Rotor 54

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Original model

Rotor 54 is part of a research program to study fan stages suitable for use in engines for quiet powered lift aircraft. Experimental studies have been conducted on fan stages suitable for use in engines for quiet powered lift aircraft using the externally blown flap. The externally blown flap aircraft requires a large flow of low velocity air for effective lift and low noise during take-off and landing. To meet the low noise requirement, the fans will be required to have low tip speed and low-pressure ratio. The pressure ratios of interest in the program range from 1.15 to 1.4. Rotor 54 has a pressure ratio of 1.2.

- Original technical report [(cite:lewis1976deisgn>Lewis. «Aerodynamic performance of a 1.20-pressure-ratio fan stage designed for low noise » 1976. pdf)]:

```
@TechReport{lewis1976deisgn,
author      = {Lewis, George W. and Moore, R. D.},
title       = {Aerodynamic performance of a 1.20-pressure-ratio fan stage
designed for low noise},
institution = {NASA Lewis Research Center Cleveland, OH, United States},
note        = {NASA-TM X-3430, url~:
\url{https://ntrs.nasa.gov/citations/19760026047}, 1976}}
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- Picture :

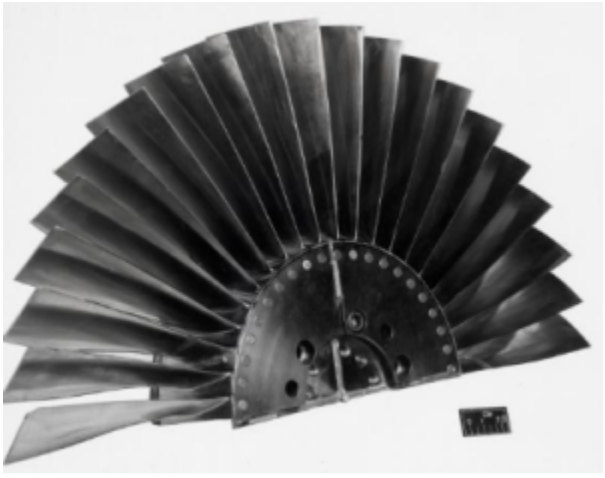


Fig1. https://catalog.archives.gov/id/17444857

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author    = {Unknown},
title     = {Stage 54 rotor. {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/17444857}{https://catalog.archives.gov/
id/17444857}, 1975 }, % for Fig. 1}
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Useful documents

- PDF of the NASA report :

  rotor54.pdf

- CSV file of the blade geometry :

  rotor54_original.csv

Geometry

The geometry of rotor 54 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 54

RP	PERCENT SPAN	RADII RI	RADII RO	BLADE ANGLES KIC	BLADE ANGLES KTC	BLADE ANGLES KOC	DELTA INC	CONE ANGLE
TIP	0.	25.400	25.403	47.46	42.16	38.61	4.33	0.057
1	5.	24.725	24.756	46.79	41.25	37.16	4.34	0.523
2	10.	24.046	24.109	46.08	40.30	35.58	4.37	1.059
3	15.	23.362	23.462	45.34	39.29	33.86	4.41	1.662
4	30.	21.287	21.522	42.89	35.89	27.65	4.60	3.676
5	50.	18.455	18.934	39.05	30.78	16.80	4.86	6.937
6	70.	15.508	16.347	34.56	25.32	2.20	4.91	11.226
7	85.	13.187	14.407	30.73	20.78	-8.38	4.61	15.566
8	90.	12.392	13.760	29.35	19.45	-10.14	4.41	17.366
9	95.	11.599	13.113	27.89	18.39	-10.68	4.16	19.374
HUB	100.	10.566	12.466	26.09	17.41	-10.16	3.79	23.257

RP	BLADE THICKNESSES TI	TM	TO	AXIAL DIMENSIONS ZIC	ZMC	ZTC	ZOC
TIP	0.056	0.226	0.034	0.605	2.180	2.505	3.872
1	0.056	0.226	0.034	0.584	2.183	2.434	3.907
2	0.057	0.228	0.034	0.561	2.185	2.358	3.942
3	0.058	0.231	0.034	0.537	2.187	2.280	3.979
4	0.061	0.245	0.037	0.452	2.190	2.019	4.098
5	0.068	0.272	0.041	0.316	2.187	1.619	4.258
6	0.077	0.306	0.046	0.163	2.182	1.174	4.391
7	0.083	0.334	0.050	0.056	2.182	0.834	4.434
8	0.086	0.343	0.051	0.030	2.181	0.733	4.435
9	0.088	0.351	0.053	0.012	2.179	0.642	4.431
HUB	0.091	0.362	0.054	-0.000	2.176	0.547	4.421

Aerodynamic design

	unit	values
pressure ratio	[-]	1.2
mass flow	[kg/s]	30.55
tip speed	[m/s]	228.6
tip solidity	[-]	1.188
aspect ratio	[-]	3.9
number of blades	[-]	42
rotative speed	[rad/s]	900

Material properties

he original material of the rotor 54 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): 1197.1 rad/s / 190.5 Hz
2. (2B): 4297.3 rad/s / 683.9 Hz
3. (1T): 7001.1 rad/s / 1114.2 Hz

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	1018.5	183,317
2	1T	3542.5	663,656
3	2B	6094.7	1055,71

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	1019.1	183,027
2	1T	3539.3	665,313
3	2B	6074.0	1052,6

- from the reduced order model:

Mode	Type	Natural angular frequency (rad/sec)	Natural frequency (Hz)
1	1B	1019.1	183,029
2	1T	3540.8	665,406
3	2B	6075.8	1052,81

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Modèle original

Le rotor 54 fait partie d'un programme de recherche visant à étudier les étages de soufflante susceptibles d'être utilisés dans des moteurs d'avions plus silencieux. Des études expérimentales ont été menées sur des étages de soufflante utilisant un volet à soufflage externe. L'utilisation de tel volets nécessite un grand débit d'air à faible vitesse pour une portance efficace et un faible niveau de bruit au décollage et à l'atterrissage. Pour répondre à cette exigence de faible bruit, les soufflantes devront avoir une faible vitesse en tête et un faible taux de compression. Les taux de compression d'intérêt dans le programme varient de 1,15 à 1,4. Le rotor 54 possède un taux de compression de 1,2.

* Rapport technique original [(cite:lewis1976deisgn>Lewis. «Aerodynamic performance of a 1.20-pressure-ratio fan stage designed for low noise » 1976. pdf)]:

```
@TechReport{lewis1976deisgn,
author      = {Lewis, George W. and Moore, R. D.},
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- Photographie :

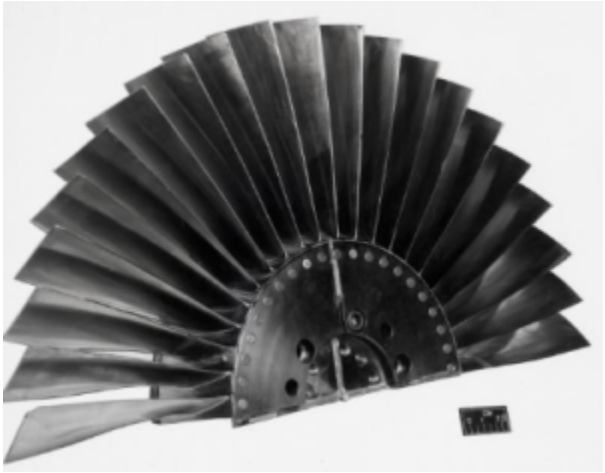


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```

Documents utiles

- PDF du rapport de la NASA : rotor54.pdf
- Fichier CSV de la géométrie : rotor54_original.csv

Géométrie

La géométrie du rotor 54 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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7	0.083	0.334	0.050	0.056	2.182	0.834	4.434
8	0.086	0.343	0.051	0.030	2.181	0.733	4.435
9	0.088	0.351	0.053	0.012	2.179	0.642	4.431
HUB	0.091	0.362	0.054	-0.000	2.176	0.547	4.421

Caractéristiques aérodynamiques

	unités	valeurs
taux de compression	[-]	1,2
débit massique	[kg/s]	30,55
vitesse en tête	[m/s]	228,6
solidité en tête	[-]	1,188
allongement	[-]	3,9
nombre d'aubes	[-]	42
vitesse de rotation	[rad/s]	900

Propriétés matériau

Le matériau original du rotor 54 n'est pas défini dans le rapport de la NASA.

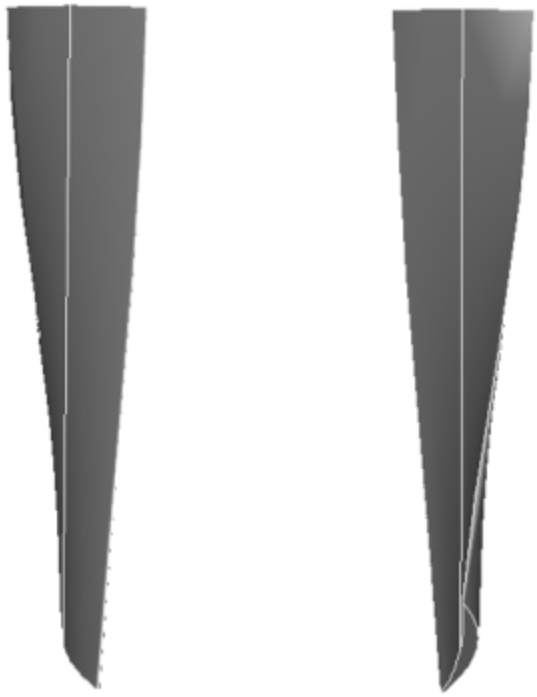
Propriétés considérées : alliage de titane Ti-6Al-4v :

	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): 1197,1 rad/s / 190,5 Hz
2. (2B): 4297,3 rad/s / 68,9 Hz
3. (1T): 7001,1 rad/s / 1114,2 Hz

CAO



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Document issu de la page wiki:
https://wiki.lava.polymtl.ca/public/modeles/rotor_54/accueil?rev=1677304327

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