# Rotor 18

- Français
- English

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**Git project**

## Original model

One way to reduce compressor weight is to obtain a high pressure ratio per stage, thereby reducing the number of stages. As a consequence, several single-stage fans have been designed to produce stage pressure ratios ranging from 1.9 to 2.2. Rotor 18 is one of those fans with a pressure ratio of 1.925.

- Original technical report [(cite:lewis1974design>Lewis. «Design and performance of a high-pressure-ratio, highly loaded axial-flow transonic compressor stage » 1974. pdf)]:

```
@TechReport{lewis1974design,
  author           = {Lewis, George W. and Reid, Lonnie and Tysl, Edward
R.},
  date             = {1974},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
  title            = {Design and performance of a high-pressure-ratio,
highly loaded axial-flow transonic compressor stage},
  number           = {NASA-TM X-3100},
  url              = {https://ntrs.nasa.gov/citations/19740025108},
}
```

- Picture :



Fig1. https://catalog.archives.gov/id/17422714

```
@Misc{huebler1974records,
author   = {Huebler, D.},
title    = {Rotor 18. {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/17422714}{https://catalog.archives.gov/
id/17422714}, 1974 }, % for Fig. 1}
```

**Useful documents**

- downloadable models (Git project)
- PDF of the NASA report :

  rotor18.pdf
- CSV file of the blade geometry :

  rotor18_original.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.

The **reference blade** is defined with multiple-circular arc profiles[(cite:Crouse_1969_computer)] given in

the original NASA report[(cite:lewis1974design)]. Corresponding models are computed with the open-source code OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

# Geometry

The geometry of rotor 18 is described in the original NASA report by the following tables. The length are in centimeters and the angles in degrees.

TABLE IV. - BLADE GEOMETRY FOR ROTOR 18

| RP | PERCENT SPAN | RADII RI | RADII RO | BLADE ANGLES KIC | BLADE ANGLES KTC | BLADE ANGLES KOC | DELTA INC | CONE ANGLE |
|---|---|---|---|---|---|---|---|---|
| TIP | 0. | 25.019 | 24.359 | 63.50 | 60.06 | 48.60 | 2.49 | -15.536 |
| 1 | 5. | 24.442 | 23.871 | 61.91 | 58.53 | 47.71 | 2.75 | -12.940 |
| 2 | 10. | 23.906 | 23.383 | 60.51 | 57.10 | 46.55 | 3.00 | -11.383 |
| 3 | 30. | 21.655 | 21.433 | 55.62 | 51.09 | 39.82 | 4.08 | -4.201 |
| 4 | 48. | 19.590 | 19.726 | 52.08 | 45.52 | 31.18 | 5.03 | 2.263 |
| 5 | 50. | 19.288 | 19.482 | 51.61 | 44.86 | 29.62 | 5.17 | 3.196 |
| 6 | 53. | 18.983 | 19.238 | 51.14 | 44.24 | 27.97 | 5.30 | 4.131 |
| 7 | 55. | 18.676 | 18.994 | 50.68 | 43.63 | 26.26 | 5.43 | 5.076 |
| 8 | 58. | 18.367 | 18.750 | 50.22 | 42.97 | 24.48 | 5.56 | 6.033 |
| 9 | 70. | 16.777 | 17.531 | 48.02 | 39.76 | 14.38 | 6.16 | 10.944 |
| 10 | 90. | 14.079 | 15.580 | 44.63 | 35.58 | -7.70 | 6.86 | 19.179 |
| 11 | 95. | 13.384 | 15.093 | 43.76 | 34.81 | -14.81 | 6.97 | 21.167 |
| HUB | 100. | 12.700 | 14.605 | 42.89 | 34.15 | -22.54 | 7.04 | 22.937 |

| RP | BLADE THICKNESSES TI | BLADE THICKNESSES TM | BLADE THICKNESSES TO | AXIAL DIMENSIONS ZIC | AXIAL DIMENSIONS ZMC | AXIAL DIMENSIONS ZTC | AXIAL DIMENSIONS ZOC |
|---|---|---|---|---|---|---|---|
| TIP | 0.051 | 0.152 | 0.051 | 1.148 | 2.212 | 2.267 | 3.523 |
| 1 | 0.051 | 0.163 | 0.051 | 1.087 | 2.213 | 2.225 | 3.573 |
| 2 | 0.051 | 0.173 | 0.051 | 1.031 | 2.213 | 2.183 | 3.626 |
| 3 | 0.051 | 0.216 | 0.051 | 0.812 | 2.205 | 1.966 | 3.847 |
| 4 | 0.051 | 0.256 | 0.051 | 0.627 | 2.193 | 1.719 | 4.048 |
| 5 | 0.051 | 0.262 | 0.051 | 0.602 | 2.191 | 1.681 | 4.076 |
| 6 | 0.051 | 0.267 | 0.051 | 0.578 | 2.188 | 1.643 | 4.105 |
| 7 | 0.051 | 0.273 | 0.051 | 0.554 | 2.185 | 1.604 | 4.133 |
| 8 | 0.051 | 0.279 | 0.051 | 0.529 | 2.182 | 1.563 | 4.160 |
| 9 | 0.051 | 0.309 | 0.051 | 0.396 | 2.164 | 1.341 | 4.296 |
| 10 | 0.051 | 0.360 | 0.051 | 0.149 | 2.126 | 0.924 | 4.466 |
| 11 | 0.051 | 0.373 | 0.051 | 0.076 | 2.117 | 0.807 | 4.488 |
| HUB | 0.051 | 0.386 | 0.051 | 0.000 | 2.107 | 0.687 | 4.502 |

# Aerodynamic design

| | unit | values |
|---|---|---|
| **pressure ratio** | [-] | 1.925 |
| **mass flow** | [kg/s] | 29.5 |
| **tip speed** | [m/s] | 422 |
| **tip solidity** | [-] | 1.7 |
| **aspect ratio** | [-] | 2.6 |
| **number of blades** | [-] | 56 |
| **rotative speed** | [rad/s] | 1686 |

# Material properties

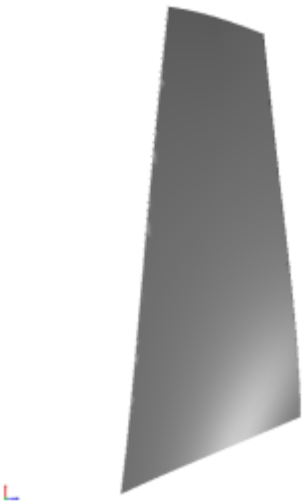
The original material of the rotor 18 is not defined in the NASA report.

Considered properties: Ti-6Al-4V, generic titanium :

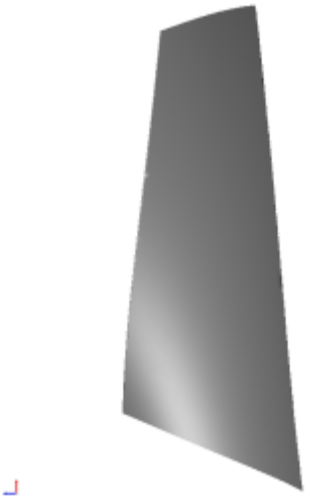
| | unité | valeurs |
|---|---|---|
| **alloy** | [-] | Ti-6Al-4V |
| **Young's modulus** | [GPa] | 108 |
| **density** | [kg/m3] | 4400 |
| **Poisson's ratio** | [-] | 0.34 |
| **yield stress** | [GPa] | 0.824 |

## 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 | 2023.14 | 321.992 |
| 2 | 2B | 6631.02 | 1055.36 |
| 3 | 1T | 10297.70 | 1638.93 |

# 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 | 2018.44 | 321.244 |
| 2 | 2B | 6628.45 | 1054.95 |
| 3 | 1T | 10299.84 | 1639.27 |

- from the reduced order model:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|---|---|---|---|
| 1 | 1B | 2018.52 | 321.258 |
| 2 | 2B | 6631.02 | 1055.36 |
| 3 | 1T | 10304.68 | 1640.04 |

Fichiers téléchargeables
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**Libre accès**

**lien vers le projet Git**

# À propos

Une façon de réduire le poids d'un compresseur est d'atteindre un rapport de pression élevé par étage, ce qui permet de réduire le nombre d'étages de ce compresseur. Par conséquent, plusieurs soufflantes à un étage ont été conçus pour produire des rapports de pression par étage allant de 1,9 à 2,2. Le rotor 18 est donc une de ces soufflantes et possède un taux de compression de 1,925.

- Rapport technique original [(cite:lewis1974design>Lewis. «Design and performance of a high-pressure-ratio, highly loaded axial-flow transonic compressor stage » 1974. pdf)]:

```
@TechReport{lewis1974design,
  author           = {Lewis, George W. and Reid, Lonnie and Tysl, Edward
R.},
```

```
  date              = {1974},
  institution       = {NASA Lewis Research Center Cleveland, OH, United
States},
  title             = {Design and performance of a high-pressure-ratio,
highly loaded axial-flow transonic compressor stage},
  number            = {NASA-TM X-3100},
  url               = {https://ntrs.nasa.gov/citations/19740025108},
}
```

- Photographie :



Fig1. https://catalog.archives.gov/id/17422714

```
@Misc{huebler1974records,
author   = {Huebler, D.},
title    = {Rotor 18. {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/17422714}{https://catalog.archives.gov/
id/17422714}, 1974 }, % for Fig. 1}
```

**Documents utiles**

- modèles téléchargeables (lien vers projet Git)
- PDF du rapport de la NASA :

  rotor18.pdf
- Fichier CSV de la géométrie :

  rotor18_original.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:lewis1974design)]. Les modèles associés sont obtenus avec le code en libre accès OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

# Géométrie

La géométrie du rotor 18 est décrite dans le rapport d'origine de la NASA par les tableaux suivants. Les grandeurs sont en centimètres et en degrés.

TABLE IV. - BLADE GEOMETRY FOR ROTOR 18

| | PERCENT | RADII | | BLADE ANGLES | | | DELTA | CONE |
|---|---|---|---|---|---|---|---|---|
| RP | SPAN | RI | RO | KIC | KTC | KOC | INC | ANGLE |
| TIP | 0. | 25.019 | 24.359 | 63.50 | 60.06 | 48.60 | 2.49 | -15.536 |
| 1 | 5. | 24.442 | 23.871 | 61.91 | 58.53 | 47.71 | 2.75 | -12.940 |
| 2 | 10. | 23.906 | 23.383 | 60.51 | 57.10 | 46.55 | 3.00 | -11.383 |
| 3 | 30. | 21.655 | 21.433 | 55.62 | 51.09 | 39.82 | 4.08 | -4.201 |
| 4 | 48. | 19.590 | 19.726 | 52.08 | 45.52 | 31.18 | 5.03 | 2.263 |
| 5 | 50. | 19.288 | 19.482 | 51.61 | 44.86 | 29.62 | 5.17 | 3.196 |
| 6 | 53. | 18.983 | 19.238 | 51.14 | 44.24 | 27.97 | 5.30 | 4.131 |
| 7 | 55. | 18.676 | 18.994 | 50.68 | 43.63 | 26.26 | 5.43 | 5.076 |
| 8 | 58. | 18.367 | 18.750 | 50.22 | 42.97 | 24.48 | 5.56 | 6.033 |
| 9 | 70. | 16.777 | 17.531 | 48.02 | 39.76 | 14.38 | 6.16 | 10.944 |
| 10 | 90. | 14.079 | 15.580 | 44.63 | 35.58 | -7.70 | 6.86 | 19.179 |
| 11 | 95. | 13.384 | 15.093 | 43.76 | 34.81 | -14.81 | 6.97 | 21.167 |
| HUB | 100. | 12.700 | 14.605 | 42.89 | 34.15 | -22.54 | 7.04 | 22.937 |

| | BLADE THICKNESSES | | | AXIAL DIMENSIONS | | | |
|---|---|---|---|---|---|---|---|
| RP | TI | TM | TO | ZIC | ZMC | ZTC | ZOC |
| TIP | 0.051 | 0.152 | 0.051 | 1.148 | 2.212 | 2.267 | 3.523 |
| 1 | 0.051 | 0.163 | 0.051 | 1.087 | 2.213 | 2.225 | 3.573 |
| 2 | 0.051 | 0.173 | 0.051 | 1.031 | 2.213 | 2.183 | 3.626 |
| 3 | 0.051 | 0.216 | 0.051 | 0.812 | 2.205 | 1.966 | 3.847 |
| 4 | 0.051 | 0.256 | 0.051 | 0.627 | 2.193 | 1.719 | 4.048 |
| 5 | 0.051 | 0.262 | 0.051 | 0.602 | 2.191 | 1.681 | 4.076 |
| 6 | 0.051 | 0.267 | 0.051 | 0.578 | 2.188 | 1.643 | 4.105 |
| 7 | 0.051 | 0.273 | 0.051 | 0.554 | 2.185 | 1.604 | 4.133 |
| 8 | 0.051 | 0.279 | 0.051 | 0.529 | 2.182 | 1.563 | 4.160 |
| 9 | 0.051 | 0.309 | 0.051 | 0.396 | 2.164 | 1.341 | 4.296 |
| 10 | 0.051 | 0.360 | 0.051 | 0.149 | 2.126 | 0.924 | 4.466 |
| 11 | 0.051 | 0.373 | 0.051 | 0.076 | 2.117 | 0.807 | 4.488 |
| HUB | 0.051 | 0.386 | 0.051 | 0.000 | 2.107 | 0.687 | 4.502 |

# Caractéristiques aérodynamiques

| | unités | valeurs |
|---|---|---|
| **taux de compression** | [-] | 1,925 |
| **débit massique** | [kg/s] | 29,5 |
| **vitesse en tête** | [m/s] | 422 |
| **solidité en tête** | [-] | 1,7 |
| **allongement** | [-] | 2,6 |
| **nombre d'aubes** | [-] | 56 |
| **vitesse de rotation** | [rad/s] | 1686 |

# Propriétés matériau

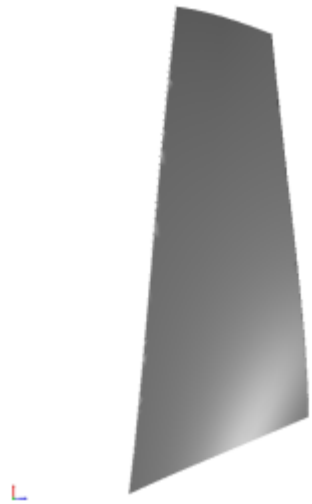
Le matériau original du rotor 18 n'est pas défini dans le rapport de la NASA.

Propriétés considérées : alliage de titane Ti-6Al-4v :

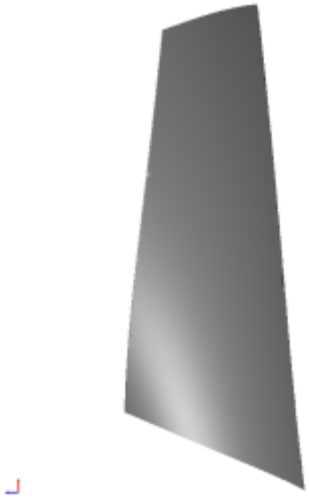
| | unité | valeurs |
|---|---|---|
| **alliage** | [-] | Ti-6Al-4v |
| **module d'Young** | [GPa] | 108 |
| **masse volumique** | [kg/m3] | 4400 |
| **coefficient de Poisson** | [-] | 0,34 |
| **limite élastique** | [GPa] | 0,824 |

## 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 | 1B | 2023,14 | 321,992 |
| 2 | 2B | 6631,02 | 1055,36 |
| 3 | 1T | 10297,70 | 1638,93 |

## 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 | 1B | 2018,44 | 321,244 |
| 2 | 2B | 6628,45 | 1054,95 |
| 3 | 1T | 10299,84 | 1639,27 |

- pour le modèle réduit :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|---|---|---|---|
| 1 | 1B | 2018,52 | 321,258 |
| 2 | 2B | 6631,02 | 1055,36 |
| 3 | 1T | 10304,68 | 1640,04 |

</tabs>

Document issu de la page wiki:
**https://wiki.lava.polymtl.ca/public/modeles/rotor_18/accueil?rev=1679263106**

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