

# Rotor 65

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## About

This report presents the overall and blade-element performances of the scaled fan stage. The stage was designated “stage 65” for tests in the Lewis facility. Data were obtained at speeds of 40 to 100 percent of design speed. Blade-element survey data were taken at 11 radial positions for the inlet guide vanes and the rotor, at 7 radial positions for the bypass stator, and at 3 radial positions for the core stator. The data presented in this report are in tabular as well as plotted form.

- Original NASA technical report <sup>[1]</sup>:

```
@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 :



Fig1. <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<sup>[2]</sup> to generate reference blade models.

## Reference blade

The **reference blade** is defined with multiple-circular arc profiles<sup>[3]</sup> given in the original NASA report<sup>[1]</sup>. Corresponding models are computed with the open-source code OpenMCAD<sup>[2]</sup>.

## Geometry

The geometry of rotor 65 is described in the [original NASA report](#) by the following table. The lengths are in inches and the angles in degrees.

TABLE VII. - BLADE GEOMETRY FOR ROTOR 65

| RP  | PERCENT RADII |        |        | BLADE ANGLES |       |        | DELTA | CCAE    |
|-----|---------------|--------|--------|--------------|-------|--------|-------|---------|
|     | SPAN          | R1     | R0     | KIC          | KTC   | KOC    | INC   | ANGLE   |
| TIP | 0.            | 25.405 | 25.029 | 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        | 49.38 | 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 |       |       | AXIAL DIMENSIONS |       |       |       |
|-----|-------------------|-------|-------|------------------|-------|-------|-------|
|     | TI                | TM    | TO    | 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            | 1.509 | 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            | 1.508 | 2.064 | 3.351 |
| 5   | 0.031             | 0.217 | 0.022 | 0.301            | 1.508 | 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            | 1.500 | 1.897 | 3.447 |
| 8   | 0.031             | 0.249 | 0.026 | 0.315            | 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

|                | unit    | value   |
|----------------|---------|---------|
| 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.

Protected considered: Ti-6Al-4V alloy

|                 | unit                 | value              |
|-----------------|----------------------|--------------------|
| alloy           | [-]                  | 18-Ni-200-maraging |
| Young's modulus | [GPa]                | 180                |
| density         | [kg/m <sup>3</sup> ] | 8000               |
| Poisson's ratio | [-]                  | 0.3                |
| yield stress    | [GPa]                | 1.38               |

## CAD model

The CAD model is computed with the open source code OpenMCAD<sup>[2]</sup>.



pressure side



suction side

## Natural frequencies

First three natural frequencies (with clamped root) for the mesh computed with OpenMCAD<sup>[2]</sup>:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|------|------|-------------------------------------|------------------------|
| 1    |      | 861.368                             | 137.091                |
| 2    |      | 3216.752                            | 511.962                |
| 3    |      | 4954.738                            | 788.571                |

## Initial blade

The **initial blade** is defined with in-house LAVA parameters<sup>[4]</sup> 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    |      | 843.807                             | 134.296                |
| 2    |      | 3125.32                             | 497.41                 |
| 3    |      | 4970.06                             | 791.01                 |

- from the reduced order model:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|------|------|-------------------------------------|------------------------|
| 1    |      | 843.826                             | 134.299                |
| 2    |      | 3125.95                             | 497.51                 |
| 3    |      | 4971.344                            | 791.214                |

Modèles téléchargeables

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**Libre accès**

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## À propos

Ce rapport présente les performances globales et des pales du ventilateur à l'échelle organiser. L'étape a été désignée «étape 65» pour les tests dans l'installation de Lewis. Les données étaient obtenu à des vitesses de 40 à 100 % de la vitesse de conception. Les données d'enquête sur les éléments de lame ont été pris en 11 positions radiales pour les aubes directrices d'admission et le rotor, en 7 positions radiales pour le stator de dérivation, et à 3 positions radiales pour le stator central. Les données présentées dans ce rapport sont présentés sous forme de tableaux et de graphiques.

- Rapport technique original <sup>[1]</sup>:

```
@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 :



Fig1. <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<sup>[2]</sup> pour générer l'aube de référence

## Aube de référence

L'**aube de référence** est définie par des profils de type arcs circulaires multiples<sup>[3]</sup>, donnés dans le rapport technique original de la NASA<sup>[1]</sup>. Les modèles associés sont obtenus avec le code en libre accès OpenMCAD<sup>[2]</sup>.

## 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 RADII |        |        | BLADE ANGLES |       |        | DELTA | CCAE    |
|-----|---------------|--------|--------|--------------|-------|--------|-------|---------|
|     | SPAN          | R1     | R0     | KIC          | KTC   | KOC    | INC   | ANGLE   |
| TIP | 0.            | 25.405 | 25.029 | 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        | 49.38 | 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 |       |       | AXIAL DIMENSIONS |       |       |       |
|-----|-------------------|-------|-------|------------------|-------|-------|-------|
|     | TI                | TM    | TO    | 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            | 1.509 | 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            | 1.508 | 2.064 | 3.351 |
| 5   | 0.031             | 0.217 | 0.022 | 0.301            | 1.508 | 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            | 1.500 | 1.897 | 3.447 |
| 8   | 0.031             | 0.249 | 0.026 | 0.315            | 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 | [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.

Propriétés considérées : alliage Ti-6Al-4V

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

## Modèle CAO

Le modèle CAO est obtenu avec OpenMCAD<sup>[2]</sup>.

intrados  
extrados



## Fréquences propres

Fréquences des trois premiers modes (noeuds du pied d'aube encastres) pour le maillage obtenu avec OpenMCAD<sup>[2]</sup> :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|------|------|----------------------------|-----------------------|
| 1    |      | 861,368                    | 137,091               |
| 2    |      | 3216,752                   | 511,962               |
| 3    |      | 4954,738                   | 788,571               |

## Aube initiale

L'**aube initiale** est définie par des paramètres spécifiques au LAVA<sup>[4]</sup> 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 encastés),

- pour le maillage complet :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|------|------|----------------------------|-----------------------|
| 1    |      | 843,807                    | 134,296               |
| 2    |      | 3125,32                    | 497,41                |
| 3    |      | 4970,06                    | 791,01                |

- pour le modèle réduit :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|------|------|----------------------------|-----------------------|
| 1    |      | 843,826                    | 134,299               |
| 2    |      | 3125,95                    | 497,51                |
| 3    |      | 4971,344                   | 791,214               |

1. <sup>a, b, c, d</sup> Moore R. D. *et al* «Aerodynamic performance of 0.4066-scale model to JT8D refan stage » 1974. [pdf](#)
2. <sup>a, b, c, d, e, f, g, h</sup> Kojtych S., Batailly A. «OpenMCAD, an open blade generator: from Multiple-Circular-Arc profiles to Computer-Aided Design model» 2022. [code en libre accès](#)
3. <sup>a, b</sup> Crouse *et al*. «A computer program for composing compressor blading from simulated circular-arc elements on conical surfaces » 1969. NASA-TN-D-5437. [pdf](#)
4. <sup>a, b</sup> 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](#)

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