Rotor 18

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Original model

One way to reduce compressor weight is to obtain a high pressure ratio per stage, thereby reducing the number of stages. As a consequence, several single-stage fans have been designed to produce stage pressure ratios ranging from 1.9 to 2.2. Rotor 18 is one of those fans with a pressure ratio of 1.925.

- Original technical report [1]:

```
@TechReport{lewis1974design,
author      = {Lewis, George W. and Reid, Lonnie and Tysl, Edward R.},
title       = {Design and performance of a high-pressure-ratio, highly
loaded axial-flow transonic compressor stage},
institution = {NASA Lewis Research Center Cleveland, OH, United States},
note        = {NASA-TM X-3100, url~:
\url{https://ntrs.nasa.gov/citations/19740025108}, 1974}}
```

- Picture :

Fig1. https://catalog.archives.gov/id/17422714

```
@Misc{huebler1974records,
author   = {Huebler, D.},
title    = {Rotor 18. {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/17422714}{https://catalog.archives.gov/
id/17422714}, 1974 }, % for Fig. 1}
```

Useful documents

- PDF of the NASA report : rotor18.pdf
- CSV file of the blade geometry : rotor18_original.csv

Geometry

The geometry of rotor 18 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 18

RP	PERCENT SPAN	RADII RI	RADII RO	BLADE ANGLES KIC	BLADE ANGLES KTC	BLADE ANGLES KOC	DELTA INC	CONE ANGLE
TIP	0.	25.019	24.359	63.50	60.06	48.60	2.49	-15.536
1	5.	24.442	23.871	61.91	58.53	47.71	2.75	-12.940
2	10.	23.906	23.383	60.51	57.10	46.55	3.00	-11.383
3	30.	21.655	21.433	55.62	51.09	39.82	4.08	-4.201
4	48.	19.590	19.726	52.08	45.52	31.18	5.03	2.263
5	50.	19.288	19.482	51.61	44.86	29.62	5.17	3.196
6	53.	18.983	19.238	51.14	44.24	27.97	5.30	4.131
7	55.	18.676	18.994	50.68	43.63	26.26	5.43	5.076
8	58.	18.367	18.750	50.22	42.97	24.48	5.56	6.033
9	70.	16.777	17.531	48.02	39.76	14.38	6.16	10.944
10	90.	14.079	15.580	44.63	35.58	-7.70	6.86	19.179
11	95.	13.384	15.093	43.76	34.81	-14.81	6.97	21.167
HUB	100.	12.700	14.605	42.89	34.15	-22.54	7.04	22.957

RP	BLADE THICKNESSES TI	BLADE THICKNESSES TM	BLADE THICKNESSES TO	AXIAL DIMENSIONS ZIC	AXIAL DIMENSIONS ZMC	AXIAL DIMENSIONS ZTC	AXIAL DIMENSIONS ZOC
TIP	0.051	0.152	0.051	1.148	2.212	2.267	3.523
1	0.051	0.163	0.051	1.087	2.213	2.225	3.573
2	0.051	0.173	0.051	1.031	2.213	2.183	3.626
3	0.051	0.216	0.051	0.812	2.205	1.966	3.847
4	0.051	0.256	0.051	0.627	2.193	1.719	4.048
5	0.051	0.262	0.051	0.602	2.191	1.681	4.076
6	0.051	0.267	0.051	0.578	2.188	1.643	4.105
7	0.051	0.273	0.051	0.554	2.185	1.604	4.133
8	0.051	0.279	0.051	0.529	2.182	1.563	4.160
9	0.051	0.309	0.051	0.396	2.164	1.341	4.296
10	0.051	0.360	0.051	0.149	2.126	0.924	4.466
11	0.051	0.373	0.051	0.076	2.117	0.807	4.488
HUB	0.051	0.386	0.051	0.000	2.107	0.687	4.502

Aerodynamic design

	unit	values
pressure ratio	[-]	1.925
mass flow	[kg/s]	29.5
tip speed	[m/s]	422
tip solidity	[-]	1.7
aspect ratio	[-]	2.6
number of blades	[-]	56
rotative speed	[rad/s]	1686

Material properties

The original material of the rotor 18 is not defined in the NASA report.

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

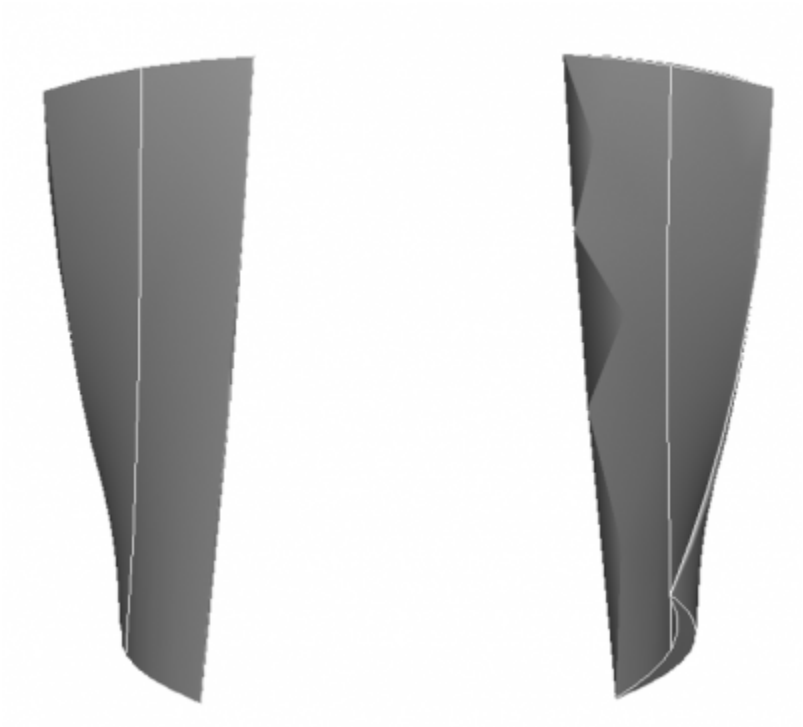
	unité	valeurs
alloy	[-]	Ti-6Al-4V
Young's modulus	[GPa]	108
density	[kg/m3]	4400
Poisson's ratio	[-]	0.34

	unité	valeurs
yield stress	[GPa]	0.824

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

1. (1B): 2040.6 rad/s / 324.8 Hz
2. (2B): 6744.2 rad/s / 1073.4 Hz
3. (1T): 10769.2 rad/s / 1714.0 Hz

CAD



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Modèle original

Une façon de réduire le poids d'un compresseur est d'atteindre un rapport de pression élevé par étage, ce qui permet de réduire le nombre d'étages de ce compresseur. Par conséquent, plusieurs soufflantes à un étage ont été conçus pour produire des rapports de pression par étage allant de 1,9 à 2,2. Le rotor 18 est donc une de ces soufflantes et possède un taux de compression de 1,925.

- Rapport technique original [1]:

```
@TechReport{lewis1974design,
```

```
author      = {Lewis, George W. and Reid, Lonnie and Tysl, Edward R.},
title       = {Design and performance of a high-pressure-ratio, highly
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- Photographie :

Fig1. https://catalog.archives.gov/id/17422714

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facilities and personnel, 1973 - 2013},
note     =
{\href{https://catalog.archives.gov/id/17422714}{https://catalog.archives.gov/
id/17422714}, 1974 }, % for Fig. 1}
```

Documents utiles

- PDF du rapport de la NASA :

rotor18.pdf

- Fichier CSV de la géométrie :

rotor18_original.csv

Géométrie

La géométrie du rotor 18 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 18

	PERCENT	RADII		BLADE ANGLES			DELTA	CONE
RP	SPAN	RI	RO	KIC	KTC	KOC	INC	ANGLE
TIP	0.	25.019	24.359	63.50	60.06	48.60	2.49	-15.536
1	5.	24.442	23.871	61.91	58.53	47.71	2.75	-12.940
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HUB	100.	12.700	14.605	42.89	34.15	-22.54	7.04	22.937

	BLADE THICKNESSES			AXIAL DIMENSIONS			
RP	TI	TM	TO	ZIC	ZMC	ZTC	ZOC
TIP	0.051	0.152	0.051	1.148	2.212	2.267	3.523
1	0.051	0.163	0.051	1.087	2.213	2.225	3.573
2	0.051	0.173	0.051	1.031	2.213	2.183	3.626
3	0.051	0.216	0.051	0.812	2.205	1.966	3.847
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10	0.051	0.360	0.051	0.149	2.126	0.924	4.466
11	0.051	0.373	0.051	0.076	2.117	0.807	4.488
HUB	0.051	0.386	0.051	0.000	2.107	0.687	4.502

Caractéristiques aérodynamiques

	unités	valeurs
taux de compression	[-]	1,925
débit massique	[kg/s]	29,5
vitesse en tête	[m/s]	422
solidité en tête	[-]	1,7
allongement	[-]	2,6
nombre d'aubes	[-]	56
vitesse de rotation	[rad/s]	1686

Propriétés matériau

Le matériau original du rotor 18 n'est pas défini dans le rapport de la NASA.

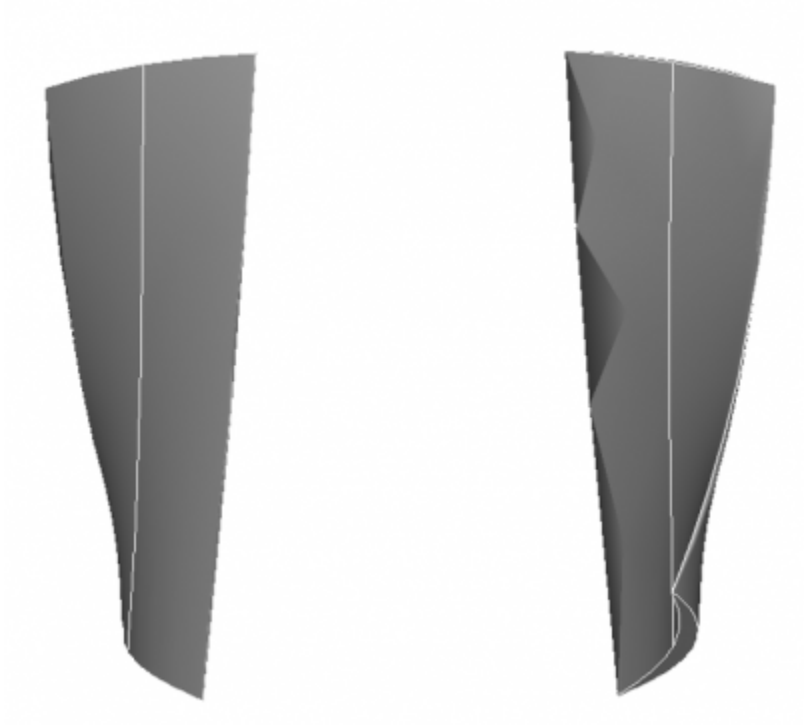
Propriétés considérées : alliage de titane Ti-6Al-4v :

	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): 2040,6 rad/s / 324,8 Hz
2. (2B): 6744,2 rad/s / 1073,4 Hz
3. (1T): 10769,2 rad/s / 1714,0 Hz

CAO



1. [a, b] Lewis. «Design and performance of a high-pressure-ratio, highly loaded axial-flow transonic compressor stage » 1974. pdf