19345,55	3078,94

Diagramme de Campbell

Comparaison de l'évolution des fréquences propres des 3 premiers modes (noeuds du pied d'aube encastrés), en fonction de la vitesse de rotation, pour l'aube initiale (orange) et l'aube de référence (gris):



ω_n = 1 800 rad/s

Note: les fréquences propres ont été trouvées avec une précharge centrifuge linéaire

ω_n : vitesse de rotation nominale

Campbell rotor 37

aube initiale (.pdf)

fichier des fréquences propres et des vitesses de rotation (.csv)

1. a, b, c, d Moore R. D., Reid L. «Performance of Single-Stage Axial-Flow Transonic Compressor With Rotor and Stator Aspect Ratios of 1.19 and 1.26, Respectively, and With Design Pressure Ratio of 2.05 » 1980. pdf
2. a, b, c, d, e, f, g, h, i, j Kojtych S., Batailly A. «OpenMCAD, an open blade generator: from Multiple-Circular-Arc profiles to Computer-Aided Design model» 2022. open source code
3. a, b 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. a, b Reid. «Design and overall performance of four highly loaded, high-speed inlet stages for and advanced high-pressure-ratio core compressor» 1978. pdf
5. a, b 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