International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(Research Article)

Check for updates

Design and analysis of helicopter rotor blades

Kolli Ramesh *, Macha Srikanth and Palanati Swetha

Vignan institute of technology and science, deshmuki (V), pochampally (M), Yadadri bhuvanagiri Dist, Telangana-508204, India.

International Journal of Science and Research Archive, 2023, 09(01), 696–703

Publication history: Received on 18 May 2023; revised on 25 June 2023; accepted on 28 June 2023

Article DOI: https://doi.org/10.30574/ijsra.2023.9.1.0508

Abstract

Rotor blades of helicopters must be stiff and strong enough to maintain structural loads within working limits. The rotating cycles change the aerodynamic and structural stresses created by the blade revolution. In this project, you will discover the structural stresses of the blades as well as the vibration frequencies studied using the Ansys programme, taking into consideration environmental consequences. This material was tested utilising Kevlar 49, carbon-epoxy, and advanced carbon fibre composite materials and found to be a lightweight, high-strength, and long-lasting material. Solidworks software was used to create the design.

Keywords: Aerodynamics forces; Helicopter blades; Solidworks simulation; Structural analysis; Vibration analysis

1 Introduction

Helicopters are available in a range of sizes and shapes, based on their intended use and payload requirements. However, the majority of them have similar portions and sections. The helicopter rotor or rotor frame is one of the most significant components (Fig. 1). Its goal is to build lifting helicopters and payloads, as well as to reduce the drag generated during forwards flight. The rotor frame's primary sections are the pole, centre, and sharp edge. The rod is linked to the gearbox via a hollow in the metal shaft of the tube. The connecting rotor edges are focused on the top pole. Sharp rotor edges are critical components of the rotor structure and are attached to the centre at various angles. There are three types of rotor framework: stiff, semi-rigid, and completely voiced. This sequence is determined by the rotor edges' connection to the centre and their speed in relation to the pole. These blades spin at high speeds to create a force called lift that allows the helicopter to rise in the air. The lift generated from the blades supports the vehicle's weight and provide forward velocity to move through the sky.

1.1 Blade Design Characteristics

- Using as few parts as possible
- Keeping the weight of the rotor system down
- Ensuring drag created by the blades is minimal
- Keep noise to a minimum
- Keep vibration to a minimum
- As you can see there are a lot of things the designers have to think about when they design the helicopters rotor system, let alone the insane amount of aerodynamic factors that also come into play!
- The bigger the rotor blade, the more lift it produces, but it also weighs more, requires more materials, costs more, creates more drag as it moves through the air, and requires more power to overcome that drag.
- Keeping cost low.

* Corresponding author: Kolli Ramesh

1.2 Force acting on helicopter

Once a helicopter leaves the ground, it is acted upon by four aerodynamic forces; thrust, drag, lift, and weight. Understanding how these forces work and knowing how to control them with the use of power and flight controls are essential to flight.

They are defined as follows:

- Lift—opposes the downward force of weight, is produced by the dynamic effect of the air acting on the airfoil and acts perpendicular to the flightpath through the center of lift.
- Weight—the combined load of the aircraft itself, the crew, the fuel, and the cargo or baggage. Weight pulls the aircraft downward because of the force of gravity. It opposes lift and acts vertically downward through the aircraft's center of gravity (CG).
- Thrust—the force produced by the power plant/ propeller or rotor. It opposes or overcomes the force of drag. As a general rule, it acts parallel to

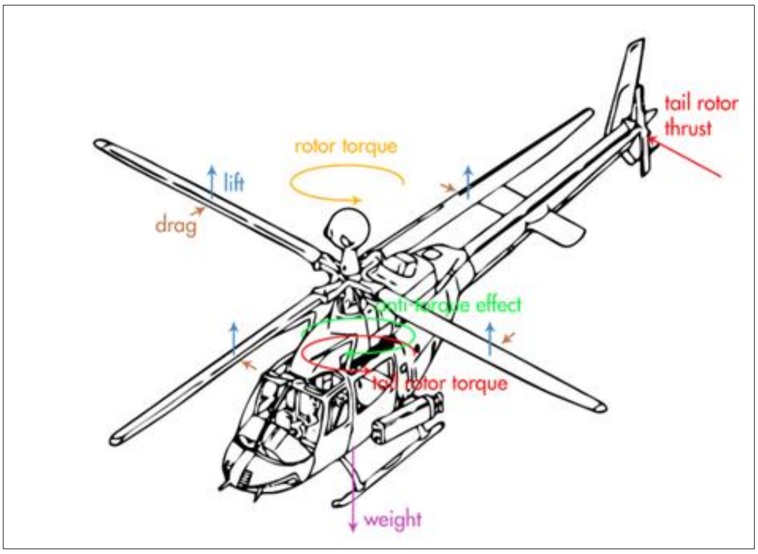

Figure 1 Forces acting on rotor blade

- The longitudinal axis. However, this is not always the case, as explained later.
- Drag—a rearward, retarding force caused by disruption of airflow by the wing, rotor, fuselage, and other protruding objects. Drag opposes thrust and acts rearward parallel to the relative wind.ss

1.3 Airfoil

An **airfoil** or **aerofoil** is a streamlined body that is capable of generating significantly more lift than drag.

1.3.1 Aerofoil Terminology

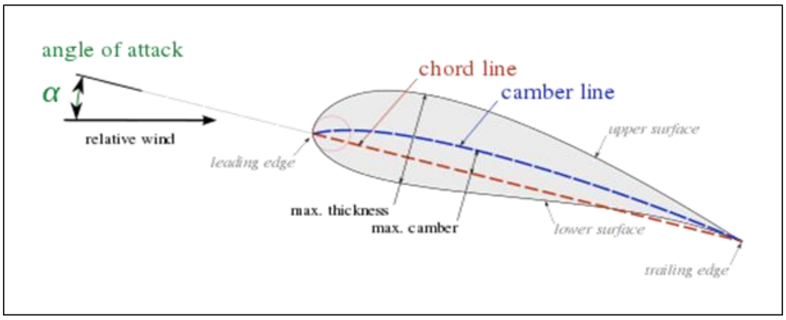

Figure 2 Terminology of aerofoil structure

- **Chord:** Chord can be defined as the distance between the leading edge, at the front of the aerofoil that is the point, and has maximum curvature and the trailing edge, at the rear of the aerofoil, that is the point with a maximum curvature along the chord line. It is a distance between the leading and trailing edges measured along the chord line.
- **Chord Line:** Chord line is the straight line connecting the leading and trailing edges.
- **Leading-Edge:** It is an edged part of an aerofoil that hits the air particles first.
- **Lower Surface:** The lower surface is a higher static pressure surface which is also known as a pressure surface. It is the surface of an aerofoil between the leading and trailing edges, on the lower side.
- **Mean Camber Line:** It is a line joining the leading and trailing edges of an aerofoil, at an equal distance from the upper and lower surfaces.
- **Maximum Camber:** It is the maximum distance of the mean camber line from the chord line.
- **Maximum Thickness:** It is the maximum distance of the lower surface from the upper surface.
- **Trailing Edge:** It is an edged part from an aerofoil that hits the air particles last.

1.4 Four-digit series

The NACA four-digit wing sections define the profile by

- **First digit describing maximum camber as percentage of the chord.**
- **Second digit describing the distance of maximum camber from the airfoil leading edge in tenths of the chord.**
- **Last two digits describing maximum thickness of the airfoil as percent of the chord.[3]**

For example, the NACA 2412 airfoil has a maximum camber of 2% located 40% (0.4 chords) from the leading edge with a maximum thickness of 12% of the chord.

The NACA 0015 airfoil is symmetrical, the 00 indicating that it has no camber. The 15 indicates that the airfoil has a 15% thickness to chord length ratio: it is 15% as thick as it is long.

2 Mechanical Design software

The 3D modelling software tools are used for a number of projects, from simulation to manufacturing. A 3D modelling software with great visualisation options can help you get a better overview of your project. A precise overview allows you to adjust and improve your parts efficiently. It is also a good method to correct the last errors.

SolidWorks (stylized as SOLIDWORKS) is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) application published by Dassault Systèmes.

3 Present existing material

The material used for making helicopter blades is typically either composite materials or metal alloys. Composite materials, such as carbon fiber reinforced plastic, are often used for helicopter blades due to their high strength-to-weight ratio and ability to withstand the high stresses and strains of helicopter flight. Metal alloys, such as aluminum and titanium, are also commonly used for helicopter blades due to their high strength and durability.

The helicopter blades was constructed from

- Aluminum alloy (Al7075-T6)
- Magnesium alloy (Mg-Li9-A3-Zn3,)

Table 1 Mechanical Properties of Aluminium

Property	Value
Mean Specific Heat (0-100°C) (cal/g.°C)	0.219
Thermal Conductivity (0-100°C) (cal/cms. °C)	0.57
Co-Efficient of Linear Expansion (0-100°C) (x10^{-6}/°C)	23.5

Density (g/cm^3)	2.6898
Modulus of Elasticity (GPa)	68.3
Modulus of Elasticity (GPa)	68.3
Poissons Ratio	0.34

4 Analytical design of helicoptermain rotor head

4.1 Design Specifications conditions

Analyzing the benefits and drawbacks of various rotor head designs was the first step in the rotor head selection process. The following criteria for a design were decided upon:

- Diameter of a rotor would be approximately one meter
- Rotor head should be fully articulated and coaxial
- Blades must be easily interchangeable to test different designs
- Number of blades should be variable

4.2 Specification of Coaxial helicopters

- Length: 16 m (52 ft 6 in)
- Height: 2.4 m (7 ft 10.78 in)
- Empty weight: 7,700 kg (16,976 lb)
- Gross weight: 9,800 kg (21,605 lb)
- Max takeoff weight: 10,800 kg (23,810 lb)
- Powerplant: 2 × Klimov VK-2500 turboshaft engines, 1,800 kW (2,400 shp) each
- Main rotor diameter: 2 × 14.5 m (47 ft 7 in)
- Main rotor area: 330.3 m2 (3,555 sq ft) contra-rotating 3-bladed main rotors

4.2.1 Kind of load

- Value Unit Aerodynamic lift force = 1500 N
- Centrifugal force of a blade =6156 N
- Aerodynamic drag force of a blade = 40 N
- Torque = 160 Nm
- Rotational speed = 180 rad/s

4.3 Design Calculations

4.3.1 Blade sizing

A very first step of our design is to determine a dimension of a rotor blade of a rotor mechanism. This part is done by following various design approach of RC helicopter blades.

A primary assumption of a dimension for a blade is, Disc radius = Blade span = R = 0.5m , Blade Chord = C = 0.1m , N = Number of blades

From Blade elementary aory,

Solidity Factor, Solidity Factor,

σ = (Blade Area)/(Disc Area)= ((N×C))/(π×R)

Now, For 3 Blade, N = 3, Solidity Factor,

σ = ((3×0.1))/((π×0.5))= 0.191

Again, For 2 Blade, N = 2, Solidity Factor,

$\sigma = ((2\times0.1))/((\pi\times0.5)) = 0.127$

4.4 Rotor blade design in solidworks

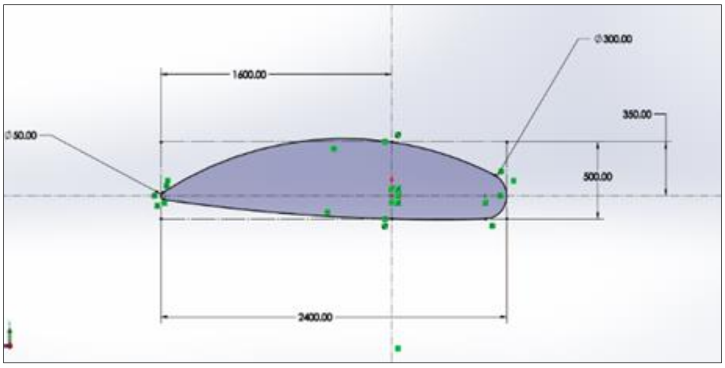

Figure 3 Aerofoil structure

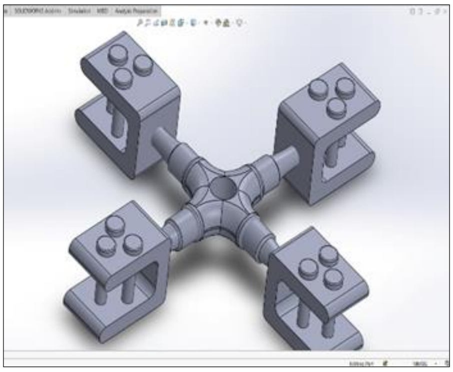

Figure 4 Rotor blade hub

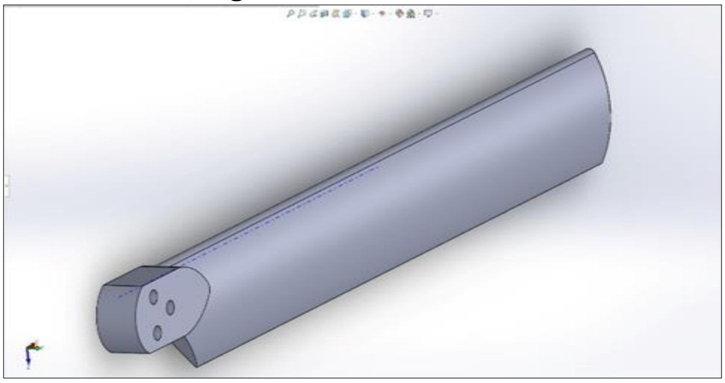

Figure 5 Rotor blade

Figure 6 Rotor blade swash plate

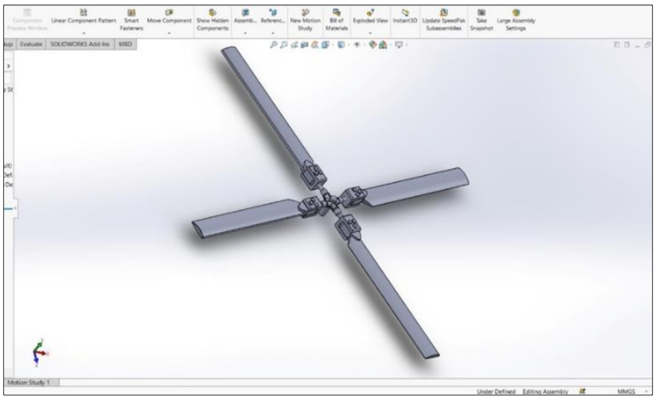

Figure 7 Rotor blade assembly

5 Simulation study

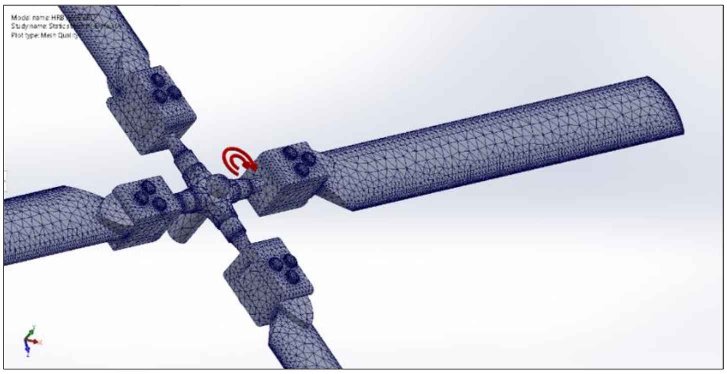

Figure 8 Meshing

5.1 Material: Aluminium

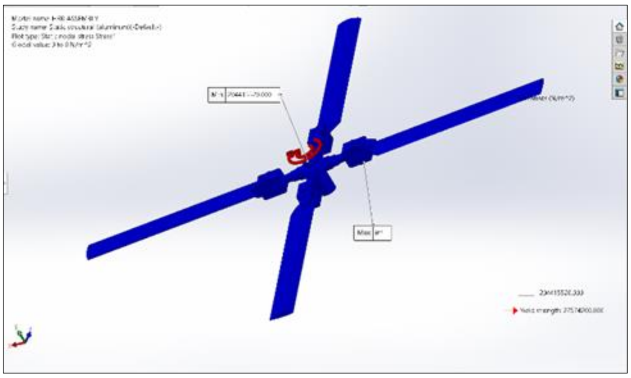

Figure 9 Static stress structural

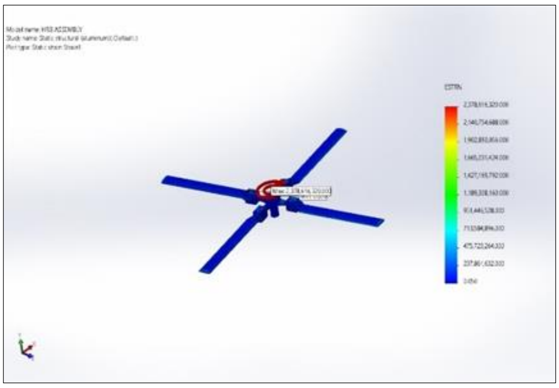

Figure 10 Static strain structural

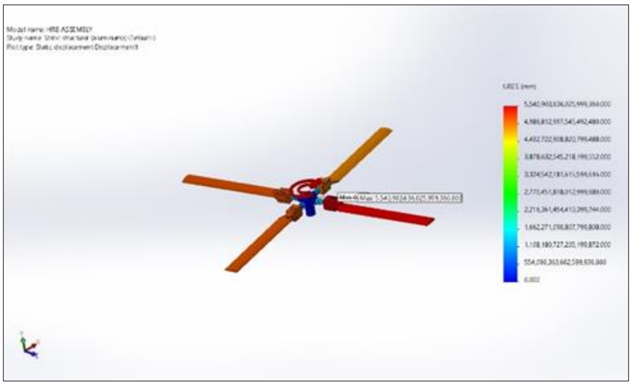

Figure 11 Static displacement

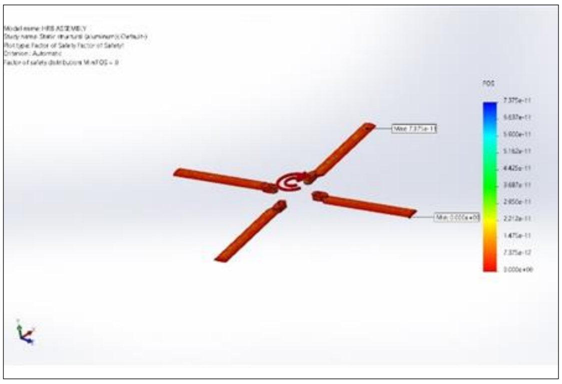

Figure 12 Factor of safety

5.2 Material: - KEVLAR 49

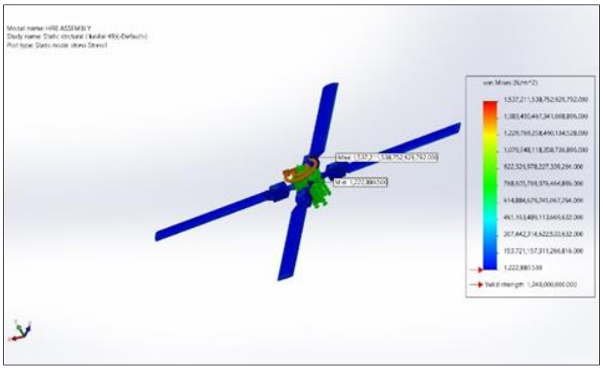

Figure 13 Static stress structural

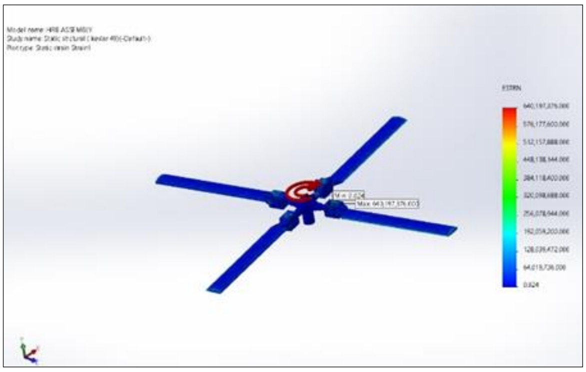

Figure 14 Static strain structural

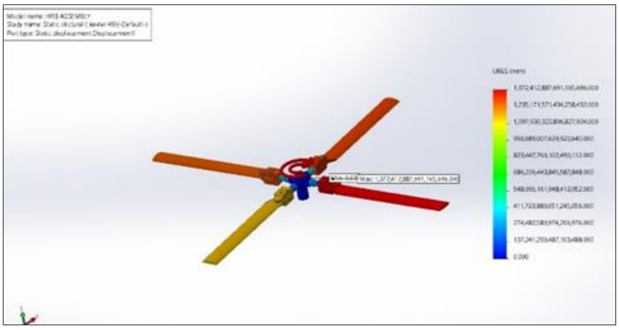

Figure 15 Static displacement

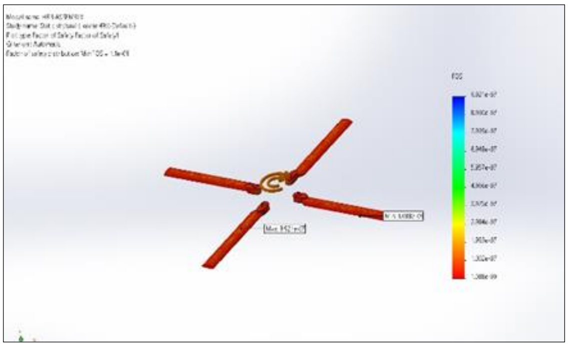

Figure 16 Factor of safety

6 Results

Table 2 Comparison of physical properties between aluminum and Kevlar 49

	Materials			
Results	**ALUMINUM**		**KEVLAR 49**	
	min	**max**	**min**	**max**
stress	204415520.00	∞	1222880.50	1537211538752929792.00
strain	0.049912	2378616320.00	0.023761	40197376.00
Displacement	0	5540903636025999360.00	0	1372412887691165696.00
Factor of safety	0	0.134893	0	1014.00

7 Conclusion

Extensive historical research makes it evident that the issue has not yet been fully resolved, and designers are still having many difficulties, particularly with stress concentration and the impact of loading other oar variables. The most well-liked strategy for analysing fracture mechanics issues is the finite element approach. Some helicopter main rotor heads made of aluminium are almost as light as those made of Kevlar 49. However, steel's key benefit is that it is more rigid and has higher fatigue strength than Kevlar 49. We can therefore conclude that Kevlar 49 is good for producing inexpensive helicopter main rotor heads whereas steel is a better material in terms of strength. SOLIDWORKS was used to successfully complete a project's design. Using SOLIDWORKS, issues that arose during the design of a machine were successfully resolved. The majority of the key components of SOLIDWORKS, a flexible and all-inclusive programme for threedimensional solid modelling, were used in the project design.

As we can conclude that by taking the considerations of the blade characteristics and aerofoil structure we completed the design procedure. the motion of the rotor blade is determined by using solidworks software As we are utilize the Kevlar 49, carbon-epoxy, and advanced carbon fibre composite materials and found to be a lightweight, high-strength, and long-lasting material.And we used composite material (Kevlar 49) to improve the durability and stiffness of the blades. As the increasing of the durability of the component the cost of the development of new component will be reduce.

Compliance with ethical standards

Acknowledgments

This research was partially supported by Macha Srikanth, Palanati Swetha . We are thankful to our collage Vignan institute of technology and science who provided expertise that greatly assisted the research.

We are also grateful to Mrs. Ch. Saikrupa for assistance and in that line improved the manuscript significantly.

Disclosure of conflict of interest

No conflict of interest.

References

[1] Prof.Amarnath.v.hegne and Prof.preethi hegne, July-august 2013,Design and power transmission of advance light helicopter.

[2] Hardeep Singh and Jag sahil saini ,Gurukul vidyapeeth institute of engineering and technology, September 2014, Detailed study of rotor blades ofhelicopter

[3] Jag sahil saini, Gurukul vidyapeeth institute of engineering and technology. June 2015 Analysis of rotor blade of helicopter Michael Roemer, Matthew Montana, Scott Novak, and Mitchell brush, spring 2016.

[4] Michael Roemer, Matthew Montana, Scott Novak, and Mitchell brush, spring 2016 The development and analysis of helicopter rotor blades.

[5] https://en.wikipedia.org/wiki/Helicopter_rotor

[6] https://www.sciencedirect.com/science/article/pii/S1000936112000167

[7] http://www.helistart.com/RotorBladeDesign.aspx

[8] https://www.britannica.com/video/187703/helicopter-rotor-blade-design

[9] sshttps://help.solidworks.com/2020/English/SolidWorks/cworks/c_SOLIDWORKS_Simulation_Fundamentals.htm

[10] Design and power transmission of an advanced light helicopter, July-August 2013, Prof. Amarnath V. Hegne and Prof. Preethi Hegne.

[11] The development and study of helicopter rotor blades, by Mitchell Brush, Scott Novak, Matthew Montana, and Michael Roemer, published in April 2016.

[12] LEISHMAN, J. GORDON. PRINCIPLES OF HELICOPTER AERODYNAMICS. CAMBRIDGE AEROSPACE SERIES, 18. CAMBRIDGE: CAMBRIDGE UNIVERSITY PRESS, 2006. ISBN 978-0-521-85860-1. PP. 7-9. WEB EXTRACT