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# Load Estimation of a Helicopter Blade Wing using CFD

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***Abstract*: To determine the load distribution in main helicopter rotor blade in Computational Fluid Dynamics (CFD). The aim of the present investigation is the understanding the aerodynamic loads and structural loads using ANSYS computation procedure and accurately simulating the flow around an isolated helicopter blade. For this purpose, the complete of main rotor blade in CATIA model are used in CATIA modeling.**

***Keywords*: CATIA, ANSYS, CFD, rotor blade**

## 1. Introduction

Nowadays, aerodynamic interaction between the main rotors of helicopter still remains a challenging task. The flow around a helicopter is dominated by complex aerodynamics and flow interaction phenomena. Today, powerful computational fluid dynamics (CFD) methods are progressively more used in the analysis of the whole helicopter avoiding experiential corrections. The problem of main rotor analyzed in relatively ANSYS Fluent and Static Structural Commercial software is applied in obtaining influence of the fuselage on the main rotor blade sectional loads for the BOEING CH-46E SEA KNIGHT helicopter [1].

## 2. CH-46E Sea Knight

### *A. About*

The now retired Vertol (Boeing) CH-46/HH-46 Sea Knight, commonly known as the "Phrog", is a medium-lift tandem rotor transport helicopter. It was used by the U.S. Marine Corps to provide all-weather, day-or-night transport of combat troops, supplies and equipment.

### *B. Problems*

CH-46 operations were plagued by major technical problems; the engines, being prone to foreign object damage (FOD) from debris being ingested when hovering close to the ground and subsequently suffering a compressor stall. According to authors Williamson Murray and Robert H Scales, the Sea Knight displayed serious reliability and maintenance problems, as well as "limited lift capabilities". So the helicopter retired in 2015 [2].

### *C. Specifications*

- Length: 13.66 m
- Rotor diameter: 15.24 m
- Height: 5.09 m
- Disc area: 364.8 m²
- Empty weight: 7,047 kg
- Max. takeoff weight: 11,000 kg
- Power plant: 2 × General Electric T58-GE-16 turbo shafts, 1,400 Kw each
- Airfoil: vr-7

## 3. VR-7 airfoil

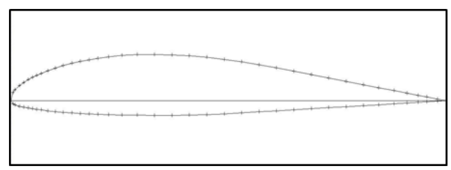

Fig. 1. Plot

Table 1
Specifications

| | |
|---|---|
| **Thickness:** | 12.0% |
| **Camber:** | 3.1% |
| **Trailing edge angle:** | 12.3° |
| **Lower flatness:** | 12.7% |
| **Leading edge radius:** | 2.5% |
| **Efficiency:** | 33.8 |
| **Max $C_L$:** | 1.237 |
| **Max $C_L$ angle:** | 15.0 |
| **Max L/D:** | 49.648 |
| **Max L/D angle:** | 5.5 |
| **Max L/D $C_L$:** | 0.871 |
| **Stall angle:** | 8.5 |
| **Zero-lift angle:** | -2.5 |

## 4. Airfoil analysis-fluent

### *A. Boundary conditions*

Table 2
Boundary conditions

| | |
|---|---|
| Inlet velocity | 75 m/s |
| Outlet pressure | 10pa |
| Fluid | air |
| Temperature | 300 k |
| Density | 1.225 kg/m$^3$ |
| Area | 1 m$^2$ |

*B. Contours*

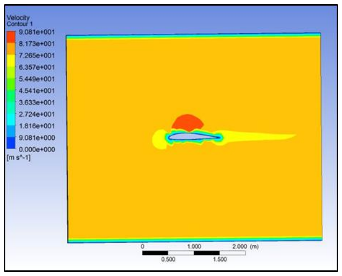
Fig. 2. Velocity

The velocity contour shows that the velocity is maximum in the upper surface of the airfoil and minimum at the lower surface of the airfoil. The velocity is at a medium range at the leading edge and trailing edge of the airfoil.

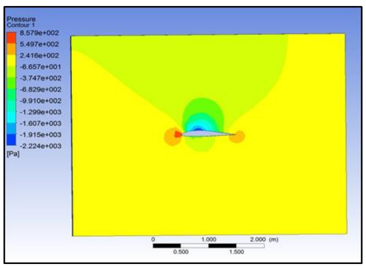
Fig. 3. Pressure

The pressure contour shows that the pressure is maximum in the leading edge and trailing edge of the airfoil. The pressure is at a medium range at the lower surface of the airfoil which produces lift.

*C. Aerodynamic loads*

Table 3
Aerodynamic loads

| | |
|---|---|
| Lift | 60.08N |
| Drag | 14.01N |

The aerodynamic loads such as lift and drag act along the x direction and y direction.

## 5. Design of a VR-7 blade wing

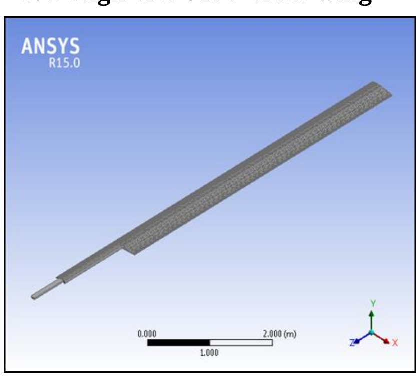

Fig. 4. ANSYS imported

The blade wing is designed from the vr-7 airfoil by inserting the coordinates into the catia v5. By using specifications, the blade wing is designed and the model is imported into the ANSYS design modeler for analysis.

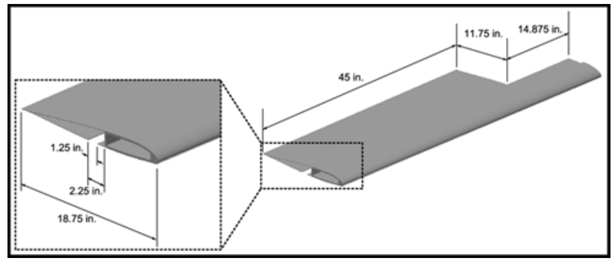

Fig. 5. 3D blade model

Table 4
Blade Specifications

| | |
|---|---|
| Total blade length | 305.90 in |
| Wing length | 229.425 in |
| Support link | 50.984 in |
| Bar | 25.49 in |

## 6. Static structural analysis

The boundary conditions are applied according to the hover case only. The materials considered for analysis are structural steel and aluminum.

*A. Boundary conditions*

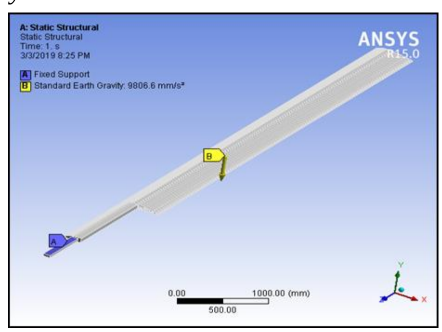

Fig. 6. Constraint

Table 5
Material data

| Young's Modulus psi | Poisson's Ratio | Bulk Modulus psi | Shear Modulus psi |
|---|---|---|---|
| 2.9008e+007 | 0.3 | 2.4173e+007 | 1.1157e+007 |

The bar of the blade wing is fixed and the gravitational loads are applied because only hover case is taken into consideration.

*B. Steel blade*

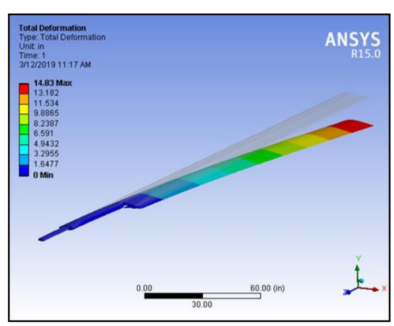

Fig. 7. Total deformation

Fig. 7 shows the total deformation of the steel blade in 14.83 inches and the maximum region is in the tip of the blade.

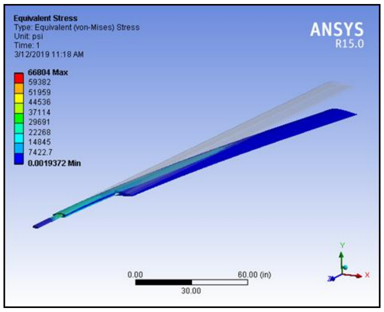

Fig. 8. Equivalent stress

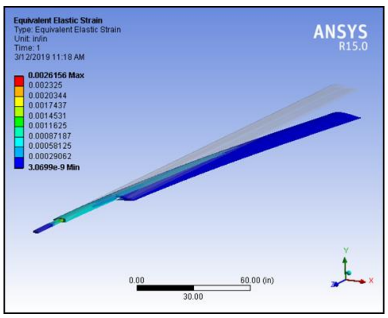

Fig. 9. Equivalent strain

From fig. 8 and fig. 9 the equivalent stress and the equivalent strain of the steel blade are 66804 psi and 0.00261 inches.

Table 6
Modal

| Mode | Frequency [Hz] |
|---|---|
| 1. | 1.0221 |
| 2. | 3.9626 |
| 3. | 6.8875 |
| 4. | 18.357 |
| 5. | 23.144 |
| 6. | 34.012 |

Table 6 shows the frequencies at which the steel blade is vibrating at different modal deformations.

### *C. Aluminium blade*

Table 7
Material data

| Young's Modulus psi | Poisson's Ratio | Bulk Modulus psi | Shear Modulus psi |
|---|---|---|---|
| 1.0298e+007 | 0.33 | 1.0096e+007 | 3.8713e+006 |

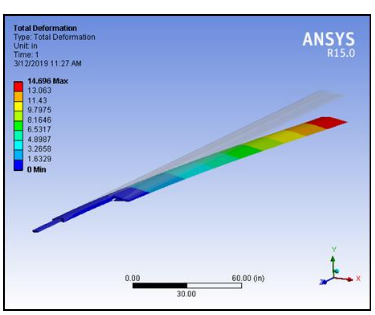

Fig. 10. Total deformation

Fig. 10 shows the total deformation of the aluminium blade in 14.69 inches and the maximum region is in the tip of the blade.

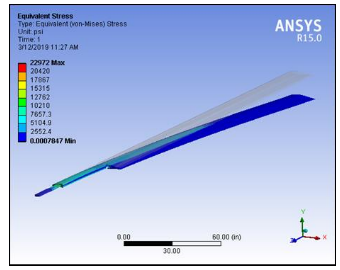

Fig. 11. Equivalent stress

From fig. 11 and fig. 12, the equivalent stress and the equivalent strain of the aluminium blade are 22972 psi and 0.00253 inches.

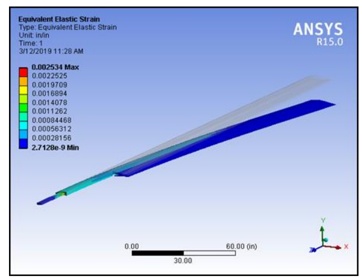

Fig. 12. Equivalent strain

Table 8
Modal

| Mode | Frequency [Hz] |
|---|---|
| 1. | 1.0271 |
| 2. | 3.9766 |
| 3. | 6.931 |
| 4. | 18.263 |
| 5. | 23.57 |
| 6. | 34.127 |

Table 8 shows the frequencies at which the aluminium blade is vibrating at different modal deformations.

Table 9
Comparison of data

| Data/Material | Steel | Aluminium |
|---|---|---|
| Total deformation | 14.83 in | 14.69 in |
| Equivalent Stress | 66804 psi | 22972 psi |
| Equivalent strain | 0.00261 in | 0.00253 in |
| Modal Frequency | 34.012 Hz | 34.127 Hz |

Table 9 shows the maximum values of the calculated data of the materials steel and aluminium by using static structural analysis.

## 7. Main rotor configuration

### *A. Design*

The design of the main rotor is done using catia v5 and the assembly consists of a rotor hub and three blade wings. The configuration is finished by connecting all the blade wings and the rotor hub using contact constraints and fixed together.

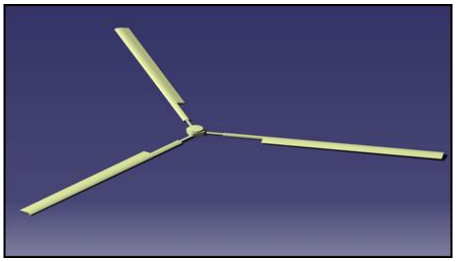

Fig. 13. Catia assembly

### B. *Specifications*

Table 10
Specifications

| | |
|---|---|
| Area | 34.138 $m^2$ |
| Mass | 341.377 kg |
| Center of gravity ($G_x$) | 0.349 in |
| Moment of Inertia($M_x$) | 4442.39 $kgm^2$ |
| Area density | 10$kgm^{-2}$ |

### C. *Flow simulations*

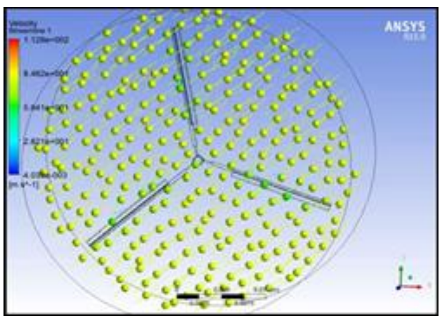


Fig. 14. Flow around main rotor

### D. *Contours*

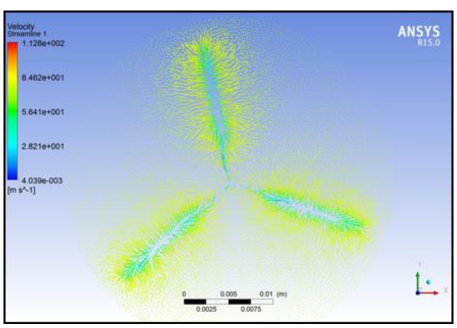


Fig 15. Velocity contour

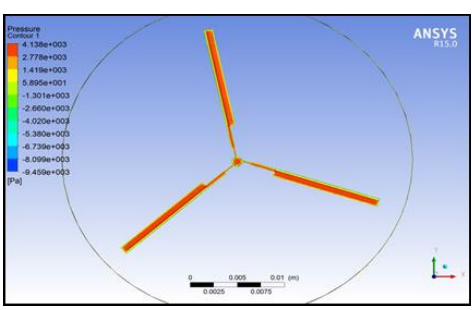


Fig. 16. Pressure contour

Figure 15 and 16 shows the velocity and pressure contours of the main rotor configuration with air velocity (75m/s) as the boundary conditions.

## 8. Conclusion

The aerodynamic and structural loads of an isolated helicopter blade wing are calculated and the flow simulations around the main rotor configuration are discussed. The reason behind the retirement of CH-46 Sea Knight helicopter is lifting capabilities of the VR-7 airfoil. The characteristics of the airfoil are also discussed and the aerodynamic loads are calculated.

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