# Rotor 65

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## About

Rotor 65 is part of a NASA research program in collaboration with Pratt & Whitney aiming at reducing the noise level of the JT8D engines (used in 1976 in Boeing 727 and 737) while maintaining their aerodynamic performance. Rotor 65 is a single-stage fan designed to replace the two-stage fan used in the JT8D engine.

- Original NASA technical report [(cite:moore1976aerodynamic>Moore R. D. *et al* «Aerodynamic performance of 0.4066-scale model to JT8D refan stage » 1974. pdf)]:

```
@TechReport{moore1976aerodynamic,
  author           = {Moore, Royce D and Kovich, George and Tysl, Edward
R},
  date             = {1976},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
  title            = {Aerodynamic performance of 0.4066-scale model to
JT8D refan stage},
  number           = {NASA-TM X-3356},
  url              = {https://ntrs.nasa.gov/citations/19760017065},
```

- Picture :



Fig. 1 https://ntrs.nasa.gov/citations/19760017065 p.114

**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:moore1976aerodynamic)]. Corresponding models are computed with the open-source code OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

## Geometry

The geometry of rotor 65 is described in the original NASA report by the following table. The lenghts are in inches and the angles in degrees.

TABLE VII. - BLADE GEOMETRY FOR ROTOR 65

| RP | PERCENT SPAN | RADII RI | RO | BLADE ANGLES KIC | KTC | KOC | DELTA INC | CORE ANGLE |
|---|---|---|---|---|---|---|---|---|
| TIP | 0. | 25.405 | 25.629 | 64.63 | 70.95 | 59.92 | 1.59 | -9.437 |
| 1 | 5. | 24.797 | 24.334 | 62.32 | 68.07 | 58.86 | 1.91 | -10.857 |
| 2 | 10. | 24.142 | 23.640 | 60.43 | 65.15 | 57.62 | 2.22 | -11.036 |
| 3 | 20. | 22.707 | 22.250 | 58.14 | 59.28 | 54.62 | 2.84 | -8.889 |
| 4 | 30. | 21.218 | 20.861 | 55.91 | 53.25 | 51.16 | 3.58 | -6.749 |
| 5 | 35. | 20.461 | 20.166 | 54.80 | 50.52 | 49.45 | 3.98 | -5.442 |
| 6 | 40. | 19.704 | 19.472 | 53.80 | 49.08 | 47.57 | 4.28 | -4.256 |
| 7 | 50. | 18.192 | 18.082 | 52.02 | 48.27 | 43.07 | 4.73 | -2.014 |
| 8 | 60. | 16.693 | 16.693 | 50.38 | 47.95 | 37.24 | 5.18 | -0.057 |
| 9 | 64. | 16.092 | 16.137 | 49.67 | 46.39 | 34.05 | 5.47 | 0.804 |
| 10 | 80. | 13.595 | 13.914 | 47.01 | 37.52 | 17.24 | 6.77 | 4.968 |
| 11 | 95. | 10.894 | 11.830 | 44.86 | 31.17 | -4.37 | 7.54 | 13.481 |
| HUB | 100. | 9.898 | 11.135 | 43.73 | 31.25 | -14.38 | 7.68 | 17.467 |

| RP | BLADE THICKNESSES TI | TM | TO | AXIAL DIMENSIONS ZIC | ZMC | ZTC | ZOC |
|---|---|---|---|---|---|---|---|
| TIP | 0.031 | 0.118 | 0.022 | 0.643 | 1.870 | 2.064 | 2.905 |
| 1 | 0.031 | 0.134 | 0.022 | 0.595 | 1.909 | 2.115 | 3.004 |
| 2 | 0.031 | 0.148 | 0.022 | 0.545 | 1.943 | 2.152 | 3.121 |
| 3 | 0.031 | 0.174 | 0.022 | 0.444 | 1.975 | 2.169 | 3.366 |
| 4 | 0.031 | 0.203 | 0.022 | 0.334 | 1.968 | 2.064 | 3.351 |
| 5 | 0.031 | 0.217 | 0.022 | 0.301 | 1.908 | 2.037 | 3.398 |
| 6 | 0.031 | 0.226 | 0.023 | 0.257 | 1.907 | 2.000 | 3.422 |
| 7 | 0.031 | 0.236 | 0.024 | 0.321 | 1.900 | 1.897 | 3.447 |
| 8 | 0.031 | 0.249 | 0.026 | 0.319 | 1.873 | 1.745 | 3.484 |
| 9 | 0.031 | 0.260 | 0.027 | 0.292 | 1.865 | 1.690 | 3.531 |
| 10 | 0.033 | 0.316 | 0.031 | 0.132 | 1.839 | 1.353 | 3.798 |
| 11 | 0.045 | 0.365 | 0.040 | 0.013 | 1.820 | 1.013 | 3.919 |
| HUB | 0.051 | 0.375 | 0.044 | -0. | 1.807 | 0.923 | 3.931 |

## Aerodynamic design

| | units | values |
|---|---|---|
| **pressure ratio** | [-] | 1.679 |
| **mass flow** | [kg/s] | 35.82 |
| **tip speed** | [m/s] | 419.1 |
| **aspect ratio** | [-] | 1.679 |
| **rotative speed** | [rad/s] | 1918.74 |

## Material properties

The material of the rotor 65 is titanium according to the report, but its characteristics are not provided. A generic titanium Ti-6Al-4V is considered:

| | units | values |
|---|---|---|
| **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 | 861.37 | 137.09 |
| 2 | 2B | 3216.75 | 511.96 |
| 3 | 1T | 4954.74 | 788.57 |

## 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 | 843.81 | 134.296 |
| 2 | 2B | 3125.32 | 497.41 |
| 3 | 1T | 4970.06 | 791.01 |

- from the reduced order model:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|---|---|---|---|
| 1 | 1B | 843.83 | 134.30 |
| 2 | 2B | 3125.95 | 497.51 |
| 3 | 1T | 4971.34 | 791.21 |

Modèles téléchargeables

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**Libre accès**

**lien vers le projet Git**

# À propos

Le rotor 65 a été étudié dans le cadre d'un programme de recherche de la NASA en collaboration avec Pratt & Whitney visant à réduire le bruit des moteurs JT8D (utilisés en 1976 pour les Boeing 727 et 737) tout en préservant leurs performances aérodynamiques. Le rotor 65 est une soufflante à un seul étage conçu pour remplacer une soufflante à deux étages utilisée dans les moteurs JT8D.

- Rapport technique original [(cite:moore1976aerodynamic>)]:

```
@TechReport{moore1976aerodynamic,
  author           = {Moore, Royce D and Kovich, George and Tysl, Edward
R},
  date             = {1976},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
  title            = {Aerodynamic performance of 0.4066-scale model to
JT8D refan stage},
  number           = {NASA-TM X-3356},
  url              = {https://ntrs.nasa.gov/citations/19760017065},
}
```

- Photographie :



Fig. 1 https://ntrs.nasa.gov/citations/19760017065 p.114

**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:moore1976aerodynamic)]. Les modèles associés sont obtenus avec le code en libre accès OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

## Géométrie

La géométrie du rotor 65 est décrite dans le rapport d'origine de la NASA par les tableaux suivants. Les grandeurs sont en pouces et en degrés.

TABLE VII. - BLADE GEOMETRY FOR ROTOR 65

| RP | PERCENT SPAN | RADII RI | RADII RO | BLADE ANGLES KIC | BLADE ANGLES KTC | BLADE ANGLES KOC | DELTA INC | CONE ANGLE |
|---|---|---|---|---|---|---|---|---|
| TIP | 0. | 25.405 | 25.629 | 64.63 | 70.95 | 59.92 | 1.59 | -9.437 |
| 1 | 5. | 24.797 | 24.334 | 62.32 | 68.07 | 58.86 | 1.91 | -10.857 |
| 2 | 10. | 24.142 | 23.640 | 60.43 | 65.15 | 57.62 | 2.22 | -11.036 |
| 3 | 20. | 22.707 | 22.250 | 58.14 | 59.28 | 54.62 | 2.84 | -8.889 |
| 4 | 30. | 21.218 | 20.861 | 55.91 | 53.25 | 51.16 | 3.58 | -6.749 |
| 5 | 35. | 20.461 | 20.166 | 54.80 | 50.52 | 49.45 | 3.98 | -5.442 |
| 6 | 40. | 19.704 | 19.472 | 53.80 | 49.08 | 47.57 | 4.28 | -4.256 |
| 7 | 50. | 18.192 | 18.082 | 52.02 | 48.27 | 43.07 | 4.73 | -2.014 |
| 8 | 60. | 16.693 | 16.693 | 50.38 | 47.95 | 37.24 | 5.18 | -0.057 |
| 9 | 64. | 16.092 | 16.137 | 49.67 | 46.39 | 34.05 | 5.47 | 0.804 |
| 10 | 80. | 13.595 | 13.914 | 47.01 | 37.52 | 17.24 | 6.77 | 4.968 |
| 11 | 95. | 10.894 | 11.830 | 44.86 | 31.17 | -4.37 | 7.54 | 13.481 |
| HUB | 100. | 9.898 | 11.135 | 43.73 | 31.25 | -14.38 | 7.68 | 17.467 |

| RP | BLADE THICKNESSES TI | TM | TO | AXIAL DIMENSIONS ZIC | ZMC | ZTC | ZOC |
|---|---|---|---|---|---|---|---|
| TIP | 0.031 | 0.118 | 0.022 | 0.643 | 1.870 | 2.064 | 2.905 |
| 1 | 0.031 | 0.134 | 0.022 | 0.595 | 1.909 | 2.115 | 3.004 |
| 2 | 0.031 | 0.148 | 0.022 | 0.545 | 1.943 | 2.152 | 3.121 |
| 3 | 0.031 | 0.174 | 0.022 | 0.444 | 1.975 | 2.169 | 3.366 |
| 4 | 0.031 | 0.203 | 0.022 | 0.334 | 1.968 | 2.064 | 3.351 |
| 5 | 0.031 | 0.217 | 0.022 | 0.301 | 1.908 | 2.037 | 3.398 |
| 6 | 0.031 | 0.226 | 0.023 | 0.257 | 1.907 | 2.000 | 3.422 |
| 7 | 0.031 | 0.236 | 0.024 | 0.321 | 1.900 | 1.897 | 3.447 |
| 8 | 0.031 | 0.249 | 0.026 | 0.319 | 1.873 | 1.745 | 3.484 |
| 9 | 0.031 | 0.260 | 0.027 | 0.292 | 1.865 | 1.690 | 3.531 |
| 10 | 0.033 | 0.316 | 0.031 | 0.132 | 1.839 | 1.353 | 3.798 |
| 11 | 0.045 | 0.365 | 0.040 | 0.013 | 1.820 | 1.013 | 3.919 |
| HUB | 0.051 | 0.375 | 0.044 | -0. | 1.807 | 0.923 | 3.931 |

## Caractéristiques aérodynamiques

| | unité | valeurs |
|---|---|---|
| **taux de compression** | [-] | 1.679 |
| **débit massique** | [kg/s] | 35.82 |
| **vitesse en tête** | [m/s] | 419.1 |
| **allongement** | [-] | 1.679 |
| **vitesse de rotation nominale $\omega_n$** | [rad/s] | 1918.74 |

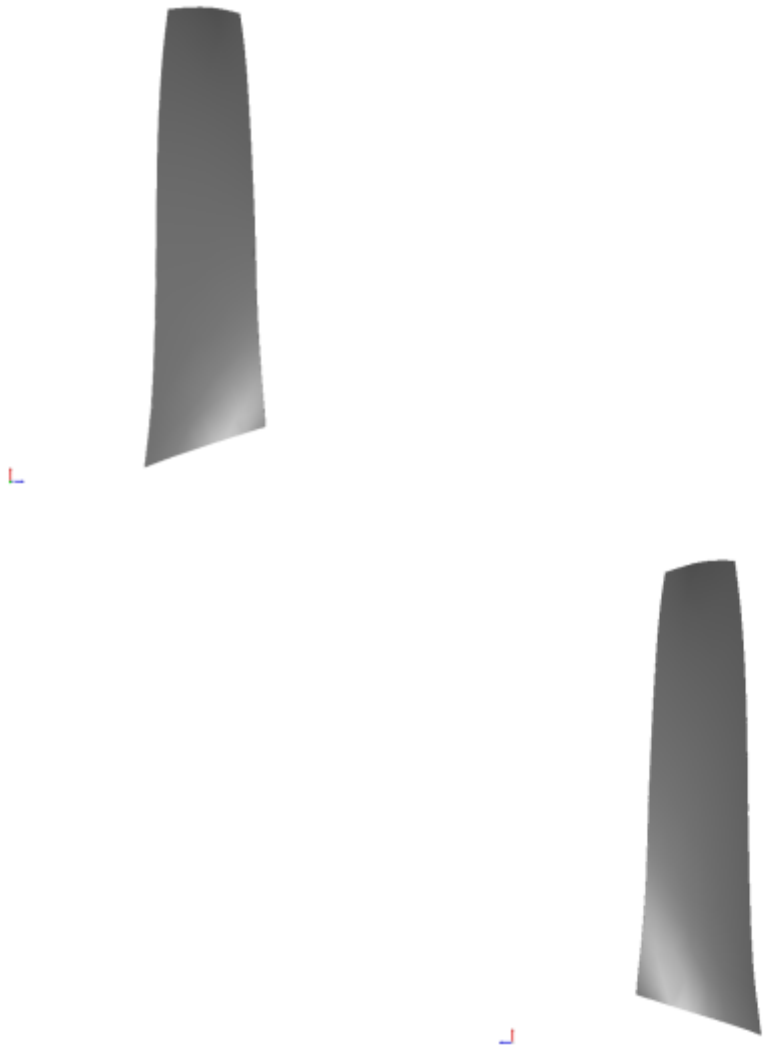
## Propriétés matériau

Le matériau du rotor 65 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 | 861,37 | 137,09 |
| 2 | 2F | 3216,75 | 511,96 |
| 3 | 1T | 4954,74 | 788,57 |

## 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 | 843,81 | 134,30 |
| 2 | 2F | 3125,32 | 497,41 |
| 3 | 1T | 4970,06 | 791,01 |

- pour le modèle réduit :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|---|---|---|---|
| 1 | 1F | 843,83 | 134,30 |
| 2 | 2F | 3125,95 | 497,51 |
| 3 | 1T | 4971,34 | 791,21 |

Document issu de la page wiki:
**https://wiki.lava.polymtl.ca/public/modeles/rotor_65/accueil?rev=1722358197**

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