# Rotor 20

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## Original model

Rotor 20 is part of a research program to study the effect of tip velocity ratio on compressors performances. It has been designed for a stage tip velocity ratio of 0.8.

- Original technical report [1]:

```
@TechReport{moore1978design,
  author           = {Moore, R. D. and Lewis, George W. and Osborn, Walter
M.},
  date             = {1978},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
  title            = {Performance of a Transonic Fan Stage Designed for a
Low Meridional Velocity Ratio},
  number           = {NASA-TP-1298},
  url              =
{https://ntrs.nasa.gov/api/citations/19780025164/downloads/19780025164.pdf
},
```

- Picture :

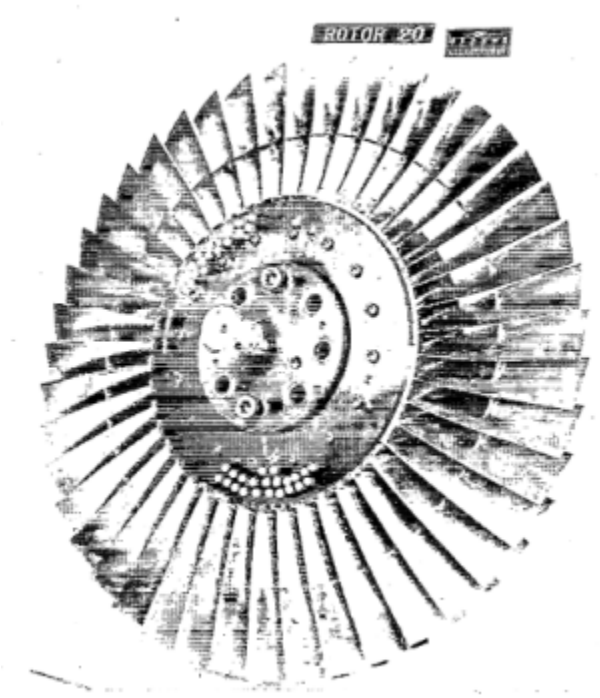



Fig1. https://ntrs.nasa.gov/api/citations/19780025164/downloads/19780025164.pdf p.61

## Useful documents

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

  rotor20.pdf
- CSV file of the blade geometry :

  rotor20_original.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 20 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 20

| RP | PERCENT SPAN | RADII RI | RADII RO | BLADE ANGLES KIC | BLADE ANGLES KTC | BLADE ANGLES KOC | DELTA INC | CONE ANGLE |
|---|---|---|---|---|---|---|---|---|
| TIP | 0. | 25.281 | 25.171 | 63.94 | 63.97 | 59.17 | 2.52 | -3.006 |
| 1 | 5. | 24.724 | 24.614 | 62.90 | 62.83 | 58.74 | 2.77 | -2.925 |
| 2 | 10. | 24.156 | 24.057 | 61.85 | 61.62 | 58.16 | 3.03 | -2.520 |
| 3 | 30. | 21.810 | 21.829 | 57.80 | 56.14 | 55.16 | 4.11 | 0.434 |
| 4 | 50. | 19.385 | 19.601 | 53.76 | 50.05 | 49.12 | 5.19 | 4.227 |
| 5 | 55. | 18.764 | 19.044 | 52.71 | 48.42 | 48.96 | 5.46 | 5.281 |
| 6 | 58. | 18.451 | 18.766 | 52.18 | 47.58 | 45.80 | 5.59 | 5.854 |
| 7 | 60. | 18.136 | 18.487 | 51.64 | 46.73 | 44.57 | 5.73 | 6.399 |
| 8 | 63. | 17.819 | 18.209 | 51.09 | 45.86 | 43.29 | 5.86 | 6.974 |
| 9 | 70. | 16.851 | 17.373 | 49.43 | 43.22 | 38.64 | 6.26 | 8.822 |
| 10 | 90. | 14.130 | 15.145 | 44.69 | 36.03 | 20.60 | 7.25 | 14.611 |
| 11 | 95. | 13.408 | 14.588 | 43.40 | 34.05 | 14.33 | 7.46 | 16.271 |
| HUB | 100. | 12.700 | 14.031 | 42.12 | 32.06 | 7.30 | 7.64 | 17.597 |

| 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 | 0.153 | 0.051 | 1.017 | 2.032 | 2.437 | 3.097 |
| 1 | 0.051 | 0.163 | 0.051 | 0.980 | 2.034 | 2.409 | 3.135 |
| 2 | 0.051 | 0.173 | 0.051 | 0.942 | 2.035 | 2.376 | 3.175 |
| 3 | 0.051 | 0.217 | 0.051 | 0.780 | 2.037 | 2.204 | 3.340 |
| 4 | 0.051 | 0.261 | 0.051 | 0.609 | 2.037 | 1.957 | 3.534 |
| 5 | 0.051 | 0.272 | 0.051 | 0.563 | 2.035 | 1.882 | 3.500 |
| 6 | 0.051 | 0.278 | 0.051 | 0.539 | 2.034 | 1.842 | 3.619 |
| 7 | 0.051 | 0.284 | 0.051 | 0.514 | 2.033 | 1.800 | 3.648 |
| 8 | 0.051 | 0.290 | 0.051 | 0.490 | 2.032 | 1.757 | 3.678 |
| 9 | 0.051 | 0.307 | 0.051 | 0.418 | 2.025 | 1.617 | 3.775 |
| 10 | 0.051 | 0.358 | 0.051 | 0.163 | 1.991 | 1.161 | 4.058 |
| 11 | 0.051 | 0.372 | 0.051 | 0.084 | 1.977 | 1.021 | 4.128 |
| HUB | 0.051 | 0.385 | 0.051 | 0.000 | 1.961 | 0.875 | 4.196 |

# Aerodynamic design

| | unit | values |
|---|---|---|
| **pressure ratio** | [-] | 1.57 |
| **mass flow** | [kg/s] | 29.5 |
| **tip speed** | [m/s] | 425 |
| **tip solidity** | [-] | 1.3 |
| **aspect ratio** | [-] | 2.5 |
| **number of blades** | [-] | 44 |
| **rotative speed** | [rad/s] | 1686 |

# Material properties

The original material of the rotor 20 is not defined in the NASA report.

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

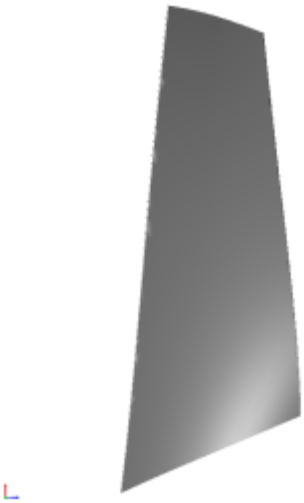
| | unité | valeurs |
|---|---|---|
| **alloy** | [-] | Ti-6Al-4V |
| **Young's modulus** | [GPa] | 108 |
| **density** | [kg/m3] | 4400 |
| **Poisson's ratio** | [-] | 0.34 |
| **yield stress** | [GPa] | 0.824 |

First three natural frequencies (with clamped root) for the mesh:

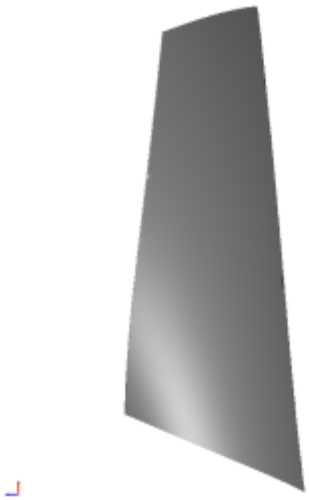
1. (1B): 1441.5 rad/s / 229.4 Hz
2. (2B): 5124.4 rad/s / 815.6 Hz
3. (1T): 8165.6 rad/s / 1299.6 Hz

## 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 | À Remplir stp | 1374.86 | 218.815 |
| 2 | À Remplir stp | 5070.79 | 807.042 |
| 3 | À Remplir stp | 7887.28 | 1255.3 |

# Initial blade

The **initial blade** is defined with in-house LAVA parameters[4] 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 | À Remplir stp | 1375.47 | 218.913 |
| 2 | À Remplir stp | 5066.25 | 806.319 |
| 3 | À Remplir stp | 7896.27 | 1256.73 |

- from the reduced order model:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|---|---|---|---|
| 1 | À Remplir stp | 1375.5 | 218.917 |
| 2 | À Remplir stp | 5068.12 | 806.617 |
| 3 | À Remplir stp | 7898.53 | 1257.09 |

Fichiers téléchargeables
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**Libre accès**

**lien vers le projet Git**

# Modèle original

Le rotor 20 fait partie d'un programme de recherche visant à étudier l'effet du rapport de vitesse en tête sur les performances des compresseurs. Il a été conçu pour un rapport de vitesse en tête de 0,8.

- Rapport technique original [1]:

```
@TechReport{moore1978design,
  author           = {Moore, R. D. and Lewis, George W. and Osborn, Walter
M.},
  date             = {1978},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
  title            = {Performance of a Transonic Fan Stage Designed for a
Low Meridional Velocity Ratio},
  number           = {NASA-TP-1298},
  url              =
{https://ntrs.nasa.gov/api/citations/19780025164/downloads/19780025164.pdf
```

```
},
  }
```

- Photographie :

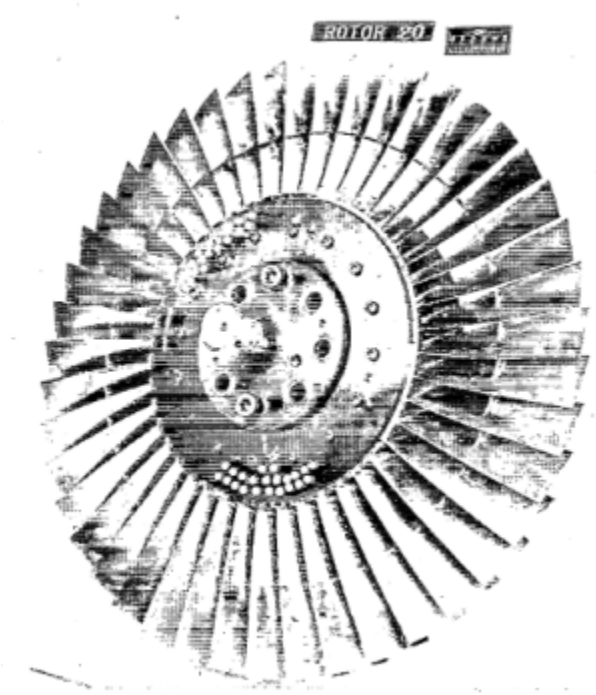


Fig1. https://ntrs.nasa.gov/api/citations/19780025164/downloads/19780025164.pdf p.61

# Documents utiles

- modèles téléchargeables (lien vers projet Git)
- PDF du rapport de la NASA :
  rotor20.pdf
- Fichier CSV de la géométrie :
  rotor20_original.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 20 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 20

| RP | PERCENT SPAN | RADII RI | RADII RO | BLADE ANGLES KIC | BLADE ANGLES KTC | BLADE ANGLES KOC | DELTA INC | CONE ANGLE |
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| 1 | 5. | 24.724 | 24.614 | 62.90 | 62.83 | 58.74 | 2.77 | -2.925 |
| 2 | 10. | 24.156 | 24.057 | 61.85 | 61.62 | 58.16 | 3.03 | -2.520 |
| 3 | 30. | 21.810 | 21.829 | 57.80 | 56.14 | 55.16 | 4.11 | 0.434 |
| 4 | 50. | 19.385 | 19.601 | 53.76 | 50.05 | 49.12 | 5.19 | 4.227 |
| 5 | 55. | 18.764 | 19.044 | 52.71 | 48.42 | 48.96 | 5.46 | 5.281 |
| 6 | 58. | 18.451 | 18.766 | 52.18 | 47.58 | 45.80 | 5.59 | 5.854 |
| 7 | 60. | 18.136 | 18.487 | 51.64 | 46.73 | 44.57 | 5.73 | 6.399 |
| 8 | 63. | 17.819 | 18.209 | 51.09 | 45.86 | 43.29 | 5.86 | 6.974 |
| 9 | 70. | 16.851 | 17.373 | 49.43 | 43.22 | 38.64 | 6.26 | 8.822 |
| 10 | 90. | 14.130 | 15.145 | 44.69 | 36.03 | 20.60 | 7.25 | 14.611 |
| 11 | 95. | 13.408 | 14.588 | 43.40 | 34.05 | 14.33 | 7.46 | 16.271 |
| HUB | 100. | 12.700 | 14.031 | 42.12 | 32.06 | 7.30 | 7.64 | 17.597 |

| 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 | 0.153 | 0.051 | 1.017 | 2.032 | 2.437 | 3.097 |
| 1 | 0.051 | 0.163 | 0.051 | 0.980 | 2.034 | 2.409 | 3.135 |
| 2 | 0.051 | 0.173 | 0.051 | 0.942 | 2.035 | 2.376 | 3.175 |
| 3 | 0.051 | 0.217 | 0.051 | 0.780 | 2.037 | 2.204 | 3.340 |
| 4 | 0.051 | 0.261 | 0.051 | 0.609 | 2.037 | 1.957 | 3.534 |
| 5 | 0.051 | 0.272 | 0.051 | 0.563 | 2.035 | 1.882 | 3.500 |
| 6 | 0.051 | 0.278 | 0.051 | 0.539 | 2.034 | 1.842 | 3.619 |
| 7 | 0.051 | 0.284 | 0.051 | 0.514 | 2.033 | 1.800 | 3.648 |
| 8 | 0.051 | 0.290 | 0.051 | 0.490 | 2.032 | 1.757 | 3.678 |
| 9 | 0.051 | 0.307 | 0.051 | 0.418 | 2.025 | 1.617 | 3.775 |
| 10 | 0.051 | 0.350 | 0.051 | 0.163 | 1.991 | 1.161 | 4.058 |
| 11 | 0.051 | 0.372 | 0.051 | 0.084 | 1.977 | 1.021 | 4.128 |
| HUB | 0.051 | 0.385 | 0.051 | 0.000 | 1.961 | 0.875 | 4.196 |

# Caractéristiques aérodynamiques

| | unités | valeurs |
|---|---|---|
| **taux de compression** | [-] | 1,57 |
| **débit massique** | [kg/s] | 29,5 |
| **vitesse en tête** | [m/s] | 425 |
| **solidité en tête** | [-] | 1,3 |
| **allongement** | [-] | 2,5 |
| **nombre d'aubes** | [-] | 44 |
| **vitesse de rotation** | [rad/s] | 1686 |

# Propriétés matériau

Le matériau original du rotor 20 n'est pas défini dans le rapport de la NASA.

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

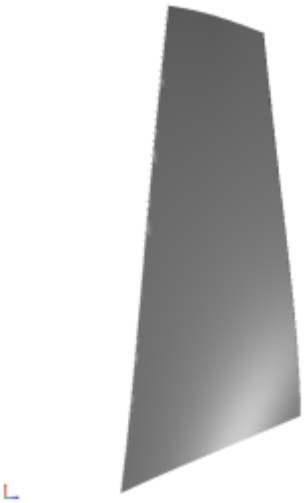
| | unité | valeurs |
|---|---|---|
| **alliage** | [-] | Ti-6Al-4v |
| **module d'Young** | [GPa] | 108 |
| **masse volumique** | [kg/m3] | 4400 |
| **coefficient de Poisson** | [-] | 0,34 |
| **limite élastique** | [GPa] | 0,824 |

Fréquences des trois premiers modes (noeuds de la base encastrés) pour le maillage :

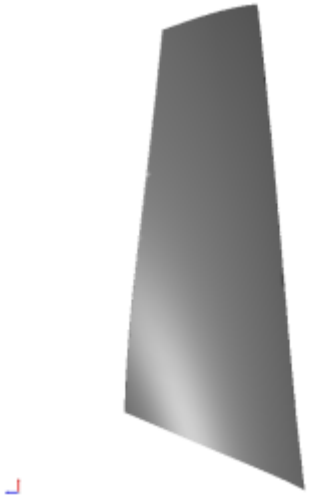
1. (1B): 1441,5 rad/s / 229,4 Hz
2. (2B): 5124,4 rad/s / 815,6 Hz
3. (1T): 8165,6 rad/s / 1299,6 Hz

## 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 | À Remplir stp | 1374.86 | 218.815 |
| 2 | À Remplir stp | 5070.79 | 807.042 |

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|---|---|---|---|
| 3 | À Remplir stp | 7887.28 | 1255.3 |

# Aube initiale

L'**aube initiale** est définie par des paramètres spécifiques au LAVA[4] 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 | À Remplir stp | 1375.47 | 218.913 |
| 2 | À Remplir stp | 5066.25 | 806.319 |
| 3 | À Remplir stp | 7896.27 | 1256.73 |

- pour le modèle réduit :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|---|---|---|---|
| 1 | À Remplir stp | 1375.5 | 218.917 |
| 2 | À Remplir stp | 5068.12 | 806.617 |
| 3 | À Remplir stp | 7898.53 | 1257.09 |

</tabs>

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1. [a, b, c, d] Moore. «Performance of a Transonic Fan Stage Designed for a Low Meridional Velocity Ratio » 1978. pdf
2. [a, b, c, d, e, f, g, h] Kojtych S., Batailly A. «OpenMCAD, an open blade generator: from Multiple-Circular-Arc profiles to Computer-Aided Design model» 2022. code en libre accès
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] 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

Document issu de la page wiki:
**https://lava-wiki.meca.polymtl.ca/public/modeles/rotor_20/accueil?rev=1677127244**

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