

# NASA Rotor 37

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This page contains various informations associated to one of the rotor 37 blade model used in LAVA publications.

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## Original model

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

```
@TechReport{reid1978design,  
author      = {Reid, L. and Moore, R. D.},  
title       = {Design and overall performance of four highly loaded, high  
speed inlet stages for an advanced high-pressure-ratio core compressor},  
institution = {NASA Lewis Research Center Cleveland, OH, United States},  
note        = {NASA-TP-1337, url~:  
\url{https://ntrs.nasa.gov/citations/19780025165}, 1978 (accessed  
2020-10-29)}}}
```

- Pictures :



Fig1. <https://catalog.archives.gov/id/17468361>



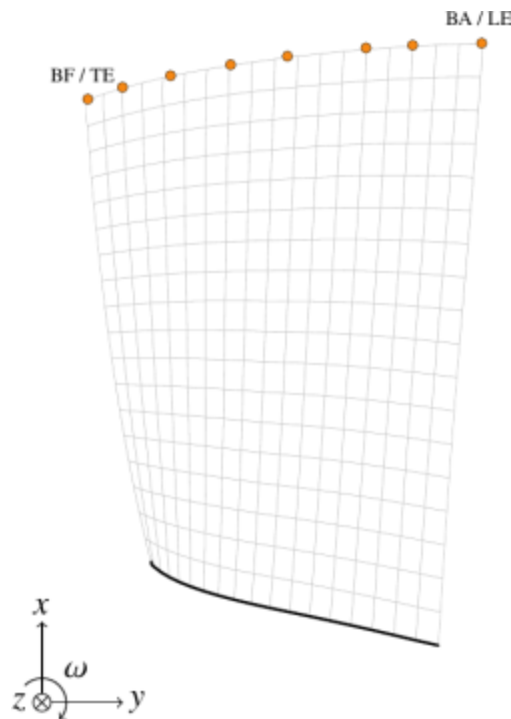
Fig2. <https://catalog.archives.gov/id/17468389>

```
@Misc{huebler1977records,  
author   = {Huebler, D.},  
title    = {Rotor 37 and stator 37 assembly. {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/17468361}{https://catalog.archives.  
gov/id/17468361}}, 1977 (accessed 2020-10-29)}, % for Fig. 1
```

note =  
 {\href{https://catalog.archives.gov/id/17468389}{https://catalog.archives.gov/id/17468389}}, 1977 (accessed 2020-10-29)}, % for Fig. 2}

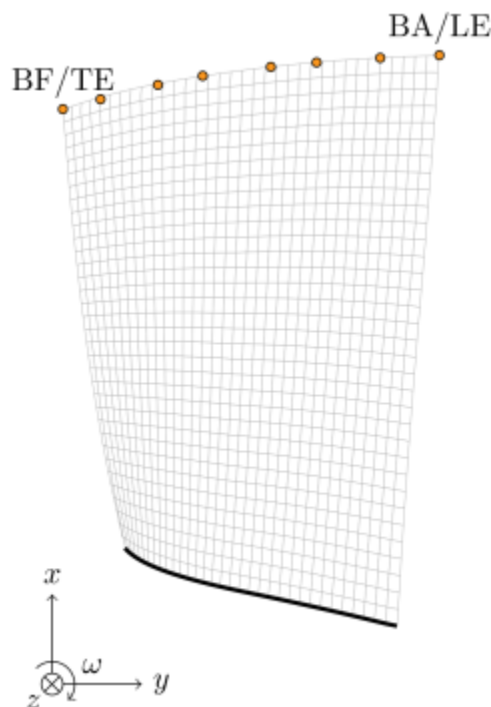
## Finite element mesh

- Number of nodes: 5745
- Total number of elements: 1800
- Number of degrees of freedom: 16524
- Element type: quadratic pentahedron



finite element mesh overview (coarse mesh)

- Number of nodes: 20657
- Total number of elements: 6664
- Number of degrees of freedom: 60588
- Element type: quadratic pentahedron



[finite element mesh overview \(refined mesh\)](#) -

[LaTeX source files](#)

## Material properties

- Rotor 37 is made of a 200-grade maraging steel <sup>[1]</sup>
- Considered properties : 18-Ni 200-maraging alloy <sup>[2] [3]</sup>:
  1. Young's modulus  $E = 180 \text{ GPa}$
  2. density  $\rho = 8000 \text{ kg/m}^3$
  3. Poisson's ratio  $\nu = 0.3$
  4. yield stress  $\sigma_Y = 1.38 \text{ GPa}$  (200 000 psi)
- First three predicted natural frequencies (with clamped root) for the coarse mesh:
  1. 1B: 5272.3 rad/s / 839.1 Hz
  2. 1T: 15760.5 rad/s / 2508.4 Hz
  3. 2B: 19071.3 rad/s / 3035.3 Hz
- First three predicted natural frequencies (with clamped root) for the refined mesh:
  1. 1B: 5368.7 rad/s / 838.5 Hz
  2. 1T: 15754.7 rad/s / 2507.4 Hz
  3. 2B: 19032.9 rad/s / 3029.2 Hz

## Featured articles from the LAVA

- *The harmonic balance method with arc-length continuation in blade-tip/casing contact problems* <sup>[2]</sup>  
BibTex  
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```
@Article{colaitis2021harmonic,  
  author    = {Cola\{"i}tis, Y. and Batailly, A},
```

```

title    = {{The harmonic balance method with arc-length continuation in
blade-tip/casing contact problems}},
journal  = {J. Sound Vib.},
year     = {2021},
volume   = {502},
pages    = {116070},
issn     = {0022-460X},
note     = {\href{https://doi.org/10.1016/j.jsv.2021.116070}{doi~:
10.1016/j.jsv.2021.116070} -
\href{https://hal.archives-ouvertes.fr/hal-03163560}{oai: hal-03163560}},
abstract = {This article presents a Harmonic Balance Method-based
numerical strategy to provide a qualitative numerical characterization of
a compressor blade's dynamics when structural contacts occur with the
surrounding casing. The mitigation of the Gibbs phenomenon follows a two-
pronged approach: (1) a regularization of the unilateral contact law and
(2) the adjustment of the Fourier coefficients by means of a Lanczos
filtering technique. In order to validate the proposed approach, it is
first applied to an academic cantilever rod undergoing unilateral contact
constraints. An in-depth comparative analysis of the obtained results—with
an emphasis on displacements, contact forces and velocities—with respect
to a time integration-based reference numerical strategy underlines the
relevance and accuracy of the proposed methodology. The latter is then
applied to the vibration analysis of an industrial compressor blade: NASA
rotor 37. For a given contact configuration, obtained results are
thoroughly compared to those obtained with a previously published time
integration-based numerical strategy with a distinct contact treatment
algorithm. Particular attention is paid to demonstrate the accuracy of the
methodology for the prediction of displacements, contact forces,
velocities as well as stress fields within the blade. Notably, it is
evidenced that the proposed methodology, contrary to the reference time
integration-based numerical strategy, is able to capture the exact
location of the blade's nonlinear resonance.}}

```

- *Blade/casing rubbing interactions in aircraft engines: Numerical benchmark and design guidelines based on NASA rotor 37* <sup>[3]</sup> BibTex

x

```

@Article{piollet2019blade,
author   = {Piollet, E. and Nyssen, F. and Batailly, A.},
title    = {Blade/casing rubbing interactions in aircraft engines:
Numerical benchmark and design guidelines based on NASA rotor 37},
journal  = {J. Sound Vib.},
year     = {2019},
volume   = {460},
pages    = {114878},
issn     = {0022-460X},
note     = {\href{https://doi.org/10.1016/j.jsv.2019.114878}{doi~:

```

```
10.1016/j.jsv.2019.114878} -  
\href{https://hal.archives-ouvertes.fr/hal-02281666}{oai: hal-02281666}},  
  abstract = {In order to improve the efficiency of aircraft engines, the  
  reduction of clearances between blade tips and their surrounding casing is  
  one avenue manufacturers consider to lower aerodynamic losses. This  
  reduction increases the risk of blade tip/casing contact interactions  
  under nominal operating conditions. Designers need tools to accurately  
  predict subsequent nonlinear vibrations. Engineers and researchers have  
  developed a variety of sophisticated numerical models to predict blades'  
  responses. These models are related to distinct frameworks (time/frequency  
  domain) and various solution algorithms (explicit/implicit time  
  integration schemes, penalty/Lagrange multiplier contact treatment...) which  
  calls for comparative analyses. However, published results are often  
  limited for the sake of confidentiality thus preventing any detailed  
  confrontation. While qualitative understanding can be gained from  
  simplified academic models, full scale models are needed to predict  
  complex interactions in a realistic manner. In this context, this paper  
  proposes a benchmark featuring detailed simulations and analyses of a full  
  3D finite element model based on the open NASA rotor 37 compressor blade  
  to facilitate reproducibility and collaboration across the research  
  community. NASA rotor 37, a compressor stage widely used as a test case in  
  aerodynamic simulations and validations, has the advantage of presenting a  
  realistic blade geometry. The geometry of the blade is built from publicly  
  available reports. The paper provides details on the geometry, the  
  numerical model and the results to allow an easy use of this model across  
  the fields of structural dynamics. Two contact scenarios are investigated:  
  one with direct contact against the casing, and one with abradable  
  material deposited on the casing to mitigate contact severity through  
  wear. The nonlinear vibration response of the blade is simulated in the  
  time domain. It is evidenced that the addition of the abradable material  
  decreases the amplitude of vibration for most of the angular speeds  
  investigated. However, new interactions appear for some angular speeds.  
  The obtained results are consistent with previous simulations on  
  industrial geometries. Based on works showing improved aerodynamic  
  performances when the blade is tilted, a total of seven geometries are  
  investigated: the reference blade, with a straight vertical stacking line  
  similar to the original rotor 37, two forward-leaned blades, two backward-  
  swept blades and two full forward chordwise swept blades. The sweep and  
  lean variations are shown to have a dramatic impact on the vibration  
  response: the backward sweep results in an increased blade's robustness to  
  contact events and the full forward chordwise sweep in a reduced  
  robustness, while the forward lean leads to a robustness similar to the  
  reference blade.}}
```

Cette page contient diverses informations associées à l'un des modèles de l'aube NASA rotor 37 utilisé

dans les publications du LAVA.

Fichiers téléchargeables

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## Modèle original

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

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author      = {Reid, L. and Moore, R. D.},  
title       = {Design and overall performance of four highly loaded, high  
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- Photographies :



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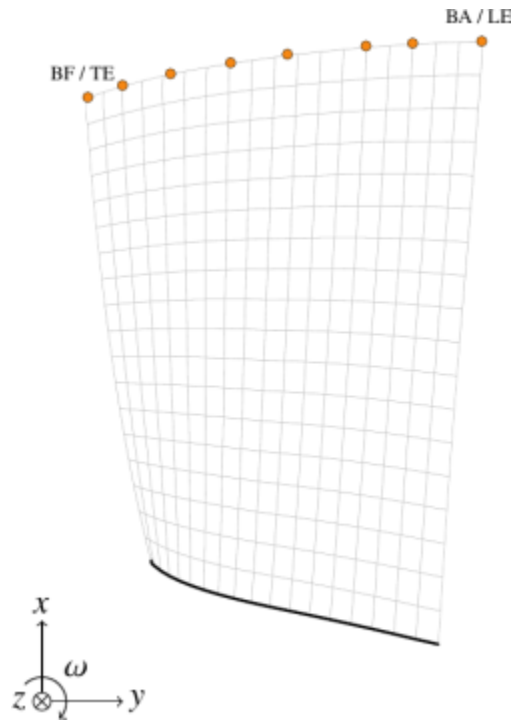
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             gov/id/17468389}, 1977 (accessed 2020-10-29)}, % for Fig. 2}
```

## Maillage éléments finis

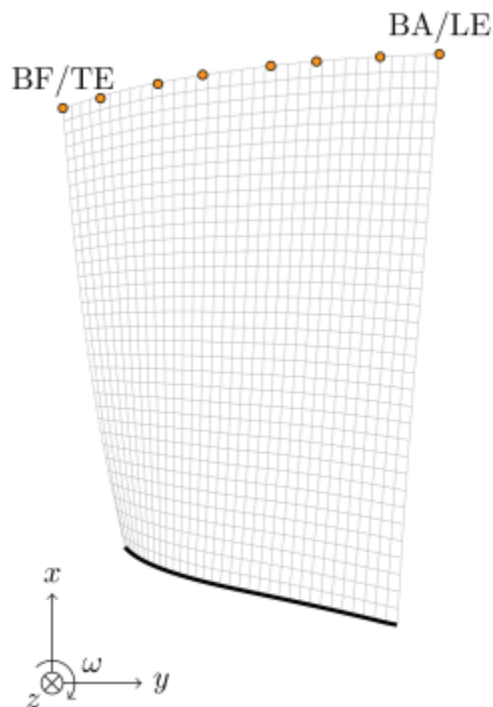
- Nombre de noeuds : 5745
- Nombre total d'éléments : 1800
- Nombre de degrés de liberté : 16524
- Type d'élément : pentaèdre quadratique





aperçu du maillage éléments finis (maillage grossier)

- Nombre de noeuds : 20657
- Nombre total d'éléments : 6664
- Nombre de degrés de liberté : 60588
- Type d'élément : pentaèdre quadratique



aperçu du maillage éléments finis (maillage fin) -

sources LaTeX

## Propriétés matériau

- Le matériau du rotor 37 est un alliage à base de nickel : un acier maraging de grade 200 <sup>[1]</sup>
- Propriétés considérées : alliage 18-Ni 200-maraging <sup>[2] [3]</sup>:
  - Module d'Young  $E = 180$  GPa
  - masse volumique  $\rho = 8000$  kg/m<sup>3</sup>
  - coefficient de Poisson  $\nu = 0,3$
  - limite élastique  $\sigma_Y = 1,38$  GPa (200 000 psi)
- Trois premiers modes prévus (noeuds de la base encastres) pour le maillage grossier :
  - 1F : 5272,3 rad/s / 839,1 Hz
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## Articles du laboratoire

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BibTex

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  author    = {Cola\''tis, Y. and Batailly, A},
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  abstract  = {This article presents a Harmonic Balance Method-based numerical strategy to provide a qualitative numerical characterization of a compressor blade's dynamics when structural contacts occur with the surrounding casing. The mitigation of the Gibbs phenomenon follows a two-pronged approach: (1) a regularization of the unilateral contact law and (2) the adjustment of the Fourier coefficients by means of a Lanczos filtering technique. In order to validate the proposed approach, it is first applied to an academic cantilever rod undergoing unilateral contact constraints. An in-depth comparative analysis of the obtained results—with an emphasis on displacements, contact forces and velocities—with respect to a time integration-based reference numerical strategy underlines the relevance and accuracy of the proposed methodology. The latter is then
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  note      = {\href{https://doi.org/10.1016/j.jsv.2019.114878}{doi~:
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1. [a](#), [b](#), [c](#), [d](#) Reid. «Design and overall performance of four highly loaded, high speed inlet stages for an advanced high-pressure-ratio core compressor » 1978. p64 [pdf](#)
2. [a](#), [b](#), [c](#), [d](#) Colaïtis. «The harmonic balance method with arc-length continuation in blade-tip/casing contact problems » 2021. [doi/oai](#)
3. [a](#), [b](#), [c](#), [d](#) Piollet. «Blade/casing rubbing interactions in aircraft engines: Numerical benchmark and design guidelines based on NASA rotor 37 » 2019. [doi/oai](#)

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