# Rotor 74A2

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## About

Compressor 74A is part of a research program to study fans and compressors for advanced airbreathing engines to assess and improve the technology needed for high pressure ratio, good efficiency, and adequate stall margin in as few stages as possible. This compressor consists of inlet guide vanes and five stages, and it is designed for a 9.271 pressure ratio. Rotor 74A2 is the rotor of the second stage of this compressor.

- Original technical report [(cite:steinke1986design>Steinke R.J. «Design of 9.271-Pressure-Ratio Five-Stage Core Compressor and Overall Performance for First Three Stages » 1986. pdf)]:

```
@TechReport{steinke1986design,
  author           = {Steinke, Ronald J.},
  date             = {1986},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
  title            = {Design of 9.271-Pressure-Ratio Five-Stage Core
Compressor and Overall Performance for First Three Stages},
  number           = {NASA-TP-2597},
  url              = {https://ntrs.nasa.gov/citations/19870008266},
}
```

* Pictures :

**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 osurce 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:steinke1986design)]. Corresponding models are computed with the open-source code OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

## Geometry

The geometry of rotor 74A2 is described in the original NASA report by the following tables. The length are in centimeters and the angles in degrees.

(d) Rotor 2

| RP | PERCENT SPAN | RADII RI | RADII RD | BLADE ANGLES KIC | BLADE ANGLES KTC | BLADE ANGLES KOC | DELTA INC | CONE ANGLE |
|---|---|---|---|---|---|---|---|---|
| TIP | 0. | 24.778 | 24.300 | 63.49 | 54.90 | 46.37 | 3.35 | -8.299 |
| 1 | 5. | 24.307 | 23.868 | 61.92 | 53.79 | 45.88 | 3.64 | -7.345 |
| 2 | 10. | 23.867 | 23.504 | 60.51 | 52.77 | 45.40 | 3.92 | -5.895 |
| 3 | 20. | 23.025 | 22.800 | 58.15 | 50.89 | 44.17 | 4.46 | -3.478 |
| 4 | 30. | 22.201 | 22.110 | 56.40 | 49.13 | 42.43 | 4.97 | -1.351 |
| 5 | 40. | 21.390 | 21.433 | 54.91 | 47.30 | 40.06 | 5.47 | .610 |
| 6 | 50. | 20.581 | 20.765 | 53.48 | 45.47 | 37.09 | 5.96 | 2.505 |
| 7 | 60. | 19.773 | 20.107 | 52.11 | 43.53 | 33.48 | 6.43 | 4.367 |
| 8 | 70. | 18.966 | 19.462 | 50.81 | 41.51 | 29.22 | 6.88 | 6.218 |
| 9 | 80. | 18.161 | 18.835 | 49.63 | 39.37 | 24.01 | 7.30 | 8.087 |
| 10 | 90. | 17.355 | 18.230 | 48.67 | 36.98 | 16.95 | 7.64 | 9.992 |
| 11 | 95. | 16.950 | 17.937 | 48.30 | 35.61 | 12.43 | 7.78 | 10.961 |
| HUB | 100. | 16.487 | 17.556 | 47.87 | 34.05 | 6.70 | 7.94 | 11.527 |

| RP | BLADE THICKNESSES TI | BLADE THICKNESSES TM | BLADE THICKNESSES TO | AXIAL DIMENSIONS ZI | AXIAL DIMENSIONS ZMC | AXIAL DIMENSIONS ZTC | AXIAL DIMENSIONS ZO |
|---|---|---|---|---|---|---|---|
| TIP | .028 | .201 | .027 | 14.275 | 15.749 | 16.341 | 17.549 |
| 1 | .030 | .219 | .030 | 14.201 | 15.745 | 16.279 | 17.603 |
| 2 | .032 | .236 | .032 | 14.136 | 15.743 | 16.221 | 17.647 |
| 3 | .037 | .268 | .038 | 14.029 | 15.741 | 16.103 | 17.729 |
| 4 | .042 | .300 | .042 | 13.941 | 15.737 | 15.979 | 17.806 |
| 5 | .046 | .331 | .047 | 13.859 | 15.732 | 15.849 | 17.888 |
| 6 | .051 | .362 | .051 | 13.778 | 15.727 | 15.711 | 17.976 |
| 7 | .055 | .393 | .056 | 13.697 | 15.721 | 15.564 | 18.070 |
| 8 | .059 | .425 | .061 | 13.611 | 15.710 | 15.405 | 18.166 |
| 9 | .064 | .457 | .065 | 13.520 | 15.698 | 15.237 | 18.270 |
| 10 | .069 | .490 | .070 | 13.414 | 15.681 | 15.048 | 18.384 |
| 11 | .071 | .506 | .072 | 13.349 | 15.665 | 14.941 | 18.443 |
| HUB | .074 | .525 | .074 | 13.275 | 15.647 | 14.820 | 18.519 |

## Aerodynamic design

| | units | values |
|---|---|---|
| **pressure ratio** | [-] | 1.691 |
| **mass flow** | [kg/s] | 29.71 |
| **tip speed** | [m/s] | 416 |
| **tip solidity** | [-] | 1.25 |
| **aspect ratio** | [-] | 1.17 |
| **number of blades** | [-] | 32 |
| **rotative speed** | [rad/s] | 1680 |

## Material properties

Rotor 74A2 is made of titanium according to the NASA report, but the exact properties are not provided. A generic titanium Ti-6Al-4V is considered:

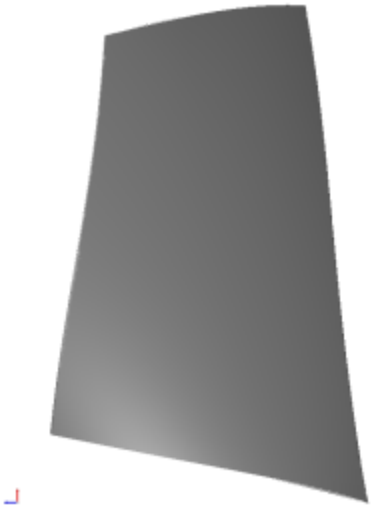
| | units | values |
|---|---|---|
| **alloy** | [-] | Ti-6Al-4V |
| **Young's modulus** | [GPa] | 108 |
| **density** | [kg/m3] | 4400 |
| **Poisson's ratio** | [-] | 0.34 |
| **yield stress** | [GPa] | 0.824 |

## 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 | 4884.844 | 777.447 |

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|---|---|---|---|
| 2 | 1T | 15222.59 | 2422.75 |
| 3 | 2B | 17870.82 | 2844.23 |

# 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 | 4883.512 | 777.235 |
| 2 | 1T | 15179.04 | 2415.82 |
| 3 | 2B | 17886.78 | 2846.77 |

- from the reduced order model:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|---|---|---|---|
| 1 | 1B | 4884.14 | 777.335 |
| 2 | 1T | 15188.03 | 2417.25 |
| 3 | 2B | 17907.64 | 2850.09 |

Fichiers téléchargeables
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**Libre accès**

**lien vers le projet Git**

# À propos

Le compresseur 74A fait partie d'un programme de recherche visant à étudier les soufflantes et les compresseurs pour les moteurs avancés afin d'évaluer et d'améliorer la technologie nécessaire pour obtenir un rapport de pression élevé, un bon rendement et une marge de décrochage adéquate avec le moins d'étages possible. Ce compresseur est composé d'aubes directrices en entrée et de cinq étages, et il est conçu pour un rapport de pression de 9,271. Le rotor 74A2 est le rotor du deuxième étage de ce compresseur.

- Rapport technique original [(cite:steinke1986design>)]:

```
@TechReport{steinke1986design,
  author           = {Steinke, Ronald J.},
```

```
  date             = {1986},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
  title            = {Design of 9.271-Pressure-Ratio Five-Stage Core
Compressor and Overall Performance for First Three Stages},
  number           = {NASA-TP-2597},
  url              = {https://ntrs.nasa.gov/citations/19870008266},
}
```

* Photographies

**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:steinke1986design)]. Les modèles associés sont obtenus avec le code en libre accès OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

## Géométrie

La géométrie du rotor 74A2 est décrite dans le rapport d'origine de la NASA par les tableaux suivants. Les grandeurs sont en centimètres et en degrés.

(d) Rotor 2

| RP | PERCENT SPAN | RADII RI | RADII RD | BLADE ANGLES KIC | BLADE ANGLES KTC | BLADE ANGLES KOC | DELTA INC | CONE ANGLE |
|---|---|---|---|---|---|---|---|---|
| TIP | 0. | 24.778 | 24.300 | 63.49 | 54.90 | 46.37 | 3.35 | -8.299 |
| 1 | 5. | 24.307 | 23.868 | 61.92 | 53.79 | 45.88 | 3.64 | -7.345 |
| 2 | 10. | 23.867 | 23.504 | 60.51 | 52.77 | 45.40 | 3.92 | -5.895 |
| 3 | 20. | 23.025 | 22.800 | 58.15 | 50.89 | 44.17 | 4.46 | -3.478 |
| 4 | 30. | 22.201 | 22.110 | 56.40 | 49.13 | 42.43 | 4.97 | -1.351 |
| 5 | 40. | 21.390 | 21.433 | 54.91 | 47.30 | 40.06 | 5.47 | .610 |
| 6 | 50. | 20.581 | 20.765 | 53.48 | 45.47 | 37.09 | 5.96 | 2.505 |
| 7 | 60. | 19.773 | 20.107 | 52.11 | 43.53 | 33.48 | 6.43 | 4.367 |
| 8 | 70. | 18.966 | 19.462 | 50.81 | 41.51 | 29.22 | 6.88 | 6.218 |
| 9 | 80. | 18.161 | 18.835 | 49.63 | 39.37 | 24.01 | 7.30 | 8.087 |
| 10 | 90. | 17.355 | 18.230 | 48.67 | 36.98 | 16.95 | 7.64 | 9.992 |
| 11 | 95. | 16.950 | 17.937 | 48.30 | 35.61 | 12.43 | 7.78 | 10.961 |
| HUB | 100. | 16.487 | 17.556 | 47.87 | 34.05 | 6.70 | 7.94 | 11.527 |

| RP | BLADE THICKNESSES TI | BLADE THICKNESSES TM | BLADE THICKNESSES TO | AXIAL DIMENSIONS ZI | AXIAL DIMENSIONS ZMC | AXIAL DIMENSIONS ZTC | AXIAL DIMENSIONS ZO |
|---|---|---|---|---|---|---|---|
| TIP | .028 | .201 | .027 | 14.275 | 15.749 | 16.341 | 17.549 |
| 1 | .030 | .219 | .030 | 14.201 | 15.745 | 16.279 | 17.603 |
| 2 | .032 | .236 | .032 | 14.136 | 15.743 | 16.221 | 17.647 |
| 3 | .037 | .268 | .038 | 14.029 | 15.741 | 16.103 | 17.729 |
| 4 | .042 | .300 | .042 | 13.941 | 15.737 | 15.979 | 17.806 |
| 5 | .046 | .331 | .047 | 13.859 | 15.732 | 15.849 | 17.888 |
| 6 | .051 | .362 | .051 | 13.778 | 15.727 | 15.711 | 17.976 |
| 7 | .055 | .393 | .056 | 13.697 | 15.721 | 15.564 | 18.070 |
| 8 | .059 | .425 | .061 | 13.611 | 15.710 | 15.405 | 18.166 |
| 9 | .064 | .457 | .065 | 13.520 | 15.698 | 15.237 | 18.270 |
| 10 | .069 | .490 | .070 | 13.414 | 15.681 | 15.048 | 18.384 |
| 11 | .071 | .506 | .072 | 13.349 | 15.665 | 14.941 | 18.443 |
| HUB | .074 | .525 | .074 | 13.275 | 15.647 | 14.820 | 18.519 |

## Caractéristiques aérodynamiques

| | unités | valeurs |
|---|---|---|
| **taux de compression** | [-] | 1,691 |
| **débit massique** | [kg/s] | 29,71 |
| **vitesse en tête** | [m/s] | 416 |
| **solidité en tête** | [-] | 1,25 |
| **allongement** | [-] | 1,17 |
| **nombre d'aubes** | [-] | 32 |
| **vitesse de rotation** | [rad/s] | 1680 |

## Propriétés matériau

Le matériau du rotor 74A2 est le titane d'après le rapport, mais ses caractéristiques ne sont pas fournies. Un alliage de titane Ti-6Al-4v est considéré :

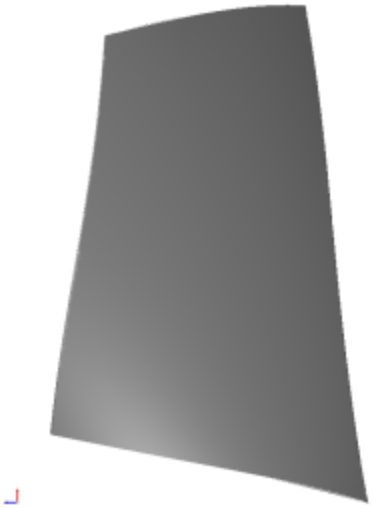
| | unité | valeurs |
|---|---|---|
| **alliage** | [-] | Ti-6Al-4V |
| **module d'Young** | [GPa] | 108 |
| **masse volumique** | [kg/m3] | 4400 |
| **coefficient de Poisson** | [-] | 0,34 |
| **limite élastique** | [GPa] | 0,824 |

## 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 | 4884,844 | 777,447 |
| 2 | 1T | 15222,59 | 2422,75 |
| 3 | 2B | 17870,82 | 2844,23 |

## 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 | 4883,512 | 777,235 |
| 2 | 1T | 15179,04 | 2415,82 |
| 3 | 2B | 17886,78 | 2846,77 |

- pour le modèle réduit :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|---|---|---|---|
| 1 | 1B | 4884,14 | 777,335 |
| 2 | 1T | 15188,03 | 2417,25 |
| 3 | 2B | 17907,64 | 2850,09 |

Document issu de la page wiki:
**https://wiki.lava.polymtl.ca/public/modeles/rotor_74a2/accueil?rev=1680814341**

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