

# 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 <sup>[1]</sup>:

```
@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}}
```

- Picture :



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

```
@Misc{unknown1975records,
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}
```

## 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 RADII		BLADE ANGLES			DELTA INC	CONE ANGLE	
	SPAN	RI	RO	KIC	KTC			KOC
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	40.50	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.	11.519	13.113	27.89	18.39	-10.68	4.16	19.374
HUB	100.	10.506	12.466	26.89	17.41	-10.16	3.79	23.257

RP	BLADE THICKNESSES			AXIAL DIMENSIONS			
	TI	TM	TO	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

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

## Material properties

The original material of the rotor 54 is not defined in the NASA report.

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

	<b>unité</b>	<b>valeurs</b>
<b>alloy</b>	[-]	Ti-6Al-4V
<b>Young's modulus</b>	[GPa]	108
<b>density</b>	[kg/m <sup>3</sup> ]	4400
<b>Poisson's ratio</b>	[-]	0.34
<b>yield stress</b>	[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<sup>[2]</sup>.



pressure side



suction side

## Natural frequencies

First three natural frequencies (with clamped root) for the mesh computed with OpenMCAD<sup>[2]</sup>:

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<sup>[3]</sup> 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 <sup>[1]</sup>:

```
@TechReport{lewis1976deisgn,  
author      = {Lewis, George W. and Moore, R. D.},  
title       = {Aerodynamic performance of a 1.20-pressure-ratio fan stage  
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\url{https://ntrs.nasa.gov/citations/19760026047}, 1976}}
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- Photographie :



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

```
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{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}

## 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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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

## 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

	unités	valeurs
<b>allongement</b>	[-]	3,9
<b>nombre d'aubes</b>	[-]	42
<b>vitesse de rotation</b>	[rad/s]	900

## Propriétés matériau

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

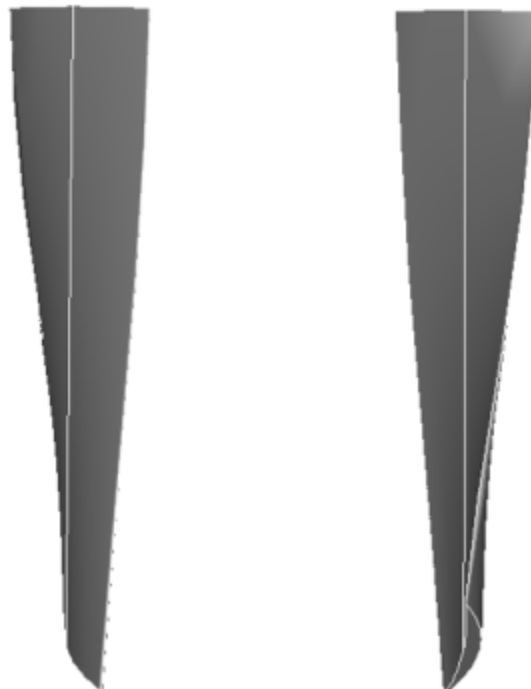
Propriétés considérées : alliage de titane Ti-6Al-4v :

	unité	valeurs
<b>alliage</b>	[-]	Ti-6Al-4v
<b>module d'Young</b>	[GPa]	108
<b>masse volumique</b>	[kg/m <sup>3</sup> ]	4400
<b>coefficient de Poisson</b>	[-]	0,34
<b>limite élastique</b>	[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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1. <sup>a, b</sup> Lewis. «Aerodynamic performance of a 1.20-pressure-ratio fan stage designed for low noise » 1976. [pdf](#)

Document issu de la page wiki:

[https://lava-wiki.meca.polymtl.ca/public/modeles/rotor\\_54/accueil?rev=1677304327](https://lava-wiki.meca.polymtl.ca/public/modeles/rotor_54/accueil?rev=1677304327)

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