Rotor 67

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Original model

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 [1]:

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

- Picture :

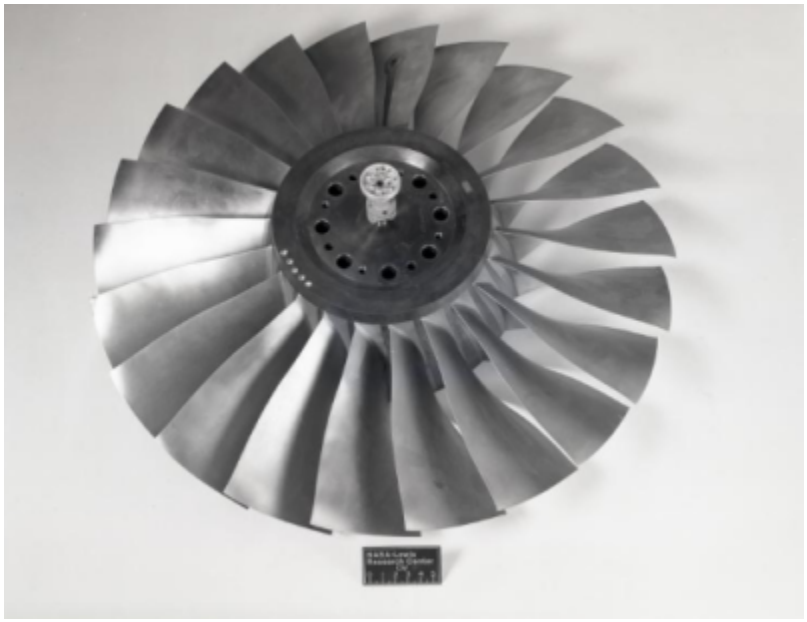


Fig1. https://catalog.archives.gov/id/17500556

```
@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, 1903 - 2006.
{P}hotographs relating to agency activities, facilities and personnel, 1973 -
2013},
note     =
{\href{https://catalog.archives.gov/id/17500556}{https://catalog.archives.gov/
id/17500556}, 1980 }, % for Fig. 1}
```

Useful documents

- PDF of the NASA report :

  rotor67.pdf

- CSV file of the blade geometry :

  rotor67_original.csv

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	.099	.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.

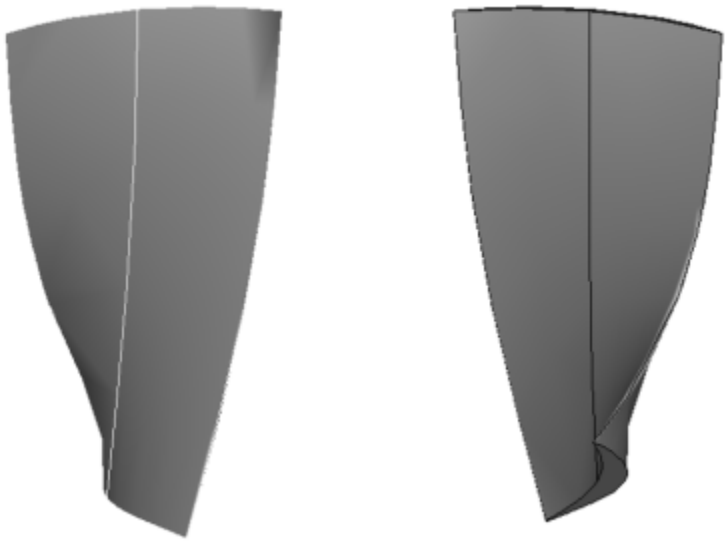
Considered properties: Ti-6Al-4V, generic titanium :

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

First three natural frequencies (with clamped root) for the mesh:

1. (1B): 2323.2 rad/s / 369.7 Hz
2. (2B): 6270.9 rad/s / 998.1 Hz
3. (1T): 10884.9 rad/s / 1732.4 Hz

CAD



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Modèle original

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 [1]:

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

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title       = {Performance of two-stage fan having low-aspect-ratio first-
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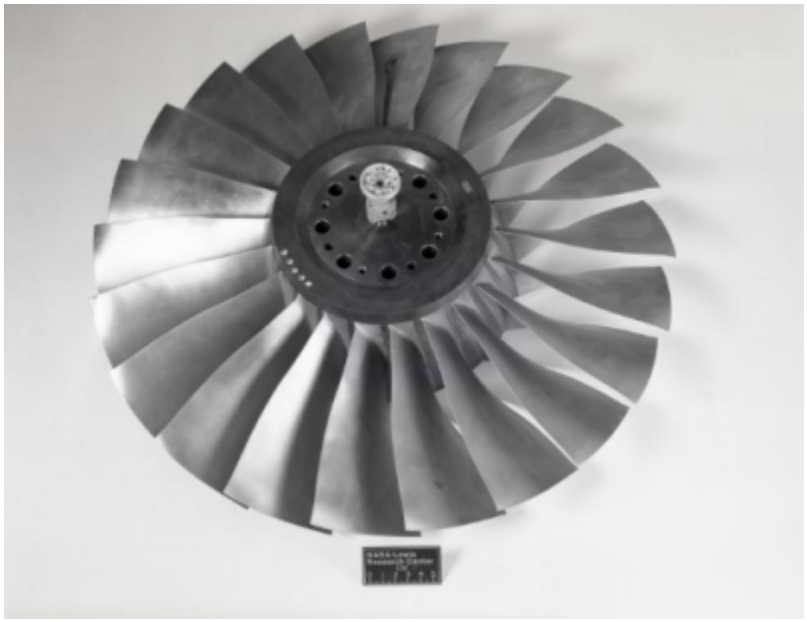
- Photographie :



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id/17500556}, 1980 }, % for Fig. 1}
```

Documents utiles

- PDF du rapport de la NASA : rotor67.pdf
- Fichier CSV de la géométrie : rotor67_original.csv

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.

TABLE III. – BLADE GEOMETRY

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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
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.

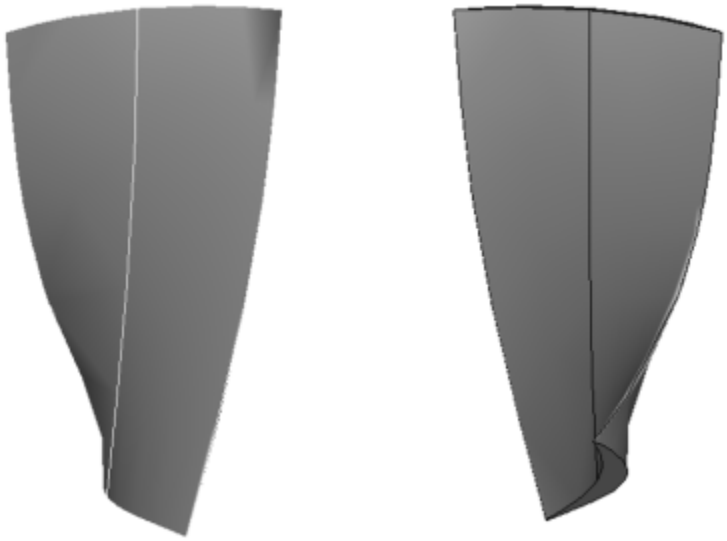
Propriétés considérées : alliage de titane Ti-6Al-4v :

	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

Fréquences des trois premiers modes (noeuds de la base encastrés) pour le maillage :

1. (1B): 2323,2 rad/s / 369,7 Hz
2. (2B): 6270,9 rad/s / 998,1 Hz
3. (1T): 10884,9 rad/s / 1732,4 Hz

CAO



1. [a, b] Reid. «Performance of two-stage fan having low-aspect-ratio first-stage rotor blading » 1979. pdf