Design and Analysis of an Aircraft Propeller Structure Using the Finite Element Method

Objectives:

The goal is to simulate the stress distribution and deformation of the structural steel propellers with different blades and find the effects of the number of blades under the given load and constraint conditions(Figure1).

FE Models:

The FEM was applied in this project. Several FE models including the propellers with 2 to 4 blades were used for this study. The mesh element size is 2.0mm for all the model analysis. For static analysis, the BCs are rotational velocity with 100 rad/s across the central line and no displacement, see Figures 1. For modal analysis, the BCs is fixed support on the bottom, see Figures 2. For harmonic response analysis, the BCs is pressure subjected on the upper surface of the blades, see Figures 3. For failure analysis, the mean stress theory is Goodman, and the BCs are fixed support on the bottom and lift force 10 N on the tip of the blades, see Figures 4.

Results:

The results of maximum deflection and maximum von Mises stress for each propeller are shown in Table 1. Locations of the deformation and stress are indicated in Figure 5-10.

Table 1 - FEM Results for Deflection and Maximum Stress

Blades	Elements Number	Max Def (mm)	Max Str(MPa)	Min Str (Mpa)
2	20166	0.015102	2.5563	0.0019905
3	27524	0.015083	2.5582	0.0041978
4	34717	0.015097	2.5680	0.0065274

The mode freqency of one single balde is shown in Table 2. Vibration modes are indicated in Figure 11.

Table 2 - Mode Freqency of One Single Blade

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

The shortest life of the propellers with 2, 3 and 4 blades are 26971 cycles, 27477 cycles and 27611 cycles respectively.

Conclusions:

Based on the FEM results, it is recommended to reinforce the blades' root under the given rotational velocity conditions. Meanwhile, the propeller’s shortest life increases with more blades under the given condition of tip lift force.

Discussions:

1. The propeller is designed for remote control model aircraft.
2. The loads are applied statically to the model, which may cause deviations.
3. The results would be better to use fluid-solid coupling analysis.

Appendices

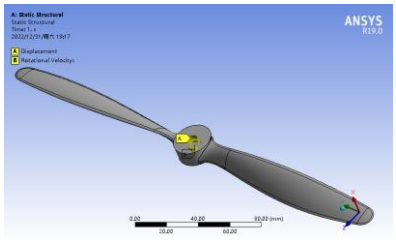

Figure1

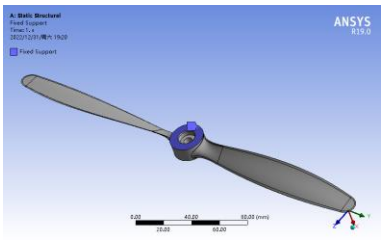

Figure2

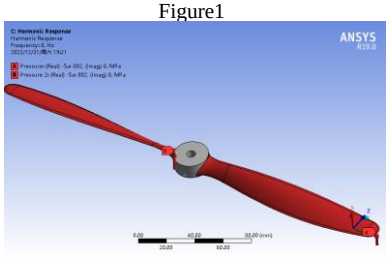

Figure3

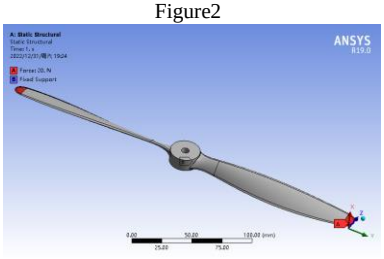

Figure4

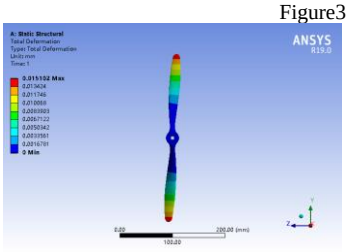

Figure5

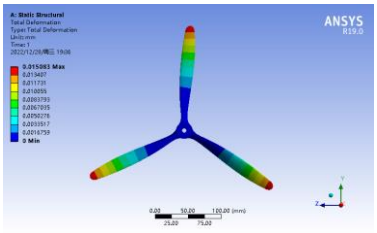

Figure6

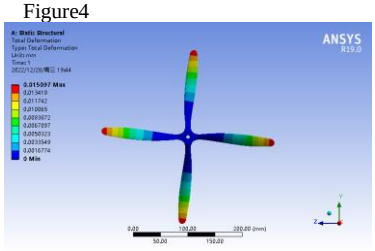

Figure7

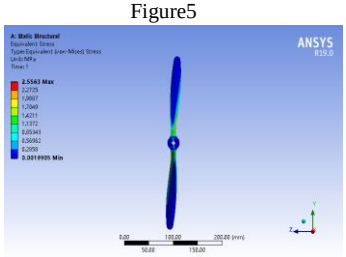

Figure8

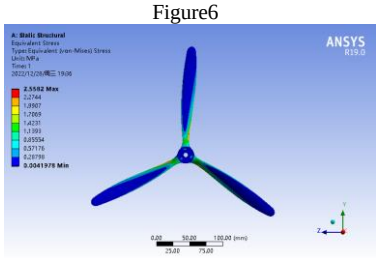

Figure9

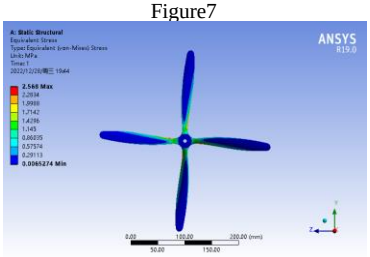

Figure10

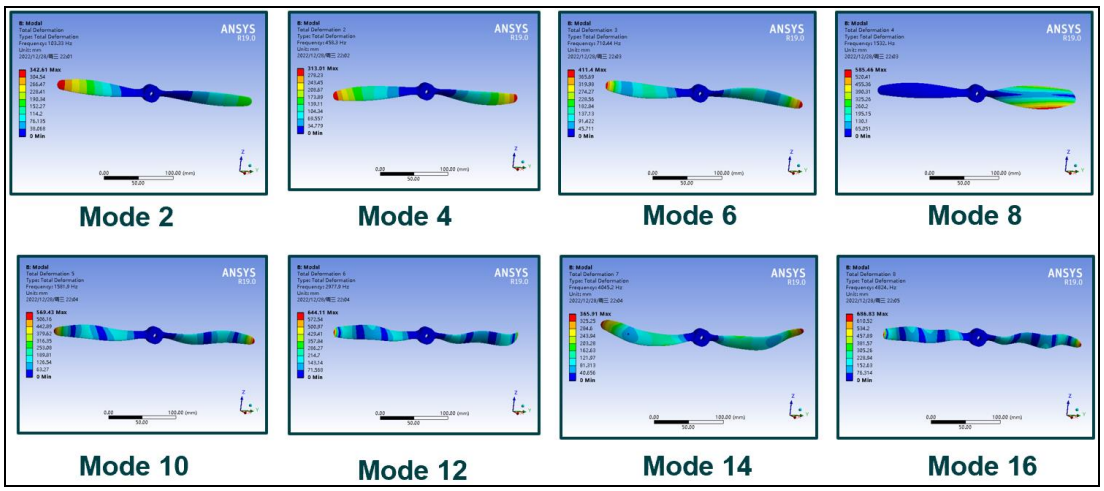

Figure11