

Rotor 66

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Original model

Rotor 66 is part of a 51 centimeter-diameter, five-stage compressor having a design weight flow of 29.7 kilograms per second with a pressure ratio of 9.27. Performance data obtained from tests indicated that the first stage was not meeting its design performance.

- Original technical report ^[1]:

```
@TechReport{urasek1976design,  
  author      = {Urasek, Donald C. and Steinke, Ronald J. and Lewis,  
George W.},  
  date        = {1976},  
  institution  = {NASA Lewis Research Center Cleveland, OH, United  
States},  
  title       = {Performance of inlet stage of transonic compressor},  
  number      = {NASA-TM X-3345},  
  url         = {https://ntrs.nasa.gov/citations/19760009935},  
}
```

- Picture :



Fig1. <https://catalog.archives.gov/id/17423368>

```
@Misc{brown1974records,  
  author   = {Brown, M.},  
  title     = {First stage rotor wheel from 5 stage compressor. {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/17423368}{https://catalog.archives.gov/  
id/17423368}, 1974 }, % for Fig. 1}
```

Useful documents

- [downloadable models](#) (Git project)
 - NASA technical report
(.pdf)
 - geometrical parameters file
(.csv), usable as input of OpenMCAD^[2] to generate reference blade models.

Reference blade

The **reference blade** is defined with multiple-circular arc profiles^[3] given in the original NASA report^[1]. Corresponding models are computed with the open-source code OpenMCAD^[2].

Geometry

[The geometry of rotor 66 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 66

RP	PERCENT RADII		BLADE ANGLES			DELTA INC	CONE ANGLE
	SPAN	RI RO	KIC	KTC	KOC		
TIP	0.	25.324 25.222	62.51	63.11	58.81	2.68	-3.238
1	5.	24.794 24.657	61.59	62.04	57.92	2.93	-4.225
2	10.	24.216 24.092	60.60	60.87	57.03	3.20	-3.688
3	20.	23.041 22.962	58.61	58.47	55.18	3.75	-2.213
4	30.	21.841 21.831	56.67	55.94	52.98	4.27	-0.268
5	38.	20.866 20.927	55.14	53.75	50.75	4.69	1.522
6	46.	19.878 20.023	53.63	51.48	48.06	5.07	3.444
7	50.	19.378 19.571	52.87	50.29	46.46	5.26	4.458
8	70.	16.811 17.310	48.96	44.21	35.52	6.08	10.070
9	80.	15.470 16.180	46.91	40.93	27.52	6.39	13.261
10	90.	14.079 15.049	44.75	37.49	17.34	6.59	16.722
11	95.	13.361 14.484	43.60	35.80	11.47	6.65	18.571
HUB	100.	12.700 13.919	42.52	34.26	5.34	6.68	19.462

RP	BLADE THICKNESSES			AXIAL DIMENSIONS			
	TI	TM	TO	ZIC	ZMC	ZTC	ZOC
TIP	0.025	0.115	0.025	0.808	1.689	1.936	2.604
1	0.028	0.126	0.028	0.778	1.688	1.910	2.636
2	0.030	0.138	0.030	0.746	1.687	1.879	2.667
3	0.035	0.161	0.035	0.681	1.684	1.809	2.730
4	0.041	0.184	0.041	0.615	1.680	1.726	2.795
5	0.044	0.202	0.044	0.561	1.677	1.650	2.852
6	0.048	0.218	0.048	0.505	1.672	1.565	2.913
7	0.050	0.227	0.050	0.476	1.670	1.518	2.946
8	0.059	0.265	0.059	0.320	1.650	1.244	3.130
9	0.062	0.282	0.062	0.226	1.635	1.075	3.237
10	0.066	0.298	0.066	0.117	1.616	0.879	3.347
11	0.068	0.305	0.068	0.057	1.606	0.772	3.399
HUB	0.069	0.312	0.069	0.000	1.596	0.672	3.450

Aerodynamic design

	unit	values
pressure ratio	[-]	1.61
mass flow	[kg/s]	29.7
tip speed	[m/s]	426
tip solidity	[-]	1.4
aspect ratio	[-]	3.1
number of blades	[-]	57
rotative speed	[rad/s]	1679.94

Material properties

The original material of the rotor 66 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

CAD model

The CAD model is computed with the open source code OpenMCAD^[2].



pressure side



suction side

Natural frequencies

First three natural frequencies (with clamped root) for the mesh computed with OpenMCAD^[2]:

Mode	Type	Natural angular frequency (rad/sec)	Natural frequency (Hz)
1	1B	1249.77	198.907
2	2B	4502.58	716.609
3	1T	7703.69	1226.08

Initial blade

The **initial blade** is defined with in-house LAVA parameters^[4] 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	1248.51	198.706
2	2B	4487.89	714.27
3	1T	7721.85	1228.97

- from the reduced order model:

Mode	Type	Natural angular frequency (rad/sec)	Natural frequency (Hz)
1	1B	1248.525	198.709
2	2B	4488.921	714.434
3	1T	7723.73	1229.27

Fichiers téléchargeables

x

Libre accès

[lien vers le projet Git](#)

Modèle original

Le rotor 66 fait partie d'un compresseur à cinq étages de 51 centimètres de diamètre ayant un débit nominal de 29,7 kilogrammes par seconde et un taux de compression de 9,27. Les données de performance obtenues lors de tests ont indiqué que le premier étage n'atteignait pas ses performances de conception.

- Rapport technique original ^[1]:

```
@TechReport{urasek1976design,
  author      = {Urasek, Donald C. and Steinke, Ronald J. and Lewis,
George W.},
  date        = {1976},
  institution = {NASA Lewis Research Center Cleveland, OH, United
States},
  title       = {Performance of inlet stage of transonic compressor},
  number      = {NASA-TM X-3345},
  url         = {https://ntrs.nasa.gov/citations/19760009935},
```

```
comment      = {rotor66},  
}
```

- Photographie :



Fig1. <https://catalog.archives.gov/id/17423368>

```
@Misc{brown1974records,  
author   = {Brown, M.},  
title    = {First stage rotor wheel from 5 stage compressor. {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 -  
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note     =  
{\href{https://catalog.archives.gov/id/17423368}{https://catalog.archives.gov/  
id/17423368}, 1974 }, % for Fig. 1}
```

Documents utiles

- [modèles téléchargeables](#) (lien vers projet Git)
 - rapport technique original de la NASA (.pdf)
 - fichier de paramètres géométriques (.csv), utilisable en entrée de OpenMCAD^[2] pour générer l'aube de référence

Aube de référence

L'**aube de référence** est définie par des profils de type arcs circulaires multiples^[3], donnés dans le rapport technique original de la NASA^[1]. Les modèles associés sont obtenus avec le code en libre accès OpenMCAD^[2].

Géométrie

La géométrie du rotor 66 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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4	30.	21.841	21.831		56.67	55.94	52.98	4.27	-0.268
5	38.	20.866	20.927		55.14	53.75	50.75	4.69	1.522
6	46.	19.878	20.023		53.63	51.48	48.06	5.07	3.444
7	50.	19.378	19.571		52.87	50.29	46.46	5.26	4.458
8	70.	16.811	17.310		48.96	44.21	35.52	6.08	10.070
9	80.	15.470	16.180		46.91	40.93	27.52	6.39	13.261
10	90.	14.079	15.049		44.75	37.49	17.34	6.59	16.722
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1	0.028	0.126	0.028	0.778	1.688	1.910	2.636
2	0.030	0.138	0.030	0.746	1.687	1.879	2.667
3	0.035	0.161	0.035	0.681	1.684	1.809	2.730
4	0.041	0.184	0.041	0.615	1.680	1.726	2.795
5	0.044	0.202	0.044	0.561	1.677	1.650	2.852
6	0.048	0.218	0.048	0.505	1.672	1.565	2.913
7	0.050	0.227	0.050	0.476	1.670	1.518	2.946
8	0.059	0.265	0.059	0.320	1.650	1.244	3.130
9	0.062	0.282	0.062	0.226	1.635	1.075	3.237
10	0.066	0.298	0.066	0.117	1.616	0.879	3.347
11	0.068	0.305	0.068	0.057	1.606	0.772	3.399
HUB	0.069	0.312	0.069	0.000	1.596	0.672	3.450

Caractéristiques aérodynamiques

	unités	valeurs
taux de compression	[-]	1,61
débit massique	[kg/s]	29,7
vitesse en tête	[m/s]	426
solidité en tête	[-]	1,4
allongement	[-]	3,1
nombre d'aubes	[-]	57
vitesse de rotation	[rad/s]	1679,94

Propriétés matériau

Le matériau original du rotor 66 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

Modèle CAO

Le modèle CAO est obtenu avec OpenMCAD^[2].

intrados



extrados

Fréquences propres

Fréquences des trois premiers modes (noeuds du pied d'aube encastres) pour le maillage obtenu avec OpenMCAD^[2] :

Mode	Type	Pulsation propre (rad/sec)	Fréquence propre (Hz)
1	1B	1249,77	198,907
2	2B	4502,58	716,609
3	1T	7703,69	1226,08

Aube initiale

L'**aube initiale** est définie par des paramètres spécifiques au LAVA^[4] obtenus à partir du modèle CAO de l'aube de référence. L'aube initiale est classiquement utilisée comme point de départ dans le cadre de procédures d'optimisation; sa géométrie est similaire à celle de l'aube de référence.

Fréquences propres

Fréquences des trois premiers modes (noeuds du pied d'aube encastres),

- pour le maillage complet :

Mode	Type	Pulsation propre (rad/sec)	Fréquence propre (Hz)
1	1B	1248,51	198,706
2	2B	4487,89	714,27
3	1T	7721,85	1228,97

- pour le modèle réduit :

Mode	Type	Pulsation propre (rad/sec)	Fréquence propre (Hz)
1	1B	1248,525	198,709
2	2B	4488,921	714,434
3	1T	7723,73	1229,27

1. ^{a, b, c, d} Urasek. «Performance of inlet stage of transonic compressor» 1976 [pdf](#)
2. ^{a, b, c, d, e, f, g, h} Kojtych S., Batailly A. «OpenMCAD, an open blade generator: from Multiple-Circular-Arc profiles to Computer-Aided Design model» 2022. [code en libre accès](#)
3. ^{a, b} Crouse et al. «A computer program for composing compressor blading from simulated circular-arc elements on conical surfaces » 1969. NASA-TN-D-5437. [pdf](#)
4. ^{a, b} Kojtych S. et al. «Methodology for the Redesign of Compressor Blades Undergoing Nonlinear Structural Interactions: Application to Blade-Tip/Casing Contacts » 2022. Journal of Engineering for Gas Turbines and Power, Vol. 145, No. 5. [pdf](#)

Document issu de la page wiki:

https://lava-wiki.meca.polymtl.ca/public/modeles/rotor_66/accueil?rev=1680388065

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