SUSTech Southern University of Science and Technology

MAE307 Final Project Report, 04 Jan 2023

FEM Analysis For Model Plane Propellers

邹佳驹

Department of Mechanics and Aerospace Engineering

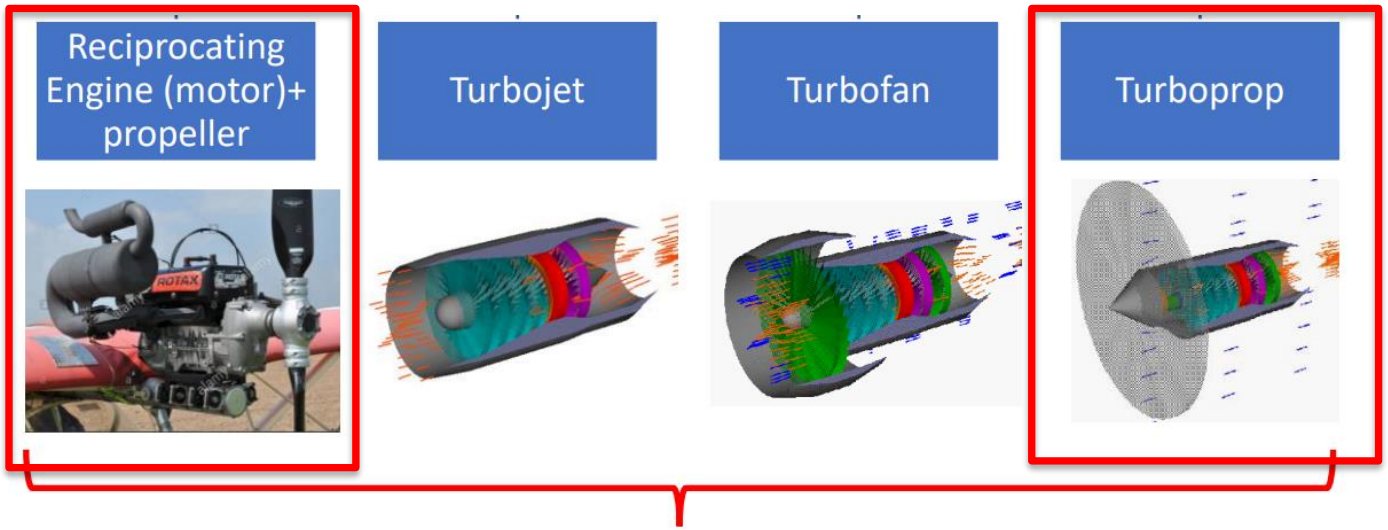
Southern University of Science and Technology

04 Jan 2023

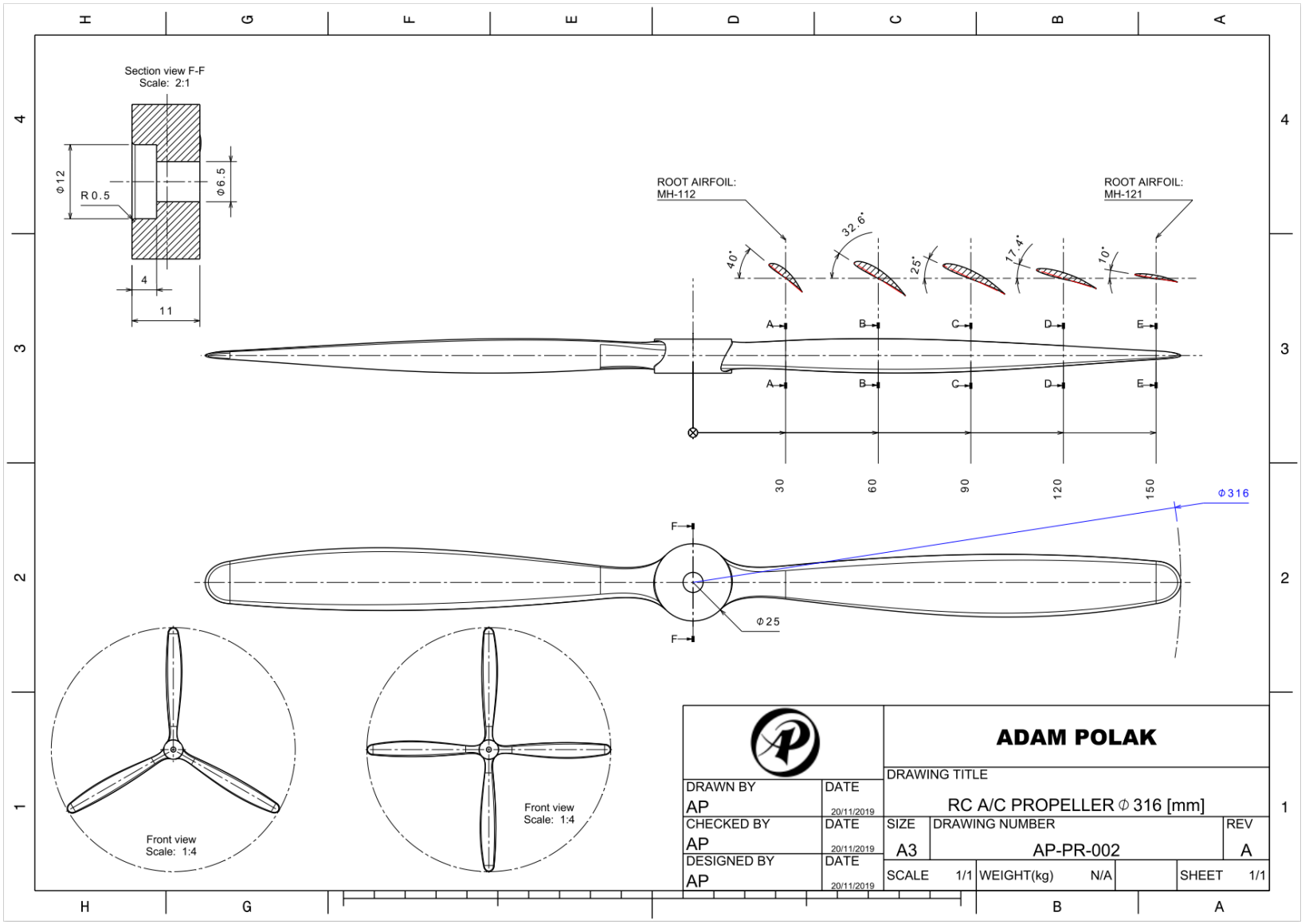
Contents

Analysis Background

A propeller is a device that relies on the rotation of the propeller blades in the air or water to convert the power of engine rotation into propulsion.



Model Setting



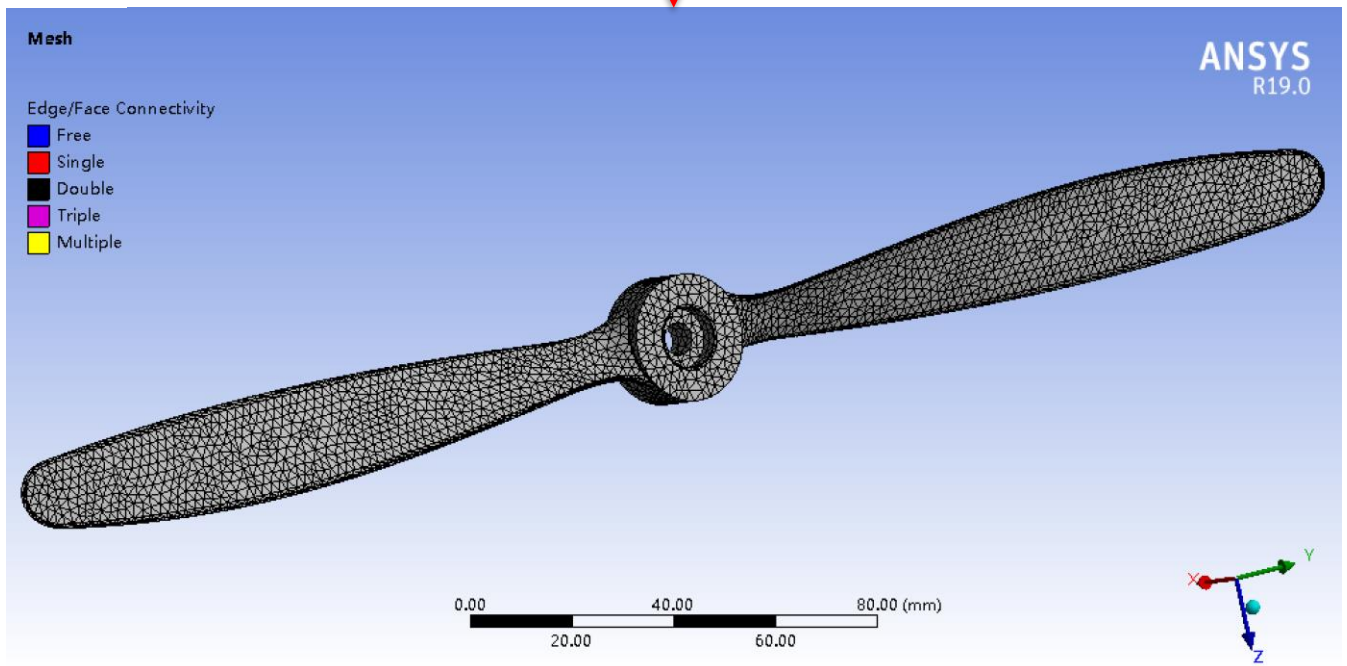
Simulation Goal

- **Stress distribution and deformation**
- **Frequency of the propeller**
- **Failure and life of the propeller**
- **The effect of the number of blades**

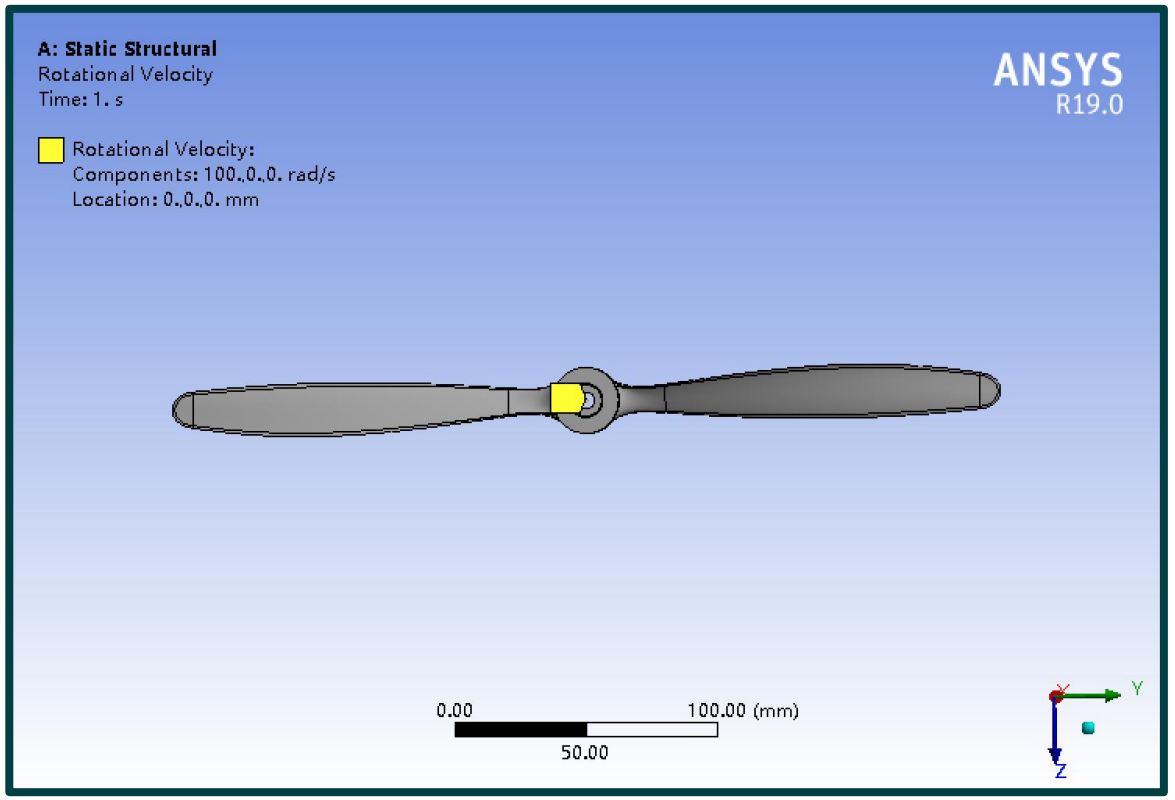
[PROPELLER AP-PR-002 | 3D CAD Model Library | GrabCAD]

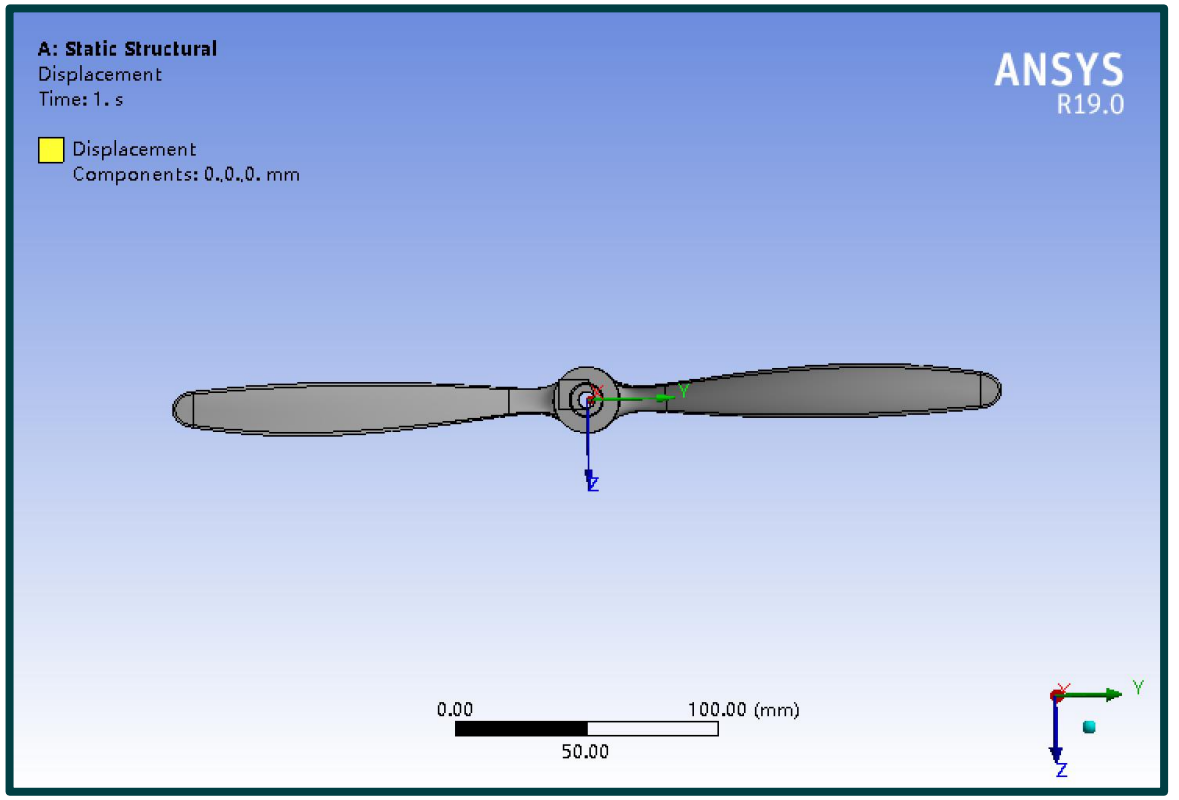
Mesh Sizing

M.S (mm)	Nodes	Elements	Max Deformation (mm)	Max Stress (MPa)
10	5118	2609	0.013874	2.3552
8	5405	2738	0.014101	2.3277
5	8102	4033	0.014955	2.4573
4	10618	5255	0.015074	2.5392
3	16067	8254	0.015092	2.5088
2	36066	20166	0.015102	2.5563
1	195453	124673	0.015103	2.6811
0.5	1378341	948524	0.015093	2.6165

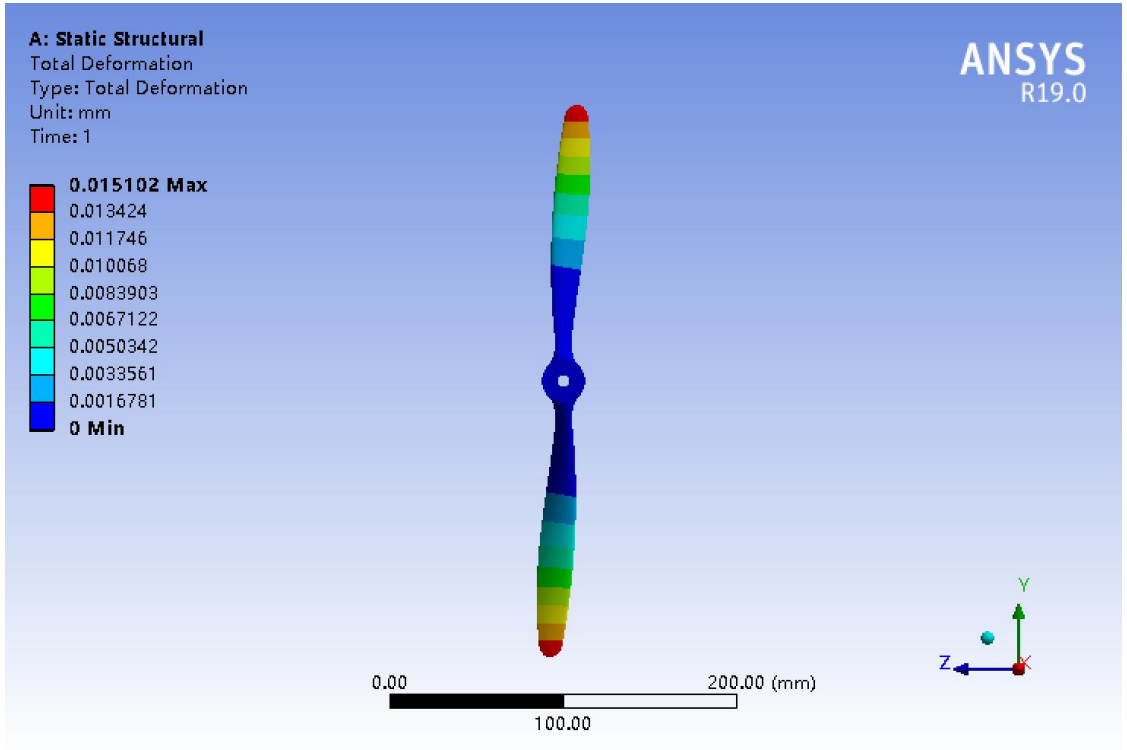


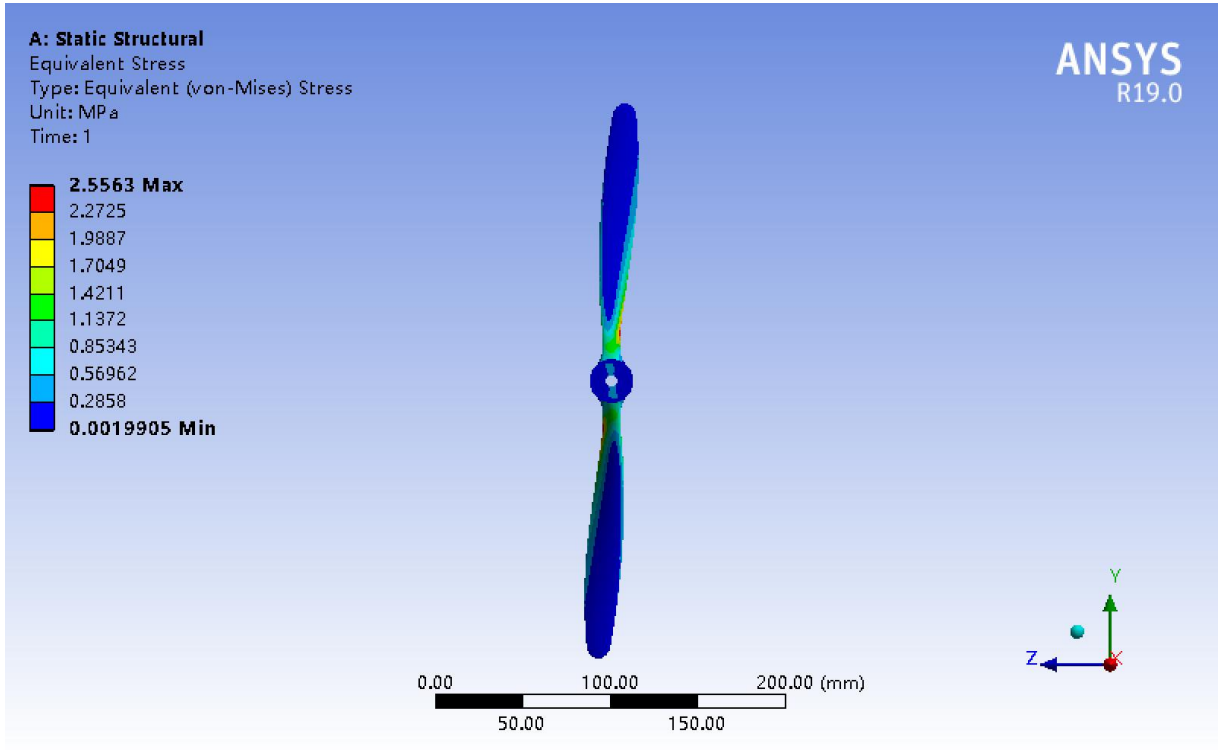
Boundary Condition



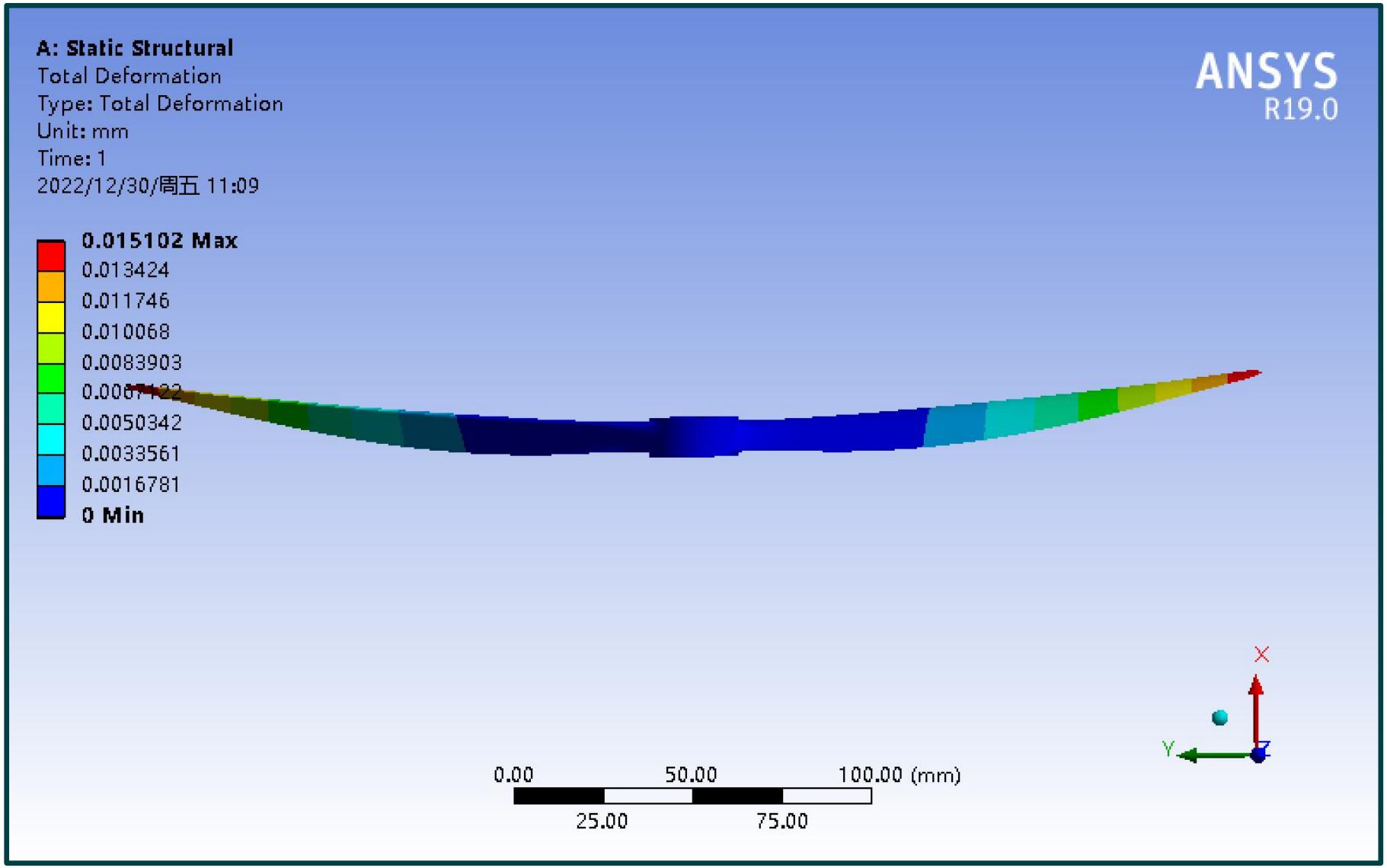


Static Results

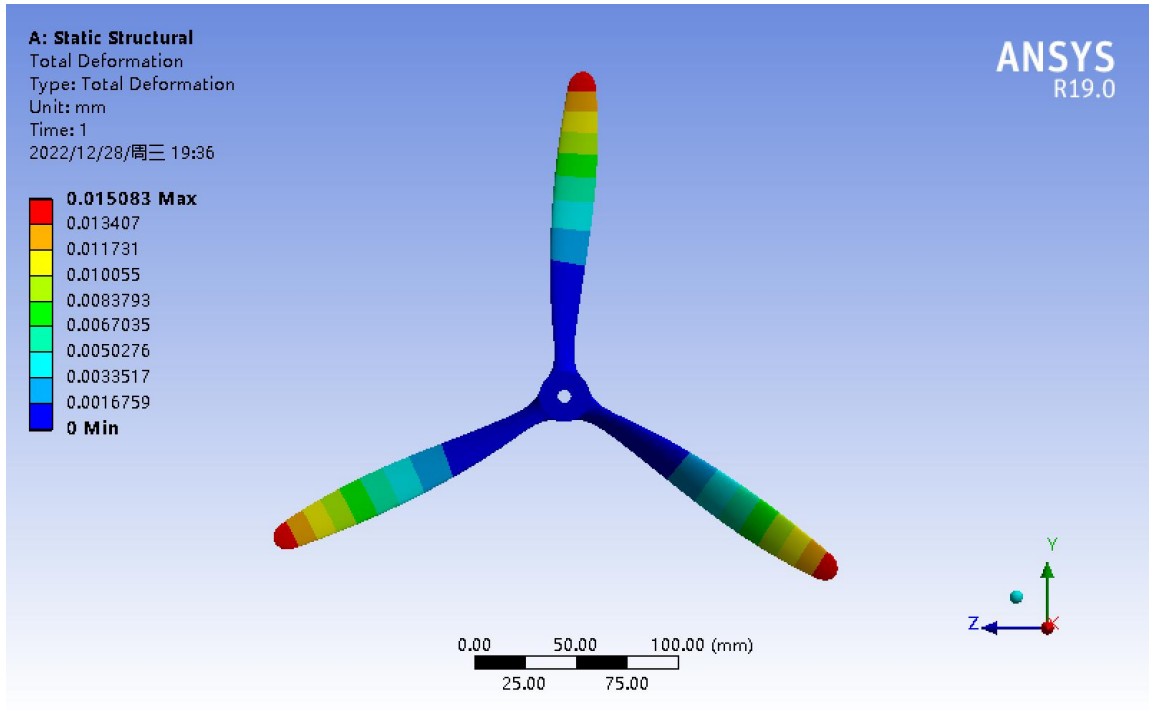


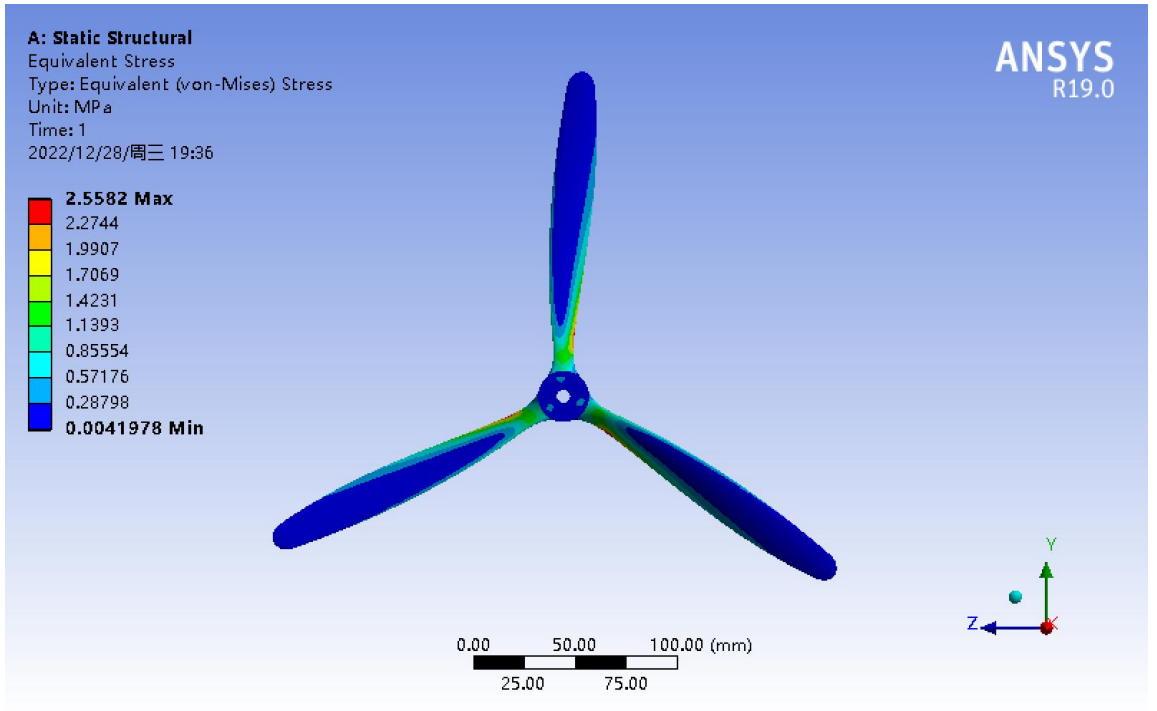


Static Results

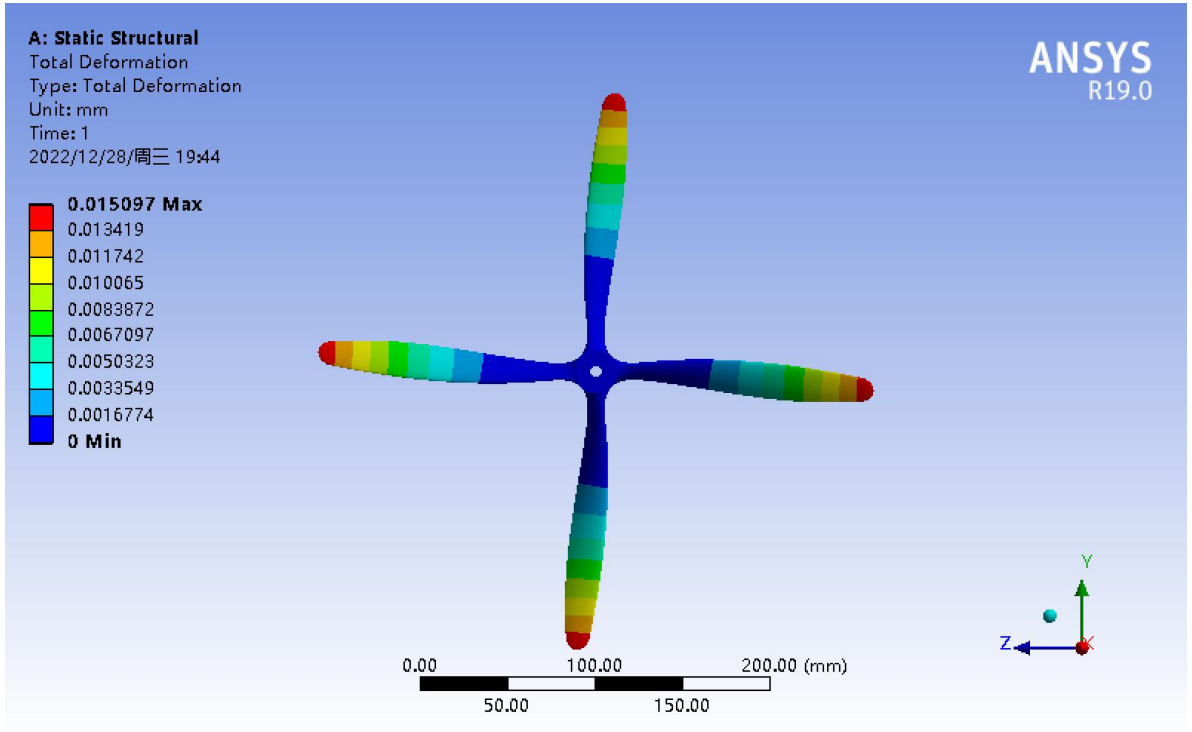


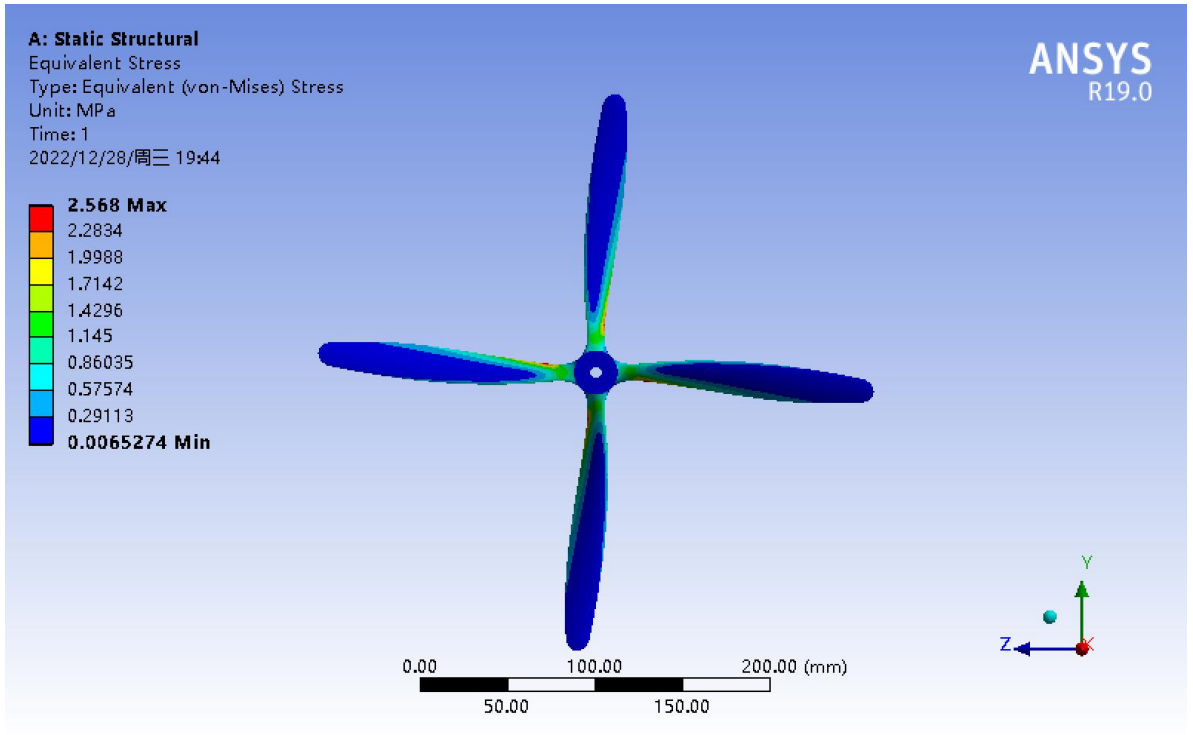
Static Results





Static Results



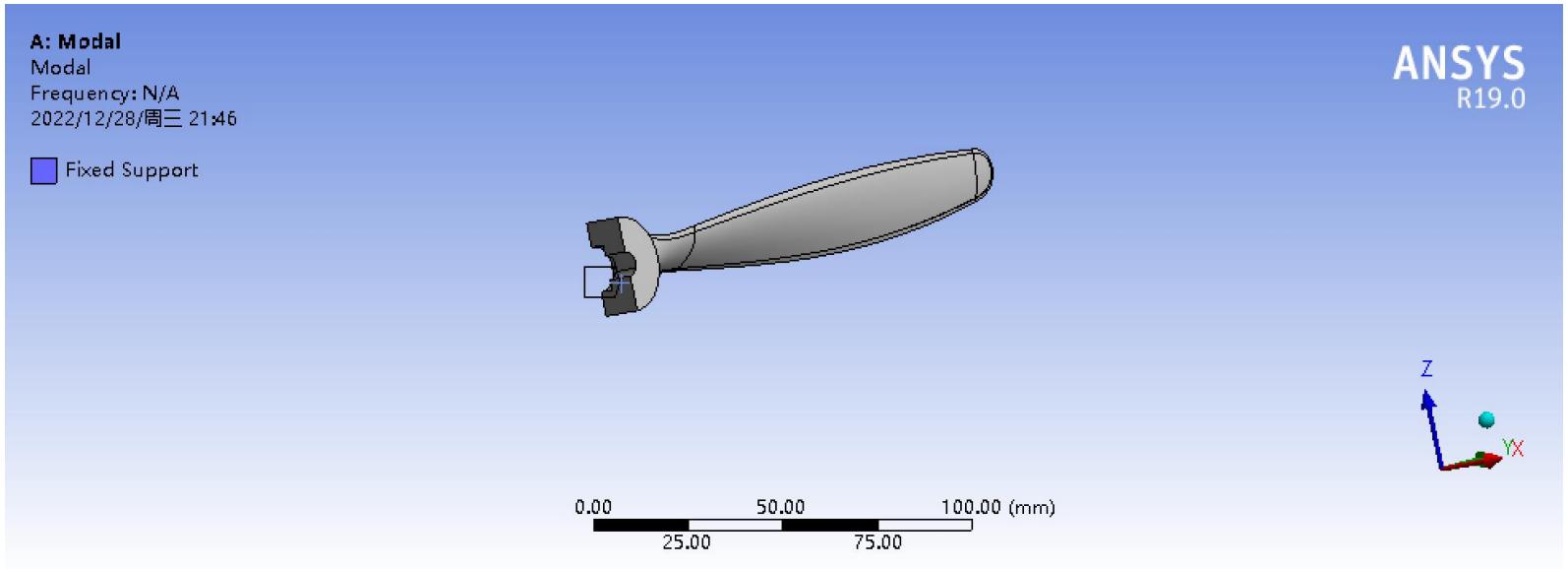


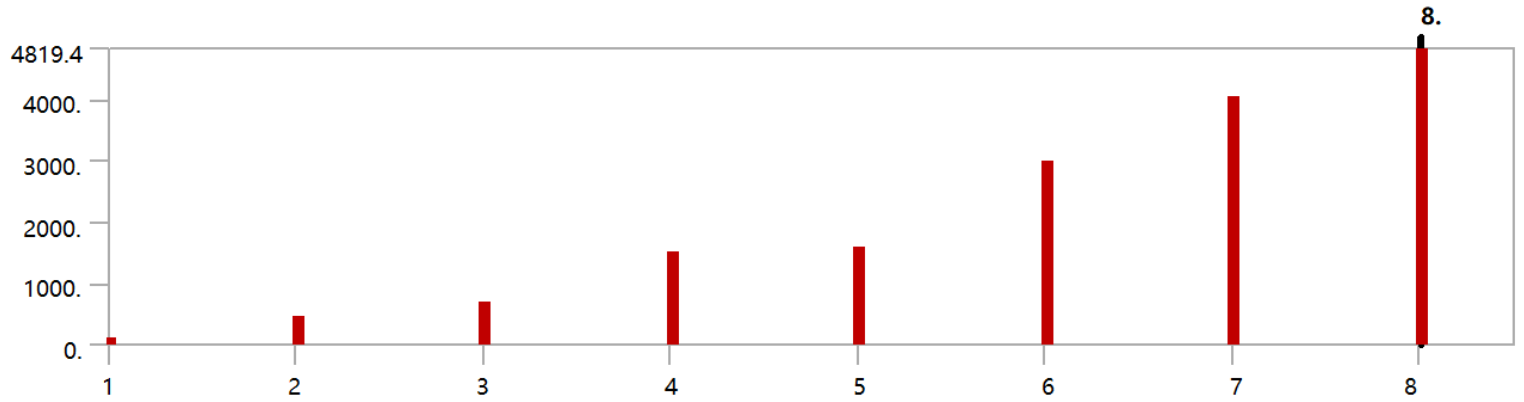
Static Results

Blades	Max Deformation (mm)	Max Stress (MPa)	Min Stress (Mpa)
2	0.015102	2.5563	0.0019905
3	0.015083	2.5582	0.0041978
4	0.015097	2.5680	0.0065274

- **The root of the blade is enduring a large stress.**
- **And the largest deformation occur at the tip of the blade.**
- **Min stress increases with more blades at same rotational velocity.**

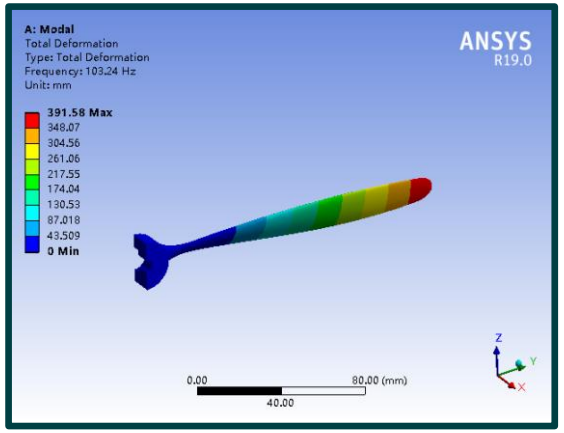
Modal Analysis



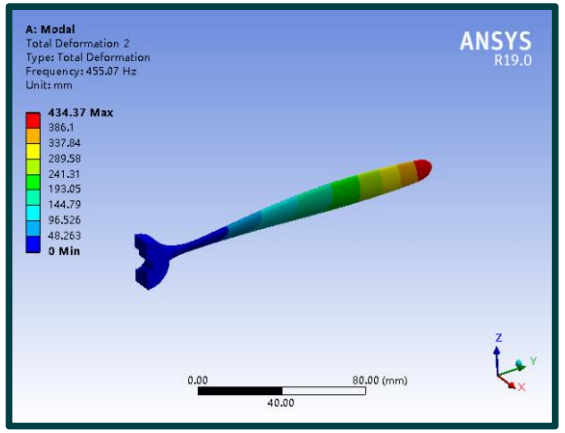


	Mode	Frequency [Hz]
1	1.	103.3
2	2.	456.33
3	3.	708.94
4	4.	1531.9
5	5.	1581.3
6	6.	2976.3
7	7.	4025.
8	8.	4819.4

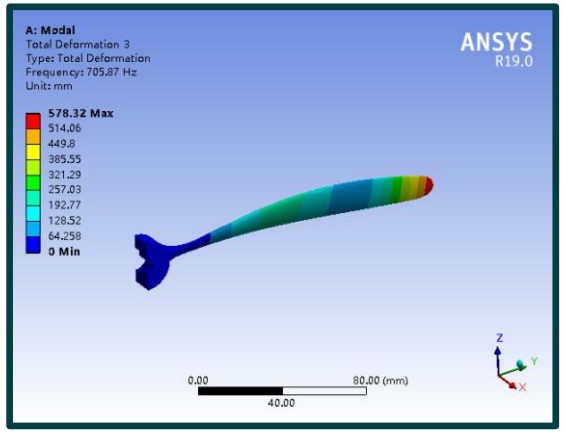
Modal Analysis



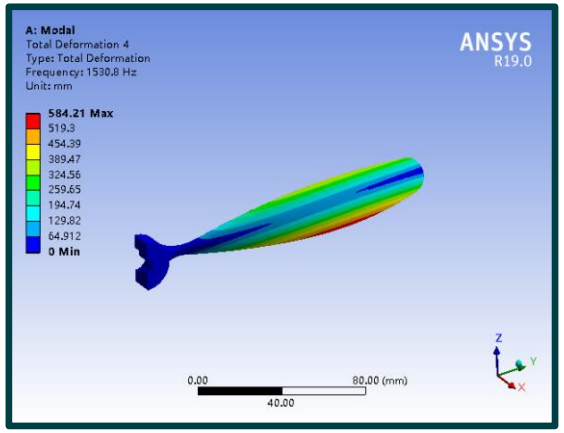
Mode 1



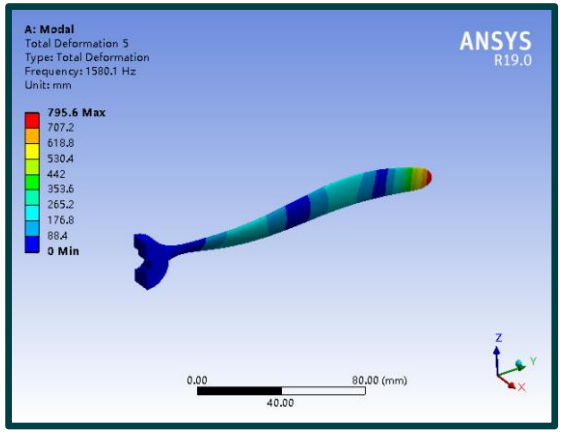
Mode 2



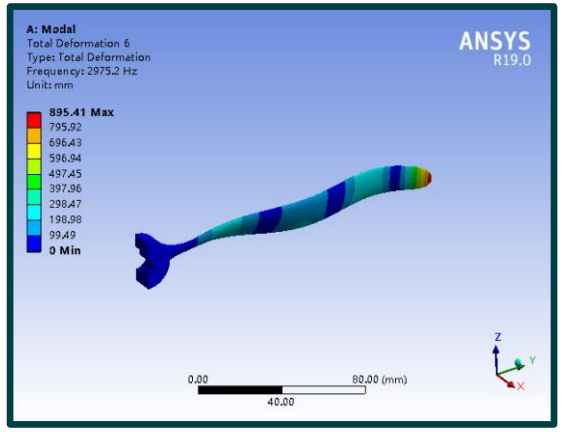
Mode 3



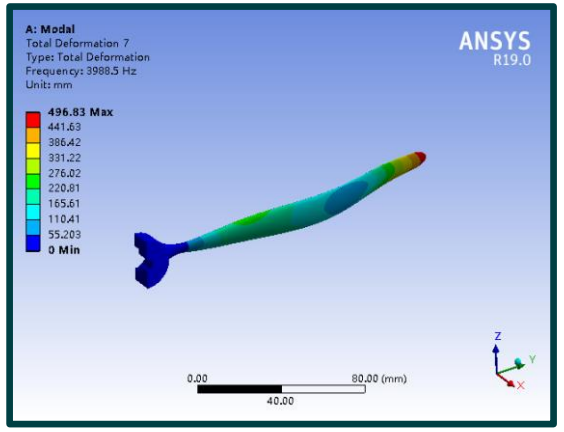
Mode 4



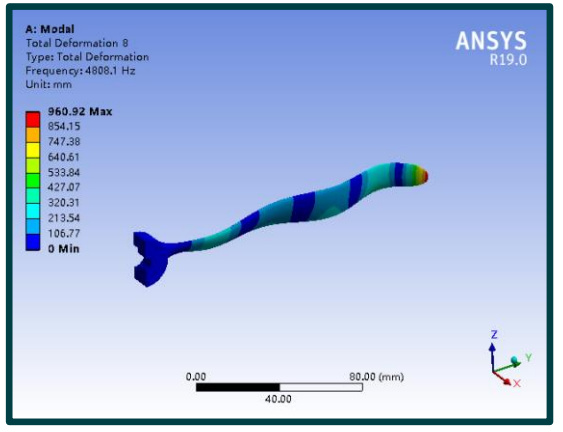
Mode 5



Mode 6

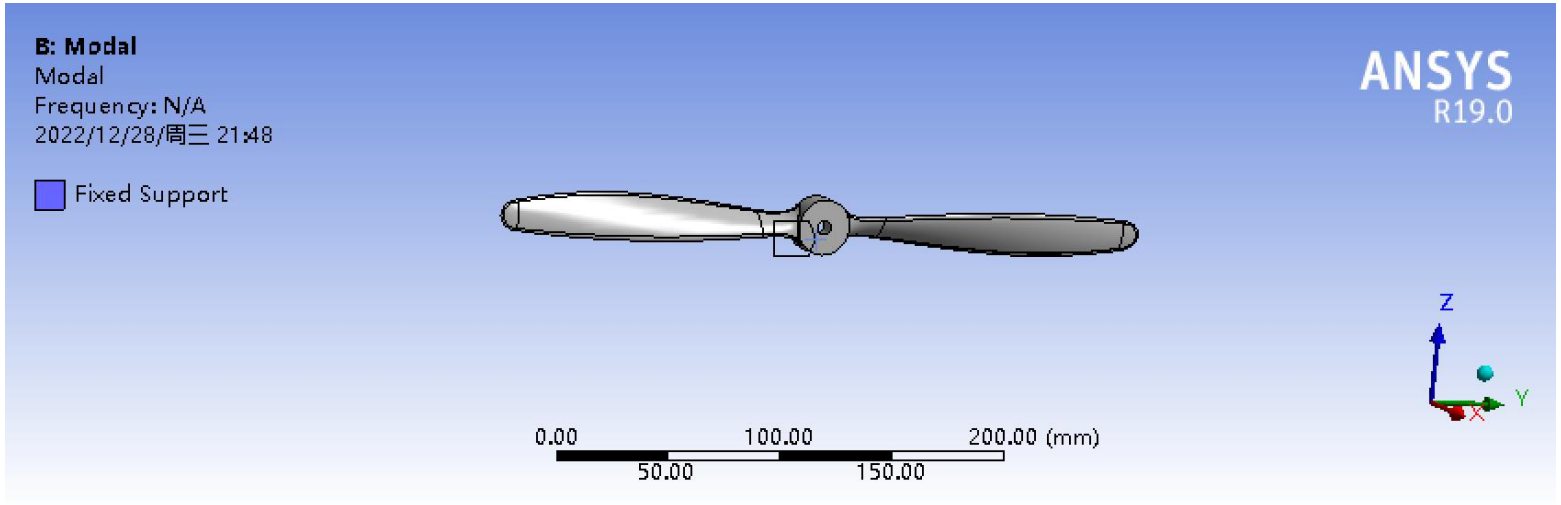


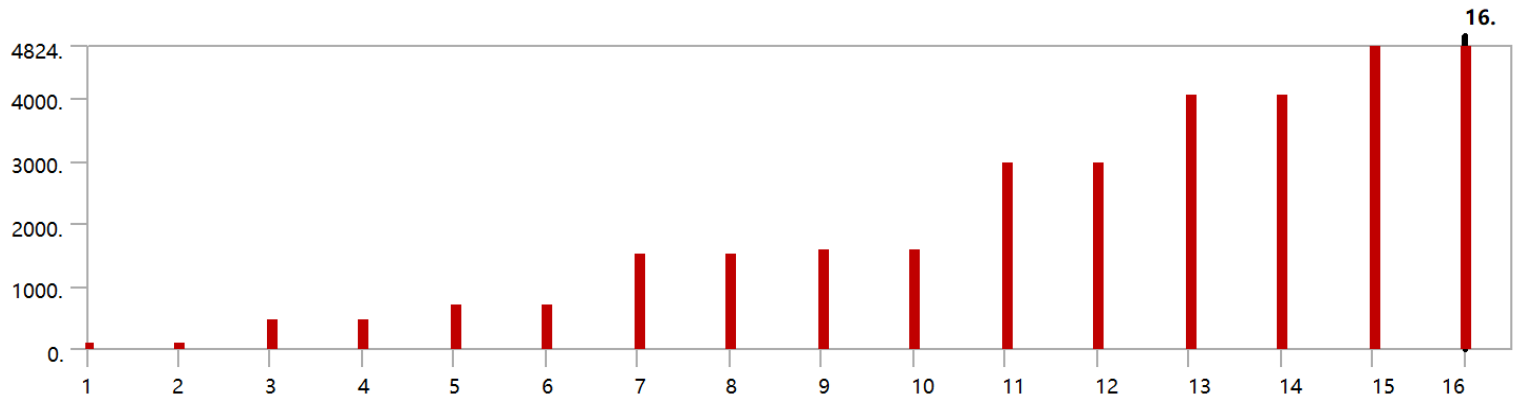
Mode 7



Mode 8

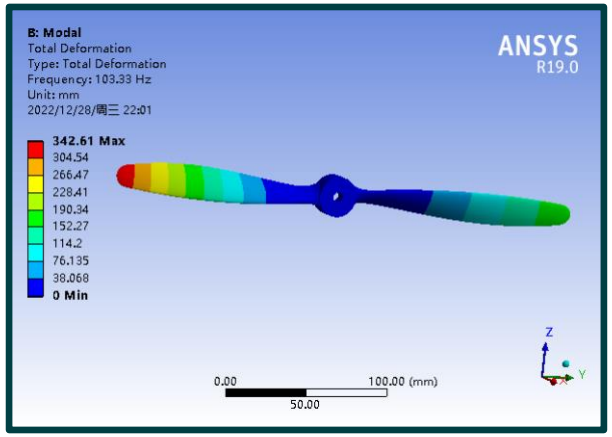
Modal Analysis



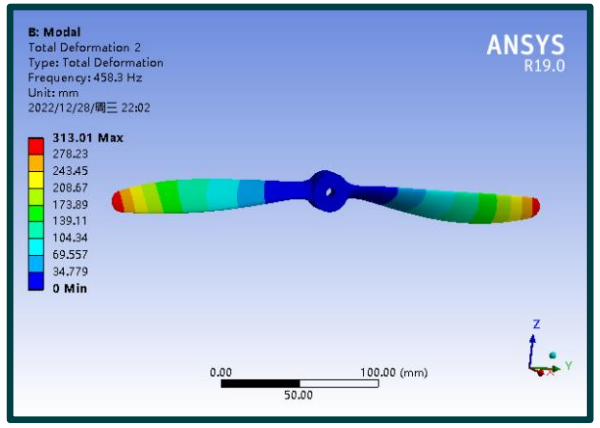


	Mode	Frequency [Hz]
1	1.	103.33
2	2.	103.33
3	3.	458.01
4	4.	458.3
5	5.	710.02
6	6.	710.44
7	7.	1532.
8	8.	1532.
9	9.	1581.8
10	10.	1581.9
11	11.	2977.1
12	12.	2977.9
13	13.	4044.
14	14.	4045.2
15	15.	4822.6
16	16.	4824.

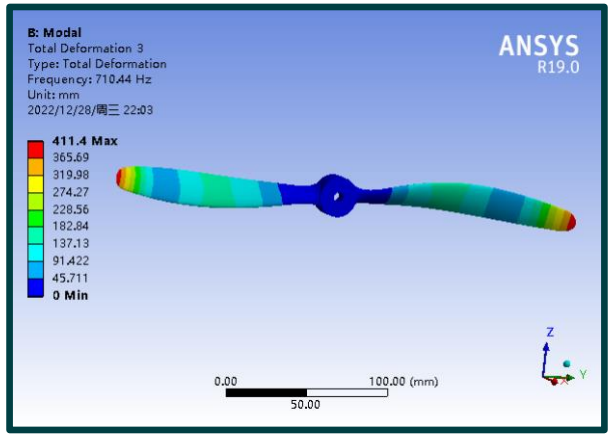
Modal Analysis



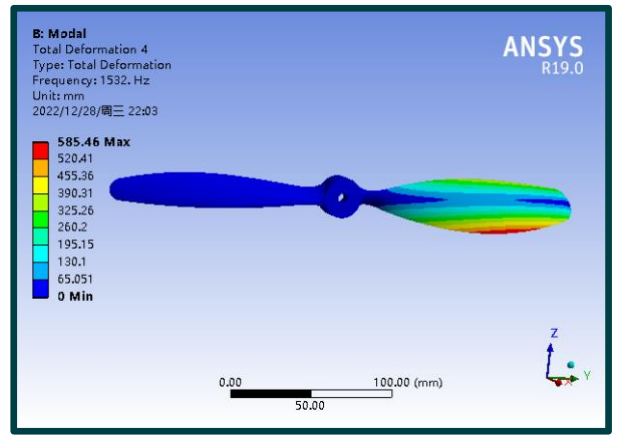
Mode 2



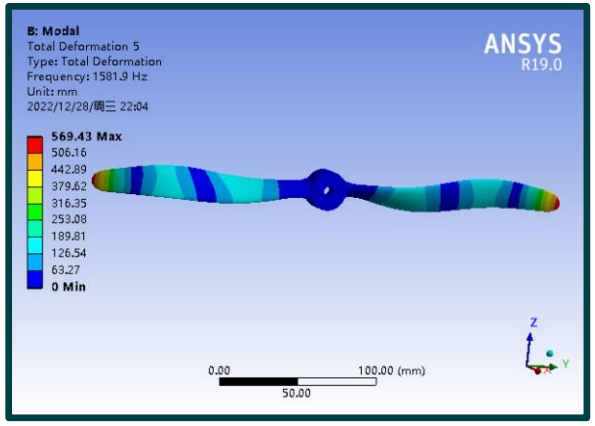
Mode 4



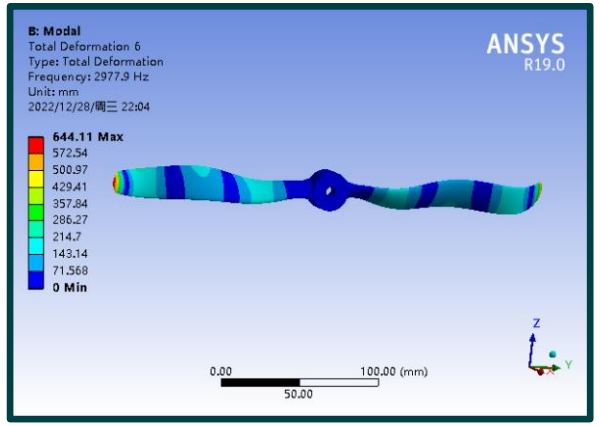
Mode 6



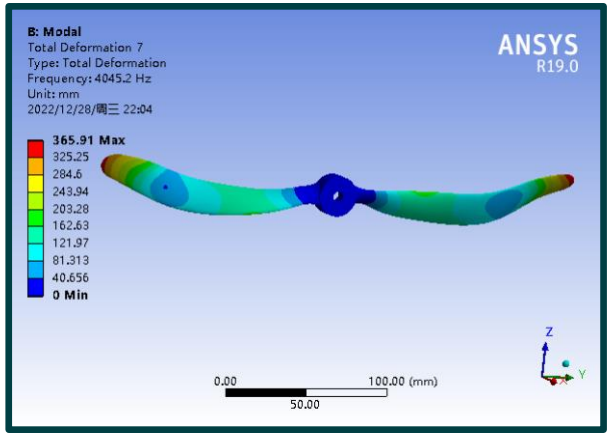
Mode 8



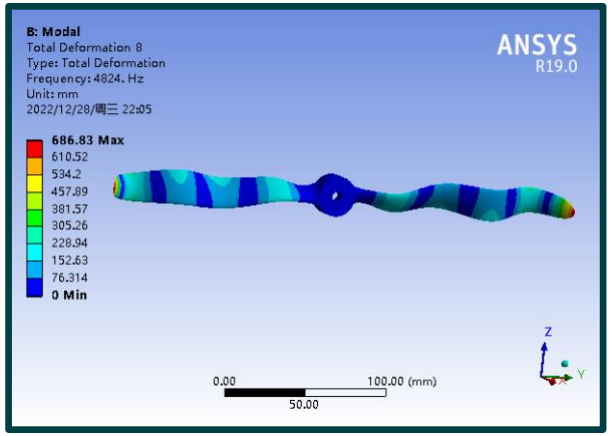
Mode 10



Mode 12

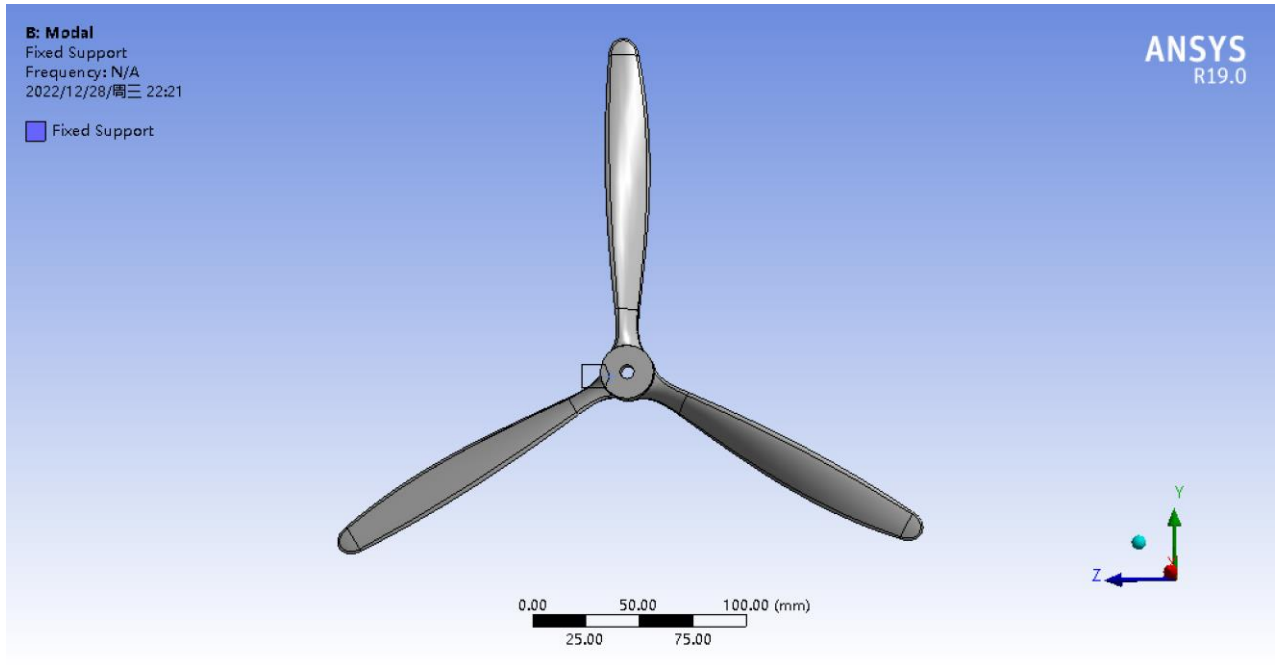


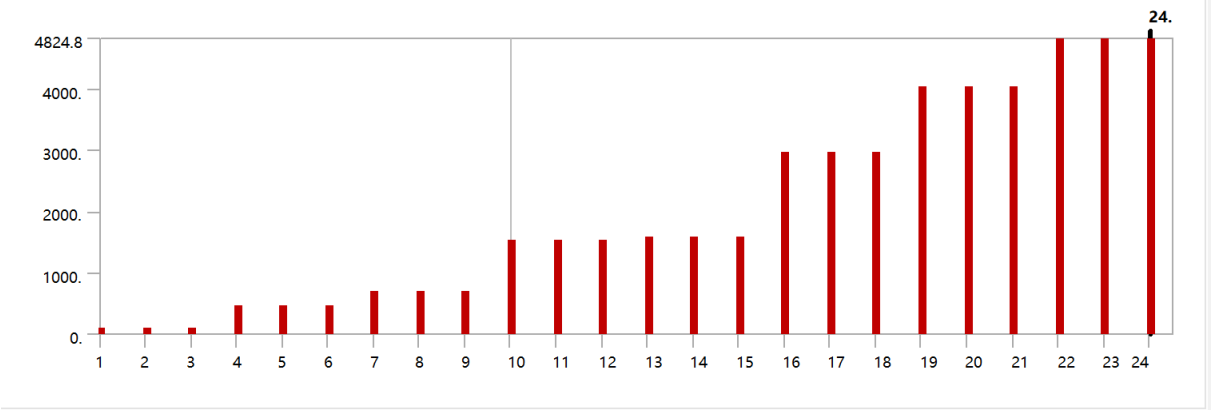
Mode 14



Mode 16

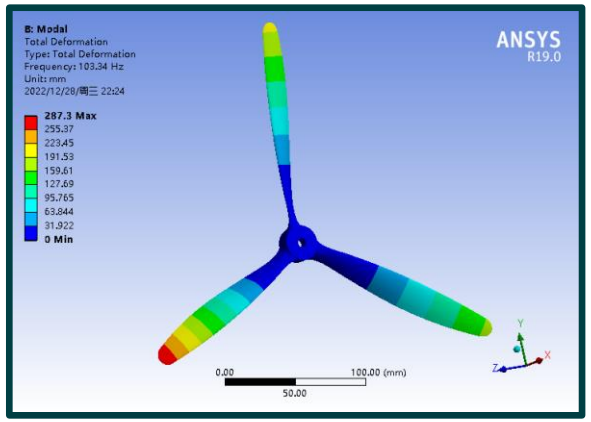
Modal Analysis



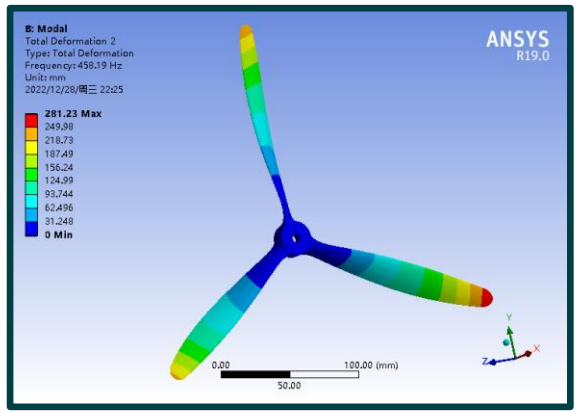


	Mode	Frequency [Hz]
1	1.	103.32
2	2.	103.33
3	3.	103.34
4	4.	458.15
5	5.	458.16
6	6.	458.19
7	7.	709.98
8	8.	710.
9	9.	710.7
10	10.	1531.9
11	11.	1531.9
12	12.	1532.
13	13.	1581.8
14	14.	1581.8
15	15.	1581.8
16	16.	2976.9
17	17.	2977.8
18	18.	2977.8
19	19.	4044.1
20	20.	4045.1
21	21.	4045.1
22	22.	4822.6
23	23.	4822.6
24	24.	4824.8

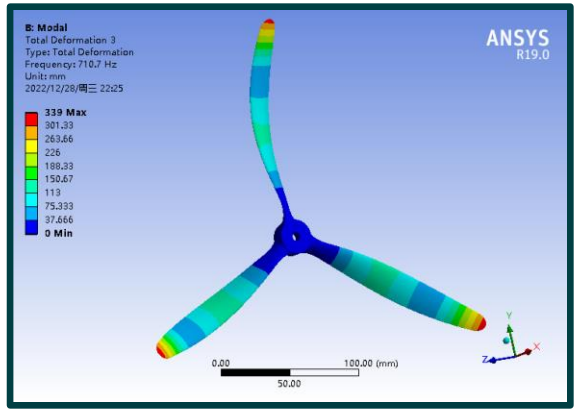
Modal Analysis



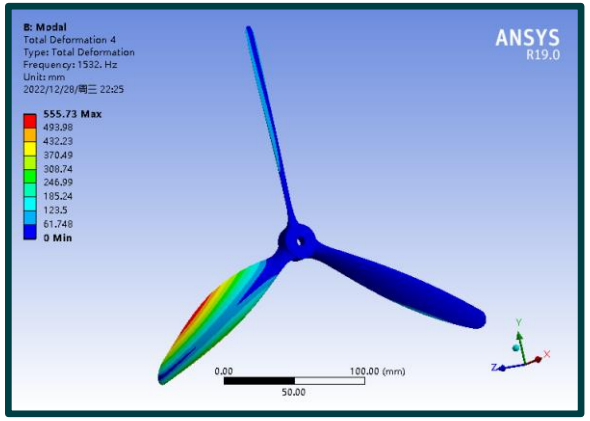
Mode 3



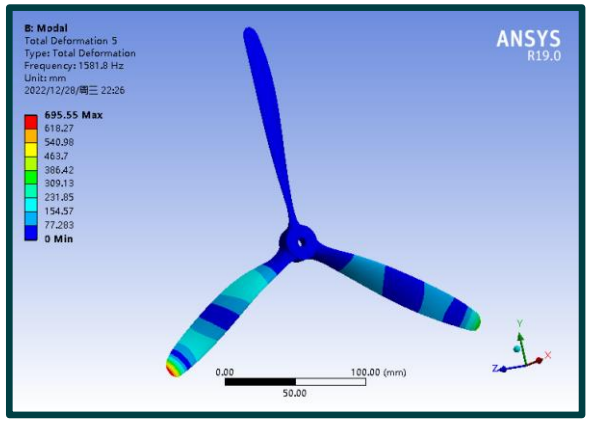
Mode 6



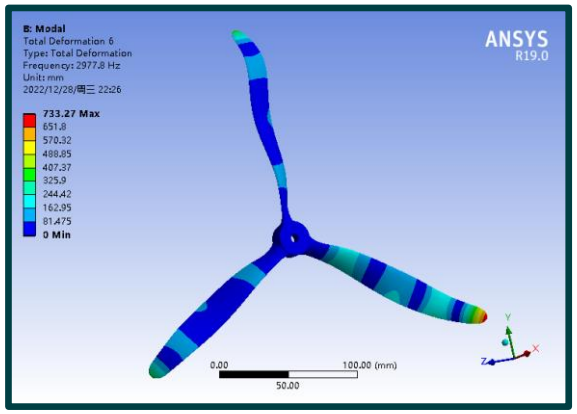
Mode 9



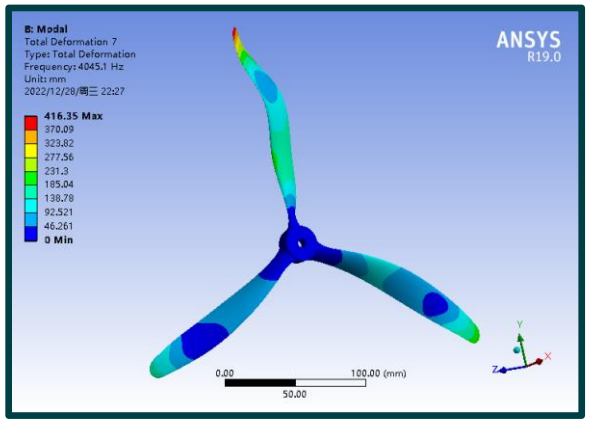
Mode 12



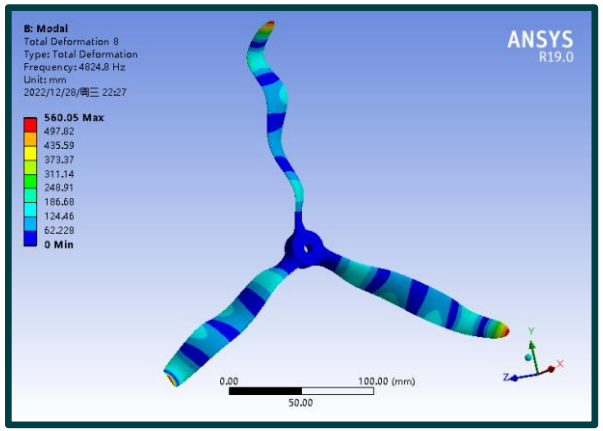
Mode 15



Mode 18

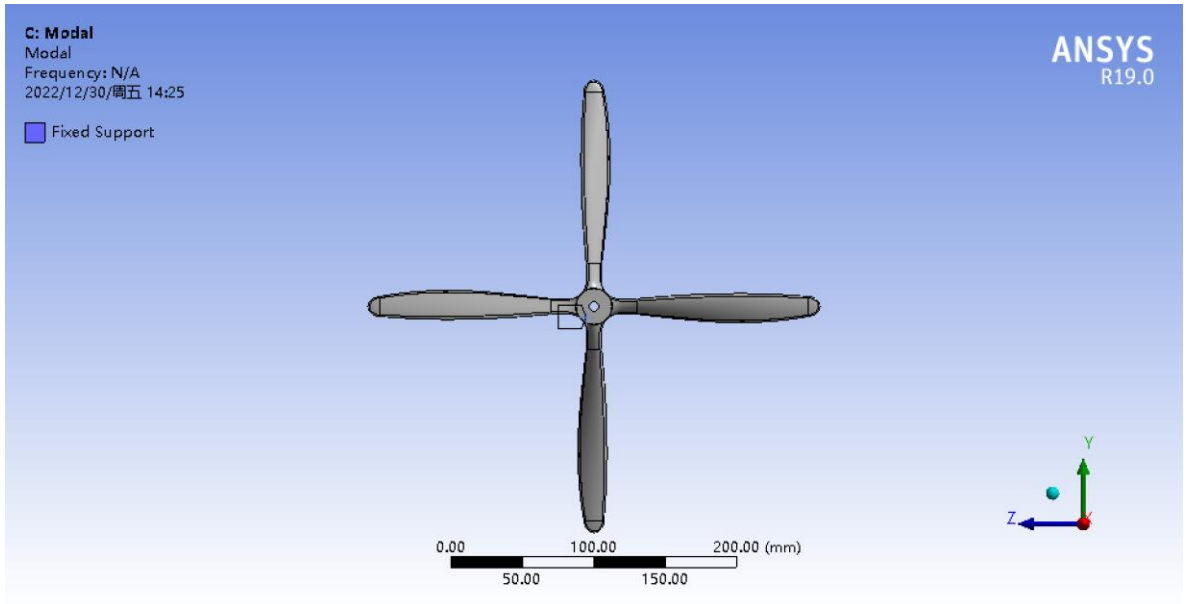


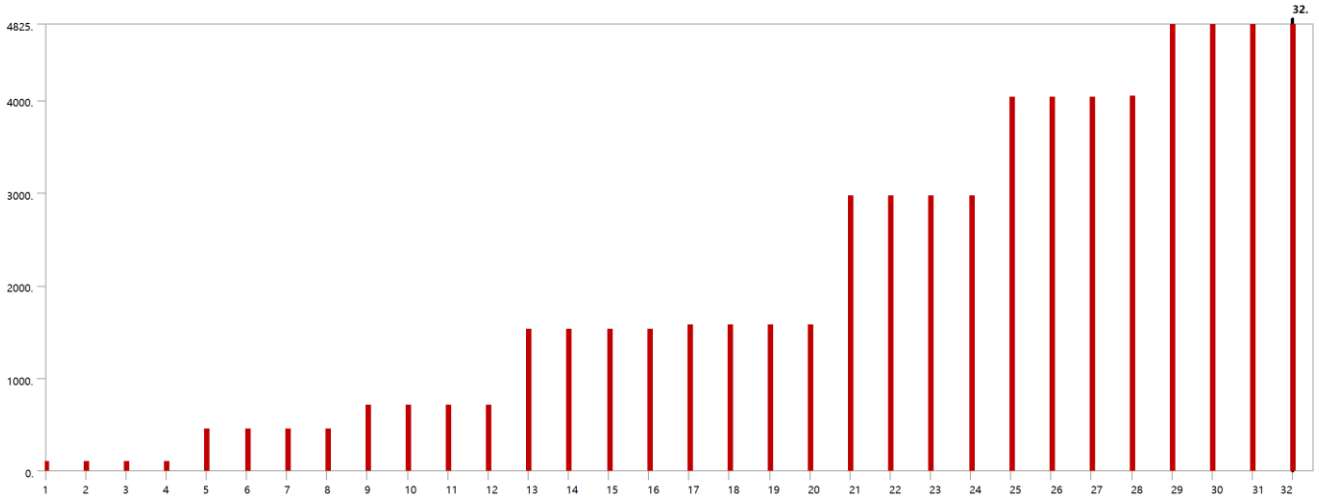
Mode 21



Mode 24

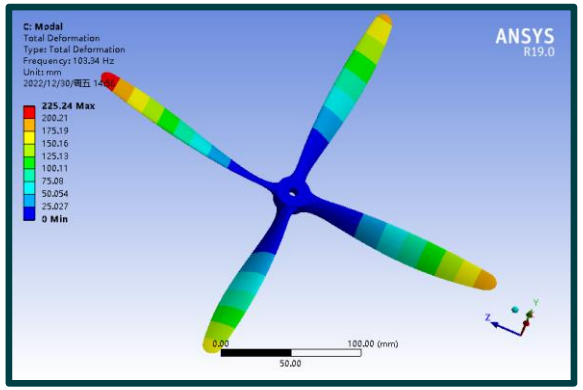
Modal Analysis



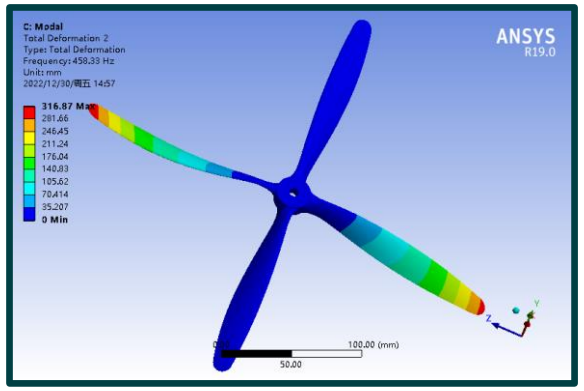


	Mode	Frequency [Hz]
1	1.	103.32
2	2.	103.33
3	3.	103.33
4	4.	103.34
5	5.	457.94
6	6.	458.15
7	7.	458.33
8	8.	458.33
9	9.	710.02
10	10.	710.05
11	11.	710.11
12	12.	710.78
13	13.	1531.9
14	14.	1531.9
15	15.	1532.
16	16.	1532.1
17	17.	1581.8
18	18.	1581.8
19	19.	1581.9
20	20.	1581.9
21	21.	2976.6
22	22.	2977.7
23	23.	2977.9
24	24.	2977.9
25	25.	4041.7
26	26.	4045.5
27	27.	4045.5
28	28.	4047.2
29	29.	4822.7
30	30.	4822.7
31	31.	4823.1
32	32.	4825.

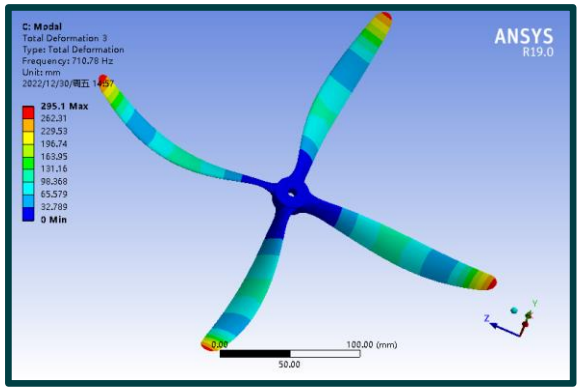
Modal Analysis



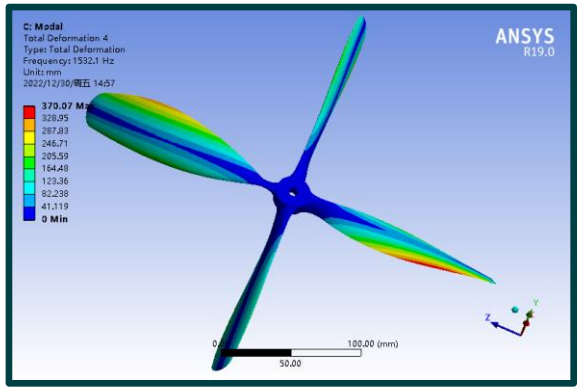
Mode 4



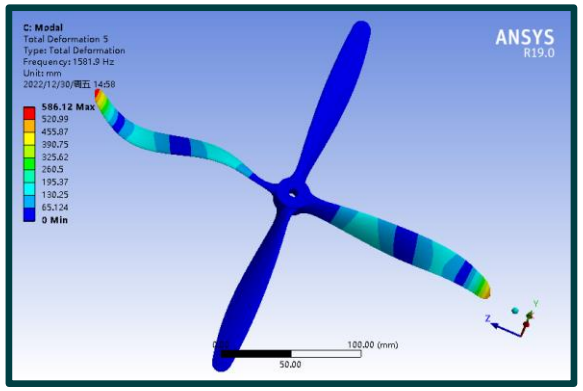
Mode 8



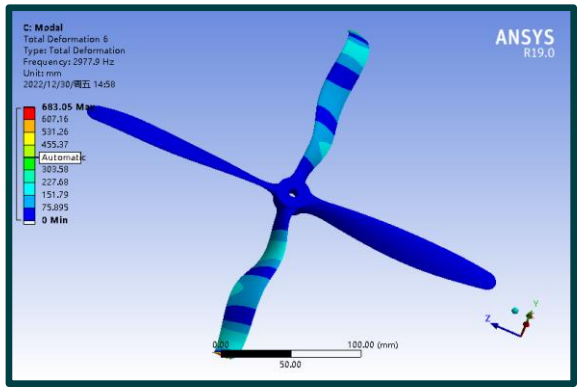
Mode 12



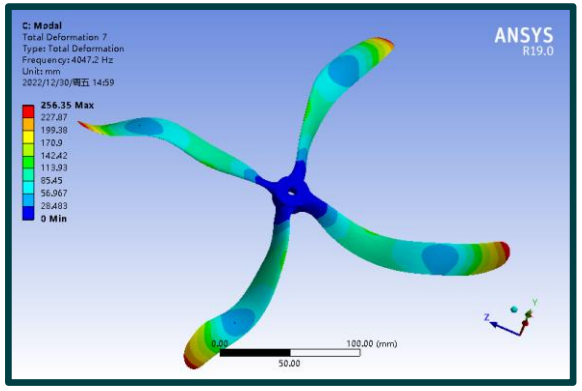
Mode 16



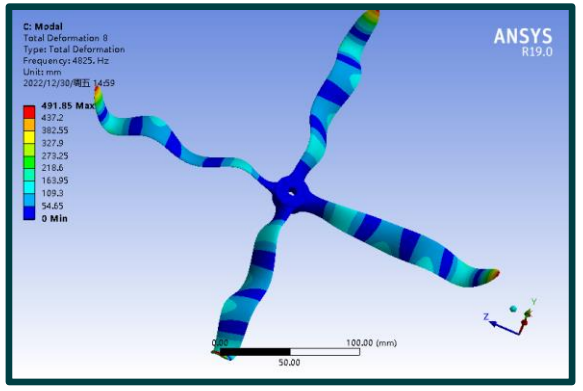
Mode 20



Mode 24

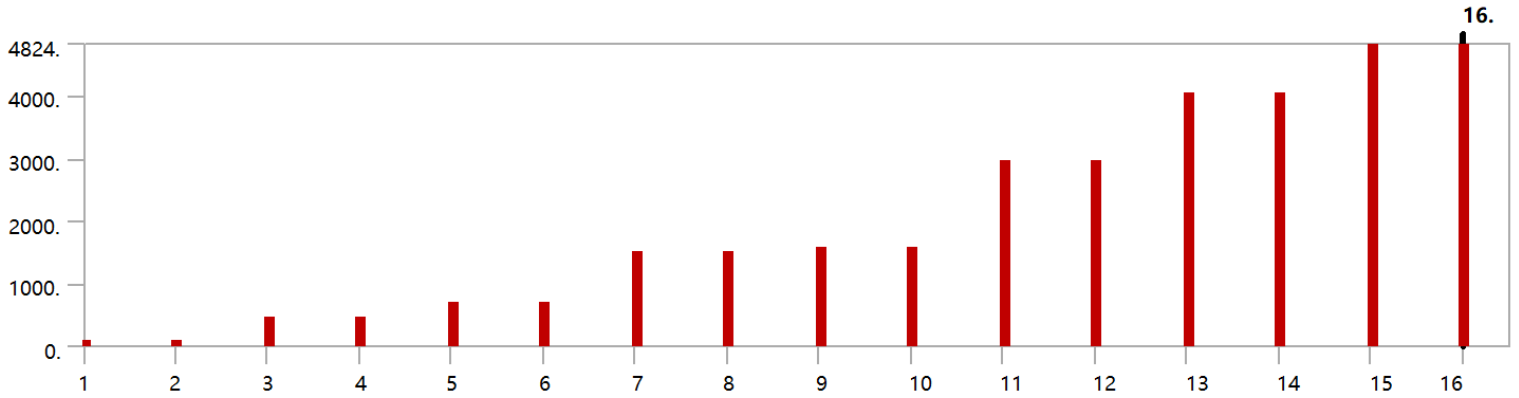


Mode 28



Mode 32

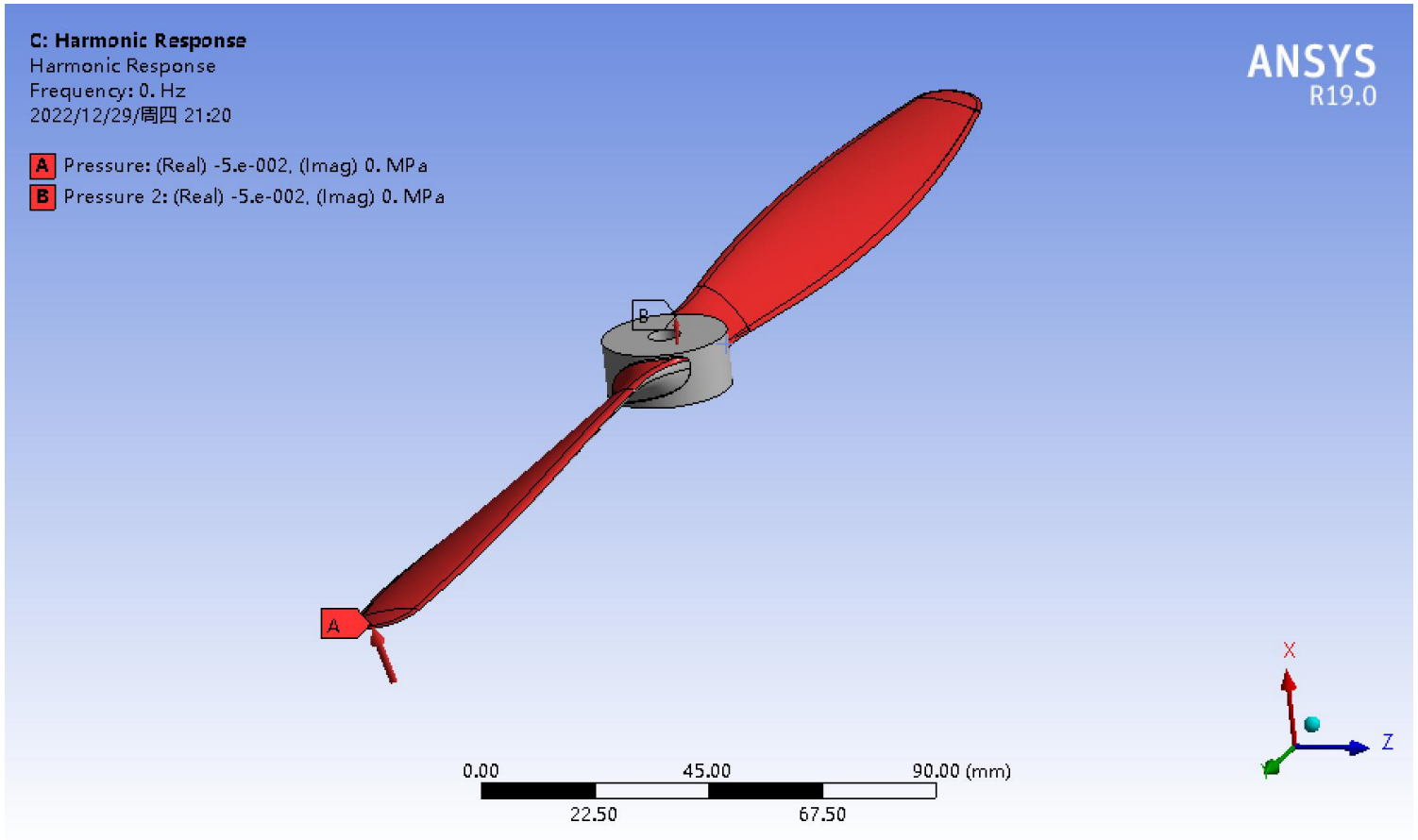
Modal Analysis



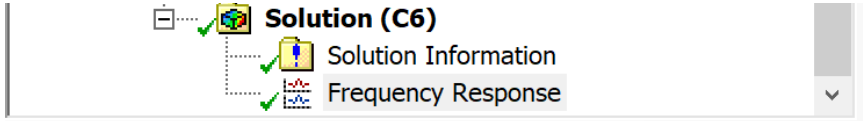
	Mode	Frequency [Hz]
1	1.	103.3
2	2.	456.33
3	3.	708.94
4	4.	1531.9
5	5.	1581.3
6	6.	2976.3
7	7.	4025.
8	8.	4819.4

- **Symmetric structure may have asymmetric modes.**
- **Single blade vibration mode in one propeller is dependent of the number of blades.**

Harmonic Response Analysis



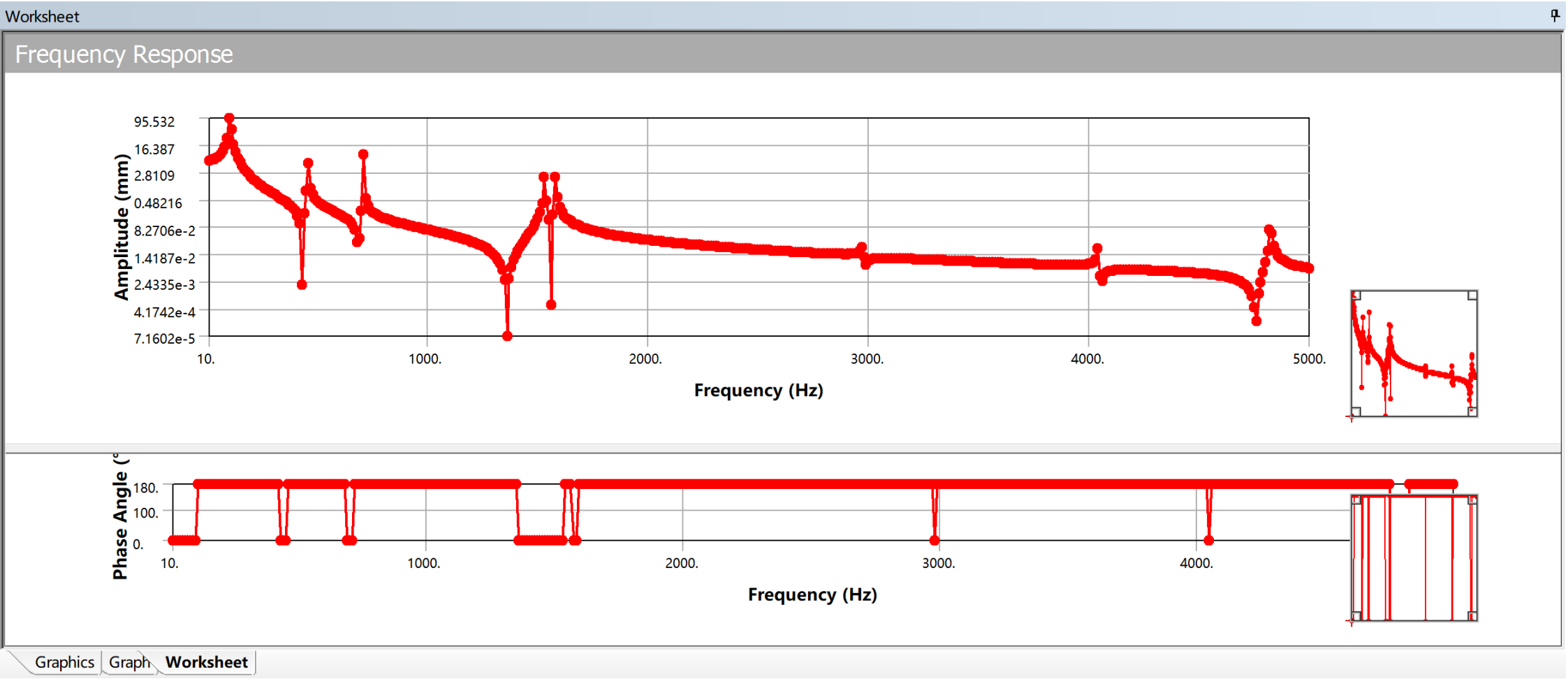
Frequency Spacing	Linear
Range Minimum	0. Hz
Range Maximum	5000. Hz
Solution Intervals	500



Details of "Frequency Response"

Scope	
Scoping Method	Geometry Selection
Geometry	16 Faces
Spatial Resolution	Use Average
Definition	
Type	Directional Deformation
Orientation	X Axis
Coordinate System	Global Coordinate System
Suppressed	No

Harmonic Response Analysis

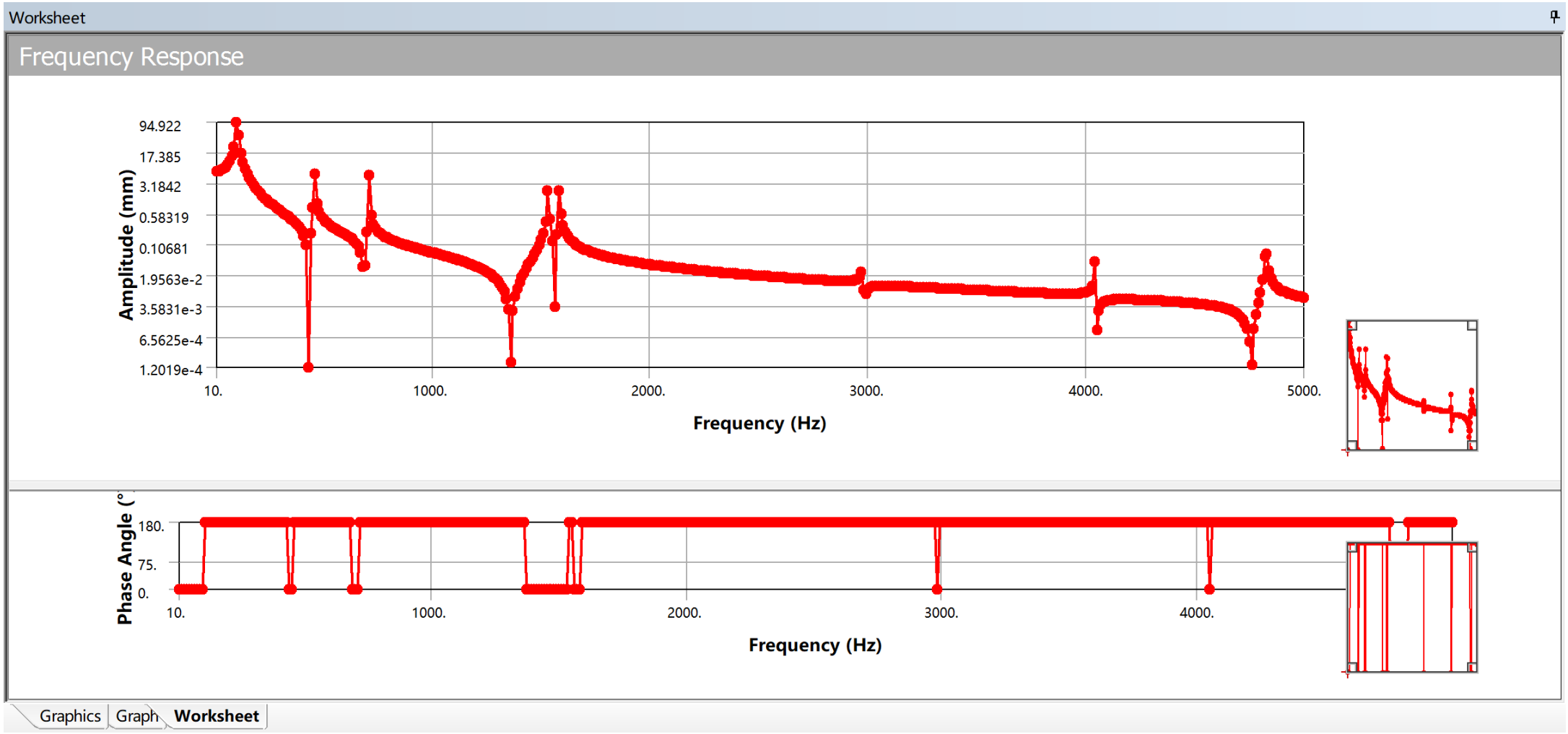


Harmonic Response Analysis

3 blades

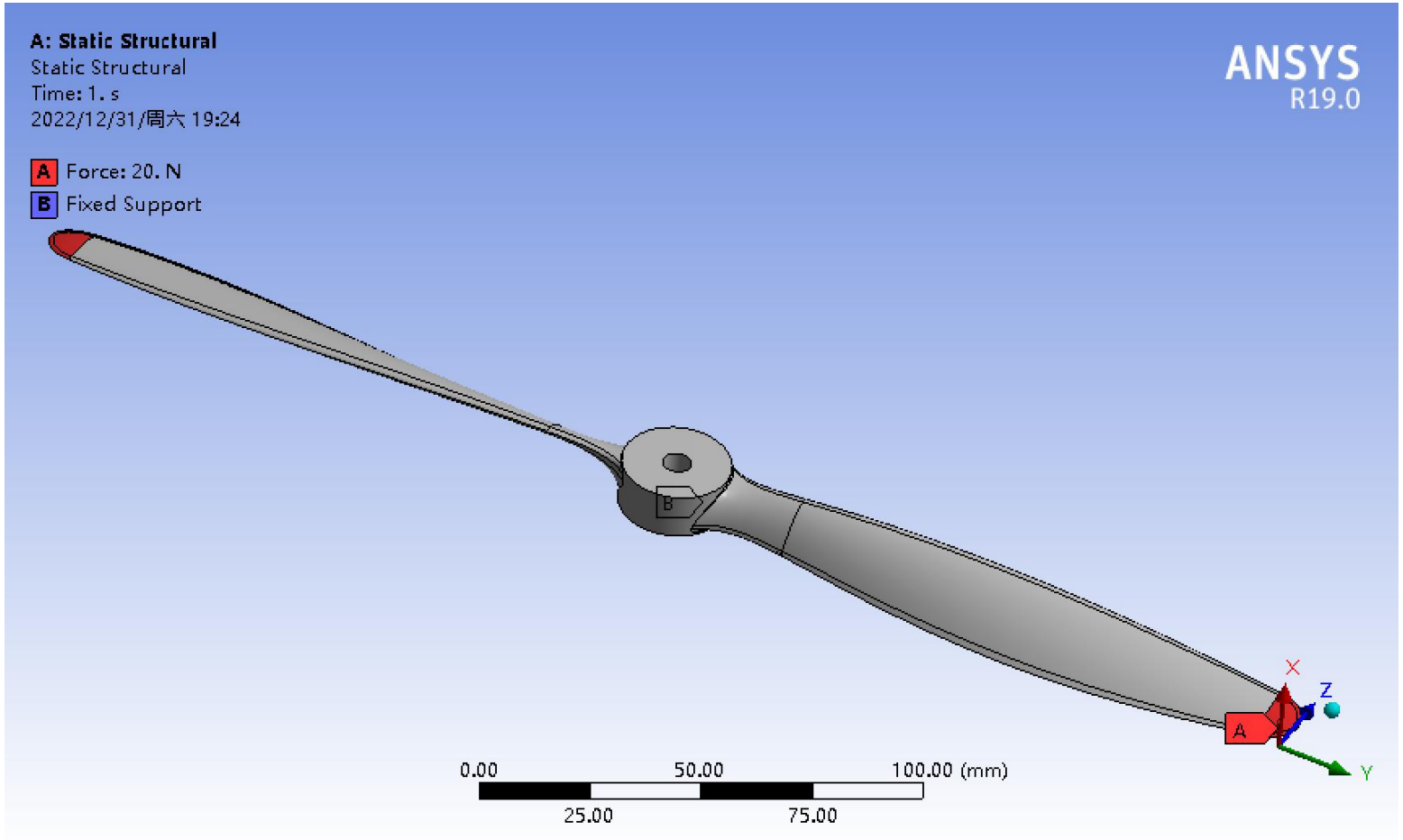
Harmonic Response Analysis

4 blades



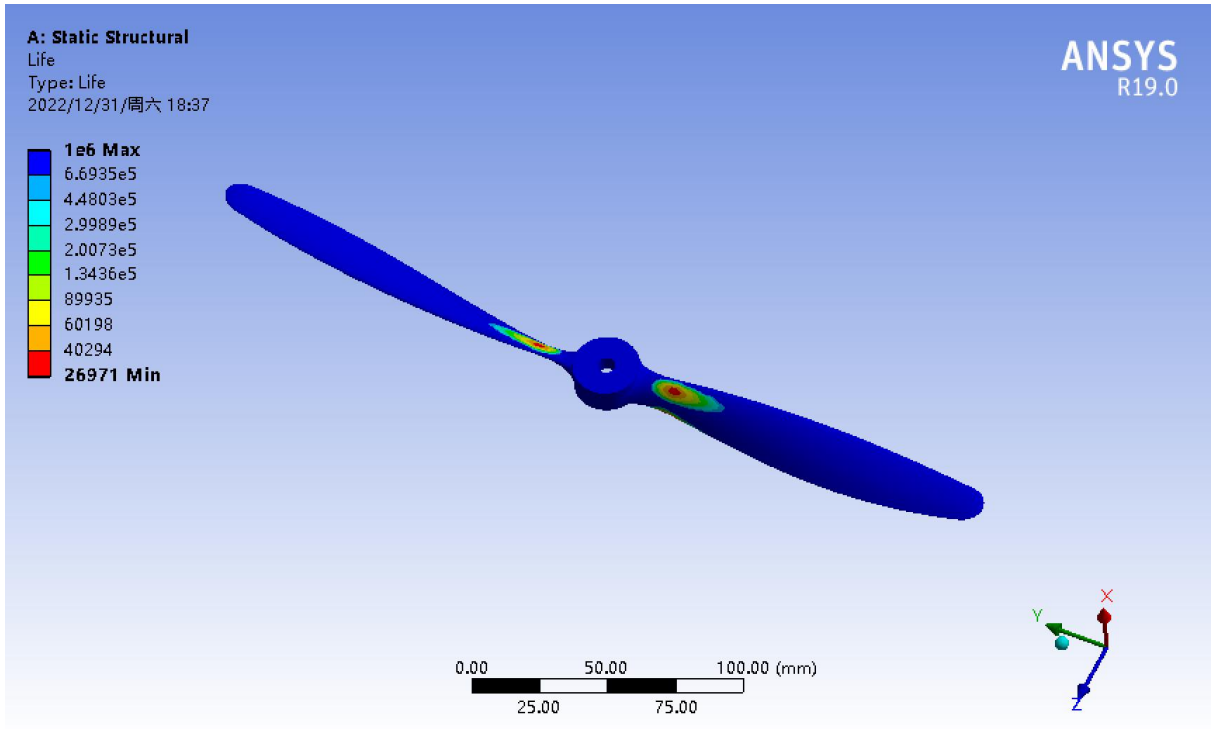
- **Frequency response is independent of the number of blades.**

Failure



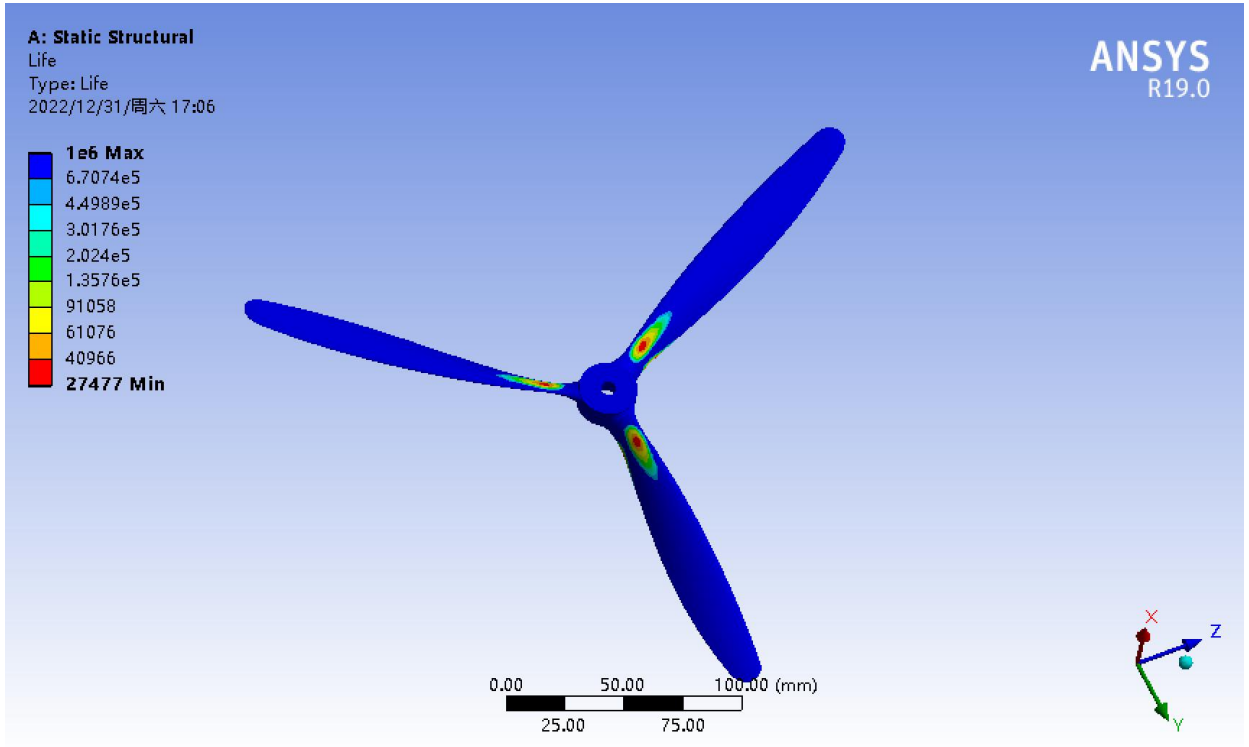
Loading		
	Type	Fully Reversed
	Scale Factor	1.
Definition		
	Display Time	End Time
Options		
	Analysis Type	Stress Life
	Mean Stress Theory	Goodman
	Stress Component	Equivalent (von-Mises)
Life Units		
	Units Name	cycles
	1 cycle is equal to	1. cycles

Failure


A: Static Structural
Life
Type: Life
2022/12/31/周六 18:37
1e6 Max
6.6935e5
4.4803e5
2.9989e5
2.0073e5
1.3436e5
89935
60198
40294
26971 Min
ANSYS
R19.0
0.00
50.00
100.00 (mm)
25.00
75.00
X
Y
Z

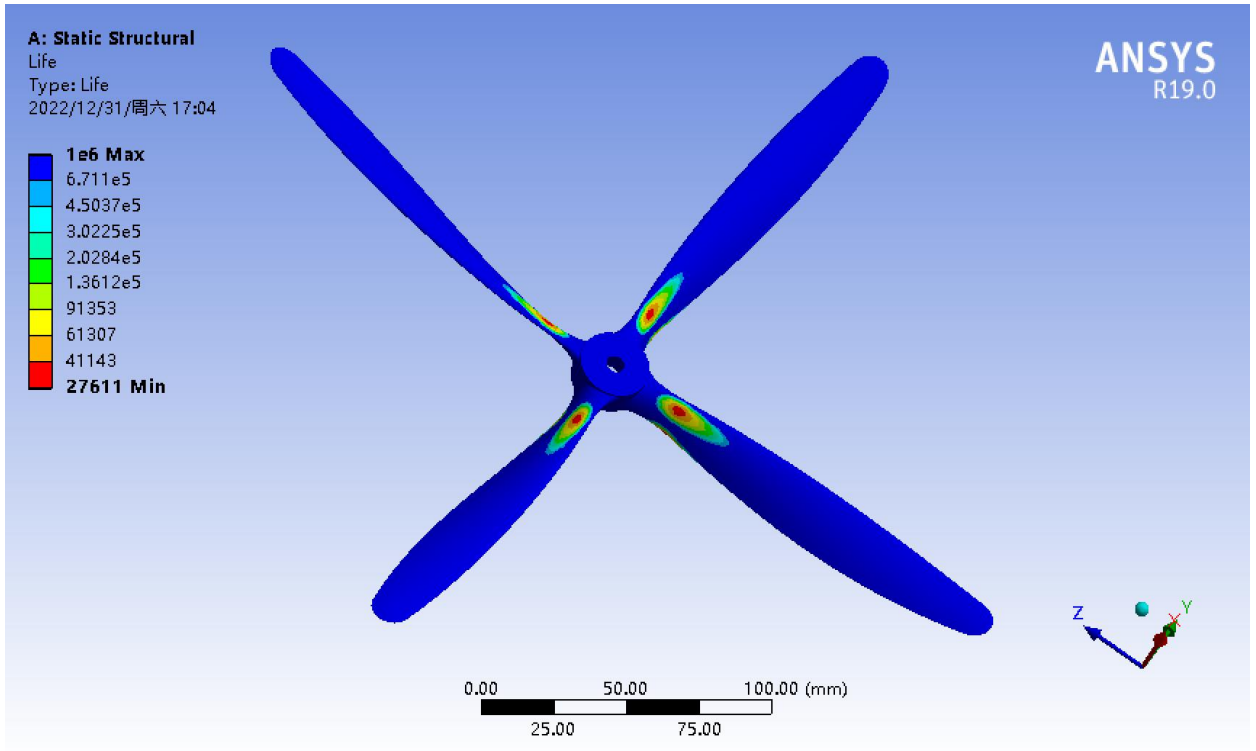
Failure

3 blades



Failure

4 blades



- **The propeller shortest life increases with more blades.**

Summary

- **Static Analysis**

  The root of the blade is enduring a large stress.

  And the largest deformation occur at the tip of the blade.

  Min stress increases with more blades at same rotational velocity.

- **Modal Analysis**

  Symmetric structure may have asymmetric modes.

  Single blade vibration mode in one propeller is dependent of the number of blades.

- **Harmonic Response Analysis**

  Frequency response is independent of the number of blades.

- **Failure Analysis**

  The propeller shortest life increases with more blades.

Conclusion

- ✓ **Static Analysis**

  Reinforce the blades' root under the given rotational velocity conditions.

  Hard materials are recommended to use from the middle to the tip of the blade to control deformation.

- ✓ **Modal Analysis**

  Modal analysis cannot be simplified because of symmetric structures.

- ✓ **Harmonic Response Analysis**

  Frequency response is independent of the number of blades.

- ✓ **Failure Analysis**

  Where aerodynamic performance permits, multiple blades are used to increase service life.

Thank you!

Questions?