

# Rotor 12

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## Original model

Rotor 12 is part of a research program to study the effects of blade row solidity on efficiency and stall margin of an axial-flow compressor rotor. It is one of a series of rotors designed to further study the effects of solidity : rotor 8 with a tip solidity of 1.5, rotor 12 with a tip solidity of 1.7 and rotor 14 with a tip solidity of 1.3. Tip solidity are being changed by varying the number of blades while maintaining the same velocity diagrams and flow path. These stages were designed such that the tip solidity of both the rotor and stator blades are the same.

- Original technical report [(cite:reid1972design>Reid. «Performance of a single-stage transonic compressor with a blade-tip solidity of 1.7 » 1972. [pdf](#))]:

```
@TechReport{reid1972design,
  author      = {Reid, L. and Moore, R. D.},
  date        = {1972},
  institution = {NASA Lewis Research Center Cleveland, OH, United
States},
  title       = {Performance of a single-stage transonic compressor
with a blade-tip solidity of 1.7},
  number      = {NASA-TM X-2658},
  url         = {https://ntrs.nasa.gov/citations/19730006256},
}
```

- Picture :

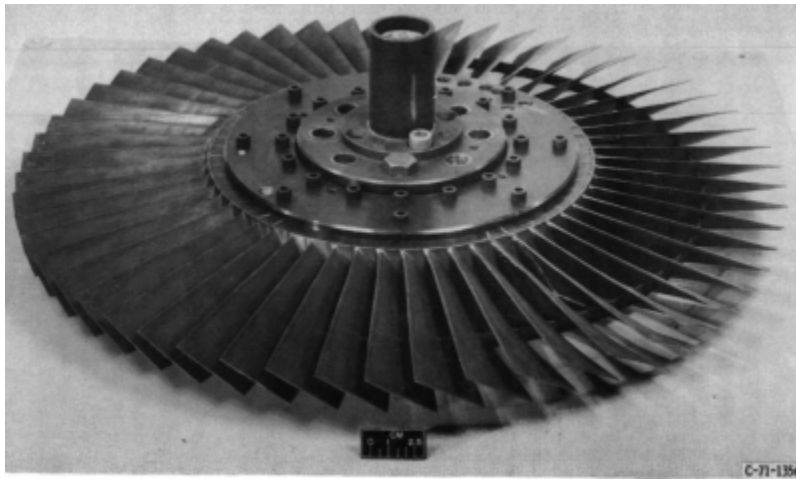


Fig1. <https://ntrs.nasa.gov/citations/19730006256> p.66

### Useful documents

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

rotor12.pdf

- CSV file of the blade geometry :

rotor12\_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:reid1972design)]. Corresponding models are computed with the open-source code OpenMCAD[(cite:Kojtych\_2022\_gene\_aubes)]

## Geometry

The [geometry of rotor 12](#) 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 12

| RP  | PERCENT |        | RADII  |       | BLADE ANGLES |       |      | DELTA  | CONE |
|-----|---------|--------|--------|-------|--------------|-------|------|--------|------|
|     | SPAN    | RI     | RO     | KIC   | KTC          | KOC   | INC  | ANGLE  |      |
| TIP | 0.      | 25.082 | 24.701 | 62.94 | 59.88        | 53.63 | 2.48 | -9.153 |      |
| 1   | 5.      | 24.574 | 24.193 | 61.72 | 58.75        | 53.00 | 2.71 | -8.837 |      |
| 2   | 10.     | 24.026 | 23.685 | 60.46 | 57.49        | 52.18 | 2.97 | -7.649 |      |
| 3   | 30.     | 21.755 | 21.653 | 55.97 | 52.11        | 47.29 | 4.05 | -1.993 |      |
| 4   | 43.     | 20.286 | 20.383 | 53.51 | 48.61        | 42.81 | 4.72 | 1.777  |      |
| 5   | 45.     | 19.988 | 20.129 | 53.04 | 47.88        | 41.76 | 4.86 | 2.547  |      |
| 6   | 48.     | 19.687 | 19.875 | 52.57 | 47.18        | 40.61 | 4.99 | 3.330  |      |
| 7   | 50.     | 19.385 | 19.621 | 52.11 | 46.48        | 39.39 | 5.13 | 4.118  |      |
| 8   | 53.     | 19.081 | 19.367 | 51.66 | 45.78        | 38.10 | 5.26 | 4.912  |      |
| 9   | 70.     | 16.881 | 17.589 | 48.56 | 41.34        | 27.00 | 6.15 | 10.867 |      |
| 10  | 90.     | 14.154 | 15.557 | 45.46 | 37.53        | 7.52  | 6.98 | 18.794 |      |
| 11  | 95.     | 13.423 | 15.049 | 44.84 | 37.06        | 0.79  | 7.13 | 21.014 |      |
| HUB | 100.    | 12.700 | 14.541 | 44.32 | 36.83        | -6.63 | 7.23 | 22.968 |      |

| RP  | BLADE THICKNESSES |       |       | AXIAL DIMENSIONS |       |       |       |
|-----|-------------------|-------|-------|------------------|-------|-------|-------|
|     | TI                | TM    | TO    | ZIC              | ZMC   | ZTC   | ZOC   |
| TIP | 0.051             | 0.153 | 0.051 | 1.032            | 2.136 | 2.188 | 3.397 |
| 1   | 0.051             | 0.162 | 0.051 | 0.986            | 2.136 | 2.152 | 3.435 |
| 2   | 0.051             | 0.172 | 0.051 | 0.938            | 2.136 | 2.109 | 3.474 |
| 3   | 0.051             | 0.216 | 0.051 | 0.744            | 2.127 | 1.901 | 3.648 |
| 4   | 0.051             | 0.244 | 0.051 | 0.626            | 2.118 | 1.741 | 3.766 |
| 5   | 0.051             | 0.250 | 0.051 | 0.602            | 2.116 | 1.706 | 3.791 |
| 6   | 0.051             | 0.256 | 0.051 | 0.579            | 2.113 | 1.671 | 3.816 |
| 7   | 0.051             | 0.262 | 0.051 | 0.555            | 2.110 | 1.634 | 3.842 |
| 8   | 0.051             | 0.267 | 0.051 | 0.531            | 2.107 | 1.596 | 3.868 |
| 9   | 0.051             | 0.309 | 0.051 | 0.362            | 2.079 | 1.312 | 4.054 |
| 10  | 0.051             | 0.360 | 0.051 | 0.138            | 2.026 | 0.921 | 4.260 |
| 11  | 0.051             | 0.373 | 0.051 | 0.070            | 2.007 | 0.809 | 4.304 |
| HUB | 0.051             | 0.387 | 0.051 | 0.000            | 1.986 | 0.694 | 4.345 |

## Aerodynamic design

|                  | unit    | values |
|------------------|---------|--------|
| pressure ratio   | [-]     | 1.75   |
| mass flow        | [kg/s]  | 29.5   |
| tip speed        | [m/s]   | 423    |
| tip solidity     | [-]     | 1.7    |
| aspect ratio     | [-]     | 2.4    |
| number of blades | [-]     | 56     |
| rotative speed   | [rad/s] | 1686   |

## Material properties

The original material of the rotor 12 is not defined in the NASA report.

Considered properties: 200-grade maraging steel :

|                 | unité   | valeurs            |
|-----------------|---------|--------------------|
| alloy           | [-]     | 18-Ni-200-maraging |
| Young's modulus | [GPa]   | 180                |
| density         | [kg/m3] | 8000               |
| Poisson's ratio | [-]     | 0.3                |

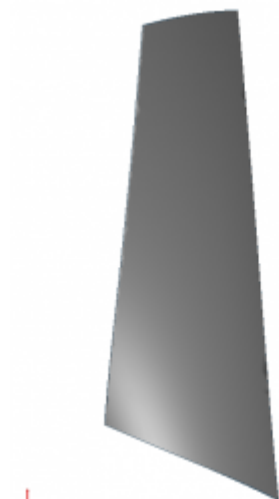
|              | unité | valeurs |
|--------------|-------|---------|
| yield stress | [GPa] | 1.38    |

## 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   | 1655.46                             | 263.475                |
| 2    | 2B   | 5955.84                             | 947.902                |
| 3    | 1T   | 8466.78                             | 1347.53                |

## 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   | 1654.05                             | 263.25                 |
| 2    | 2B   | 5951.13                             | 947.151                |
| 3    | 1T   | 8470.80                             | 1348.17                |

- from the reduced order model:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|------|------|-------------------------------------|------------------------|
| 1    | 1B   | 1654.12                             | 263.261                |
| 2    | 2B   | 5953.62                             | 947.548                |
| 3    | 1T   | 8473.76                             | 1348.64                |

Fichiers téléchargeables

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## Libre accès

[lien vers le projet Git](#)

## Modèle original

Le rotor 12 fait partie d'un programme de recherche visant à étudier les effets de la solidité des rangées d'aubes sur l'efficacité et la marge de décrochage d'un rotor de compresseur à flux axial. Il fait partie d'une série de rotors conçus pour étudier plus profondément les effets de la solidité : le rotor 8 avec une solidité en tête de 1.5, le rotor 12 avec une solidité en tête de 1.7 et le rotor 14 avec une solidité en tête de 1.3. La solidité est modifiée en faisant varier le nombre d'aubes tout en conservant les mêmes triangles de vitesse et le même trajet d'écoulement. Ces étages ont été conçus de manière à ce que la solidité en tête du rotor et du stator soit la même.

- Rapport technique original [(cite:reid1972design>Reid. «Performance of a single-stage transonic compressor with a blade-tip solidity of 1.7 » 1972. [pdf](#))]:

```
@TechReport{reid1972design,
  author      = {Reid, L. and Moore, R. D.},
  date        = {1972},
  institution = {NASA Lewis Research Center Cleveland, OH, United States},
```

```
title      = {Performance of a single-stage transonic compressor  
with a blade-tip solidity of 1.7},  
number    = {NASA-TM X-2658},  
url       = {https://ntrs.nasa.gov/citations/19730006256},  
}
```

- Photographie :

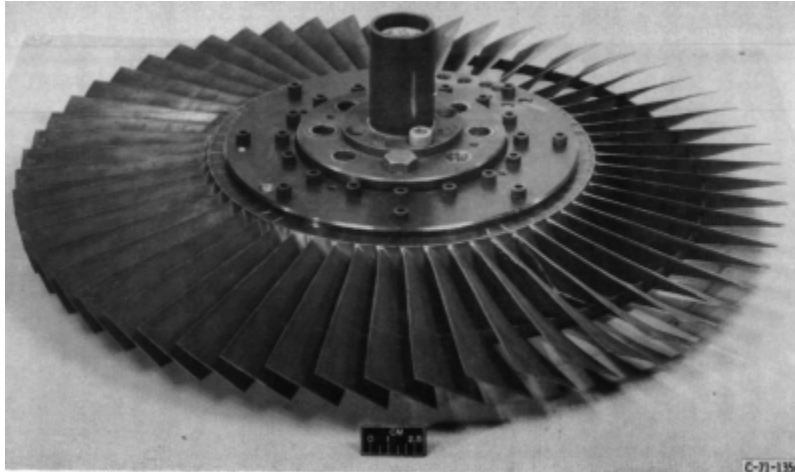


Fig1. <https://ntrs.nasa.gov/citations/19730006256> p.66

### Documents utiles

- [modèles téléchargeables](#) (lien vers projet Git)

- PDF du rapport de la NASA :

rotor12.pdf

- Fichier CSV de la géométrie :

rotor12\_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:reid1972design)]. Les modèles associés sont obtenus avec le code en libre accès OpenMCAD[(cite:Kojtych\_2022\_gene\_aubes)].

## Géométrie

La géométrie du rotor 12 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 12

| RP  | PERCENT |        | RADIUS |       | BLADE ANGLES |       |      | DELTA  | CONE |
|-----|---------|--------|--------|-------|--------------|-------|------|--------|------|
|     | SPAN    | RI     | RO     | KIC   | KTC          | KOC   | INC  |        |      |
| TIP | 0.      | 25.082 | 24.701 | 62.94 | 59.88        | 53.63 | 2.48 | -9.153 |      |
| 1   | 5.      | 24.574 | 24.193 | 61.72 | 58.75        | 53.00 | 2.71 | -8.837 |      |
| 2   | 10.     | 24.026 | 23.685 | 60.46 | 57.49        | 52.18 | 2.97 | -7.649 |      |
| 3   | 30.     | 21.755 | 21.653 | 55.97 | 52.11        | 47.29 | 4.05 | -1.993 |      |
| 4   | 43.     | 20.286 | 20.383 | 53.51 | 48.61        | 42.81 | 4.72 | 1.777  |      |
| 5   | 45.     | 19.988 | 20.129 | 53.04 | 47.88        | 41.76 | 4.86 | 2.547  |      |
| 6   | 48.     | 19.687 | 19.875 | 52.57 | 47.18        | 40.61 | 4.99 | 3.330  |      |
| 7   | 50.     | 19.385 | 19.621 | 52.11 | 46.48        | 39.39 | 5.13 | 4.118  |      |
| 8   | 53.     | 19.081 | 19.367 | 51.66 | 45.78        | 38.10 | 5.26 | 4.912  |      |
| 9   | 70.     | 16.881 | 17.589 | 48.56 | 41.34        | 27.00 | 6.15 | 10.867 |      |
| 10  | 90.     | 14.154 | 15.557 | 45.46 | 37.53        | 7.52  | 6.98 | 18.794 |      |
| 11  | 95.     | 13.423 | 15.049 | 44.84 | 37.06        | 0.79  | 7.13 | 21.014 |      |
| HUB | 100.    | 12.700 | 14.541 | 44.32 | 36.83        | -6.63 | 7.23 | 22.968 |      |

| RP  | BLADE THICKNESSES |       |       | AXIAL DIMENSIONS |       |       |       |
|-----|-------------------|-------|-------|------------------|-------|-------|-------|
|     | TI                | TM    | TO    | ZIC              | ZMC   | ZTC   | ZOC   |
| TIP | 0.051             | 0.153 | 0.051 | 1.032            | 2.136 | 2.188 | 3.397 |
| 1   | 0.051             | 0.162 | 0.051 | 0.986            | 2.136 | 2.152 | 3.435 |
| 2   | 0.051             | 0.172 | 0.051 | 0.938            | 2.136 | 2.109 | 3.474 |
| 3   | 0.051             | 0.216 | 0.051 | 0.744            | 2.127 | 1.901 | 3.648 |
| 4   | 0.051             | 0.244 | 0.051 | 0.626            | 2.118 | 1.741 | 3.766 |
| 5   | 0.051             | 0.250 | 0.051 | 0.602            | 2.116 | 1.706 | 3.791 |
| 6   | 0.051             | 0.256 | 0.051 | 0.579            | 2.113 | 1.671 | 3.816 |
| 7   | 0.051             | 0.262 | 0.051 | 0.555            | 2.110 | 1.634 | 3.842 |
| 8   | 0.051             | 0.267 | 0.051 | 0.531            | 2.107 | 1.596 | 3.868 |
| 9   | 0.051             | 0.309 | 0.051 | 0.362            | 2.079 | 1.312 | 4.054 |
| 10  | 0.051             | 0.360 | 0.051 | 0.138            | 2.026 | 0.921 | 4.260 |
| 11  | 0.051             | 0.373 | 0.051 | 0.070            | 2.007 | 0.809 | 4.304 |
| HUB | 0.051             | 0.387 | 0.051 | 0.000            | 1.986 | 0.694 | 4.345 |

## Caractéristiques aérodynamiques

|                     | unités  | valeurs |
|---------------------|---------|---------|
| taux de compression | [-]     | 1,75    |
| débit massique      | [kg/s]  | 29,5    |
| vitesse en tête     | [m/s]   | 423     |
| solidité en tête    | [-]     | 1,7     |
| allongement         | [-]     | 2,4     |
| nombre d'aubes      | [-]     | 56      |
| vitesse de rotation | [rad/s] | 1686    |

## Propriétés matériau

Le matériau original du rotor 12 n'est pas défini dans le rapport de la NASA.

Propriétés considérées : un acier maraging de grade 200 :

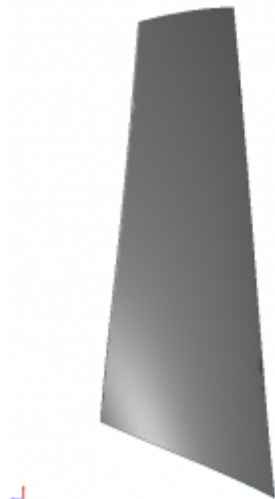
|                               | unité   | valeurs            |
|-------------------------------|---------|--------------------|
| <b>alliage</b>                | [-]     | 18-Ni-200-maraging |
| <b>module d'Young</b>         | [GPa]   | 180                |
| <b>masse volumique</b>        | [kg/m3] | 8000               |
| <b>coefficient de Poisson</b> | [-]     | 0,3                |
| <b>limite élastique</b>       | [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    | 1B   | 1655,46                    | 263,475               |
| 2    | 2B   | 5955,84                    | 947,902               |
| 3    | 1T   | 8466,78                    | 1347,53               |

## 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 encastres),

- pour le maillage complet :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|------|------|----------------------------|-----------------------|
| 1    | 1B   | 1654,05                    | 263,25                |
| 2    | 2B   | 5951,13                    | 947,151               |
| 3    | 1T   | 8470,80                    | 1348,17               |

- pour le modèle réduit :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|------|------|----------------------------|-----------------------|
| 1    | 1B   | 1654,12                    | 263,261               |
| 2    | 2B   | 5953,62                    | 947,548               |
| 3    | 1T   | 8473,76                    | 1348,64               |

</tabs>

Document issu de la page wiki:

[https://lava-wiki.meca.polymtl.ca/public/modeles/rotor\\_12/accueil?rev=1677285743](https://lava-wiki.meca.polymtl.ca/public/modeles/rotor_12/accueil?rev=1677285743)

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