Rotor 67

- Français
- English

Downloadable files
×

Open access

Git project

About

To reduce fan noise, an advanced, two-stage, high-pressure-ratio fan having widely spaced blade rows was build and tested. Rotor 67 is the rotor of the first stage of this fan. But, the overall efficiency of this two-stage fan was approximately 5 percentage points less than its design value. Analysis of the test results indicated that the first-stage stator and the second stage had potential for good performance but were hampered mainly by the dampered first-stage rotor. The dampers were responsible for large radial gradients of total pressure and deviation angle across a large portion of the blade height, resulting in mismatches in later blade rows. To improve performance of the first stage as well as the stage matching, the original two-stage fan was reconfigured with a newly designed first-stage rotor. Lower-aspect-ratio blading was selected for the rotor to eliminate both the need for part span dampers and their associated penalties on aerodynamic performance.

- Original technical report [(cite:urasek1979design>Urasek D. C. *et al* «Performance of two-stage fan having low-aspect-ratio first-stage rotor blading » 1979. pdf)]:

```
@TechReport{urasek1979design,
  author           = {Urasek, D. C. and Gorrell, W. T. and Cunnan, W. S.},
  date             = {1979},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
  title            = {Performance of two-stage fan having low-aspect-ratio
first-stage rotor blading},
  number           = {NASA-TP-1493},
  url              = {https://ntrs.nasa.gov/citations/19790018972},
}
```

- Picture :



Fig. 1 https://catalog.archives.gov/id/17500556

- ```
  @Misc{laity1980records,
  author   = {Laity, D.},
  title    = {Stage 67 rotor and stage 67 casing half stators mounted.
  {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},
  year     = {1980},
  url      = {https://catalog.archives.gov/id/17500556}}
  ```

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:urasek1979design)]. Corresponding models are computed with the open-source code OpenMCAD[(cite:Kojtych_2022_gene_aubes)].
  ```

Geometry

The geometry of rotor 67 is described in the original NASA report by the following tables. The length are in centimeters and the angles in degrees.

TABLE III. - BLADE GEOMETRY

(a) First-stage rotor

RP	PERCENT SPAN	RADII RI	RADII RO	BLADE ANGLES KIC	BLADE ANGLES KTC	BLADE ANGLES KOC	DELTA INC	CONE ANGLE
TIP	0.	25.530	24.773	66.61	64.83	54.06	2.30	-10.639
1	5.	24.880	24.125	64.56	62.39	53.15	2.36	-9.797
2	10.	24.178	23.478	62.83	60.14	52.50	2.42	-8.542
3	20.	22.753	22.184	60.85	56.86	51.60	2.58	-6.433
4	30.	21.294	20.889	59.01	53.98	48.25	2.74	-4.239
5	40.	19.810	19.595	56.81	50.88	43.24	3.13	-2.073
6	50.	18.291	18.301	54.27	47.40	36.70	3.79	.086
7	60.	16.723	17.006	51.40	43.47	29.05	4.56	2.299
8	70.	15.081	15.712	47.44	39.04	19.53	6.24	4.679
9	80.	13.349	14.418	43.79	34.97	7.60	7.28	7.330
10	90.	11.493	13.123	41.40	31.81	-6.39	6.56	10.521
11	95.	10.503	12.476	40.30	30.59	-13.82	5.93	12.427
HUB	100.	9.583	11.829	39.35	29.60	-21.38	5.24	13.854

RP	BLADE THICKNESSES TI	BLADE THICKNESSES TM	BLADE THICKNESSES TO	AXIAL DIMENSIONS ZI	AXIAL DIMENSIONS ZMC	AXIAL DIMENSIONS ZTC	AXIAL DIMENSIONS ZO
TIP	.033	.269	.033	2.578	4.987	5.238	6.607
1	.033	.272	.034	2.397	4.999	5.159	6.767
2	.034	.279	.035	2.236	5.002	5.064	6.896
3	.038	.309	.039	2.013	4.973	4.838	7.061
4	.044	.360	.046	1.798	4.921	4.562	7.250
5	.050	.423	.053	1.573	4.843	4.239	7.500
6	.057	.496	.061	1.335	4.732	3.867	7.806
7	.067	.574	.070	1.066	4.616	3.418	8.128
8	.075	.653	.078	.805	4.441	2.896	8.514
9	.082	.725	.084	.528	4.329	2.337	8.837
10	.089	.781	.088	.236	4.336	1.785	9.014
11	.091	.800	.090	.110	4.332	1.531	9.065
HUB	.092	.814	.092	-.000	4.329	1.305	9.104

Aerodynamic design

	unit	values
pressure ratio	[-]	1.63
mass flow	[kg/s]	33.248
tip speed	[m/s]	427
tip solidity	[-]	1.288
aspect ratio	[-]	1.56
number of blades	[-]	22
rotative speed	[rad/s]	1680

Material properties

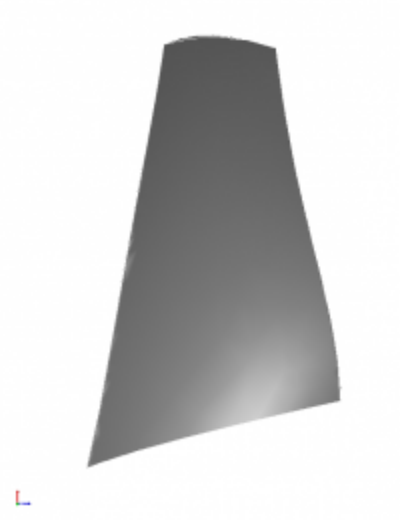
The original material of the rotor 67 is not defined in the NASA report. A generic titanium Ti-6Al-4V is considered:

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

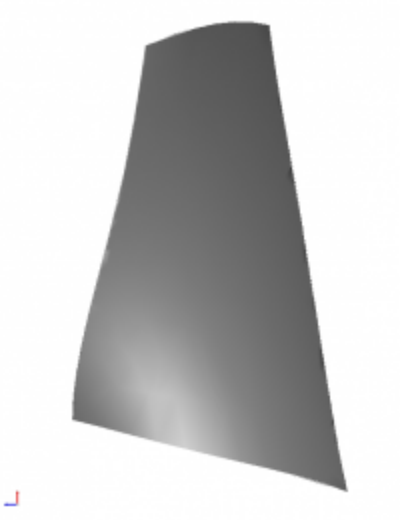
	units	values
yield stress	[GPa]	0.824

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	2318.539	369.007
2	2B	6244.462	993.837
3	1T	10871.29	1730.22

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	2310.044	367.655
2	2B	6215.77	989.27
3	1T	10842.26	1725.60

- from the reduced order model:

Mode	Type	Natural angular frequency (rad/sec)	Natural frequency (Hz)
1	1B	2310.36	367.705
2	2B	6222.559	990.351
3	1T	10866.01	1729.38

Fichiers téléchargeables
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Libre accès

lien vers le projet Git

À propos

Pour réduire le bruit des soufflantes, une soufflante a deux étages a été construite et testée. Cette soufflante possède un grand taux de compression (2.4) et ses rangées d'aubes sont très espacées. Le rotor 67 est le rotor du premier étage de cette soufflante. Cependant, le rendement global de cette soufflante à deux étages était inférieur d'environ 5% au rendement prévu. L'analyse des résultats des essais a montré que le stator du premier étage et le deuxième étage avaient un potentiel de bonnes performances, mais qu'ils étaient entravés principalement par le rotor du premier étage qui était amorti. Les amortisseurs étaient responsables d'importants gradients de pression totale et d'angle de déviation sur une grande partie de la hauteur des aubes, ce qui a entraîné des déséquilibres dans les rangées d'aubes ultérieures. Pour améliorer les performances du premier étage ainsi que l'appariement des étages, le rotor du premier étage a été reconfiguré. Des aubes à faible allongement d'aspect ont été privilégiées.

- Rapport technique original [(cite:urasek1979design>)]:

```
@TechReport{urasek1979design,
  author          = {Urasek, D. C. and Gorrell, W. T. and Cunnan, W. S.},
```

```
  date             = {1979},
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- Photographie :



Fig1. https://catalog.archives.gov/id/17500556

- ```
  @Misc{laity1980records,
  author   = {Laity, D.},
  title    = {Stage 67 rotor and stage 67 casing half stators mounted.
  {R}ecords of the {N}ational {A}eronautics and {S}pace {A}dministration,
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  personnel, 1973 - 2013},
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  url      = {https://catalog.archives.gov/id/17500556}}
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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:urasek1979design)]. Les modèles associés sont obtenus avec le code en libre accès OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

Géométrie

La géométrie du rotor 67 est décrite dans le rapport d'origine de la NASA par les tableaux suivants. Les grandeurs sont en centimètres et en degrés.

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11	.091	.800	.090	.110	4.332	1.531	9.065
HUB	.092	.814	.092	-.000	4.329	1.305	9.104

Caractéristiques aérodynamiques

	unités	valeurs
taux de compression	[-]	1,63
débit massique	[kg/s]	33,248
vitesse en tête	[m/s]	427
solidité en tête	[-]	1,288
allongement	[-]	1,56

	unités	valeurs
nombre d'aubes	[-]	22
vitesse de rotation	[rad/s]	1680

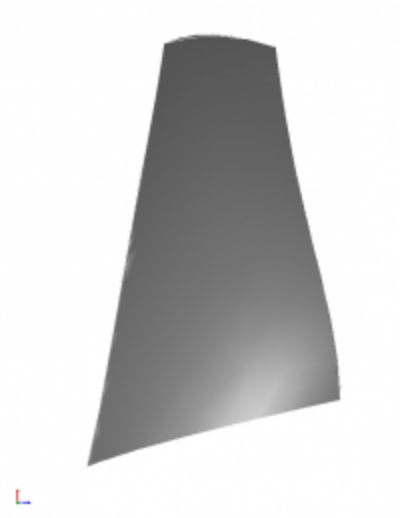
Propriétés matériau

Le matériau original du rotor 67 n'est pas défini dans le rapport de la NASA. Un alliage de titane Ti-6Al-4v est considéré :

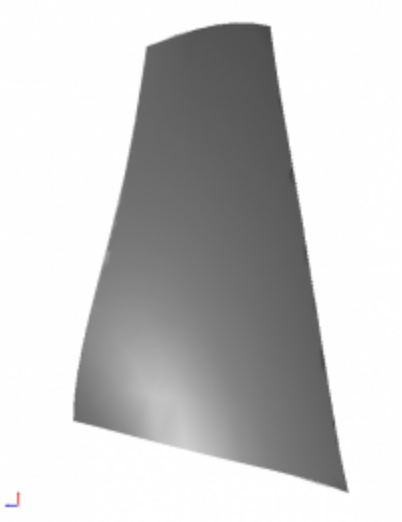
	unités	valeurs
alliage	[-]	Ti-6Al-4v
module d'Young	[GPa]	108
masse volumique	[kg/m3]	4400
coefficient de Poisson	[-]	0,34
limite élastique	[GPa]	0,824

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	1F	2318,539	369,007
2	2F	6244,462	993,837
3	1T	10871,29	1730,22

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	2310,044	367,655
2	2F	6215,77	989,27
3	1T	10842,26	1725,60

- pour le modèle réduit :

Mode	Type	Pulsation propre (rad/sec)	Fréquence propre (Hz)
1	1F	2310,36	367,705
2	2F	6222,559	990,351
3	1T	10866,01	1729,38

Document issu de la page wiki:
https://wiki.lava.polymtl.ca/public/modeles/rotor_67/accueil?rev=1681490168

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