Rotor 16

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Original model

Rotor 16 is part of a research program to study the effect of weight flow per unit annulus area on the performance of axial-flow fan stages. A series of three stage: rotor 11, 16 and 17 were designed with a weight flow per unit annulus area of 198, 178, and 208 kilograms per second per square meter. All three stages were designed to produce a pressure ratio of 1.57, and all had the same meridional flow path geometry.

- Original technical report [1]:

```
@TechReport{moore1973design,
author      = {Moore, R. D. and Urasek, Donald C. and Kovlch, George},
title       = {Performance of transonic fan stage with weight flow per
unit annulus area of 178 kilograms per sercond per square meter (36.5
(lb/sec)/ft²)},
institution = {NASA Lewis Research Center Cleveland, OH, United States},
note        = {NASA-TM X-2904, url~:
\url{https://ntrs.nasa.gov/citations/19740001906}, 1973 }}
```

- Picture :

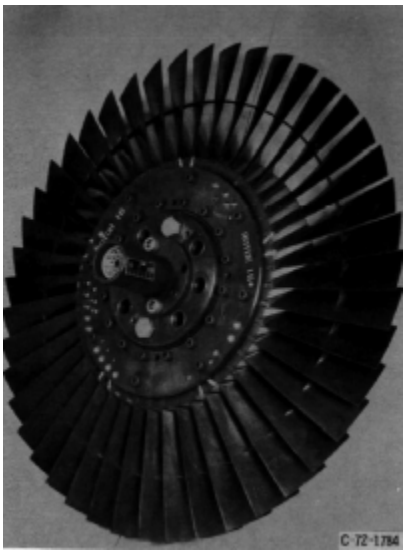


Fig1. https://ntrs.nasa.gov/citations/19740001906 p.64

Useful documents

- PDF of the NASA report : rotor16.pdf
- CSV file of the blade geometry : rotor16_original.csv

Geometry

The geometry of rotor 16 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 16

RP	PERCENT SPAN	RADII RI	RO	BLADE ANGLES KIC	KTC	KOC	DELTA INC	CONE ANGLE
TIP	0.	25.204	24.905	67.60	66.34	61.49	2.51	-9.339
1	5.	24.683	24.364	66.48	65.43	60.78	2.75	-9.519
2	10.	24.123	23.824	65.30	64.30	60.02	3.00	-8.557
3	30.	21.814	21.662	60.91	58.82	56.21	4.07	-3.692
4	45.	20.034	20.041	57.80	54.80	51.78	4.90	0.161
5	48.	19.733	19.771	57.28	54.09	50.84	5.04	0.819
6	50.	19.430	19.501	56.76	53.37	49.85	5.18	1.482
7	53.	19.126	19.231	56.24	52.64	48.79	5.32	2.149
8	55.	18.821	18.960	55.72	51.89	47.68	5.46	2.817
9	70.	16.946	17.339	52.48	47.42	39.33	6.29	7.105
10	90.	14.280	15.178	47.87	41.70	21.76	7.35	13.772
11	95.	13.570	14.637	46.64	40.42	15.40	7.59	15.655
HUB	100.	12.700	14.097	45.12	39.00	8.18	7.85	19.355

RP	BLADE THICKNESSES TI	TM	TO	AXIAL DIMENSIONS ZIC	ZMC	ZTC	ZOC
TIP	0.051	0.151	0.051	1.016	1.891	2.284	2.839
1	0.051	0.161	0.051	0.978	1.892	2.263	2.879
2	0.051	0.171	0.051	0.935	1.894	2.239	2.923
3	0.051	0.213	0.051	0.756	1.895	2.101	3.111
4	0.051	0.247	0.051	0.629	1.895	1.950	3.258
5	0.051	0.252	0.051	0.608	1.894	1.921	3.284
6	0.051	0.258	0.051	0.585	1.893	1.889	3.311
7	0.051	0.263	0.051	0.562	1.892	1.857	3.339
8	0.051	0.269	0.051	0.538	1.890	1.822	3.367
9	0.051	0.304	0.051	0.394	1.878	1.591	3.551
10	0.051	0.355	0.051	0.168	1.843	1.190	3.832
11	0.051	0.369	0.051	0.096	1.827	1.065	3.904
HUB	0.051	0.386	0.051	0.000	1.804	0.902	3.977

Aerodynamic design

	unit	values
pressure ratio	[-]	1.57
mass flow	[kg/s]	26.5
tip speed	[m/s]	425
tip solidity	[-]	1.3
aspect ratio	[-]	2.6
number of blades	[-]	44
rotative speed	[rad/s]	1686

Material properties

The original material of the rotor 16 is not defined in the NASA report.

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

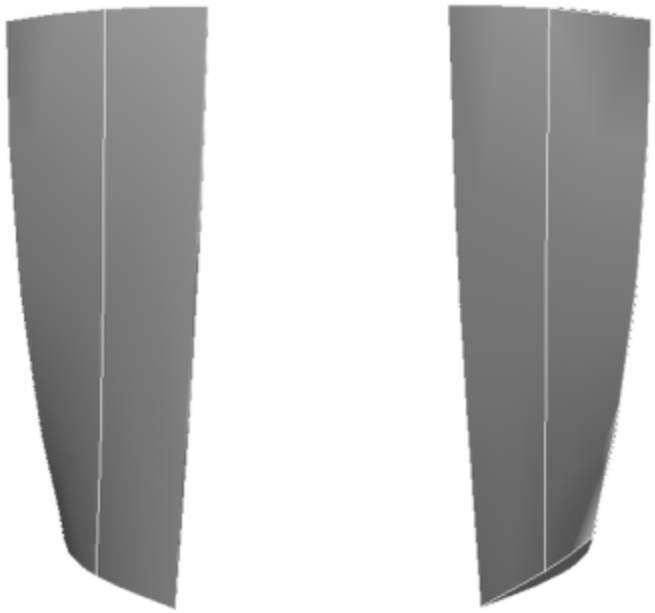
	unité	valeurs
alloy	[-]	Ti-6Al-4V
Young's modulus	[GPa]	108
density	[kg/m3]	4400
Poisson's ratio	[-]	0.34

	unité	valeurs
yield stress	[GPa]	0.824

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

1. (1B): 1440.5 rad/s / 229.3 Hz
2. (2B): 5543.8 rad/s / 882.3 Hz
3. (1T): 7959.1 rad/s / 1266.7 Hz

CAD



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Modèle original

Le rotor 16 fait partie d'un programme de recherche visant à étudier l'effet du débit massique par unité de surface annulaire sur les performances des soufflantes à flux axiaux. Une série de trois étages comprenant le rotor 11, 16 et 17 ont été conçus avec un débit massique par unité de surface annulaire de 198, 178 et 208 kilogrammes par seconde par mètre carré. Les trois étages ont été conçus pour produire un rapport de pression de 1.57.

- Rapport technique original [1]:

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@TechReport{moore1973design,
author      = {Moore, R. D. and Urasek, Donald C. and Kovlch, George},
title       = {Performance of transonic fan stage with weight flow per
unit annulus area of 178 kilograms per sercond per square meter (36.5
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- Photographie :

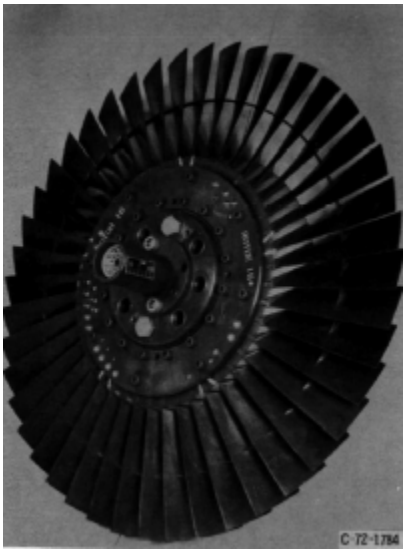

Fig1. https://ntrs.nasa.gov/citations/19740001906 p.64

Documents utiles

- PDF du rapport de la NASA : rotor16.pdf
- Fichier CSV de la géométrie : rotor16_original.csv

Géométrie

La géométrie du rotor 16 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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HUB	0.051	0.386	0.051	0.000	1.804	0.902	3.977

Caractéristiques aérodynamiques

	unités	valeurs
taux de compression	[-]	1,57
débit massique	[kg/s]	26,5
vitesse en tête	[m/s]	425
solidité en tête	[-]	1,3
allongement	[-]	2,6
nombre d'aubes	[-]	44
vitesse de rotation	[rad/s]	1686

Propriétés matériau

Le matériau original du rotor 16 n'est pas défini dans le rapport de la NASA.

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

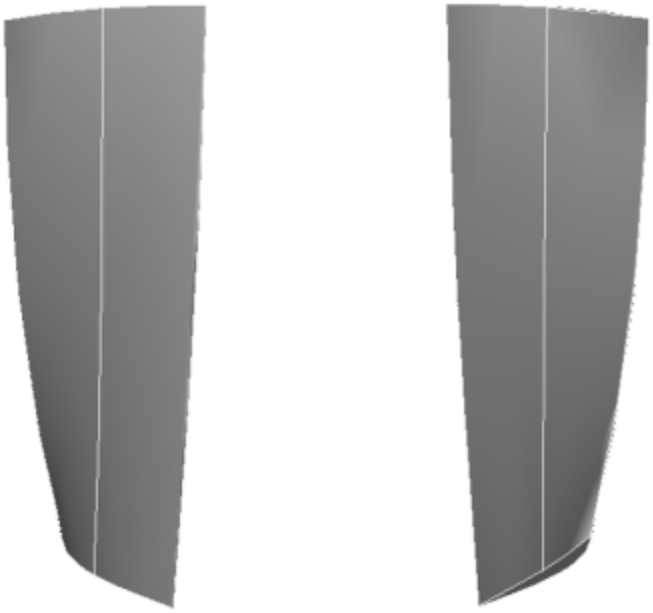
	unité	valeurs
alliage	[-]	Ti-6Al-4v
module d'Young	[GPa]	108
masse volumique	[kg/m3]	4400
coefficient de Poisson	[-]	0,34

	unité	valeurs
limite élastique	[GPa]	0,824

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

1. (1B): 1440,5 rad/s / 229,3 Hz
2. (2B): 5543,8 rad/s / 882,3 Hz
3. (1T): 7959,1 rad/s / 1266,7 Hz

CAO



1. [a, b] Moore. «Performance of transonic fan stage with weight flow per unit annulus area of 178 kilograms per sercond per square meter (36.5 (lb/sec)/ft²) » 1973. pdf