# Rotor 38

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## About

Rotor 38 is part of a research program to study a advanced-core compressor design with a high compression ratio (20:1). It is therefore the fourth 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 report from NASA.

- Original technical report [(cite:moore1982design>Moore R.D., Reid L. «Performance of Single-Stage Axial-Flow Transonic Compressor With Rotor and Stator Aspect Ratios of 1.63 and 1.77, Respectively, and With Design Pressure Ratio of 2.05 » 1982. pdf)]:

```
@TechReport{moore1982design,
  author           = {Moore, R. D. and Reid, Lonnie},
  date             = {1982},
  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 1.63 and 1.77,
Respectively, and With Design Pressure Ratio of 2.05},
  number           = {NASA-TP-2001},
  url              = {https://ntrs.nasa.gov/citations/19820014395},
}
```

- Picture :




Fig1. https://catalog.archives.gov/id/17466806

```
@Misc{brown1977records,
author   = {Brown, M.},
title    = {Rotor 35 - Rotor 38 - Stator 35 in casing. {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/17466806}{https://catalog.archives.gov/
id/17466806}, 1977 }, % for Fig. 1}
```

### 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:moore1982design)]. Corresponding models are computed with the open-source code OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

## Geometry

The geometry of rotor 38 is described in the original NASA report by the following tables. The length are in centimeters and the angles in degrees.

(a) Rotor 38

| RP | PERCENT SPAN | RADII RI | RADII RO | BLADE ANGLES KIC | BLADE ANGLES KTC | BLADE ANGLES KOC | DELTA INC | CONE ANGLE |
|---|---|---|---|---|---|---|---|---|
| TIP | 0. | 25.283 | 24.770 | 62.69 | 65.32 | 55.39 | 2.38 | -15.363 |
| 1 | 5. | 24.979 | 24.459 | 62.05 | 64.34 | 53.70 | 2.68 | -14.949 |
| 2 | 10. | 24.641 | 24.148 | 61.34 | 63.25 | 52.12 | 2.98 | -13.674 |
| 3 | 15. | 24.297 | 23.837 | 60.59 | 62.14 | 50.83 | 3.22 | -12.304 |
| 4 | 30. | 23.231 | 22.904 | 58.53 | 58.87 | 47.21 | 3.63 | -7.979 |
| 5 | 50. | 21.762 | 21.660 | 56.51 | 54.97 | 41.52 | 4.35 | -2.243 |
| 6 | 70. | 20.236 | 20.416 | 54.16 | 51.32 | 34.46 | 5.63 | 3.612 |
| 7 | 85. | 19.020 | 19.483 | 52.74 | 48.16 | 26.64 | 6.61 | 8.643 |
| 8 | 90. | 18.593 | 19.172 | 52.55 | 47.49 | 23.76 | 6.88 | 10.561 |
| 9 | 95. | 18.151 | 18.861 | 52.51 | 47.06 | 20.74 | 7.18 | 12.701 |
| HUB | 100. | 17.780 | 18.550 | 52.52 | 46.76 | 17.69 | 7.43 | 13.547 |

| RP | BLADE THICKNESSES TI | BLADE THICKNESSES TM | BLADE THICKNESSES TO | AXIAL DIMENSIONS ZI | AXIAL DIMENSIONS ZMC | AXIAL DIMENSIONS ZTC | AXIAL DIMENSIONS ZO |
|---|---|---|---|---|---|---|---|
| TIP | .021 | .149 | .021 | .504 | 1.738 | 1.717 | 2.371 |
| 1 | .022 | .157 | .022 | .479 | 1.717 | 1.706 | 2.425 |
| 2 | .022 | .166 | .022 | .450 | 1.695 | 1.687 | 2.477 |
| 3 | .023 | .174 | .023 | .418 | 1.672 | 1.656 | 2.525 |
| 4 | .025 | .202 | .026 | .311 | 1.622 | 1.526 | 2.648 |
| 5 | .029 | .239 | .030 | .200 | 1.586 | 1.409 | 2.797 |
| 6 | .032 | .278 | .033 | .109 | 1.522 | 1.304 | 2.958 |
| 7 | .036 | .311 | .036 | .039 | 1.485 | 1.277 | 3.083 |
| 8 | .037 | .323 | .037 | .021 | 1.468 | 1.226 | 3.122 |
| 9 | .038 | .336 | .038 | .009 | 1.452 | 1.179 | 3.159 |
| HUB | .039 | .346 | .039 | .000 | 1.438 | 1.138 | 3.194 |

## 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** | [-] | 1.63 |
| **number of blades** | [-] | 48 |
| **rotative speed** | [rad/s] | 1800 |

## Material properties

Rotor 38 is made of a 200-grade maraging steel[(cite:reid1978designandoverall>Reid. «Design and overall performance of four highly loaded, high-speed inlet stages for and advanced high-pressure-ratio core compressor» 1978. pdf)], 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 |

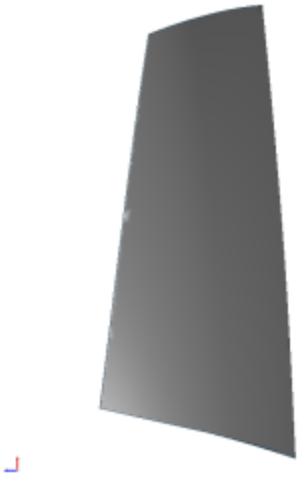
| | unit | value |
|---|---|---|
| **density** | [kg/m3] | 8000 |
| **Poisson's ratio** | [-] | 0.3 |
| **yield stress** | [GPa] | 1.38 |

## CAD model

The CAD model is computed with the open source code OpenMCAD[(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 | 3761.51 | 598.663 |
| 2 | 1T | 13484.22 | 2146.08 |

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|---|---|---|---|
| 3 | 2B | 14745.63 | 2346.84 |

# 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 | 3789.68 | 603.147 |
| 2 | 1T | 13601.09 | 2164.68 |
| 3 | 2B | 14970.57 | 2382.64 |

- from the reduced order model:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|---|---|---|---|
| 1 | 1B | 3789.92 | 603.185 |
| 2 | 1T | 13606.43 | 2165.53 |
| 3 | 2B | 14983.45 | 2384.69 |

Fichiers téléchargeables
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**Libre accès**

**lien vers le projet Git**

# À propos

Le rotor 38 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 quatrième 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 rapport de la NASA.

- Rapport technique original[(cite:moore1982design>)]:

```
@TechReport{moore1982design,
  author           = {Moore, R. D. and Reid, Lonnie},
  date             = {1982},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
```

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




Fig1. https://catalog.archives.gov/id/17466806

```
@Misc{brown1977records,
author   = {Brown, M.},
title    = {Rotor 35 - Rotor 38 - Stator 35 in casing. {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/17466806}{https://catalog.archives.gov/
id/17466806}, 1977 }, % for Fig. 1}
```

**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:moore1982design)]. Les modèles associés sont obtenus avec le code en libre accès OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

## Géométrie

La géométrie du rotor 38 est décrite dans le rapport d'origine de la NASA par les tableaux suivants. Les grandeurs sont en centimètres et en degrés.

(a) Rotor 38

| RP | PERCENT SPAN | RADII RI | RADII RO | BLADE ANGLES KIC | BLADE ANGLES KTC | BLADE ANGLES KOC | DELTA INC | CONE ANGLE |
|---|---|---|---|---|---|---|---|---|
| TIP | 0. | 25.283 | 24.770 | 62.69 | 65.32 | 55.39 | 2.38 | -15.363 |
| 1 | 5. | 24.979 | 24.459 | 62.05 | 64.34 | 53.70 | 2.68 | -14.949 |
| 2 | 10. | 24.641 | 24.148 | 61.34 | 63.25 | 52.12 | 2.98 | -13.674 |
| 3 | 15. | 24.297 | 23.837 | 60.59 | 62.14 | 50.83 | 3.22 | -12.304 |
| 4 | 30. | 23.231 | 22.904 | 58.53 | 58.87 | 47.21 | 3.63 | -7.979 |
| 5 | 50. | 21.762 | 21.660 | 56.51 | 54.97 | 41.52 | 4.35 | -2.243 |
| 6 | 70. | 20.236 | 20.416 | 54.16 | 51.32 | 34.46 | 5.63 | 3.612 |
| 7 | 85. | 19.020 | 19.483 | 52.74 | 48.16 | 26.64 | 6.61 | 8.643 |
| 8 | 90. | 18.593 | 19.172 | 52.55 | 47.49 | 23.76 | 6.88 | 10.561 |
| 9 | 95. | 18.151 | 18.861 | 52.51 | 47.06 | 20.74 | 7.18 | 12.701 |
| HUB | 100. | 17.780 | 18.550 | 52.52 | 46.76 | 17.69 | 7.43 | 13.547 |

| RP | BLADE THICKNESSES TI | BLADE THICKNESSES TM | BLADE THICKNESSES TO | AXIAL DIMENSIONS ZI | AXIAL DIMENSIONS ZMC | AXIAL DIMENSIONS ZTC | AXIAL DIMENSIONS ZO |
|---|---|---|---|---|---|---|---|
| TIP | .021 | .149 | .021 | .504 | 1.738 | 1.717 | 2.371 |
| 1 | .022 | .157 | .022 | .479 | 1.717 | 1.706 | 2.425 |
| 2 | .022 | .166 | .022 | .450 | 1.695 | 1.687 | 2.477 |
| 3 | .023 | .174 | .023 | .418 | 1.672 | 1.656 | 2.525 |
| 4 | .025 | .202 | .026 | .311 | 1.622 | 1.526 | 2.648 |
| 5 | .029 | .239 | .030 | .200 | 1.586 | 1.409 | 2.797 |
| 6 | .032 | .278 | .033 | .109 | 1.522 | 1.304 | 2.958 |
| 7 | .036 | .311 | .036 | .039 | 1.485 | 1.277 | 3.083 |
| 8 | .037 | .323 | .037 | .021 | 1.468 | 1.226 | 3.122 |
| 9 | .038 | .336 | .038 | .009 | 1.452 | 1.179 | 3.159 |
| HUB | .039 | .346 | .039 | .000 | 1.438 | 1.138 | 3.194 |

## 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** | [-] | 1,63 |
| **nombre d'aubes** | [-] | 48 |
| **vitesse de rotation** | [rad/s] | 1800 |

## Propriétés matériau

Le matériau du rotor 38 est un alliage à base de nickel : un acier maraging de grade 200[(cite:reid1978designandoverall>Reid. «Design and overall performance of four highly loaded, high-speed inlet stages for and advanced high-pressure-ratio core compressor» 1978. pdf)], mais ses caractéristiques ne sont pas fournies dans le raport de la NASA. Les propriétés considérées sont :

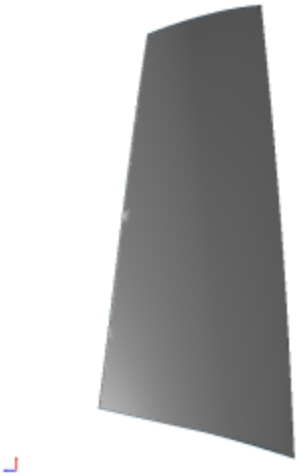
| | **unité** | **valeurs** |
|---|---|---|
| **alliage** | [-] | 18-Ni-200-maraging |
| **module d'Young** | [GPa] | 180 |
| **masse volumique** | [kg/m3] | 8000 |
| **coefficient de Poisson** | [-] | 0,3 |
| **limite élastique** | [GPa] | 1,38 |

## Modèle CAO

Le modèle CAO est obtenu avec OpenMCAD[(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 | 3761,51 | 598,663 |
| 2 | 1T | 13484,22 | 2146,08 |
| 3 | 2F | 14745,63 | 2346,84 |

## 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 | 3789,68 | 603,147 |
| 2 | 1T | 13601,09 | 2164,68 |
| 3 | 2F | 14970,57 | 2382,64 |

- pour le modèle réduit :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|---|---|---|---|
| 1 | 1F | 3789,92 | 603,185 |
| 2 | 1T | 13606,43 | 2165,53 |
| 3 | 2F | 14983,45 | 2384,69 |

Document issu de la page wiki:
**https://wiki.lava.polymtl.ca/public/modeles/rotor_38/accueil?rev=1680017112**

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