

# Tail Rotor Blade Assignment

*by* Michael Cheeseman

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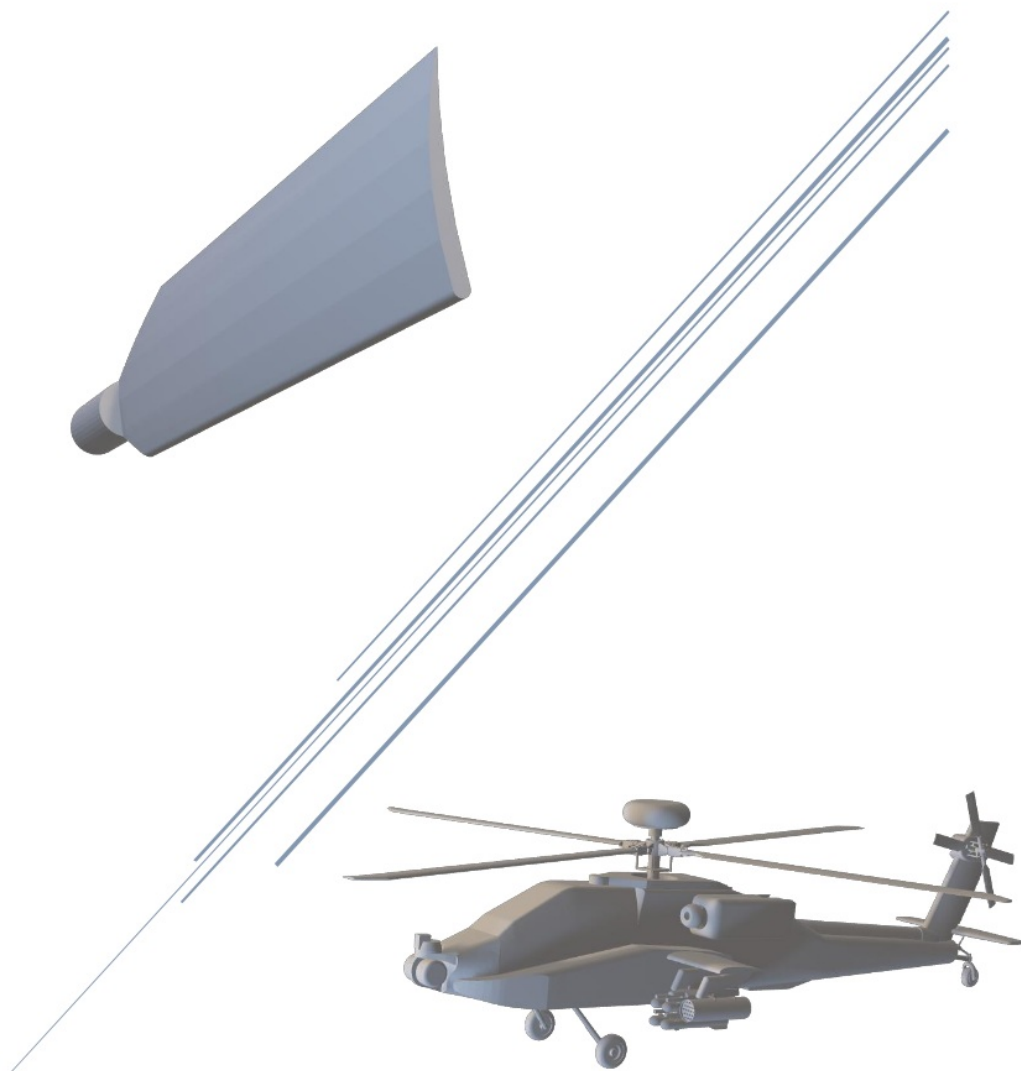
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# ADVANCED COMPUTATIONAL METHODS

Assessment of a Helicopter Tail Rotor



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## 1 Executive Summary

This report is an assessment on a Helicopter rotor blade given to the author to be used. This part will be subjected to three sets of tests using solidworks simulation study, these are Static Study, Fatigue Study and a Natural Frequency Study. this blade is scaled down version of the apache helicopter at a scale of 1:3.4. The author has looked into the forces required to be able to ensure that the part given will be loaded as correctly as possible to the actual rotor blade to ensure the accuracy of the results.

The report will go through how each force was found either by equations or through researched materials. The material that was used for the part is Titanium grade, Ti 6Al 4V due to it being one of the most common grades of Titanium for aerospace industry. This was also used to the simplicity of the model given that the actual assembly could not be put in with each material selected. The forces that were applied to the model were Lift, Drag and Centrifugal force. All three were found by research and calculations based on an apache helicopter. These forces were found to be the following:

- Lift Force: 42.195 N
- Drag Force: 0.1164 N
- Centrifugal Force: 1564 N

5. Proof Read

Using the forces above with This report will go through each test result and appraise them individually to state whether this result shows that the part is fit for purpose or not. The report will then conclude to say whether the part is fit for use or not and the reasons why this statement has been made. The author will then make a few recommendations to show how this process could be improved if it was conducted again.

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### 3 Introduction

This report is an FEA Study carried out using various solidworks simulation studies on a CAD model of a helicopter tail rotor that was given to use. The studies carried out are a static study showing stress, displacement and strain of the part under normal operating loading conditions. The second is a Fatigue study using the results from the static study and lastly a natural frequency study on the part. The two models that were given are the tail rotor as shown in Figure 1, and a model of a helicopter, which is a scaled down model of an apache helicopter are shown Figure 2. The scale ratio is 1:3.4 as shown in Equation 4, taking the values from the CAD Model given by (Lake, 2019) and from Figure 3.

An apache helicopter has been designed to be “a ground attack helicopter” (Swopes, 2016). This system had its first test flight on the “30<sup>th</sup> September 1975” (Swopes, 2016) and is still in service today. There have been a few variations to the original design since 1975 due to the change in armament and technology since the first flight, but the mechanical design as shown little change. The tail rotor for an apache is 8.33ft in diameter with two blades offset by 55° and 125° to each second two blades. These blades are constructed using similar materials and the same method as shown in figure 4, (Harris, 2019) and (Newkirk, 2007).

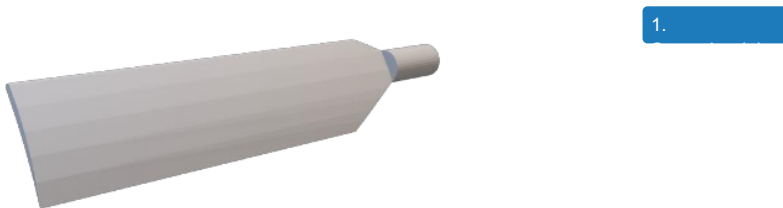


Figure 1: CAD Model of the tail rotor (Lake, 2019).



Figure 2: CAD Model of the full Helicopter Assembly (Lake, 2019).

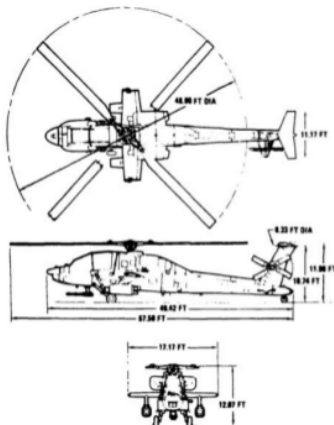


Figure 3: Apache Helicopter Drawing (Swopes, 2016).

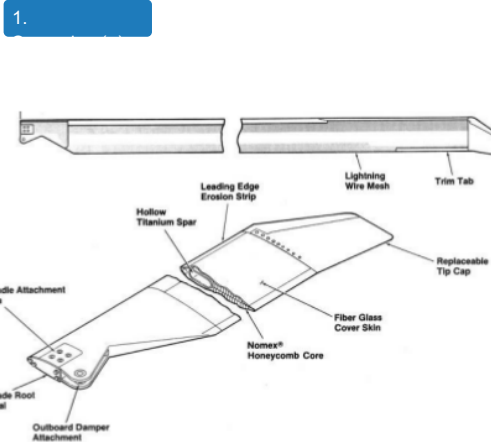


Figure 4: Tail rotor blade cross section (Lockheed Martin, 2016)

## 4 Methodology

The analysis was conducted using Solidworks simulation studies, three studies were run a static study, fatigue study and a frequency study. These two studies were applied to the model supplied for this report. Due to the model being a 1:3.4 scaled down version of a real helicopter the real rpm value has been used for the calculations. According to (Swopes, 2016) the "Tail rotor of an apache helicopter rotates at 1411 rpm", this one value will be the foundation of most of the calculations as shown in Appendix 1 Equation 4.

3. Loading (+)

#### 4.1 Material used

The rotor blade is manufactured using five stainless steel spars, these are then surrounded by a fiberglass skeleton. The trailing edge of each blade is then covered with a sturdy graphite composite material, while the leading edge is made of titanium. Due to the simplicity of the model given to be used. The study conducted has been done using the blade as a solid body made out of the outer shell of the actual rotor blade which is Titanium (Newkirk, 2007). The options for titanium that solidworks use is shown in Figure 5.

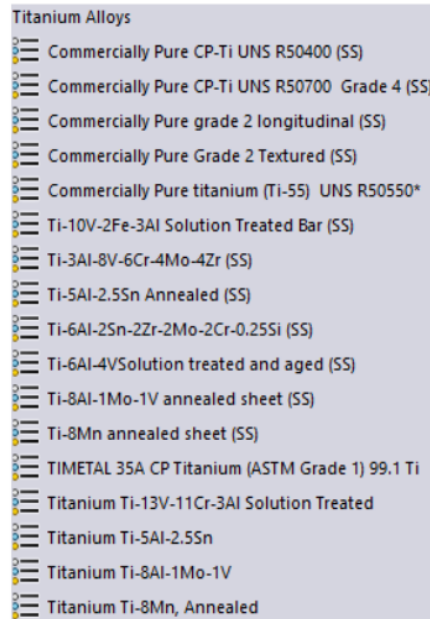


Figure 5: List of Titanium found in Solidworks Material Library (Solidworks, 2019).

The titanium that was used for the analysis was Ti-6Al-4v as it is one of the most common grade of titanium alloy that is used in the aerospace industry according to (United Performance Metals, 2019). The properties for this material can be found in table 1:

| Properties      | Value                                         |
|-----------------|-----------------------------------------------|
| Young's Modulus | 104.80031x10 <sup>9</sup> (N/m <sup>2</sup> ) |
| Poisson's Ratio | 0.31                                          |
| Shear Modulus   | 41.023807x10 <sup>9</sup> (N/m <sup>2</sup> ) |
| Mass Density    | 4428.784 (Kg/m <sup>3</sup> )                 |
| Yield strength  | 827370880 (N/m <sup>2</sup> )                 |

Table 1: Material Properties for Titanium Alloy Ti-6Al-4v (Solidworks, 2019).

## 4.2 Boundary Conditions

### 4.2.1 Fixtures

The tail rotor assembly is as shown in Figure 7. Is an assembly that is made up of various parts, the rotor blade itself is fixed to the shaft by no visible fittings therefore the decision was to replicate this fixing on the single rotor blade to the shaft. How the blade was fixed was to apply a fixed geometry to the end of the rotor as shown in Figure 6. This sort of fixing will hold this side of the blade in all six degrees of freedom just as it would in the assembly as shown in Figure 7.

2. BCs(-)

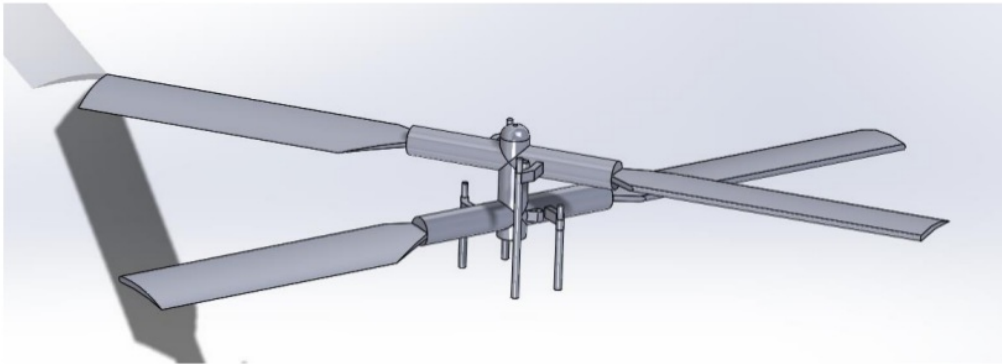


Figure 7: Tail Rotor Assembly (Lake, 2019).

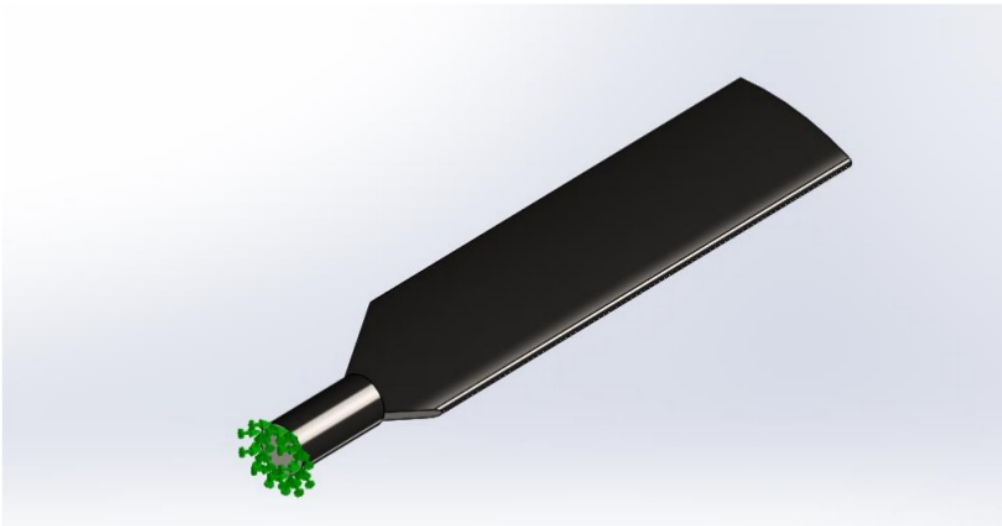


Figure 6: Tail Rotor with applied Fix Geometry (Cheeseman, 2019).

#### 4.2.2 Forces Applied

The three main forces acting on the rotor blade are the lift force, the drag force, and the centrifugal force as shown in figure 8. Therefore, the analysis was conducted using the three forces. The lift is the opposing force to the thrust which acts perpendicular to the movement of the rotor blade. This force is the effect of the airflow as the rotor is moving. The lift force acts on the underside of the rotor blade acting in the opposite direction to the thrust it is producing. The Drag force is the force acting on the rotor blade as it passes through the air.

 1 And the centrifugal force is the force that is created when mass of the rotor blades rotates through the air (Mpower, 2018), (Federal Aviation Administration, 2019) and (Roemer, et al., 2016).

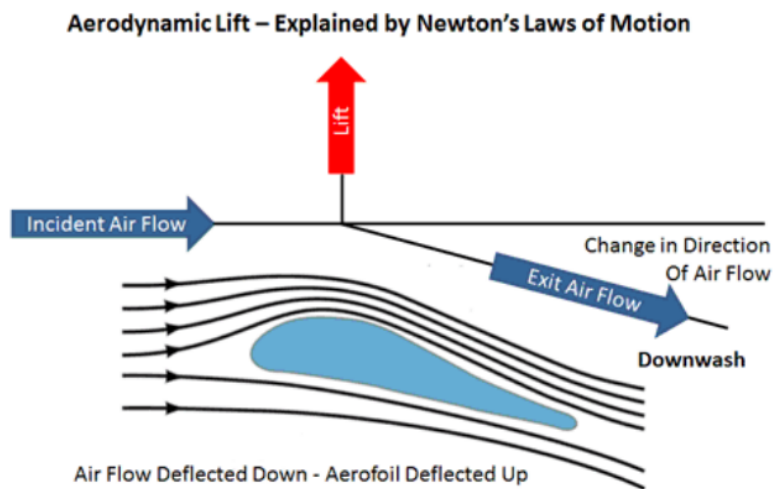


Figure 8: Aerodynamic Lift Image (Mpower, 2018).

### Lift Force

Lift can be calculated in two way it can be worked out by working out the necessary force required to counteract the torsional force created by the main rotor or it can be worked out using Equation 1.

$$F_L = \frac{1}{2} (C_L \cdot \rho \cdot A \cdot v^2)$$

Equation 1: Lift Force Equation (*Benson, 2018*).

| Notation | Meaning             | Value                                       | Attained             |
|----------|---------------------|---------------------------------------------|----------------------|
| $F_L$    | Lift Force          | 42.195 N                                    | (Equation 7)         |
| $C_L$    | Coefficient of lift | 1.45                                        | (Newkirk, 2007)      |
| $\rho$   | Fluid Density       | 1.225 (Kg/m <sup>3</sup> )                  | (Helmenstinem, 2019) |
| $A$      | Surface Area        | 16.24455x10 <sup>-3</sup> (m <sup>2</sup> ) | (Solidworks, 2019)   |
| $v$      | Velocity            | 54.085 (m/s)                                | (Equation 6)         |

The value for the coefficient of lift was attained by using (Newkirk, 2007) which said that for a tail rotor blade for an apache helicopter is 1.45. The lift force was applied to the underside of the rotor blade where the force would be acting according to (Newkirk, 2007) and (Mpower, 2018) as shown in figure 9.

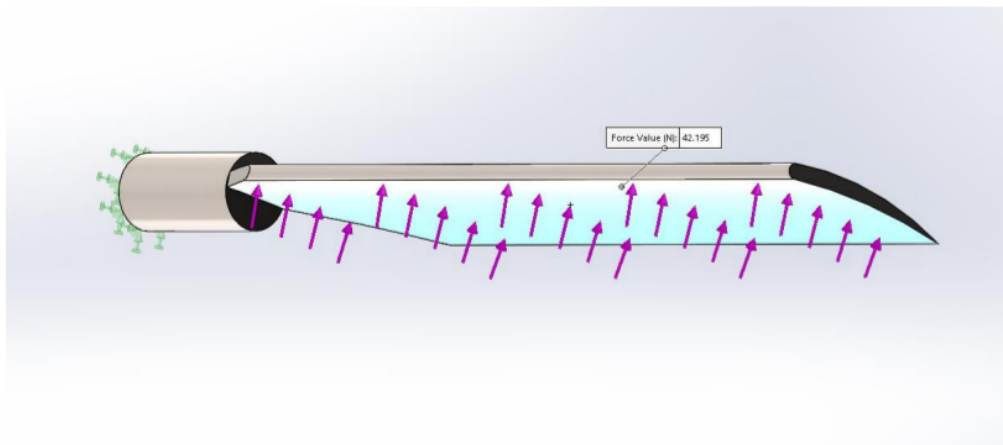


Figure 9: Lift Force being applied to the underside of the rotor blade (*Cheeseman, 2019*)

## Drag Force

Drag is the force of the air resisting the movement of the rotor blade this will act in the opposite direction to the movement of the rotor.

Drag can be worked out using the following equation 2

$$F_D = \frac{1}{2} (C_D \cdot \rho \cdot A \cdot v^2)$$

Equation 2: Drag Force Equation (*Beck, 2018*).

Where the notations for the equations are described in the table 2:

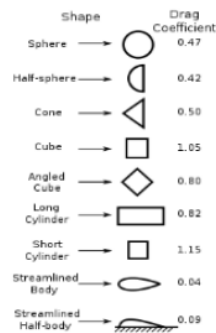
| Notation | Meaning             | Value                                      | Attained             |
|----------|---------------------|--------------------------------------------|----------------------|
| $F_D$    | Drag Force          | 0.1164 (N)                                 | (Equation 8)         |
| $C_D$    | Coefficient of Drag | 0.04                                       | (Aziz, et al., 2008) |
| $\rho$   | Fluid Density       | 1.225 (Kg/m <sup>3</sup> )                 | (Helmenstinem, 2019) |
| $A$      | Surface Area        | 2.01361x10 <sup>-3</sup> (m <sup>2</sup> ) | (Solidworks, 2019)   |
| $v$      | Velocity            | 54.085 (m/s)                               | (Equation 6)         |

Table 2: Explanation for drag force equation.



The value for the coefficient of lift was given by figure 10, as this shows that for a streamlined body the drag coefficient is 0.04. Due to the shape of the rotor blade the author concluded that as the rotor blade is a streamlined body that the rather a half-sphere the value to be used in the equation should be 0.04.

1.



5. Resolution(-)

Figure 10: Coefficient of Drag equation (*Aziz, et al., 2008*).

This force is applied to the very front of the blade as shown in figure 11, due to the rotation of the rotor those faces will be affected by the drag force as it is moving in real life. (Mpower, 2018) and (Swopes, 2016)

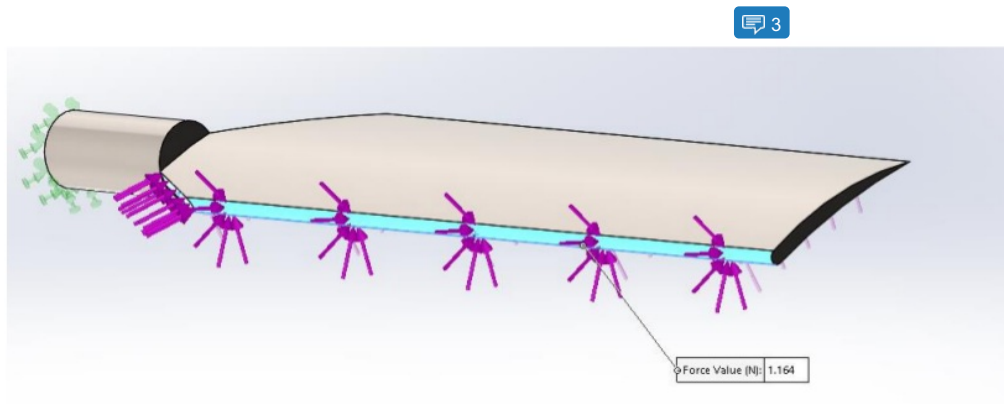


Figure 11: Application of drag force onto body (Cheeseman, 2019).

### Centrifugal Force

As previously stated centrifugal Force is the force that is created when an object is spinning. The equation for Centrifugal force can be found in Equation 3.

$$F_c = M\omega^2 r$$

Equation 3: Centrifugal Force Equation (*Engineers Edge, 2019*).

| Notation | Meaning           | Value                        | Attained           |
|----------|-------------------|------------------------------|--------------------|
| $F_c$    | Centrifugal Force | 1564.735 (N)                 | (Equation 9)       |
| $M$      | Mass              | $381.55 \times 10^{-3}$ (Kg) | (Solidworks, 2019) |
| $\omega$ | Angular Velocity  | 147.76 (Rad/s <sup>2</sup> ) | (Equation 5)       |
| $r$      | Radius            | $187.86 \times 10^{-3}$ (m)  | (Solidworks, 2019) |

Table 3: Notations for the Centrifugal Force Equations.

The Value of mass has come from Figure 12 which was found using Solidworks mass properties (Solidworks, 2019).

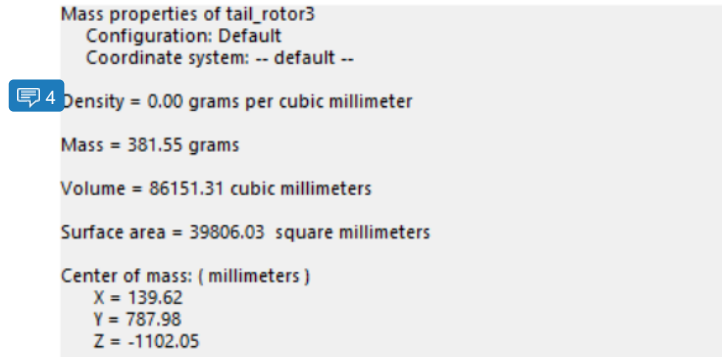


Figure 12: Image of mass properties from (*Solidworks, 2019*).

The radius used in the equation 3 is the radius from the centreline of the assembly to the center of mass due the part having the centrifugal force being applied to the center of mass. The angular velocity was worked out using the rpm value of the apache helicopter tail rotor from (Newkirk, 2007) which was 1411 rpm, in equation 4 found in appendix 1.

To be able to put the centrifugal force onto the part, a remote load was used. When using this form of loading Solidworks require certain information included a face that the load applies too, the co-ordinates of the force and the magnitude of the force in each direction. The force was applied to the center of mass taken from the mass properties as shown in figure 12. The Force was applied to the end of the rotor blade as shown in figure 13, and the coordinates for the applied load was taken from the mass properties center of mass feature from figure 12. The magnitude of the forces came from using trigonometry using the angle in Figure 14, to work out how much of the centrifugal force is working in the Y axis and Z axis of the part. The X axis was neglected due to it acting perpendicular to the part. Using Equation 9 and Equation 10 the forces where found as shown in the table 4.

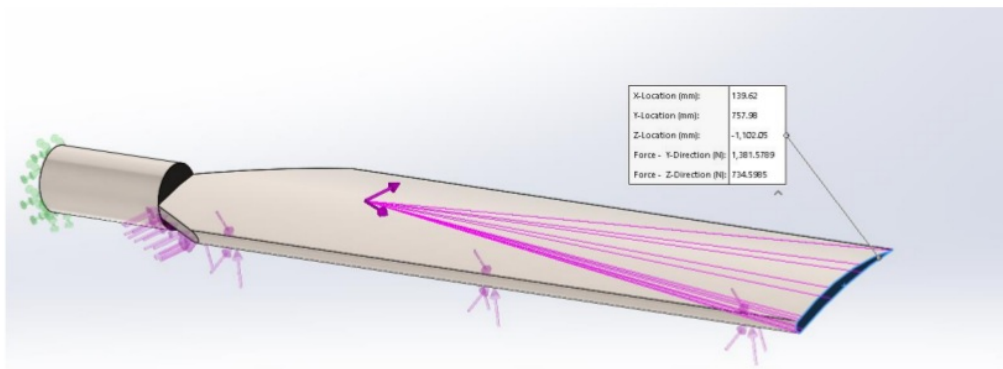


Figure 13: Centrifugal force being applied to the centre of gravity (Cheeseman, 2019).

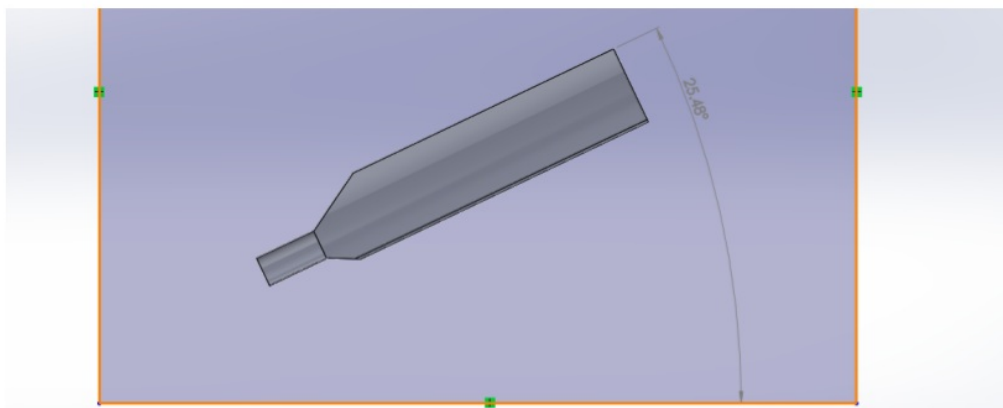


Figure 14: Measured Angle from edge of the rotor blade to Y axis (Cheeseman, 2019).

| Direction of Force | Magnitude of Force | Attained from |
|--------------------|--------------------|---------------|
| <b>Y Axis</b>      | 1412.5417 N        | Equation 11   |
| <b>Z Axis</b>      | 673.1427 N         | Equation 10   |

Table 4: Resultant forces (*Cheeseman, 2019*).

### 4.3 Mesh used

When meshing the component to be able to run the study the author did a comparison of meshes using 4mm, 2mm and 1mm mesh. Results are shown in table 5.

| Size of Mesh | Number of Nodes | Number of elements | Number of DOF | Solve Time  |
|--------------|-----------------|--------------------|---------------|-------------|
| 4mm          | 19172           | 10493              | 57066         | 4 seconds   |
| 2mm          | 121362          | 75687              | 362538        | 15 Seconds  |
| 1mm          | 766801          | 515318             | 2294568       | 1:34 Minute |

Table 5: Comparison of mesh sizes (*Cheeseman, 2019*).



Due to the size of the part the author used a 1 mm mesh for this report whereas it will have a more accurate result on the part in service. The time to take to solve was deemed to be acceptable for the accuracy of the results gathered. The study was run with 1mm with an adapted mesh using a 5-cycle loop. This means that Solidworks will run the study once to find the stress points and it will re-run the same study refining the mesh size at the stress points to enable more accurate values across these areas. The mesh 1mm mesh is shown in figure 15 (Solidworks, 2019)

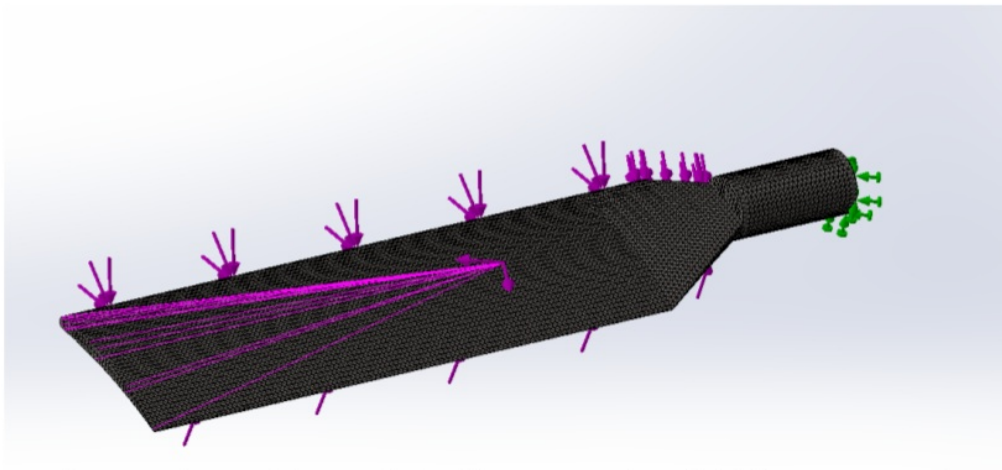


Figure 15: Image of the rotor blade with a 1mm mesh applied (*Cheeseman, 2019*).

## 5 Analysis

### 5.1 Static Simulation Analysis

Solidworks static simulation analysis gives results for three different sections, one is stress of the part, the second is the displacement of the part and the last is the strain of the part with the boundary conditions set previously.

#### 5.1.1 Stress

In Figure 16, Figure 17, and Figure 18, shows the maximum stress as a value of  $4.728 \times 10^8$  N/m<sup>2</sup>. For the titanium alloy chosen for the studies, solidworks is showing that it has a maximum yield stress of  $8.234 \times 10^8$  N/m<sup>2</sup> (Solidworks, 2019). Thus, allowing the presumption that the part is fit for purpose as it is under the maximum yield stress of the material.

The stress result shows a stress concentration in Figure 17, on the underside of the part. As the maximum stress is below the yield stress this would suggest that the part can withstand the forces applied to it. Both Figure 17 and Figure 18, shows that there is stress across the top and bottom of the blade. For further consideration a redesign using fillets in these  6 locations would significantly reduce the stress seen at these two points according to (Thomas, 2019).

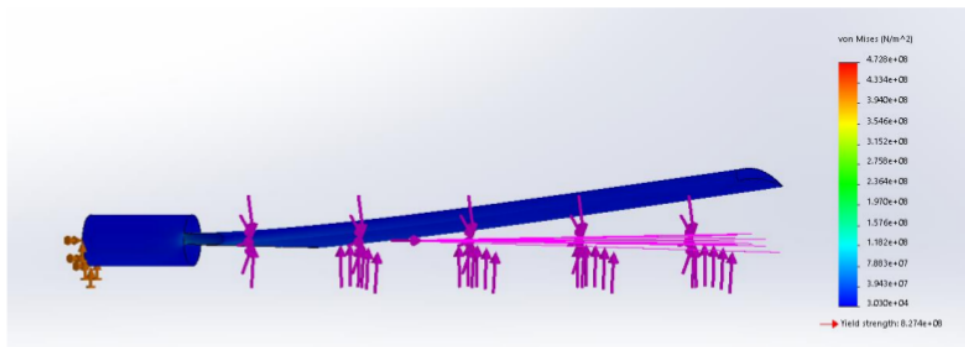


Figure 16: Front view of tail rotor stress result (Cheeseman, 2019).

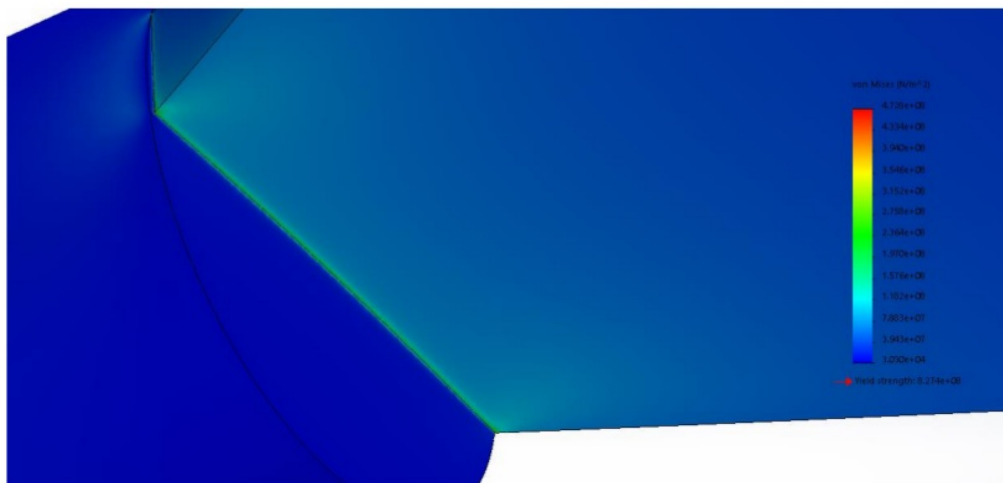


Figure 18: Bottom Iso View of Tail Rotor Stress Result (Cheeseman, 2019).

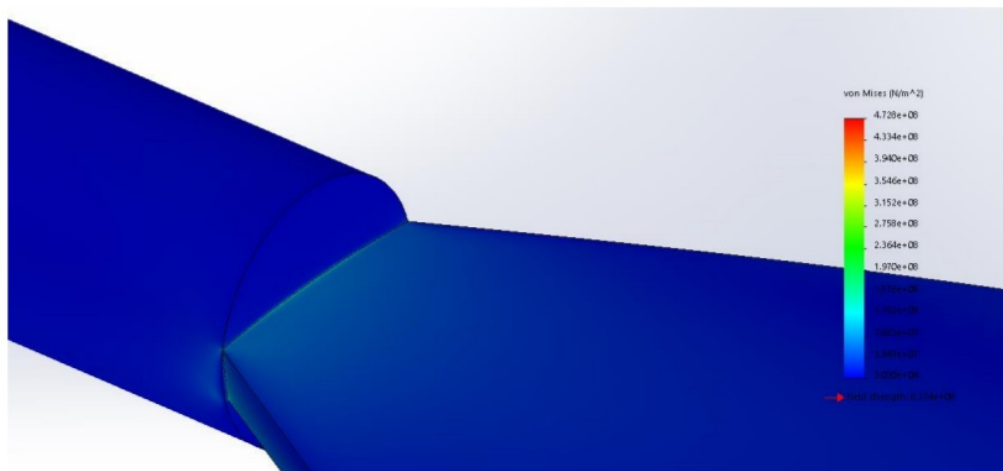


Figure 17: Top Iso View of Tail Rotor Stress Result (Cheeseman, 2019).

### 5.1.2 Displacement

Whilst doing a static study the part had a small displacement from the original location which was 3.067 mm as shown in Figure 19 and Figure 20. This size of displacement is expected due to the thickness of the part and the size of the forces applied to this part.

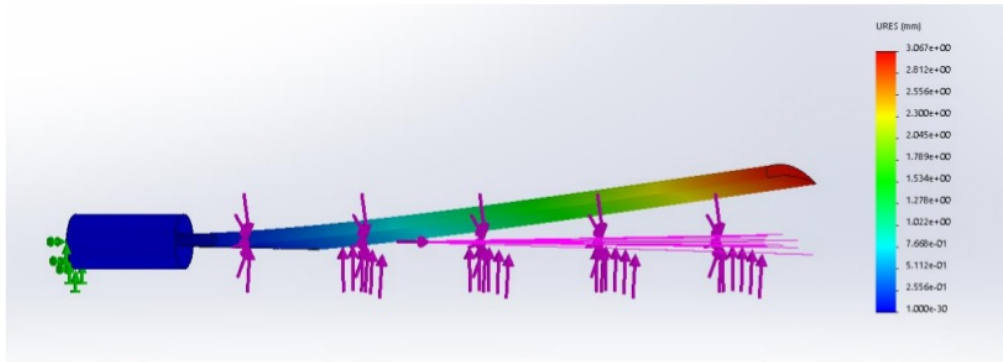


Figure 19: Front View of Tail Rotor Displace results (Cheeseman, 2019).

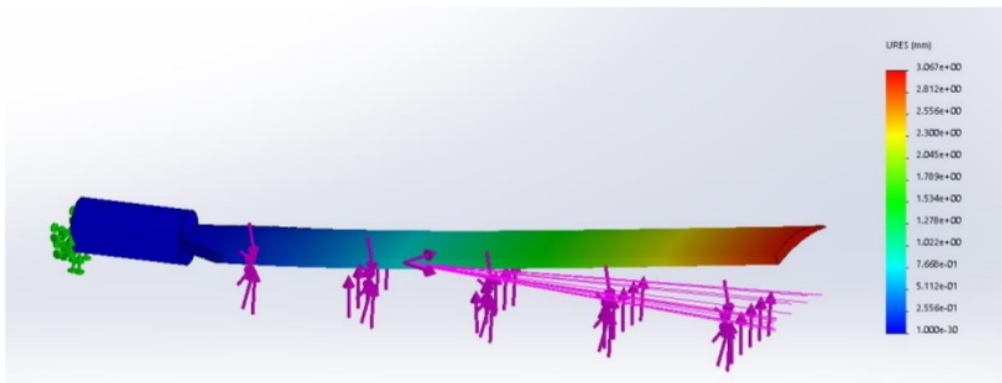


Figure 20: Top Iso View of Tail Rotor Displacement Result (Cheeseman, 2019).

### 5.1.3 Strain

From the static study performed the results of the strain can be found in Figure 21, Figure 22 and Figure 23. The strain result is the equivalent result from the stress calculated by the study. This is due to Solidworks being a linear solver it has used the stress result and calculated the equivalent strain result, which is a value of  $2.682 \times 10^{-3}$ . Using this result in equation 14 enables the change in length to be calculated of the part, this is 0.982mm over the length of the blade. This value is what would be expected to happen to a part under these loading conditions.

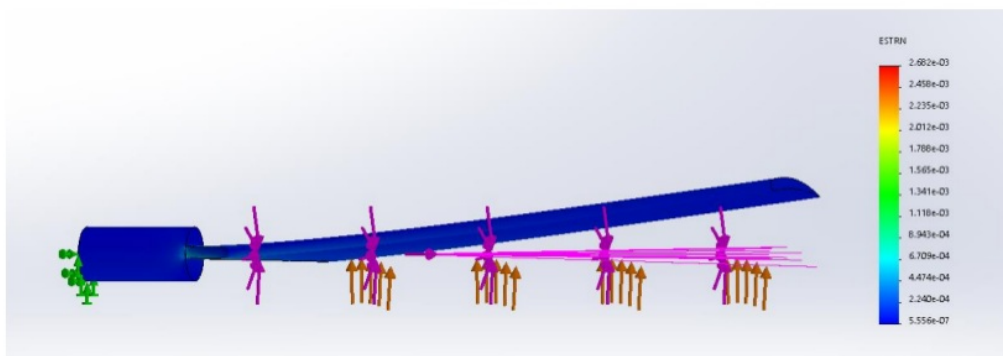


Figure 21: Front View of Tail Rotor Strain Result (Cheeseman, 2019).

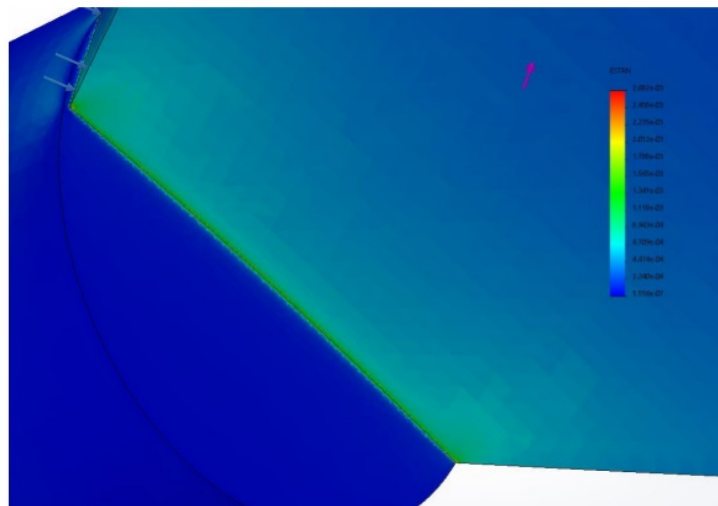


Figure 22: Bottom Iso View of Tail Rotor Strain Result (Cheeseman, 2019).

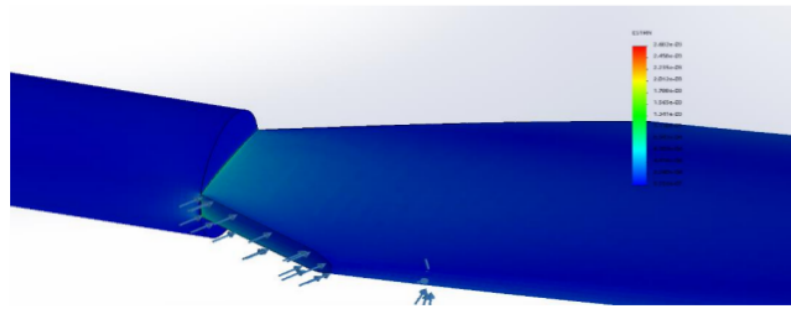


Figure 23: Top Iso View of Tail Rotor Strain Result (Cheeseman, 2019).

The Young's modulus can be worked out from the value of stress and strain gathered in the study conducted. Using these values in equation 13 the worked solution was  $176 \text{ GN/m}^2$ . Where according to (Solidworks, 2019) the material properties for the material used shows that the material has a young's modulus of  $104 \text{ GN/m}^2$  as shown in figure 12. This is concerning as the stresses have exceeded the young's modulus and therefore make the results gathered questionable. This is likely due to solidworks being a linear solver it is unable to calculate beyond the plastic deformation region of any materials.

## 5.2 Fatigue Study

A fatigue study was created using the results from the static study above, and using an SN curve of "ASME Austenitic Steel Curve" (Solidworks, 2019), as shown in figure 26. A life analysis of the part as shown in figure 24, figure 25 and figure 26. These result shows that the part will start to fail at 1212 cycles at the edge of the blade as it meets the cylindrical boss as shown in figure 25 and figure 27. In figure 27 the part shows a major crack across the blade and acting up into the blade. If 1 cycle is equivalent to 1 flight, this data would suggest that the blade would be needed to be inspected after 1212 flights with the aim of changing the blade at that time. Realistically this could be costly, and would suggest the blade in this design is not fit for purpose. Using solidworks for this solver isn't exactly realistic as it is not using the SN Curve for the titanium alloy used for the rest of the analysis. This is possible to obscure the data collected.



Figure 24: Front view of tail rotor fatigue analysis (Cheeseman, 2019).

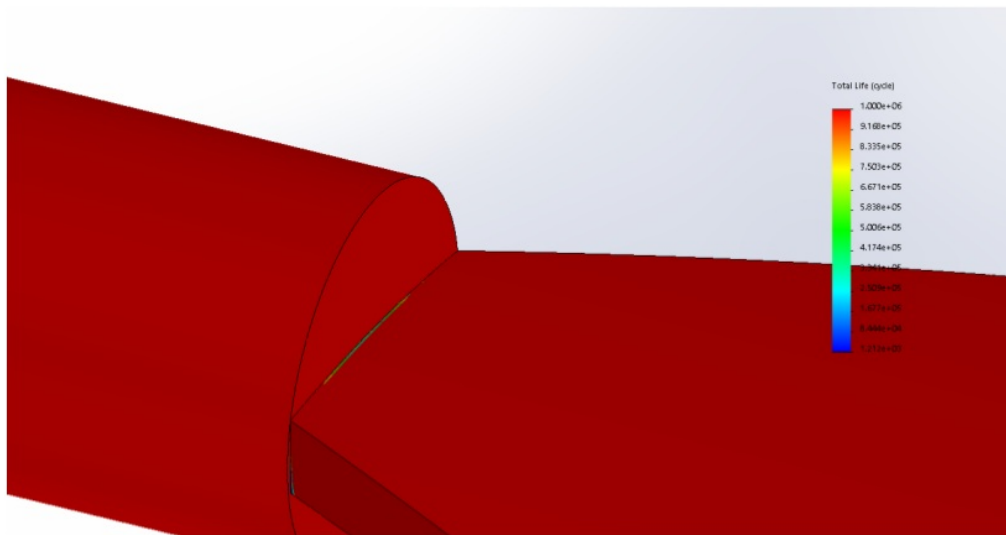


Figure 25: Isometric view of tail rotor fatigue analysis (Cheeseman, 2019).

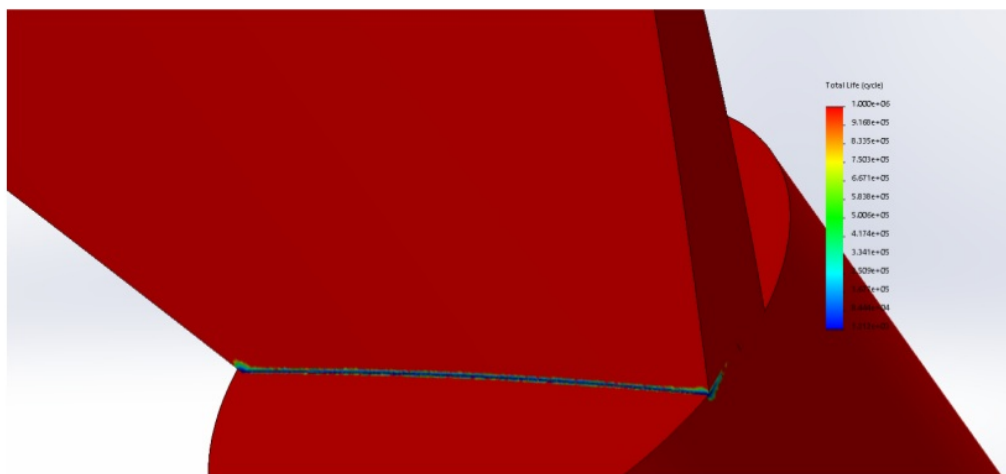


Figure 27: Bottom view of fatigue analysis (Cheeseman, 2019).

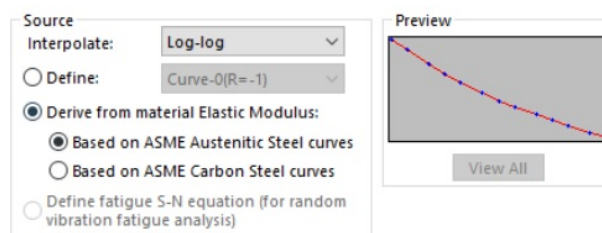


Figure 26: SN Curve Data (Solidworks, 2019).

### 5.3 Frequency Simulation Analysis

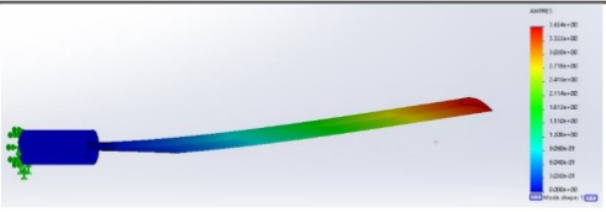
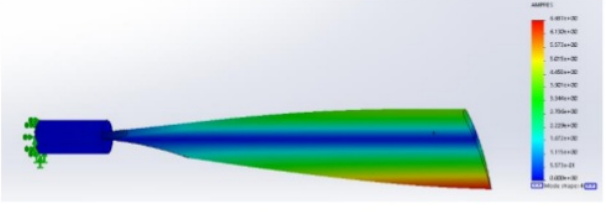
| Mode Number | Frequency (Hz) | Image                                                                                |
|-------------|----------------|--------------------------------------------------------------------------------------|
| 1           | 45.996         |    |
| 2           | 220            |    |
| 3           | 300.63         |   |
| 4           | 422.83         |  |
| 5           | 839.84         |  |

Table 6: Frequency Results (Cheeseman, 2019).

If the tail rotor starts to vibrate at any of the frequencies found in table 6, the rotor blade can be expected to vibrate and deform as shown in the image. The frequency that the rotor spins through was calculated using equation 11 is 23.516 Hz. The first frequency mode is showing that it has a natural frequency of 45.996 Hz, as it is greater than the calculated

frequency. Therefore, this value is not a concern at this moment. But further analysis should be conducted to ensure no other part of the helicopter vibrates at any of the frequency as shown in table 6 or in appendix 2, as it could cause excitement in the rotor blades.

## 6 Conclusion

The design its current form is suggest that it is not fit for its purpose as under the fatigue study it shows failure at 1212 cycles, this would be the equivalent of 1212 flights. This is also backed up using the results from the young's modulus hand calculations from equation 13 which has a value of  $176 \text{ GN/m}^2$  where the material proprieties for the chosen material used has a young's modulus of  $104 \text{ GN/m}^2$ . This would suggest the strain results are questionable and further analysis and possible further development of the part is required. Although The stress showing on the part is  $4.728 \times 10^8 \text{ N/m}^2$ , which is below the maximum yield stress of the material of  $8.234 \times 10^8 \text{ N/m}^2$ . This would imply that the part can handle the stresses whilst in operation. From the results of the natural frequency the part would not spin at the natural frequency of the blade thus causing no effect on the blade. Further analysis is needed to understand if any other of the full assemblies' components give of a vibration and to see if they are the same frequency of the rotor blade. Due to the model being a scaled down and a simplified, certain assumptions had to be made to be able to perform the analysis, such as cad model being used as a solid body with only one material chosen rather than the full assembly of the rotor blade.

## 7 Recommendation

For further studies on the tail rotor blade, the author would suggest using a better CAD Model using the actual blade assembly to be able to apply all the different material two it in the correct proportions or, to redesign the current model to remove the stress concentration areas. Further studies are needed to ensure result are reliable and preferably to run the same study across different software that are able to calculate into the plastic deformation region. If this report was carried out again the author would suggest a larger word count for the report to ensure that the adequate detail can be put into the report.



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1.

## 9 Appendix 1

Equation 4: Scale Ratio Equation.

$$\begin{aligned} \text{Scale Ratio} &= \frac{\text{Model Rotor Blade Diameter}}{\text{Real Rotor Blade Diameter}} \\ \text{Scale Ratio} &= \frac{0.732}{2.4888} \\ \text{Scale Ratio} &= 1:3.4 \end{aligned}$$

Equation 5: Solution of Angular Velocity (*Engineers Edge, 2019*).

$$\begin{aligned} \omega &= \frac{\text{rpm} \times 2\pi}{60} \\ \omega &= \frac{1411 \times 2\pi}{60} \\ \omega &= 147.76 \text{ rads/s} \end{aligned}$$

Equation 6: Solution Tip Velocity on CAD Model (*Engineers Edge, 2019*).

$$\begin{aligned} v &= \omega \cdot r \\ v &= 147.75 \times 0.366 \\ v &= 54.0765 \text{ m/s} \end{aligned}$$

Equation 7: Solution Lift Equation Solution (*Benson, 2018*).

$$\begin{aligned} F_L &= \frac{1}{2} (C_L \cdot \rho \cdot A \cdot v^2) \\ F_L &= \frac{1}{2} (1.45 \times 1.225 \times (16.24455 \times 10^{-3}) \times 54.0765^2) \\ F_L &= 42.195 \text{ N} \end{aligned}$$

Equation 8: Solution Drag Equation Solution (*Benson, 2018*).

$$\begin{aligned} F_D &= \frac{1}{2} (C_D \cdot \rho \cdot A \cdot v^2) \\ F_D &= \frac{1}{2} (0.04 \times 1.255 \times 2.01361 \times 10^{-3} \times 54.0765^2) \\ F_D &= 0.1164 \text{ N} \end{aligned}$$

Equation 9: Solution Centrifugal Force Equation Solution (*Engineers Edge, 2019*).

$$F_C = M\omega^2 r$$

$$F_C = 0.38155 \times 147.75^2 \times 0.18786$$

$$F_C = 1564.735 \text{ N}$$

Equation 10: Solution Force Acting Along Y Plane.

$$\sin \theta = \frac{\text{Opposite}}{\text{Hypotenuse}}$$

$$\sin \theta = \frac{F_z}{F}$$

$$F_z = F \times \sin \theta$$

$$F_z = 1564.735 \times \sin 25.48$$

$$F_z = 673.1427 \text{ N}$$

Equation 11: Solution Force Acting Along Z Plane.

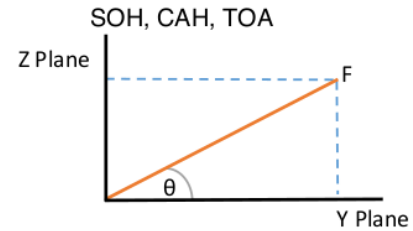
$$\cos \theta = \frac{\text{Adjacent}}{\text{Hypotenuse}}$$

$$\cos \theta = \frac{F_y}{F}$$

$$F_y = F \times \cos \theta$$

$$F_y = 1564.735 \times \cos 25.48$$

$$F_y = 1412.5417 \text{ N}$$



Equation 12: Solution for Frequency that the Tail Rotor Spins at.

$$\text{Frequency} = \frac{\text{rpm}}{60}$$

$$\text{Frequency} = \frac{1411}{60}$$

$$\text{Frequency} = 23.516 \text{ Hz}$$

Equation 13: Solution for Youngs Modulus.

$$E = \frac{\sigma}{\varepsilon}$$

$$E = \frac{4.728 \times 10^8}{2.682 \times 10^{-3}}$$

$$E = 176 \times 10^9 \text{ N/m}^2$$

Equation 14: Change in length equation.

$$\varepsilon = \frac{\Delta L}{L}$$

$$\Delta L = \varepsilon \times L$$

$$\Delta L = 2.682 \times 10^{-3} \times 0.366$$

$$\Delta L = 0.000982m$$

$$\Delta L = 0.982mm$$

## 10 Appendix 2

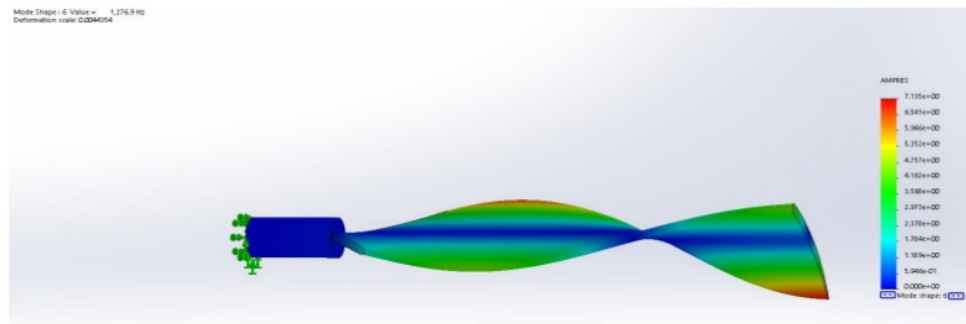


Figure 28: Mode 6 of Frequency Study (Cheeseman, 2019).

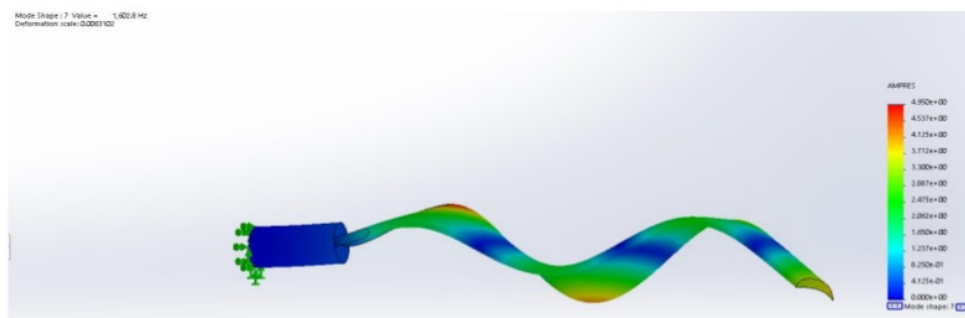


Figure 29: Mode 7 of Frequency Study (Cheeseman, 2019).

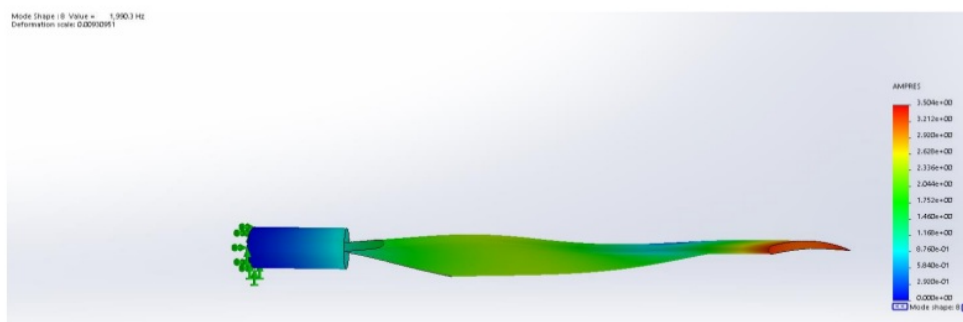


Figure 30: Mode 8 of Frequency Study (Cheeseman, 2019).

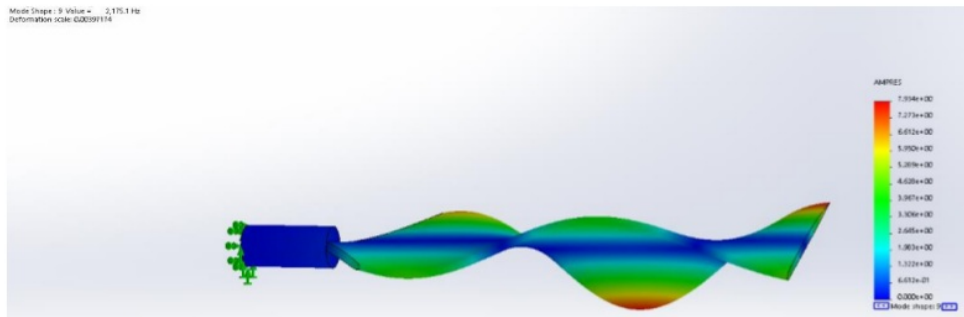


Figure 31: Mode 9 of Frequency Study (Cheeseman, 2019).

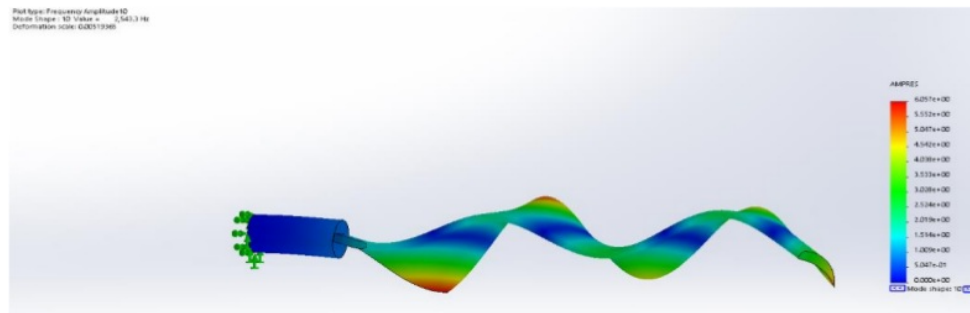


Figure 32: Mode 10 of Frequency Study (Cheeseman, 2019).

# Tail Rotor Blade Assignment

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## GRADEMARK REPORT

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FINAL GRADE

GENERAL COMMENTS

**Instructor**

**72**/100

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PAGE 1

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PAGE 2

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QM

### 5. Proof Read

Proof read your work before you submit it.

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PAGE 3

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QM

### 5. Presentation(+)

Generally your presentation is good

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PAGE 4

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PAGE 5

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PAGE 6

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QM

### 1. Secondary(+)

Good secondary research

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PAGE 7

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QM

### 1. Secondary(+)

Good secondary research

QM

### 3. Loading (+)

---

Good explanation of how you have calculated your forces.

PAGE 8

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QM

### 3. Material (+)

Good explanation as to what you have assumed regarding the material choice. The real blade will almost certainly be made up of an assembly, however for this analysis it is reasonable to assume that it is made up of an isotropic material.

PAGE 9

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QM

### 2. BCs(-)

Do you think that your boundary conditions were correct? Do you think that the analysis that you have carried out would be representative of the way in which the product would behave?

PAGE 10

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### Comment 1

Don't start sentences with And

PAGE 11

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QM

### 1. Secondary(+)

Good secondary research

PAGE 12

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### Comment 2

drag

QM

### 1. Secondary(+)

Good secondary research

QM

### 5. Resolution(-)

Make sure that any images that you take from other sources are of good enough resolution to be clear in your report

PAGE 13

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### Comment 3

The drag force would act in one direction only which is opposite to the direction of travel

The drag force would act in one direction only which is opposite to the direction of travel.

PAGE 14

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#### **Comment 4**

Why is density 0?

PAGE 15

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PAGE 16

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PAGE 17

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#### **Comment 5**

It would have been good to see how these mesh sizes influenced the results as well as the solve time.

PAGE 18

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#### **Comment 6**

Good practical recommendation

PAGE 19

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PAGE 20

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#### **Comment 7**

Given the assumptions that you have made, do you think that quoting displacement to such accuracy is appropriate?

PAGE 21

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PAGE 22

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PAGE 23

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#### **Comment 8**

Contextualise: "If the helicopter took two flights a day, every day, all year then this would suggest that the blade would need replacing every year and a half."

PAGE 24

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PAGE 25

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Comment 9

Your recommendations should relate to the report that you have carried out - not comment on the assignment.



1. Secondary(+)

Good secondary research

GRADING FORM: APACHE ACM

MICHAEL  
CHEESEMAN

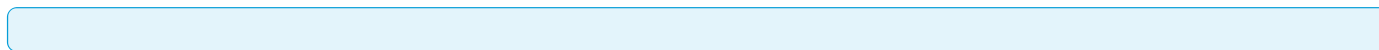
71.50

RESEARCH INFORMED LIT



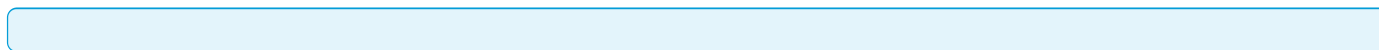
14.4

## KNOWLEDGE & UNDERSTANDING



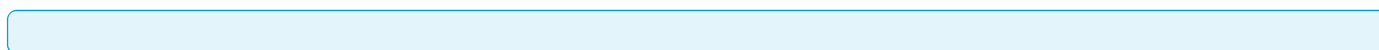
13

## ANALYSIS



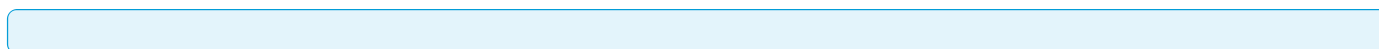
22.5

## PRACT APP & DEPLOYMENT



14.6

## SKILLS FOR PROF PRAC



7