# Rotor 15

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## Original model

Rotor 15 is a fan which was the first of a series of designs in support of NASA’s low-noise conventional aircraft engine program. The fan designed in this program have unconventional geometric and aerodynamic features because of noise considerations.

- Original technical report [(cite:gelder1974design>Gelder. «Aerodynamic performance of 0.5-meter-diameter, 337-meter-per-second tip speed, 1.5-pressure-ratio, single-stage fan designed for low noise aircraft engines » 1974. pdf)]:

```
@TechReport{gelder1974design,
  author           = {Gelder, Thomas F. and Lewis, George W.},
  date             = {1974},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
  title            = {Aerodynamic performance of 0.5-meter-diameter, 337-
meter-per-second tip speed, 1.5-pressure-ratio, single-stage fan designed
for low noise aircraft engines},
  number           = {NASA-TN D-7836},
  url              = {https://ntrs.nasa.gov/citations/19750006695},
}
```

- Picture :

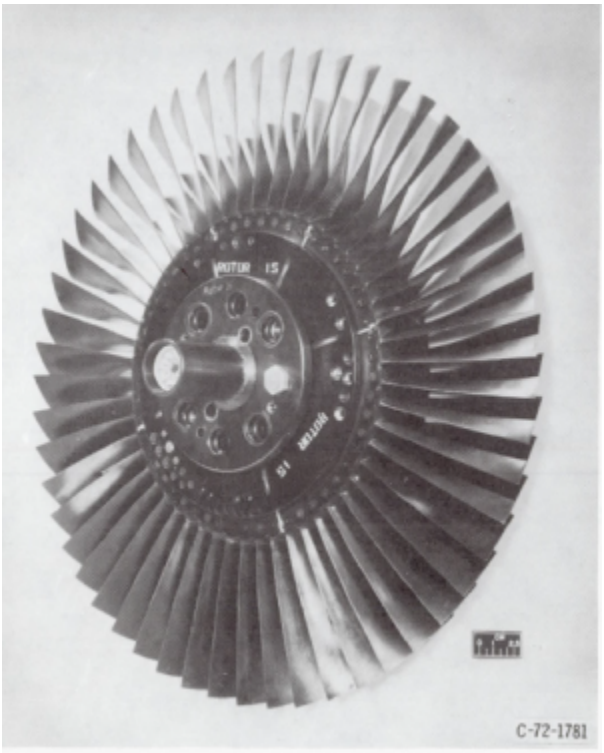



Fig1. https://ntrs.nasa.gov/citations/19750006695 p.153

# Useful documents

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

  rotor15.pdf
- CSV file of the blade geometry :

  rotor15_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.

# Reference blade

The **reference blade** is defined with multiple-circular arc profiles[(cite:Crouse_1969_computer)] given in the original NASA report[(cite:hager1974design)]. Corresponding models are computed with the open-source code OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

# Geometry

The geometry of rotor 15 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 15

| RP | PERCENT SPAN | RADII RI | RADII RO | BLADE ANGLES KIC | BLADE ANGLES KTC | BLADE ANGLES KOC | DELTA INC | CONE ANGLE |
|---|---|---|---|---|---|---|---|---|
| TIP | 0. | 24.750 | 23.962 | 60.18 | 56.04 | 37.62 | 3.32 | -20.375 |
| 1 | 5. | 24.132 | 23.424 | 58.16 | 53.63 | 37.89 | 3.37 | -17.428 |
| 2 | 10. | 23.510 | 22.886 | 56.33 | 51.57 | 37.68 | 3.46 | -14.752 |
| 3 | 15. | 22.884 | 22.347 | 54.69 | 49.88 | 37.00 | 3.58 | -12.262 |
| 4 | 30. | 21.021 | 20.732 | 50.52 | 45.02 | 31.80 | 4.17 | -5.998 |
| 5 | 50. | 18.560 | 18.579 | 45.41 | 38.87 | 20.63 | 5.49 | 0.349 |
| 6 | 70. | 16.075 | 16.425 | 39.39 | 32.45 | 4.28 | 7.78 | 5.833 |
| 7 | 85. | 14.192 | 14.810 | 33.67 | 27.61 | -11.12 | 10.32 | 9.632 |
| 8 | 90. | 13.573 | 14.272 | 31.22 | 26.10 | -16.53 | 11.60 | 10.738 |
| 9 | 95. | 12.960 | 13.734 | 28.47 | 24.63 | -22.01 | 13.13 | 11.756 |
| HUB | 100. | 12.352 | 13.195 | 25.42 | 23.22 | -27.59 | 14.88 | 12.727 |

| RP | BLADE THICKNESSES TI | TM | TO | AXIAL DIMENSIONS ZIC | ZMC | ZTC | ZOC |
|---|---|---|---|---|---|---|---|
| TIP | 0.036 | 0.143 | 0.032 | 0.711 | 1.655 | 1.926 | 2.831 |
| 1 | 0.036 | 0.145 | 0.031 | 0.666 | 1.683 | 1.914 | 2.920 |
| 2 | 0.037 | 0.147 | 0.032 | 0.620 | 1.700 | 1.886 | 2.990 |
| 3 | 0.038 | 0.151 | 0.032 | 0.573 | 1.706 | 1.841 | 3.042 |
| 4 | 0.042 | 0.167 | 0.034 | 0.448 | 1.673 | 1.674 | 3.196 |
| 5 | 0.050 | 0.199 | 0.038 | 0.313 | 1.624 | 1.408 | 3.407 |
| 6 | 0.062 | 0.246 | 0.045 | 0.203 | 1.625 | 1.114 | 3.638 |
| 7 | 0.074 | 0.295 | 0.052 | 0.082 | 1.631 | 0.825 | 3.723 |
| 8 | 0.079 | 0.315 | 0.055 | 0.048 | 1.637 | 0.731 | 3.734 |
| 9 | 0.084 | 0.337 | 0.058 | 0.022 | 1.648 | 0.641 | 3.738 |
| HUB | 0.090 | 0.360 | 0.061 | 0.000 | 1.664 | 0.554 | 3.734 |

# Aerodynamic design

| | unit | values |
|---|---|---|
| **pressure ratio** | [-] | 1.5 |
| **mass flow** | [kg/s] | 29.16 |
| **tip speed** | [m/s] | 337 |
| **tip solidity** | [-] | 1.344 |
| **aspect ratio** | [-] | 3 |
| **number of blades** | [-] | 53 |
| **rotative speed** | [rad/s] | 1363.45 |

# Material properties

The original material of the rotor 15 is not defined in the NASA report.

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

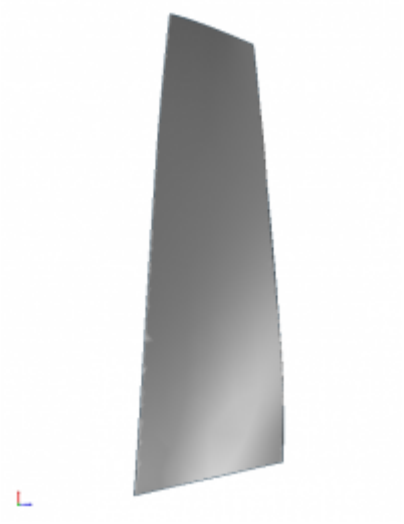
| | unité | valeurs |
|---|---|---|
| **alloy** | [-] | Ti-6Al-4V |
| **Young's modulus** | [GPa] | 108 |
| **density** | [kg/m3] | 4400 |
| **Poisson's ratio** | [-] | 0.34 |
| **yield stress** | [GPa] | 0.824 |

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

1. (1B): 1480.4 rad/s / 235.6 Hz
2. (2B): 4860.4 rad/s / 773.6 Hz
3. (1T): 8961.4 rad/s / 1426.2 Hz

## 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 | 1018.5 | 162.1 |
| 2 | 1T | 3542.5 | 563.8 |
| 3 | 2B | 6094.7 | 970.0 |

# 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 | 1019.1 | 162.2 |
| 2 | 1T | 3539.3 | 563.3 |
| 3 | 2B | 6074.0 | 966.7 |

- from the reduced order model:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|---|---|---|---|
| 1 | 1B | 1019.1 | 162.2 |
| 2 | 1T | 3540.8 | 563.5 |
| 3 | 2B | 6075.8 | 967.0 |

Fichiers téléchargeables
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**Libre accès**

**lien vers le projet Git**

# Modèle original

Le rotor 15 une la soufflante, qui a été le premier d'une série à l'appui du programme de la NASA pour des moteurs d'avion conventionnels à faible bruit. Les soufflantes conçus dans le cadre de ce programme présentent des caractéristiques géométriques et aérodynamiques non conventionnelles pour des raisons de réduction du bruit.

- Rapport technique original [(cite:gelder1974design>Gelder. «Aerodynamic performance of 0.5-meter-diameter, 337-meter-per-second tip speed, 1.5-pressure-ratio, single-stage fan designed for low noise aircraft engines » 1974. pdf)]:

```
@TechReport{gelder1974design,
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  institution      = {NASA Lewis Research Center Cleveland, OH, United
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  title            = {Aerodynamic performance of 0.5-meter-diameter, 337-
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```

```
for low noise aircraft engines},
  number           = {NASA-TN D-7836},
  url              = {https://ntrs.nasa.gov/citations/19750006695},
}
```

- Photographie :

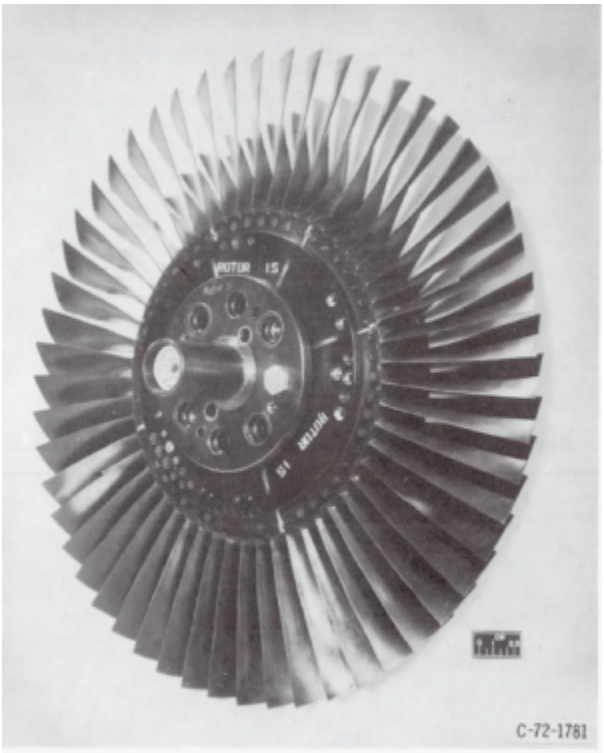



Fig1. https://ntrs.nasa.gov/citations/19750006695 p.153

# Documents utiles

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

  rotor15.pdf
- Fichier CSV de la géométrie :

  rotor15_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:hager1974design)]. Les modèles associés sont obtenus avec le code en libre accès OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

# Géométrie

La géométrie du rotor 15 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 15

| RP | PERCENT SPAN | RADII RI | RADII RO | BLADE ANGLES KIC | BLADE ANGLES KTC | BLADE ANGLES KOC | DELTA INC | CONE ANGLE |
|---|---|---|---|---|---|---|---|---|
| TIP | 0. | 24.750 | 23.962 | 60.18 | 56.04 | 37.62 | 3.32 | -20.375 |
| 1 | 5. | 24.132 | 23.424 | 58.16 | 53.63 | 37.89 | 3.37 | -17.428 |
| 2 | 10. | 23.510 | 22.886 | 56.33 | 51.57 | 37.68 | 3.46 | -14.752 |
| 3 | 15. | 22.884 | 22.347 | 54.69 | 49.88 | 37.00 | 3.58 | -12.262 |
| 4 | 30. | 21.021 | 20.732 | 50.52 | 45.02 | 31.80 | 4.17 | -5.998 |
| 5 | 50. | 18.560 | 18.579 | 45.41 | 38.87 | 20.63 | 5.49 | 0.349 |
| 6 | 70. | 16.075 | 16.425 | 39.39 | 32.45 | 4.28 | 7.78 | 5.833 |
| 7 | 85. | 14.192 | 14.810 | 33.67 | 27.61 | -11.12 | 10.32 | 9.632 |
| 8 | 90. | 13.573 | 14.272 | 31.22 | 26.10 | -16.53 | 11.60 | 10.738 |
| 9 | 95. | 12.960 | 13.734 | 28.47 | 24.63 | -22.01 | 13.13 | 11.756 |
| HUB | 100. | 12.352 | 13.195 | 25.42 | 23.22 | -27.59 | 14.88 | 12.727 |

| RP | BLADE THICKNESSES TI | TM | TO | AXIAL DIMENSIONS ZIC | ZMC | ZTC | ZOC |
|---|---|---|---|---|---|---|---|
| TIP | 0.036 | 0.143 | 0.032 | 0.711 | 1.655 | 1.926 | 2.831 |
| 1 | 0.036 | 0.145 | 0.031 | 0.666 | 1.683 | 1.914 | 2.920 |
| 2 | 0.037 | 0.147 | 0.032 | 0.620 | 1.700 | 1.886 | 2.990 |
| 3 | 0.038 | 0.151 | 0.032 | 0.573 | 1.706 | 1.841 | 3.042 |
| 4 | 0.042 | 0.167 | 0.034 | 0.448 | 1.673 | 1.674 | 3.196 |
| 5 | 0.050 | 0.199 | 0.038 | 0.313 | 1.624 | 1.408 | 3.407 |
| 6 | 0.062 | 0.246 | 0.045 | 0.203 | 1.625 | 1.114 | 3.638 |
| 7 | 0.074 | 0.295 | 0.052 | 0.082 | 1.631 | 0.825 | 3.723 |
| 8 | 0.079 | 0.315 | 0.055 | 0.048 | 1.637 | 0.731 | 3.734 |
| 9 | 0.084 | 0.337 | 0.058 | 0.022 | 1.648 | 0.641 | 3.738 |
| HUB | 0.090 | 0.360 | 0.061 | 0.000 | 1.664 | 0.554 | 3.734 |

# Caractéristiques aérodynamiques

| | unités | valeurs |
|---|---|---|
| **taux de compression** | [-] | 1,5 |
| **débit massique** | [kg/s] | 29,16 |
| **vitesse en tête** | [m/s] | 337 |
| **solidité en tête** | [-] | 1,344 |
| **allongement** | [-] | 3 |
| **nombre d'aubes** | [-] | 53 |
| **vitesse de rotation** | [rad/s] | 1363,45 |

# Propriétés matériau

Le matériau original du rotor 12 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 |

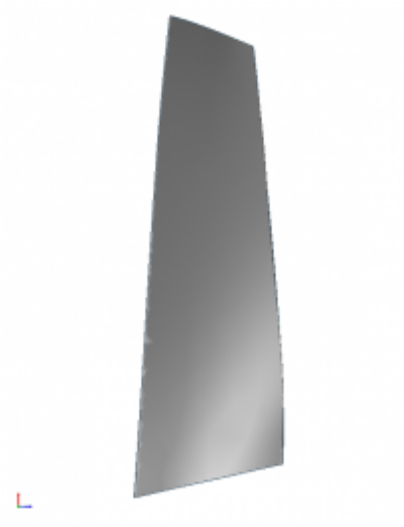
| | unité | valeurs |
|---|---|---|
| **masse volumique** | [kg/m3] | 4400 |
| **coefficient de Poisson** | [-] | 0,34 |
| **limite élastique** | [GPa] | 0,824 |

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

1. (1B): 1480,4 rad/s / 235,6 Hz
2. (2B): 4860,4 rad/s / 773,6 Hz
3. (1T): 8961,4 rad/s / 1426,2 Hz

## 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 | | 1547.59 | 246.307 |
| 2 | | 4839.27 | 770.194 |
| 3 | | 9194.69 | 1463.38 |

# 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 | | 1527.69 | 243.139 |
| 2 | | 4863.1 | 773.986 |
| 3 | | 9105.65 | 1449.21 |

- pour le modèle réduit :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|---|---|---|---|
| 1 | | 1527.74 | 243.147 |
| 2 | | 4863.79 | 774.096 |
| 3 | | 9109.93 | 1449.89 |

</tabs>

Document issu de la page wiki:
**https://wiki.lava.polymtl.ca/public/modeles/rotor_15/accueil?rev=1677118046**

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