A Project Report

On

DESIGN, FABRICATION AND DEMONSTRATION OF AN RC HELICOPTER FOR SURVEILLANCE PURPOSE

Submitted to

Amity University Uttar Pradesh

in partial fulfilment of the requirements for the award of the degree of

Bachelor of Technology

at

AMITY INSTITUTE OF AEROSPACE ENGINEERING

by

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DEPARTMENT OF AEROSPACE ENGINEERING

AMITY INSTITUTE OF AEROSPACE ENGINEERING

AMITY UNIVERSITY, UTTAR PRADESH

NOIDA (U.P.)

MAY 2012

DECLARATION

We, Deepak Bhati, Krishi Mridul, Kavya Varma, Madhavi Bhattad, Mani Agarwal, Mohit Mehndiratta student(s) of B.Tech (Aerospace Engineering) hereby declare that the project titled "Design, Fabrication and Demonstration of an RC Helicopter" which is submitted by us to Department of Aerospace Engineering, Amity Institute of Aerospace Engineering, Amity University Uttar Pradesh, Noida, in partial fulfilment of requirement for the award of the degree of Bachelor of Technology in Aerospace Engineering, has not been previously formed the basis for the award of any degree, diploma or other similar title or recognition.

Noida

10-04-2012

Name and Signature of Students

DEEPAK BHATI

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KAVYA VARMA

MADHAVI BHATTAD

MANI AGARWAL

MOHIT MEHNDIRATTA

CERTIFICATE

On the basis of declaration submitted by Deepak Bhati, Krishi Mridul, Kavya Varma, Madhavi Bhattad, Mani Agarwal, Mohit Mehndiratta student(s) of B. Tech (Aerospace Engineering) I hereby certify that the project titled "Design Fabrication and Demonstration Of An RC Helicopter for Surveillance Purpose" which is submitted to Department of Aerospace Engineering, Amity Institute of Aerospace Engineering, Amity University Uttar Pradesh, Noida, in partial fulfillment of the requirement for the award of the degree of Bachelor of Technology in Aerospace Engineering, is an original contribution with existing knowledge and faithful record of work carried out by him/them under my guidance and supervision.

To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Noida

Date

(Guide)
Department of ……………….
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ABSTRACT

The report deals with the study of components of helicopters varying from the main rotor system to the tail rotor system. Based on this study, the design requirements have been understood and hence design calculations have been done leading to the decision of an RC model.

Radio-controlled helicopters (also RC helicopters) are model aircraft which are distinct from RC airplanes because of the differences in construction, aerodynamics, and flight training.

In the report the airfoil characteristics are studied and calculations have been done to calculate the bending moments and stress on the rotor blade which is one of the most important parts of the helicopter as it is responsible for the lift and thrust.

The power required calculation is done to satisfy the need of a propulsion system.

The RC helicopter's main body and other parts are attached together by the students and the helicopter is chosen based on the design calculations.

The report also talks about the trans-receiver used with the camera that is mounted on the helicopter for surveillance purposes.

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INTRODUCTION

The word helicopter is adapted from the French hélicoptère, coined by Gustave de Ponton d'Amecourt in 1861, which originates from the Greek helix/helik means "twisted, curved" and pteron means "wing".

A helicopter (informally known as a "chopper") is a type of rotorcraft in which lift and thrust are supplied by one or more engine-driven rotors. This allows the helicopter to take off and land vertically or hover, and to fly forwards, backwards, and laterally.

Helicopter as a flying body, has been instrumental in variety roles e.g.

(i) Defence
(ii) Surveillance
(iii) Rescue mission

Due to its unique capability of vertical take-off, hover and landing at small areas, helicopter is a complex piece of engineering with rotor/ fin.

In this project work, the aim is to design a helicopter which can be used for surveillance purpose. The scope of the project work is:-

(a) Preliminary Design Study of Helicopters and its payload (Surveillance device). The aim is to understand the basic aspects of design parameters of a Helicopter.

(b) Study of Video Surveillance system and data link for transmission on ground control System.

As a part of this project we designed a remote (RC) helicopter model, for explaining engineering design process. For video imaging, a small digital camera fixed focal length has been installed. The data link has been provided at wi-fi. We considered the designs of helicopters already fabricated as a reference.

SYSTEM ANALYSIS

The main system of a helicopter comprises of

- Main Rotor
- Rotor Blades
- Tail Rotor

MAIN ROTOR

The main rotor of the helicopter provides lift and allows the forward flight. A helicopter "rotor system" is the unit that is composed of a hub and the blades attached to it. Each rotor is considered a separate system, and a helicopter may have more than one main rotor.

There are three primary types of rotor systems: articulated, semi-rigid, and hingeless.

The main rotor comprises of the following of the following parts:

1. Rotor shaft driven by the power plant.
2. Rotor head which joins the rotor shaft and blades.
3. Main rotor blades.

The blades are hinged to the rotor head which permits blade motion in the vertical, the rotational and the longitudinal plane.

The lifting force is produced by the main rotor . As they spin in the air and produced the lift. Each blade produces an equal share of the lifting force. The weight of a helicopter is divided evenly between the rotor blades on the main rotor system. If a helicopter weight 4000 lbs and it has two blades, then each blade must be able to support 2000 lbs.In addition to the static weight of helicopter ,each blade must be accept dynamic load as well . For example, if a helicopter pull up in a 1.5 g manouver (1.5 time the gravity force), then the effective weight of helicopter will be 1.5 time of static helicopter weight or 6000 lbs. due to gravitational pull.

TYPES OF ROTOR SYSTEM

Fully Articulated Rotor System

A fully articulated rotor system usually consists of three or more rotor blades. The blades are allowed to flap, feather, and lead or lag independently of each other. Each rotor blade is attached to the rotor hub by a horizontal hinge, called the flapping hinge, which permits the blades to flap up and down. Each blade can move up and down independently of the others. The flapping hinge may be located at varying distances from the rotor hub, and there may be more than one. The position is chosen by each manufacturer, primarily with regard to stability and control.

Each rotor blade is also attached to the hub by a vertical hinge, called a drag or lag hinge, that permits each blade, independently of the others, to move back and forth in the plane of the rotor disc. Dampers are normally incorporated in the design of this type of rotor system to prevent excessive motion about the drag hinge. The purpose of the drag hinge and dampers is to absorb the acceleration and deceleration of the rotor blades.

The blades of a fully articulated rotor can also be feathered, or rotated about their span wise axis. To put it more simply, feathering means the changing of the pitch angle of the rotor blades.

Semi-Rigid Rotor System

A semi-rigid rotor system allows for two different movements, flapping and feathering. This system is normally comprised of two blades, which are rigidly attached to the rotor hub. The hub is then attached to the rotor mast by a trunnion bearing or teetering hinge. This allows the blades to see-saw or flap together. As one blade flaps down, the other flaps up. Feathering is accomplished by the feathering hinge, which changes the pitch angle of the blade.

Rigid Rotor System

The rigid rotor system is mechanically simple, but structurally complex because operating loads must be absorbed in bending rather than through hinges. In this system, the blades cannot flap or lead and lag, but they can be feathered.

<u>Rotor Lift</u>

The rotor lift can be controlled by the following two ways:

1. Amplitude of the rotor lift is controlled by the collective pitch variation.
2. Directional control of the rotor lift is achieved by the cyclic pitch variation.

Rotor Blades

At any angle of attack, the blade section generates an aerodynamic load which can be resolved vertically and horizontally to give lift and drag, perpendicular and parallel to the relative wind respectively. The resultant of the sectional lift and the drag loads of the blade sections act at the centre of pressure of the blade to give the blade total lift and total drag.

In case of symmetric airfoil, the centre of pressure is fixed and lies at a distance of 0.7R from the centre of rotation along the span and at 25% of chord length from the leading edge. It also coincides with the aerodynamic centre and feathering axis.

In case of cambered airfoil, the location of centre of pressure is variable. With the increase in the resultant aerodynamic force, the centre of pressure shifts forward causing nose-up moment which tends to increase the angle of attack and vice versa.

Due to this advantage, the main rotor blades of the helicopter are normally made of symmetric airfoil section.

Blade Twist and Taper

When a blade rotates, each point on it travels at a different speed. The further away from the root, the higher the velocity. This means that the contribution to lift and drag of every point on the blade differs, with each aspect getting larger when moving closer to the rotor tip. Clearly, the lift distribution over the blade is not constant. This is not a desirable situation, because the contribution diminishes when getting closer to the root. To change this distribution, blades are twisted and, sometimes, also tapered. The twist is such that the angle of attack increases when travelling towards the root, producing more lift. Tapering the blade also contributes to achieving a more evenly spaced lift distribution. With blade tapering, the blade's surface gets larger when travelling towards its root. Both tapering and twisting can be observed when looking carefully at rotorblades at rest. Note that blade tapering is not always used (especially on metal blades because of a more complicated fabrication process).

Blade Tip Speed and Noise Reduction

When the blades are very long or the helicopter is designed with a high rotor RPM, the blade tip speed can become extremely high. When the tip speed reaches the sound of speed, pressure waves come into existence, which causes rotor drag. A high tip speed is also the single most important design parameter influencing generated noise levels. It is, therefore, logical to expect more designs with lower RPM and very efficient (larger L/D ratio) performance blades. In this way, blade efficiency is traded off for noise reduction instead of better flight performance.

TAIL ROTOR

The tail rotor is very important. If you spin a rotor with an engine, the rotor will rotate, but the engine and helicopter body will tend to rotate in opposite direction to the rotor. This is called Torque reaction. Newton's third law of motion states, "to every action there is an equal and opposite reaction". The tail rotor is used to compensate for this torque and hold the helicopter straight.

REACTION TORQUE

Compensation for torque in the single main rotor helicopter is accomplished by means of a variable pitch anti-torque rotor (tail rotor) located on the end of a tail boom extension at the rear of the fuselage. Driven by the main rotor at a constant ratio, the tail rotor produces thrust in a horizontal plane opposite to torque reaction developed by the main rotor. Since torque effect varies during flight when power changes are made, it is necessary to vary the thrust of the tail rotor. Antitorque pedals enable the pilot to compensate for torque variance. A significant part of the engine power is required to drive the tail rotor, especially during operations when maximum power is used. From 5 to 30 percent of the available engine power may be needed to drive the tail rotor depending on helicopter size and design. Normally, larger helicopters use a higher percent of engine power to counteract torque than do smaller aircraft. A helicopter with 9,500 horsepower might require 1,200 horsepower to drive the tail rotor, while a 200 horsepower aircraft might require only 10 horsepower for torque correction.

Heading Control

In addition to counteracting torque, the tail rotor and its control linkage also permit control of the helicopter heading during flight. Application of more control than is necessary to counteract torque will cause the nose of the helicopter to swing in the direction of pedal movement. To maintain a constant heading at a hover or during takeoff or approach, the pilot must use anti torque pedals to apply just enough pitch on the tail rotor to neutralize torque and hold a slip if necessary. Heading control in forward trimmed flight is normally accomplished with cyclic control, using a coordinated bank and turn to the desired heading. Application of anti torque pedals will be required when power changes are made.

In an autorotation, some degree of right pedal is required to maintain correct trim.

When torque is not present, mast thrust bearing friction tends to turn the fuselage in the same direction as main rotor rotation. To counteract this friction, the tail rotor thrust is applied in an opposite direction to counter the frictional forces.

Parameters Influencing the Tail Rotor Design

The primary criteria for the design of a tail rotor is that it must generate enough thrust to balance the main rotor reaction torque in full power climb condition with a margin of about 10% for directional control. It should also ensure control of the helicopter during autorotation.

There are two types of tail rotor systems:

1. Conventional tail rotor
   It require less power, good yaw control and directional stability in the forward flight. The tail rotor are either the pusher or the puller type.
   In case of pusher type tail rotor, it sucks the air past the vertical fin and it is mounted on the left side of the fin.
   In case of the puller type the air is blown at the fin which causes more drag on the fin. This reduce the effective net thrust of the tail rotor for the anti torque purpose.

2. Ducted tail rotor or fenestron
   This type of tail rotors are surrounded by a duct. Performance benefit similar to those of the conventional tail rotors can be achieved by a smaller fenestron since the lips of the duct produce low static pressure which add to the force being generated by the fan.

SWASH PLATE

The swash plate changes the pilot’s linear cyclic(and often collective) control inputs into rotary blade pitch angle changes in the main rotor. It is the position of the swash plate that determines which direction the rotor disk will move in.

The swash plate is usually made up of two halves. The top half rotates with the rotor (usually pulled around by the washout and washout guide), while the bottom half does not (aligned with the helicopter body by the anti-rotation bracket).Due to the use of spherical bearing in the centre, the swash plate is free to tilt in response to control inputs, and transfers those inputs through the linkages to the rotor blades.

In mechanical terms, the lower(non rotating) part of the swash plate forms a cam, and the upper rotating part its cam follower. This is slightly unusual, as it is normally the cam that is thought of as rotating, and its follower that is held stationary

Transmission System

Transmission is a gear reduction mechanism attached to the engine. The Transmission system transmits the engine power to the main rotor, tail rotor, the generator and other accessories, namely, the cooling fan, the hydraulic pump, the rotor tachometer, etc. the engine of the helicopter operates at relatively high speed in comparison to the speed of the main rotor. The speed reduction is accomplished through the reduction gears, normally in two stages, in the Transmission system and is generally between 6-1 and 9-1. The ratio of the engine rpm to the rotor rpm is the same as the gear reduction ratio.

There are two reasons for the speed reduction:-

(i) The engine produces the greatest amount of power at high rpm.
(ii) The rotor can not operate at high rpm because of the retreating blade stall and the fact that the tip speed must stay subsonic.

Main Components:

Clutch: This unit is used in the reciprocating and the turbine powered helicopters that do not use a free turbine. The clutch is necessary so as to unload the engine during the starting operation because the inertia required to move the rotor system would be too great. The clutches are always located between the power plant and the gear reduction of the transmission so that the power plant can be started without immediate engagement of the rotor system. The clutch does not provide disengagement of the engine from the main rotoe during autorotation. There are the following types of clutches in use:

FREE WHEELING UNIT

this component will be found on all the helicopters regardless of the powerplant. On multi-engined helicopters, one free wheeling unit will be located on each engine. The purpose of the free wheeling unit is to allow the engine to drive the transmission and to prevent the rotor from driving the engine. Without this unit, the engine will be driven by the rotor any time the autorotation is attempted.

Rotor Brake

The rotor brake is used to stop the rotor. Since the rotor has a very high inertia which requires a great amount of braking force, brakes are never applied until the rotor has slowed down considerably on its own. The brakes are operated either hydraulically or manually.

COLLECTIVE PITCH

When the collective pitch is varied, the pitch angle on all the rotor blades changes by the same amount irrespective of their position. Due to change in the pitch angle, the magnitude of the rotor lift varies, however, it has no effect on the direction.As the collective pitch changes, the amount of power required to keep the main rotor spinning at the same rpm changes and must be compensated for by changing the throttle control.

CYCLIC PITCH

The cyclic pitch system controls the direction of the thrust by causing the rotor disc to tilt with respect to the shaft in response to the movement of the cyclic stick. Therotor disc always tilts in the direction the cyclic stick is displaced. The cyclic pitch control basically controls the horizontal movement of the helicopter. With the movement of the cyclic stick, the control linkages act on the swash plate.

- Forward cyclic tilts or pitches the helicopter forward.
- Rear cyclic tilts or pitches the helicopter backwards.
- Right cyclic tilts or rolls the helicopter right.
- Left cyclic tilts or rolls the helicopter left.

Differential collective pitch affects the yaw of the helicopter—the turning movement of the aircraft to the right or left. Differential collective pitch control allows the collective pitch of one rotor to be increased over the collective pitch of the other. This produces an increase in resistance, and more torque in one rotor than the other, turning the craft on its vertical axis.

ANTI TORQUE PEDALS

In accordance with Newton's law of action and reaction, the helicopter fuselage tends to rotate in the direction opposite to the rotor blades . This effect is called torque . Torque must be counteracted and controlled to make flight is possible . Compensation for torque in a single main rotor helicopter is accomplished by means of a variable pitch anti torque rotor (tail rotor) located on the end of the tail boom extension at the rear of fuselage. They are attached to the pitch change mechanism in the tail rotor gear box through linkages. This permits the pilot to change the pitch of the tail rotor blades.

Two main functions of the tail rotor and its controls are:

1. To counteract the torque of the main rotor during flight and
2. To control the heading of the helicopter during hovering flight.

THROTTLE CONTROL

The function of the throttle control is to regulate rpm. The throttle is mounted on the forward end of the collective pitch lever. The throttle movement is coordinated with the collective pitch through the collective pitch-throttle synchronisation unit. Any change in the collective pitch, the rpm will be maintained constant. A clockwise movement of the throttle control increases the rpm and vice-versa.

AUTOROTATION

It refers to the descending maneuver where the engine is disengaged from the main rotor system and the rotor blades are driven solely by the upward flow of air through the rotor. The freewheeling unit is a special clutch mechanism that disengages anytime the engine rpm is less than the rotor rpm. If the engine fails, the freewheeling unit automatically disengages the engine from the main rotor allowing the main rotor to rotate freely.

The most common reason for an autorotation is an engine malfunction or failure, but autorotations can also be performed in the event of a complete tail rotor failure or following loss of tail-rotor effectiveness, since there is virtually no torque produced in an autorotation.

Various Flying Conditions of a helicopter

1. Hover
2. Vertical Flight
3. Forward Flight
4. Transverse Flight

TOTAL POWER REQUIRED

ROTOR PROFILE POWER

Rotor Profile Power is the power required just to turn the rotors. It is the power required to overcome the rotor aerodynamic drag force. Power has dimensions of Nms^{-1}, and as we know power is Rate of Rotation * Torque. The drag force we measure in Newtons, and if we apply element theory and integrate the force along the blade, we can calculate the blade and thus rotor torque. The Torque is measured in Nm. If we convert RPM into radians per second we can now multiply by this and have a figure for Rotor Profile Power.

INDUCED POWER

Induced Power is that portion of the power required to produce lift. It is the power required to overcome the portion of rotor drag which is caused by the induced flow tilting the total reaction rearwards.Induced power is the force required to move a mass of air through the disk at the induced velocity.

If T is the rotor thrust (in a hover equal to weight (Mass * g)), which is a force, and this force moves the air at a velocity $\mathbf{V_i}$ **,** $\mathbf{P_i = TV_i}$ **.**

PARASITE POWER

Parasite Power is that portion of the power required to move the rest of the airframe through the air. It is the power required to overcome parasite drag. If the Fuselage **Drag Force=** $\mathbf{C_D \frac{1}{2} \rho v^2 S}$ measured in Newtons, we know that power is force * displacement and we know that velocity is displacement in a period of time so we can calculate the power required to move the fuselage through the air by multiplying drag force by its velocity (v) this will give us a value in Watts [Nms^{-1}] . From this we conclude that Parasite Power is in fact $\mathbf{C_D \frac{1}{2} \rho v^3 S}$**.**

ANCILLARY POWER

This is the power required to drive any ancillary items such as generators, alternators, air conditioning etc.
The power required to drive an alternator (assuming no losses) would be Voltage * Current, once again in Watts.

What this means: The total power required is the sum of all the items mentioned above. All of these items are speed dependant with the exception of ancillary power which is controlled either by the designer or the pilot.

SURVEILLANCE SYSTEM

The surveillance system evolve in this project comprises a trans-reciever and a analog web camera

Camera

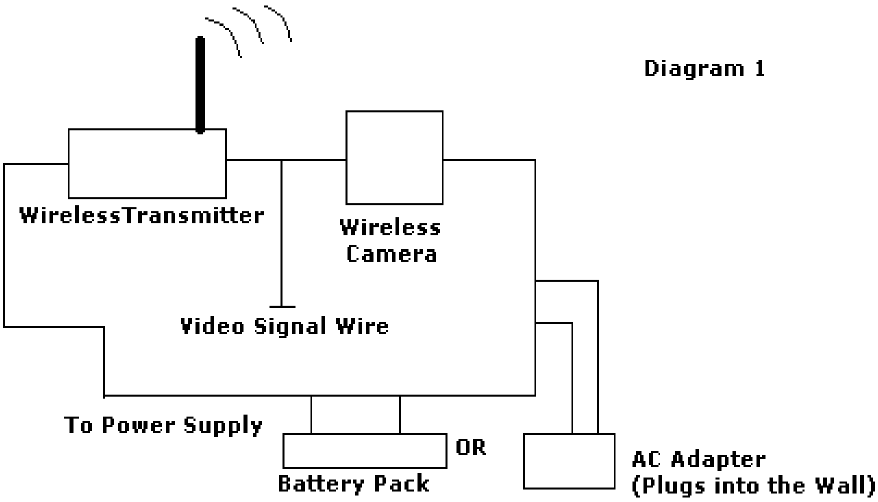
Wireless cameras are basically described as a wireless transmitter carrying a camera signal.

The Camera is wired to a wireless transmitter and the signal travels between the camera and the receiver. This works much like radio. The sound you hear on a radio is transmitted wirelessly and you tune to a certain frequency and hear the sound. Wireless cameras have a channel also. The receiver has channels to tune in and then you get the picture. The wireless camera picture is sent by the transmitter the receiver collects this signal and outputs it to your Computer OR TV Monitor depending on the receiver type.

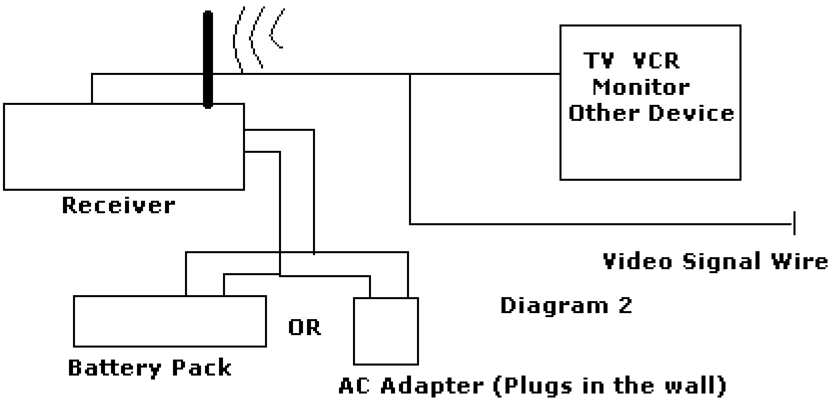
The Wireless Camera / Transmitter

The Camera sees the image, the camera then provides the video to the transmitter, then the transmitter sends the wireless signal to the receiver. There are many types of wireless cameras. You can make most any camera wireless by adding a wireless transmitter and receiver. The camera and transmitter require power.

The power is provided by battery and/ or transformer adapter. The complete (Diagram 1) wiring for the wireless camera and transmitter end follows.



As you can see by (**Diagram 1**) The camera and transmitter both need power. The camera sees an image, sends it to the transmitter, and the transmitter sends the signal out to the air. The receiver picks up the signal and outputs it to a TV / Computer / Digital Video recorder. This is a basic diagram many wireless cameras and transmitters are very small and the power is provided to both from one source. A good example of this is a Hidden wireless camera. IE: A clock radio wireless camera is powered by plugging in the clock. The camera and wireless transmitter are provided power by the clock radio internally.



The Receiver

A wireless receiver has only one function. After the camera and wireless transmitters have provided the wireless video signal the receiver collects this signal and routes it the Monitor, TV, VCR , DVR or PC (or alternative recording or viewing device). See diagram 2.

As you can see in Diagram 2, the receiver accepts the wireless transmitters signal and then out puts it to your TV, VCR, Monitor or PC. The receiver needs only power and a Device to view and or record the Signal /Video.

Video Transmitters / Receivers

Video Transmitters can be obtained separate from cameras. If you have a wired camera now you can turn it into wireless by adding a transmitter and receiver. Instead of the wire from the camera to the recording device or monitor the wireless signal will send the video. Again you will need to provide power to the camera and the transmitter. Most transmitters and receivers are sold as a package but some are not. Be sure to check with the supplier.

RADIO CONTROL AND SERVO SYSTEM

The radio system is what is responsible for moving the control surfaces of the RC aircraft.

The two most important components are

- RC Aircraft Transmitter

  The transmitter sends the radio waves which control the RC aircraft. When the pilot moves a stick on the transmitter, the transmitter emits a series of radio signals which control the RC aircraft.

- RC Aircraft Receiver

  The receiver is a device mounted inside the RC aircraft, which intercepts the radio signals sent by the transmitter. It then decodes these signals and moves the different control surfaces of the aircraft by telling the servos how to move.

WORKING OF RADIO CONTROL AND SERVO SYSTEM

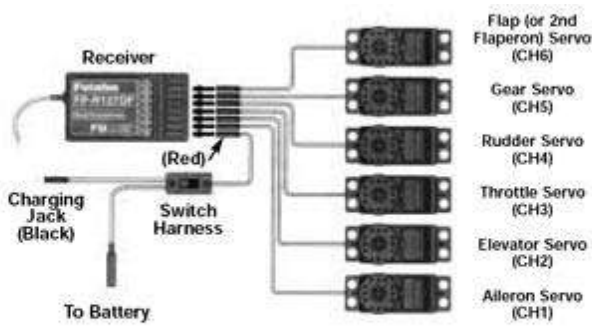
Every radio control system contains a transmitter (Tx) and receiver (Rx). There are also actuators, or servo motors. The pilot uses the transmitter to send a radio command to the receiver.

The Rx then relays this command to the servo, which moves and also creates movement of the airplane surface to which it is connected.

Most modern RC systems feature proportional control, i.e. the amount of joystick movement at the Tx determines the amount of movement of the helicopter control surface.

The transmitter converts the pilot's movements into a radio signal. The process of converting this signal is called modulation. The transmitter then broadcasts this signal. The receiver inside the airplane picks up this signal. The receiver pulls the information from the radio waves and relays this information to each servo.

The servo has a servo horn that is attached to its shaft. This horn is attached to a control surface, or engine throttle, via a push rod. When the servo rotates the horn translates the rotation into a linear movement that moves the control surfaces. The movement of the servo is directly proportional to the movement of the control sticks on the transmitter. So the control surfaces on the helicopter move exactly the way you move the stick on the transmitter.



From Futaba 6EXA Manual

The servos and receiver battery simply plug into the receiver. Mostly a switch between the battery and receiver is added. The switch allows you to turn the receiver off without removing the battery when you are not flying. A switch with a charging harness allows you to charge the battery without removing it.

SPECIFICATIONS OF RADIO CONTROL SYSTEM

2.4 GHz

6 – Channel

SPECIFICATIONS OF SERVOS

No. Of HXT 5010 servos used = 4

Dimensions: 40*20*38mm

Weight: 39gm

No. Of TURNINGY MINI SERVOs used = 1

Torque = 2.1kg/cm

Weight = 16gm

Size = 29.6*28*13.2mm

BATTERY

Battery is the sole provider of energy required to run all the electronic devices used in running and controlling this model airplane.

We have used a Nickel-Cadmium battery pack, it consists of 4 AA size rechargeable cells having a voltage of 1.2V and a current capacity of 800mAh. These are connected in series forming a net voltage of 4.8V and 800mAh current capacity.

It is used for running 5 servos and the main radio receiver system. A single servo requires 4 to 6V electricity which is why the series configuration is chosen. The current capacity is sufficient for running the equipment for 15 to 20 minutes, i.e. more than a single flight time.

DESIGN CALCULATIONS

General Requirements of a Helicopter based on surveillance system are:

1. It should be a remote controlled helicopter because its purpose is to capture the pictures for the surveillance.
2. It should be light weight so that it is portable and easy to control.
3. Modification on the helicopter should be possible.
4. Propulsion system of helicopter should be highly efficient.
5. It should have high manoeuvrability.
6. The system should not be complex.
7. Its flying height should be within the range of 30m-80m because it should be in the visual limit of the RC controller
8. It should have an endurance range of 30 min -60 min for the purpose of surveillance

WEIGHT CALCULATIONS

First, the most important thing to design a helicopter is its purpose. The values of gross weight and empty weight are calculated

Useful Load = Crew + Fuel Weight + Payload

since

Fuel Weight = Specific Fuel Consumption * Installed Power * Mission Time

$=(4.986*10^{-4})*(2.1*746)*(0.33)$

=0.2602kg

=260.2g

In this fuel weight calculation, specific fuel consumption and installed power are determined initially. When the fuel weight is calculated, the useful load can be calculated easily.

Here Payload comprises of surveillance equipments.

So Payload= 100gms(wireless camera)

Useful Load = Fuel Weight + Payload

=260.2+1730 g

=2000g (Approx)

The gross weight of the new helicopter was estimated.

$$EW = \text{Structure weight} + \text{Engine Weight} + \text{Avionics Weight}$$
$$= 2000+500+1500 \text{ g}$$
$$= 4000\text{g}$$

Where EW is Empty Weight

$$MTOW = EW + \text{Useful Weight}$$
$$= 4000+2000 \text{ g}$$
$$= 6000\text{g}$$

Where MTOW is maximum take-off weight

The empty weight is 4.0 kg; the maximum take-off weight (MTOW) is 6.00 kg.

Now,

$$G = EW/MTOW$$
$$= 4000/6000$$
$$= 0.667$$

Where

G is weight efficiency

EW is empty weight

MTOW is maximum take-off weight

DISK LOAD

The requirement for estimating disk load is to ensure that *G* has the largest property in gross weight under the certain condition of performance. The diameter of disk should be corresponding to the blade tip speed. Then disk load was determined as

$$p = MTOW / (\pi R^2)$$
$$= 35.90 \ N/m^2$$

NUMBER OF BLADES

The advantages of large k(number of blades) are to reduce the vibration of the blade and the helicopter, as well as improve the performance during flight. It also has a positive impast on the stability that is as we have more no. of blades its stability increases. On the other hand, the disadvantages of large number k are to make the rotor hub more complicated, to increase the parasite power and the maintenance of the rotor. Small number k means a simple rotor hub, light body, low cost and the little disturbance of blade tip vortex. So to reduce the complexity of the system we have taken the value of k to be 2.

No. of blades used = 2

Also to counteract the decrease in stability we have added a flybar.

AEROFOIL SELECTION

In case of symmetric airfoil, the centre of pressure is fixed and lies at a distance of 0.7R from the centre of rotation along the span and at 25% of chord length from the leading edge. It also coincides with the aerodynamic centre and feathering axis.

In case of cambered airfoil, the location of centre of pressure is variable. With the increase in the resultant aerodynamic force, the centre of pressure shifts forward causing nose-up moment which tends to increase the angle of attack and vice versa.

Due to this advantage, the main rotor blades of the helicopter are normally made of symmetric airfoil section

So in this helicopter the airfoil chosen is symmetric.

Since the airfoil is symmetric , the NACA four-digit wing sections define the profile by

1. One digit describing maximum camber as percentage of the chord will be zero
2. One digit describing the distance of maximum camber from the airfoil leading edge in tens of percent's of the chord will be zero.
3. Two digits describing maximum thickness of the airfoil as percent of the chord.

   So the the airfoil will be 00XX

Comparing the requirement to airfoil database it was found out that NACA 0014 characteristics matches to the requirement of the helicopter.

CALCULATIONS FOR POWER REQUIREMENT

There are a number of ways power is used in a helicopter, a brief summary of these follows.

- Rotor Profile Power
- Induced Power
- Parasite Power
- Ancillary Power

With the exception of ancillary power, these items are speed dependant varying as airspeed is increased.

ROTOR PROFILE POWER

Rotor Profile Power is the power required just to turn the rotors. It is the power required to overcome the rotor aerodynamic drag force.

Power has dimensions of Nms^{-1}, and as we know power is Rate of Rotation * Torque. The drag force we measure in Newtons, and if we apply element theory and integrate the force along the blade, we can calculate the blade and thus rotor torque. The Torque is measured in Nm.

If we convert RPM into radian s^{-1} we can now multiply by this and have a figure for Rotor Profile Power.

INDUCED POWER

Induced Power is that portion of the power required to produce lift. It is the power required to overcome the portion of rotor drag which is caused by the induced flow tilting the total reaction rearwards. Induced power is the force required to move a mass of air through the disk at the induced velocity.

If T is the rotor thrust (in a hover equal to weight (Mass * G)), which is a force, and this force moves the air at a velocity V_i , $P_i = TV_i$.

PARASITE POWER

Parasite Power is that portion of the power required to move the rest of the airframe through the air. It is the power required to overcome parasite drag. If the Fuselage Drag Force= $C_D½\rho v^2S$ measured in Newtons, we know that power is force * displacement and we know that velocity is displacement in a period of time so we can calculate the power required to move the fuselage through the air by multiplying drag force by its velocity (v) this will give us a value in Watts [Nms^{-1}] . From this we conclude that Parasite Power is in fact $C_D½\rho v^3S$.

After calculating this from matlab we found out that Parasite Power is 0408 hp

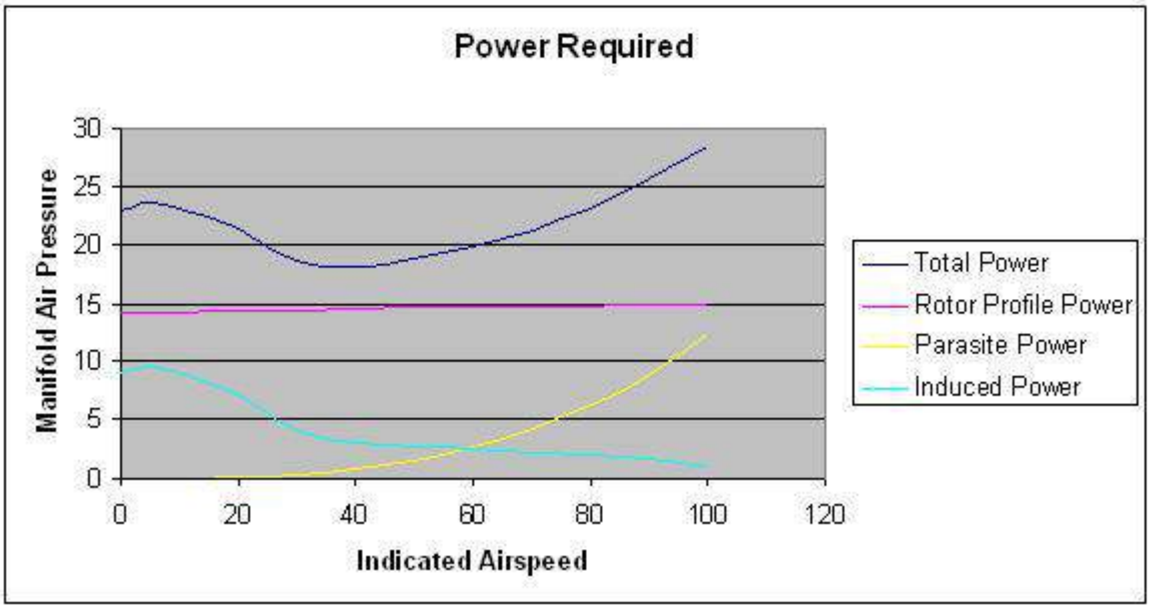
ANCILLARY POWER

This is the power required to drive any ancillary items such as generators, alternators, air conditioning etc.

The power required to drive an alternator (assuming no losses) would be Voltage * Current, once again in Watts.

What this means

The total power required is the sum of all the items mentioned above. All of these items are speed dependant with the exception of ancillary power which is controlled either by the designer or the pilot. A graph showing a typical power required curve is shown below.



ROTOR DESIGN

The primary design criterion for the Main Rotor was to satisfy the requirement of hovering in ISA+20°C conditions. However, autorotation requirements were also accounted for. Forward flight and maneuvering efficiency was of secondary concern.

Prime considerations:

Hovering: From classical momentum theory: V is inversely proportional to r, and for hovering, the induced Required Power is T·V. It follows that Main Disk Loading should be kept as low as possible for efficient hover performance.

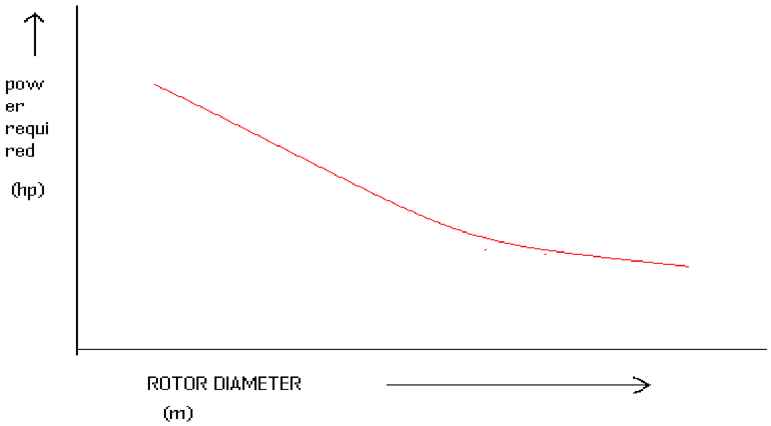


Fig. 3

Autorotation

The Main Rotor moment of inertia should be high to store a high amount of kinetic energy and have a successful landing. In addition, during autorotation the rotor is driven by air inflow, no power is supplied by the engine itself. For example in the case of vertical autorotation: $T \cdot V_d = T \cdot V_i$+(profile-drag power). Therefore, the autorotation rate of descent decreases with Main Disc Loading.

The lifting force is produced by the main rotor . As they spin in the air and produced the lift. Each blade produces an equal share of the lifting force. The weight of a helicopter is divided evenly between the rotor blades on the main rotor system. If a helicopter weight 4000 lbs and it has two blades, then each blade must be able to support 2000 lbs. In addition to the static weight of helicopter ,each blade must be accept dynamic load as well . For example, if a helicopter pull up in a 1.5 g manouver (1.5 time the gravity force), then the effective weight of helicopter will be 1.5 time of static helicopter weight or 6000 lbs. due to gravitational pull.

PARAMETERS AFFECTING THE MAIN ROTOR DESIGN

One of the most important parameters for the main rotor design is the rotor diameter which should be large enough for better hover performance. Knowing the rotor efficiency(in hover), the rotor thrust and the power available to the main rotor, the disc area can be computed which can give the optimum value of the blade diameter.

- Parameters affecting the Rotor Efficiency
  1. *The tip speed*
     For normal helicopters, at maximum speed, the tip speed ratio should be below 0.6.
     This is to avoid excessive retreating blade stall.

  2. *The blade area*
     If the blade area is too large, the average angle of attack is less than the optimum value which results in the decrease in hover performance. On most rotors, the rotor efficiency in hover is the maximum when the average angle of attack is about 6 degrees.

  3. *The number of blades*
     The advantages of large k are to reduce the vibration of the blade and the helicopter, as well as improve the performance during flight

  4. *The taper*
  5. *The twist*
  6. *The aerofoil shape*
  7. *The tip shape*

- Parameters affecting Rotor Thrust
  1. *Payload*
  2. *Fuel*
  3. *Weight*

- Parameters affecting the Power Available to Main Rotor
  1. *The sea level rating of the engine*
  2. *The effect of temperature, altitude*
  3. *The power requirement for the tail rotor*

4. *The losses in the main gear box and the tail gear box.*

NUMBER OF BLADES

A two bladed rotor was chosen for fixed thrust and tip speed, lower Number of blades means smaller Required Power, requiring larger Main Rotor Diameter, which leads to lower Main Disc Loading and improves autorotation/hover performance.

MAIN ROTOR CHORD

Main Rotor Cord and Main Rotor Diameter determine the solidity. Lower angles of attack are needed for larger solidity. MRC is 0.05 m for effective angles of attack (also C_l and L/D) along the blade, which, in turn minimizes parasite Required Power

MAIN ROTOR DIAMETER

Larger diameters mean lower Main Disc Loading, improving autorotation and hover performance. On the other hand, large a Main Rotor Diameter requires longer tail booms, thus shifting the CG significantly backwards. hence a MRD of 1.345m was selected.

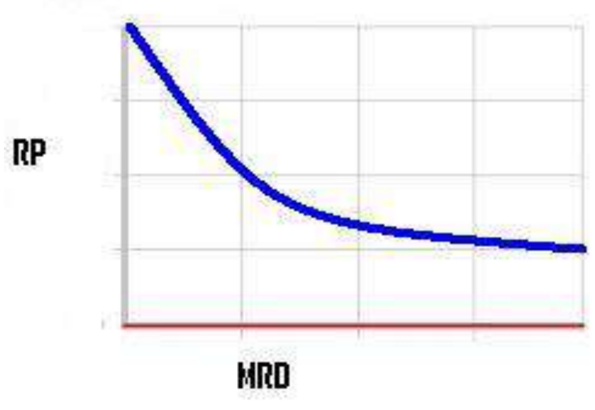


Fig. 4

HUB DESIGN

Main Rotor has two blades connected to the hub as a seesaw allowing for blade flapping. Overall hub simplicity and reduced bending stresses was of primary importance, also allowing us to use smaller parts. Trailing edge flap system control was considered, but was found inappropriate due to complexity and cost. Therefore a rather conventional swash plate was designed, minimizing costs while maximizing reliability.

TAIL ROTOR DESIGN

The Tail Rotor was designed as a pusher rotor with similar design parameters as the Main Rotor. Aerodynamic considerations were of less importance due to a Required Power of about 5-7% of the total Required Power. Manufacturing simplicity and low price were the main parameters. Twist results in some performance increase but due to an already low Required Power, this was not justified by additional cost, so no twist was applied. The final design is a two bladed NACA 0012 rotor, TRD of .236m.

THE CHOICE OF ANTI-TORQUE SYSTEM

The above considerations also lead to a Tail Rotor design, chosen as the conventional tail rotor of pusher type. The other two alternatives were: a small side wing connected to the tail boom (using the Main Rotor downwash) and a laterally ejected jet (from the end of the tail boom). These were rejected due to complicated aerodynamic analysis. The above mentioned considerations led to a conventional Tail Rotor.

We have calculated the reaction torque exerted by the rotor blade on the body. Hence using this torque and already knowing the lift characteristics of the tail rotor blade we have evaluated the required length of the tail boom.

ROTOR BLADES MATERIALS AND MANUFACTURING

Materials commonly used for blades are: composite, aluminum alloys, and titanium. From these choices, the main and TR blades are made out of carbon composites in order to maintain high strength. The all-extrude blade was chosen because of its lower drag (compared to the riveted blade which does not have the smooth surface as the all-extrude blade), higher strength qualities, and because rivets are known to cause fatigue cracks resulting in blade failures

	Advantages	Disadvantages
Composites	High strength Specific stiffness to weight ratio Bending-torsion coupling.	High cost , complicated manufacturing and repair processes, water absorption, and low inertia.
Aluminum	Stiffness, high inertia, lower cost , simple repair and maintenance.	Corrosion problems
Titanium	Similar to aluminum	Higher cost (compared to aluminum)

Table 3

AIRFRAME MATERIALS AND MANUFACTURING

Composite materials for the airframe are substituted extensively for traditional metals. Relative advantages and disadvantages are given here in table.

The airframe skin material are made of fiberglass because of its relatively low density, and low cost (compared the commonly used Graphite/Epoxy). Furthermore the skin does not require high strain range .Therefore, it is natural to choose fiberglass with a simple wet layup process.

	Advantages	Disadvantages
Composites	High strength, specific stiffness, saves up to 30% weight, reduced manufacturing cost, simpler assembly process, corrosion resistant	Damaged parts usually needs replacing (no simple repair and maintenance), conservative market, high initial cost (not an issue).
Metals	Inexpensive and well known manufacturing repair & maintenance processes	Relatively high cost for material, higher weight, requires fasteners (added complexity)

Table 4

The airframe skin material are made of fiberglass because of its relatively low density, and low cost (compared the commonly used Graphite/Epoxy). Furthermore the skin does not require high strain range, therefore it is natural to choose fiberglass with a simple wet layup process.

The model's window are made of polycarbonate which is optically clear, providing excellent total luminous transmittance and a very low haze factor. Being tough and lightweight it is ideal for "see-through" applications where impact resistance is important, and another advantage is that it maintains its properties over a wide range of temperatures from -40° F to 280°F [KMac06].

COMPOSITE AIRFRAME

Although aluminum has been preferred in the past because of its superior mechanical properties, the forgings have lead times and tooling costs that exceed schedules and budgets of many programs. There are 2 forms of forging, each having drawbacks. The open method repeatedly manipulates parts with unconfined rollers or dies until the desired method is achieved. This method is very inexact and time consuming. The second method, closed forging, confines the material within a die cavity and uses pressures to aid material flow into the unfilled portions of the die. This method is more accurate than the first but is dependent on the quality of the die. Normally several dies must be made before the desired product is formed correctly which adds to manufacturing cost and time. Composites are also significantly lighter than aluminum which have showed a reduction in weight of about 20% .

LANDING GEAR DESIGN

The landing gear provides the protection and support for the helicopter when landing and on the ground. Several landing conditions can occur as described in Table

Landing Type	Acceleration	Descent Rate	Requirements
Normal	0-3 g	10 ft/s or less	Small landing loads
Hard	3-6 g	10-20 ft/s	Fuselage must not contact the ground
Crash	~10 g	20-42 ft/s	Prevent injury/death

Table 5

These conditions are considered when designing the landing gear so that failure does not occur and injury is avoided. A skid landing gear design was selected over a wheeled design because of its simplicity, lower cost, and compatibility with the mission.

C.G. ESTIMATION

A helicopter's trim and performance is influenced directly by its CG location. CG movements can occur due to various mission definitions, different pilots, cargo, fuel quantity, and fuel consumption during flight. In this analysis fuselage stations and waterline origin were referenced to the center of the rotor hub. The fuel is located underneath the main hub, which maintains the helicopters stability characteristics while the fuel runs out.

So we have arranged various assemblies such that center of gravity nearly lies along the main rotor shaft.

MATLAB ANALYSIS

It includes the matlab program through which different lift, drag curves are drawn.Through this analysis we have calculated the different design parameters to design the system.

```
clc
clear all

%INPUTS
m=0.135;     %Kg
c=0.059;     %m
t=0.00821;   %m
s=0.6;     %m
alpha=6;   %degree
%v=20;
Cl=0.6;
Cd=0.05;
rho=1.225;   %Kg/m^3
n=240;           %rpm(ROTOR)
N=2000;          %rpm(ENGINE)
Dia_MR=0.01;      %m
Power_E=746*2.1;   %watts(ENGINE POWER)
len_TB=0.7;        %m(LENGTH OF TAIL BOOM)
W_t=0.100;         %gms(Weight of tail rotor system)

Dia_out_TB=0.022;   %m(Outer Diameter of Tail Boom)
Dia_inn_TB=0.021;   %m(Inner Diameter of Tail Boom)

%CALCULATIONS
Vang=2*3.14*n/60;      %MAIN ROTOR
r=0:0.01:s;
Vtan=r.*Vang;


L=(rho*(Vtan.^2)*(s*c)*Cl)/2;
```

```
tL=sum(L);
mLt=tL/61;

D=(rho*(Vtan.^2)*(s*c)*Cd)/2;
tD=sum(D);
mDt=tD/61;

figure(1);
plot(r,Vtan);
grid on;
xlabel('Span(m)');
ylabel('Tangential Velocity(m/sec)');
title('Velocity Distribution along Span');

figure(2);
plot(r,L);
grid on;
xlabel('Span(m)');
ylabel('Lift(N)');
title('Lift Distribution along Span');

figure(3);
plot(r,D);
grid on;
xlabel('Span(m)');
ylabel('Drag(N)');
title('Drag Distribution along Span');

for i=1:61
   if i==1
      BmL0(i,:)= [r(i:end).*L(i:end)];
      BmD0(i,:)= [r(i:end).*D(i:end)];

   else
      BmL0(i,:)= [0*r(1:i-1) r(i:end).*L(i:end)];
      BmD0(i,:)= [0*r(1:i-1) r(i:end).*D(i:end)];
   end
end
BmL=sum(BmL0');

figure(4);
plot(r,BmL);
grid on;
xlabel('Span(m)');
ylabel('Bending Moment due to Lift(N.m)');
title(' Lifts Bending Moment Distribution along Span');


BmD=sum(BmD0');

figure(5);
plot(r,BmD);
grid on;
xlabel('Span(m)');
ylabel('Bending Moment due to Drag(N.m)');
title(' Drags Bending Moment Distribution along Span');
```

```
CF=m*s*Vang^2;          %CENTRIFUGAL FORCE


IaL=(s*t^3)/12;        %Area Moment of Inertia of the Blade(ASSUMED TO BE RECTANGLE) about
an axis passing through half the Thickness
yL=t/2;              %Distance of neutral Axis from Top Surface
BsL=(yL/IaL).*BmL;      %Bending Stress due to Lift

figure(6);
plot(r,BsL);
grid on;
xlabel('Span(m)');
ylabel('Bending Stress due to Lift(N/m^2)');
title(' Lifts Bending Stress Distribution along Span');


IaD=(s*c^3)/12;        %Area Moment of Inertia of the Blade(ASSUMED TO BE RECTANGLE) about
an axis passing through half the Chord
yD=c/2;               %Distance of neutral Axis from Leading Edge
BsD=(yD/IaD).*BmD;     %Bending Stress due to Drag

figure(7);
plot(r,BsD);
grid on;
xlabel('Span(m)');
ylabel('Bending Stress due to Drag(N/m^2)');
title(' Drags Bending Stress Distribution along Span');

Im=(m*s^2)/3;           %Mass Moment of Inertia for a SINGLE BLADE about an axis at the ROOT

J_MR=pi*Dia_MR^4/32;       %POLAR momemt of inertia of MAIN ROTOR SHAFT
Torque_MR=Power_E/Vang;      %(N.m)

Vang_E=2*pi*N/60;           %ENGINE ang. velocity
Torque_E=Power_E/Vang_E;    %Torque developed by engine
Torque_Drag=D(36)*0.35;      %Resultant force is acting at 35cm from ROOT
Torque_Result=Torque_MR-2*Torque_Drag;

TS_MRS=Torque_Result*(Dia_MR/2)/J_MR;      %TORSIONAL STRESSES on MR SHAFT

L_t=Torque_E/len_TB;           %Lift of the tail rotor required to balance the anti torque
Result_Force_TB=sqrt(L_t^2+W_t^2);



r1=0:0.01:len_TB;
BmTB=[r1.*Result_Force_TB];
IaTB=pi*(Dia_out_TB^4-Dia_inn_TB^4)/62;     %Area Moment of Inertia of the TAIL
BOOM(ASSUMED TO BE HOLLOW CYLINDEE) about an axis passing through the axis
yTB=Dia_out_TB/2;                         %Distance of neutral Axis
BsTB=(yTB/IaTB).*BmTB;                    %Bending Stress on TAIL BOOM

figure(8);
plot(r1,BmTB);
grid on;
xlabel('Span of Tail Boom(m)');
ylabel('Bending Moment(N.m)');
title(' Bending Moment Distribution along Span');
```

```
figure(9);
plot(r1,BsTB);
grid on;
xlabel('Span of Tail Boom(m)');
ylabel('Bending Stress(N.m)');
title(' Bending Stress Distribution along Span');
```

INHERENT PROBLEMS WITH HELICOPTERS

STABILITY OF THE HELICOPTER

A helicopter is said to be in a state of equilibrium when the sum of all the forces and moments acting on it is zero. This condition of the helicopter is called the steady state flight condition of the helicopter. When disturbed from the equilibrium by a sudden input of controls or gust, it experiences acceleration caused by the unbalanced force or the moment, the magnitude of translational acceleration being proportional to the unbalanced moment.

Static stability

Static longitudinal stability: it is determined in terms of pitching moment which is caused by the changes in the forward speed and the main rotor angle of attack from trimmed conditions. Two ways of defining:

(1) **Speed stability:** It is related to the pitching moments which are produced about the centre of gravity of the helicopter due to change in the forward speed.
Increase in the speed causes rotor to flap back thereby producing nose up pitching moment about the centre of the gravity of the helicopter. This change in the pitching moment which is the result of change in the forward speed is known as the speed stability.

(2) **Angle of attack stability:** It is related to the pitching moment produced about the centre of gravity of the helicopter by a change in the rotor and the fuselage angles of attack which is caused by the sudden collective pitch input or up-gust.

Static Directional stability: It is governed by the following parameters:

(1)Directional stability: It is related to the yawing moment produced by the side-slip in the forward flight. It has three main components:

(i) The aerodynamic moments on the fuselage which has de-stabilising effects.
(ii) The side force on the vertical tail has stabilising effects.
(iii) The tail rotor thrust changes with the side-slip which has stabilizing effects.

(2) Dihedral Effect: Effective dihedral is related to the rolling moment produced by the side slip. A helicopter exhibits positive dihedral effect i. e. if in a right side-slip, it tends to roll towards left and vice versa. This is due to the asymmetric velocity distribution in the azimuth. In addition, the fuselage side force above or below the roll axis also produces stable or unstable rolling moment.

(3) Side Force: The side force of a helicopter determines the roll attitude or the bank angle required to hold a specific side-slip at the constantly increasing forward speed. The increase in the speed is accompanied by a large bang angle or roll.

VIBRATIONS IN HELICOPTER

There are basically 5 main types of vibrations found in a model (or full-scale) helicopter that can create damage or pre-mature wear and tear to the mechanical and radio components. They are **lateral, vertical, low frequency, medium frequency, and high frequency** vibration.

Lateral vibration (two beats per revolution) can be caused by an unbalanced rotor system; for example, one blade is heavier than the other is. Improper span-line alignment between the two blades can also cause an unbalanced condition. Loose, worn or cracked parts often contribute to an unbalanced main rotor and manifest themselves as a lateral vibration. There are three types of lateral unbalance: **chord-wise**, **span-wise**, and a **combination** of the two.

1. To reduce **chord-wise** imbalance from a span-wise, apply a strip of masking tape around the tip of one blade and hover the helicopter.
2. To reduce **span-wise** imbalance, apply a strip of masking tape to the tip of one blade and hover the helicopter. If the vibration increases, remove the tape and install it on the opposite blade. Tape is then added one strip at a time until the vibration is eliminated.
3. For **combined** chord-wise and span-wise imbalance existing in most rotor systems. With knowledge and experience it is possible to correct both imbalances at one point on the rotor blade but it usually requires each imbalance to be corrected separately.

Vertical vibration is caused by a blade being out of track, which is identified by a helicopter bouncing up and down during hover or flight. A blade lifting the helicopter in one quadrant of rotation, and suddenly losing lift in the remaining quadrant during each rotation cycle causes the vibration. When this lifting force is experienced once during each revolution, it is referred to as a one-to-one vibration.

To correct this vibration, first apply tape to one of the blades and have an observer watch the blade path during the hover and identify which blade or tape color is high or low. If there is no observer available then run the helicopter on the ground at about 1/3 throttle/collective and kneel down to observe the blade path. You will have to make the determination based on your rotor RPM if you want to raise the low blade or lower the high blade.

Once a good ground or hover track is attained, the helicopter is then flown to determine whether **blade crossover** exists. Blade crossover is caused by one blade being more limber than the other. This condition is mostly evident in wood blades and can exist because of manufacturing tolerances.

Low frequency vibration of one or two-per-revolution is caused by the rotor. One-per-revolution are of the two basic types, the lateral or vertical. Associated with the one per revolution is an intermittent one-per-revolution vibration. This is a vibration started by a gust of wind causing a momentary increase of lift on one blade resulting in one-revolution vibration. The momentary vibration is normal, but it can be picked up by a loose collective/cyclic control system and fed back to the rotor system causing several cycles of vibration, which is undesirable.

Note: *Two-per-revolution vibrations are inherent with a two-bladed rotor system, and a low level of vibration is always present. When the two-per-revolution vibration level rises to an unacceptable level, it is caused by* ***faulty dampers*** *(O-rings) or a* ***loose and worn rotor system*** *(control rod ball and clevis, washout unit, mixing levers, etc.) or even from* ***excessive binding****.*

Loose skid mounts; struts, or canopies can be a source of vibration that feel as though they are coming from the rotor system.

Medium frequency vibration at four to six-per-revolution (6000-12000 beats per minute) is common in most rotor systems. An increase in the level of the vibration is caused by a change in the capability of the main frame/fuselage to absorb vibration from the main/tail rotor, driveshaft, and engine because of loose hardware, frame damage, or the load. Usually this vibration is caused by loose components that are either a regular part of the aircraft or external pieces.

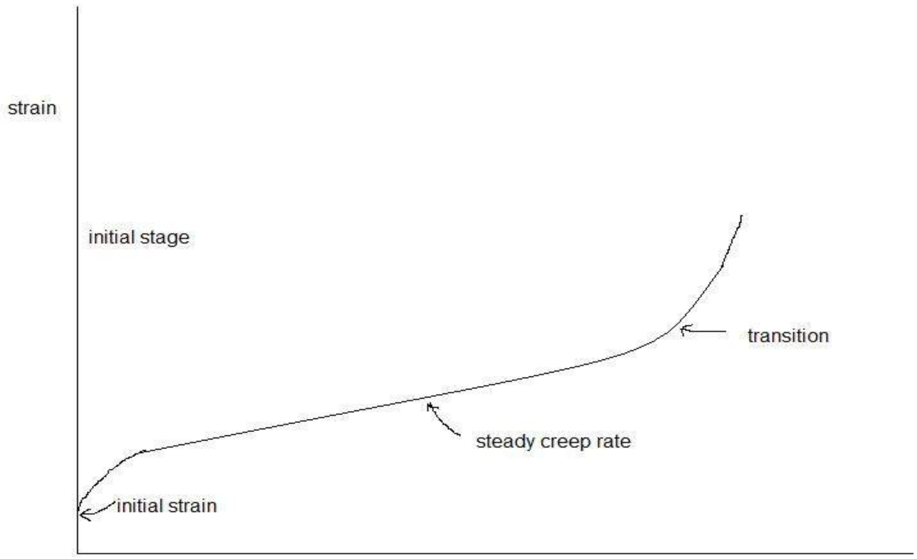
High frequency vibration can be caused by anything in the helicopter that rotates or vibrates at a speed equal to or greater than the tail rotor. This narrows it down to mostly the tail drive wire/shaft, tail rotor gears and tail rotor and engine/fan/start shaft assembly. The first step in isolating this vibration is to check the tail rotor blades for proper track and balance.

CORROSION

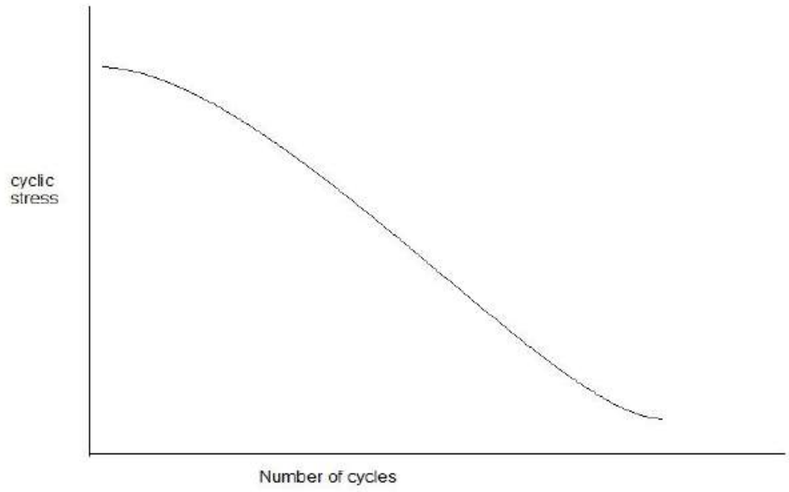
It consists of either a direct chemical attack on the metal or formation of an electro chemical reaction on the metal surface. In either case, the corrosion of a primary load carrying structure reduces its strength by a considerable amount. Another area which is of great concern is the corrosion of rotating parts. The high centrifugal forces of the rotating components can cause relatively small mass imbalance due to corrosion resulting in unwanted vibration and premature failure.

CREEP

It is a continued plastic deformation of the parts subjected to stresses. When a metal is under steady stress for a long time, particularly at a high temperature, plastic deformation or creep occurs. Its critical parts are found whenever high static stresses and high temperature conditions exist together such as in the case of turbine blades causing interference among the other rotating parts thus leading to failure of blades.



CREEP PROGRESSION



Variation of Cyclic Stress with Number of Cycles

FATIGUE

The most important factor in the consideration of the service life of the helicopter is the fatigue which is failure due to repeated cyclic loading. The helicopter structure is subjected to a variety of vibrating stresses in practically every regime of flight. In addition, since it is a highly maneuverable aircraft which is capable of forward, rearward, sideward, vertical and rotational flight.

FABRICATION

Due to lack of time of fabrication, technically we have designed (used) a model helicopter.

We have selected Raptor 50 Titan se. Since our requirement and calculation of our matches to it hence we have selected it and we have mounted a wireless analog camera on it for the purpose of surveillance.

The details of *RAPTOR 50 TITAN SE* are given:

Full Length of Fuselage(mm / in.)	**48.03" (1220mm)**
Full Width of Fuselage (mm / in.)	5.51" (140mm)
Total Height(mm / in.)	15.74" (400mm)
Main Rotor Dia (mm / in.)	54.53" (1345mm) standard
Tail Rotor Dia(mm / in.)	9.29" (236mm)
Gear Ratio	8.5:1:4.56
Full Equipped Weight (g/ lbs.)	7.5 lbs (3400g)

The aluminum tail boom spans 660mm long and is 22mm in diameter.

RESULT AND DISCUSSIONS

An understanding of helicopters was achieved and here forth Design of a Radio Controlled helicopter was specified using design techniques like weight estimation, power estimation, and rotor aerofoil definition.

Basic assembly precautions including careful placement of components, tightening of nuts and bolts and correct positioning of components were maintained.

Electronic precautions including radio controller, servo and gyro connections, voltage not exceeding the required were maintained.

Some errors were visible which were corrected and rechecked.

A working model is fabricated with the data generated from the parameter study.

CONCLUSION

The primary goal of this report is to construct an RC Helicopter for surveillance purposes.

Design of an RC Helicopter was successfully done based on a study of basic helicopter structure.

A helicopter is a type of rotorcraft in which lift and thrust are supplied by one or more engine-driven rotors. This allows the helicopter to take off and land vertically, to hover, and to fly forwards, backwards, and laterally.

The capability to efficiently hover for extended periods of time allows a helicopter to accomplish tasks that fixed-wing aircraft and other forms of vertical takeoff and landing aircraft cannot perform.

The main rotor is a complex system and of umpteen importance as it is responsible for forward as well as vertical flight.

Bending moment and stresses on the main rotor blades have been calculated using Matlab software.

Using a trans-receiver the pictures captured by the camera is viewed at the ground on television screen.

FUTURE PROSPECTS

The helicopter can be further used for surveillance with a high resolution camera.

The helicopter can be made autonomous by installing a microcontroller in it and defining a trajectory for the helicopter to move in. it can be capable of clicking pictures or tracking unidentified objects and come back.

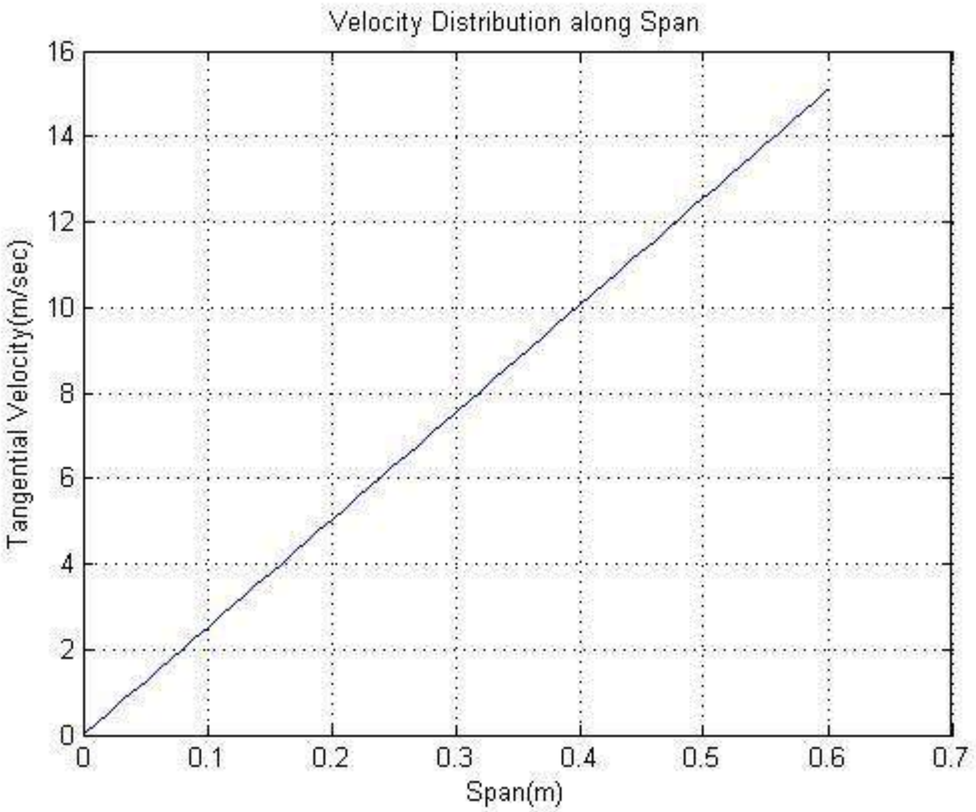
It can also be installed with an attacking facility to destroy the tracked unidentified object.

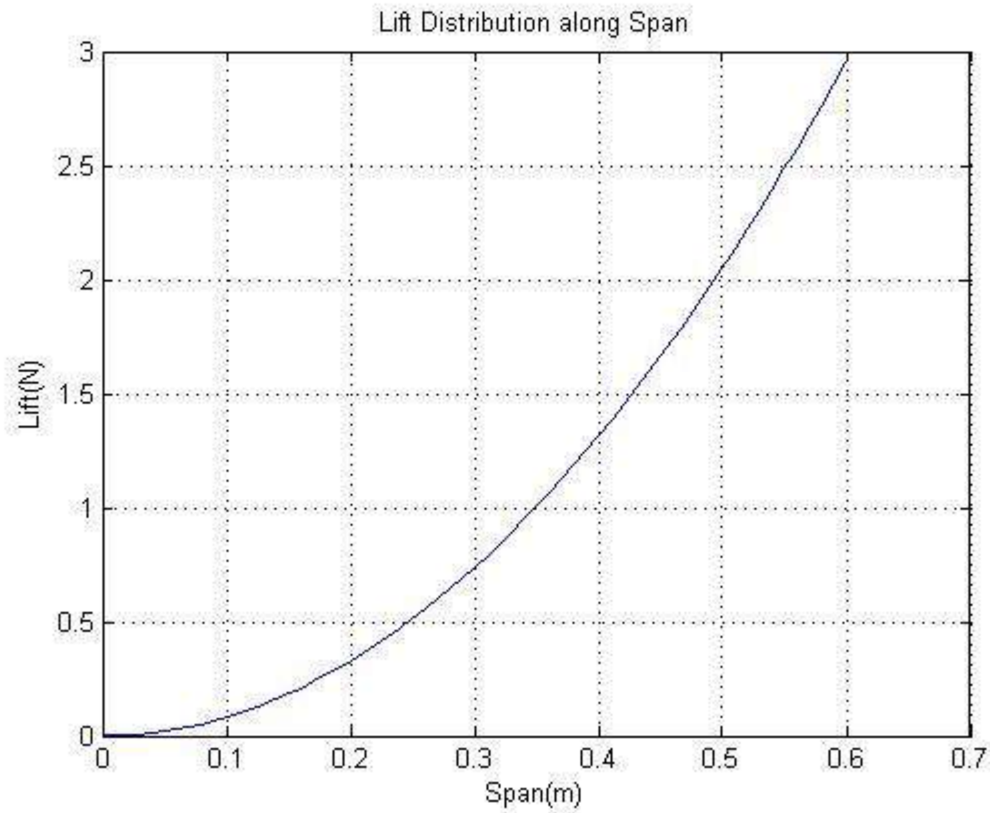
The vibrations of the helicopter can be further reduced by using devices like dampers and absorbers.

The helicopter can be used for defense purpose and also for camera shooting at places where humans cannot reach.

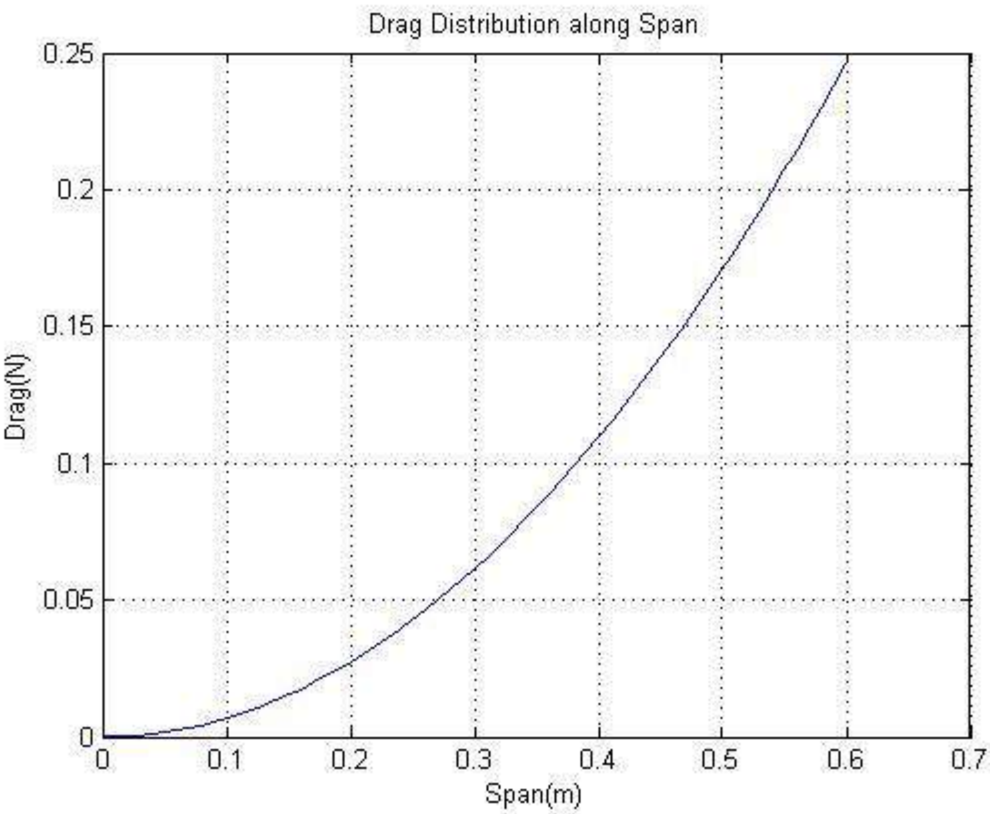
APPENDIX-(A)

Graphs of matlab programs

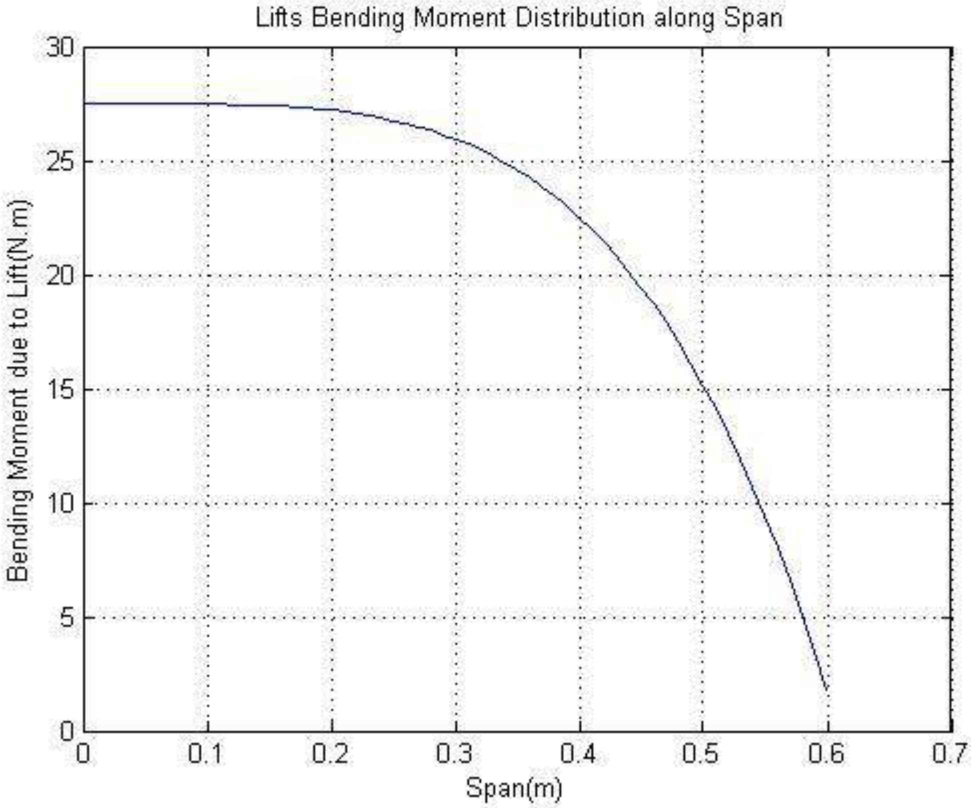


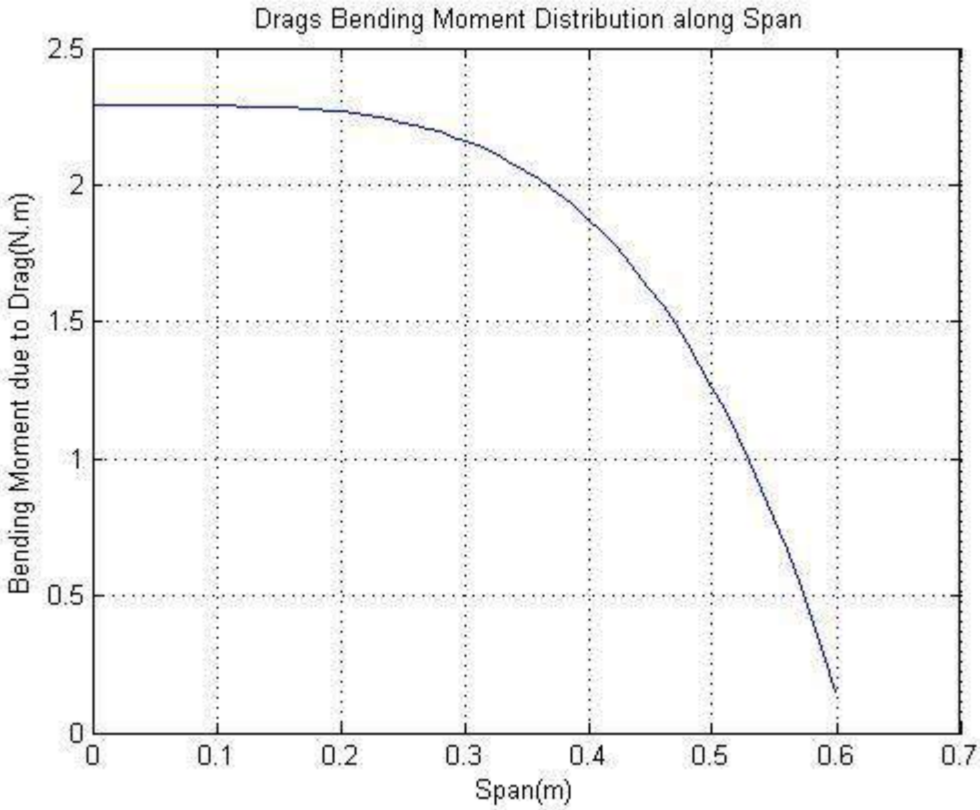


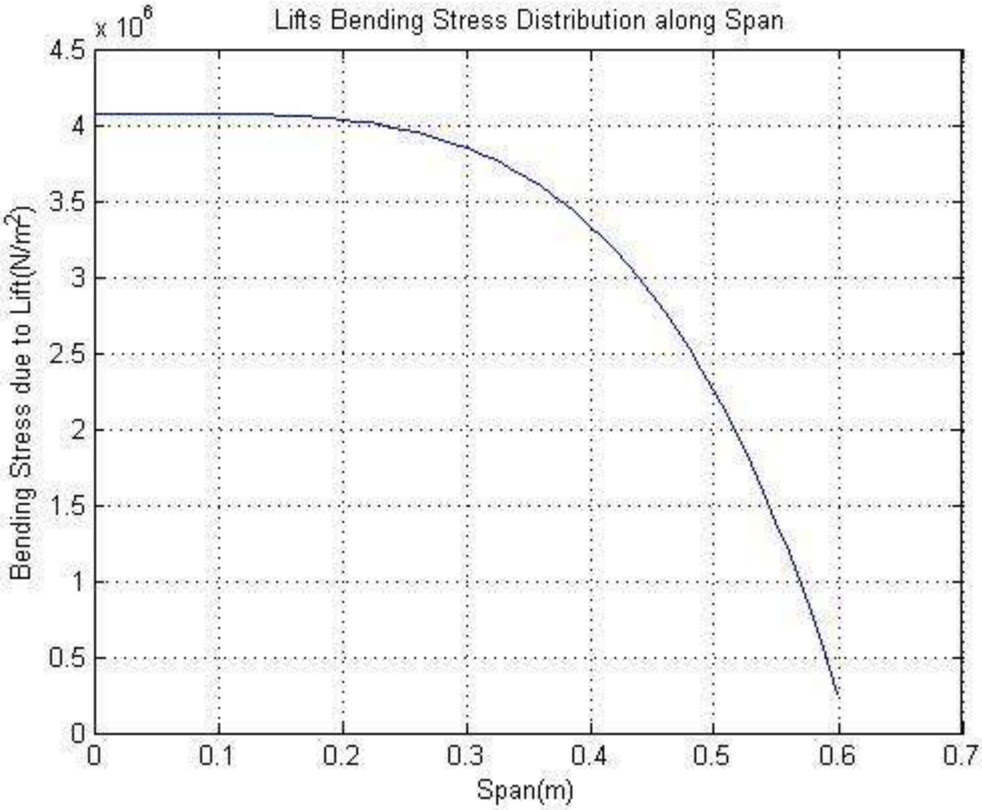
Lift Distribution along Span
Lift(N)
Span(m)
3
2.5
2
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

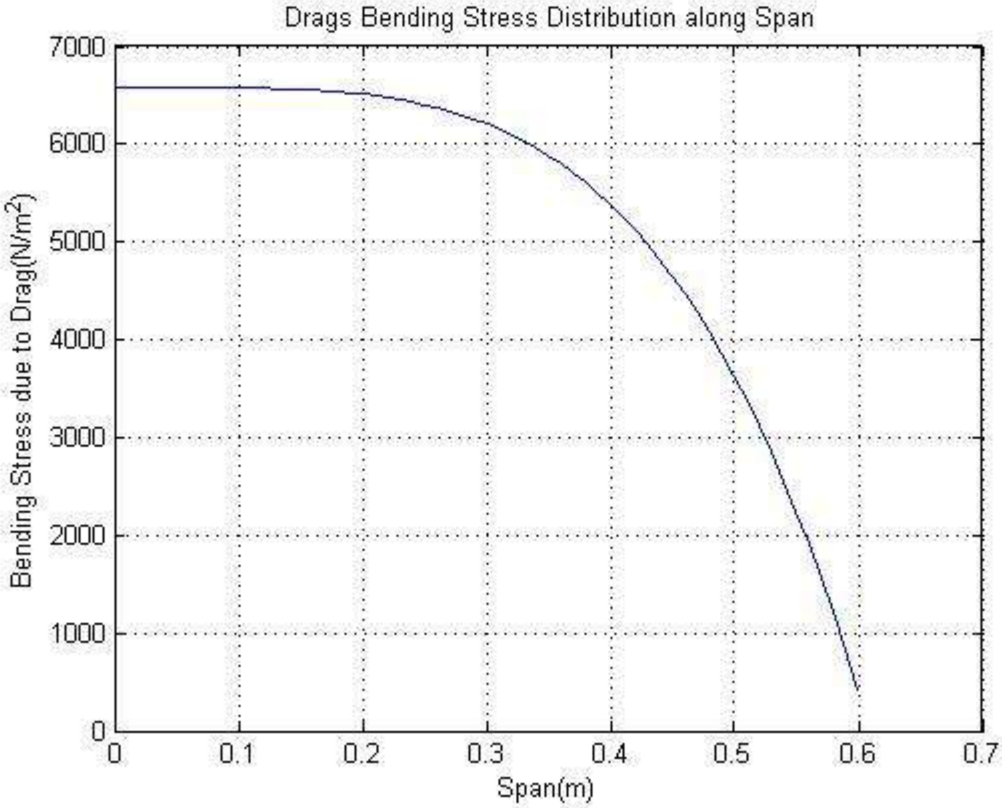


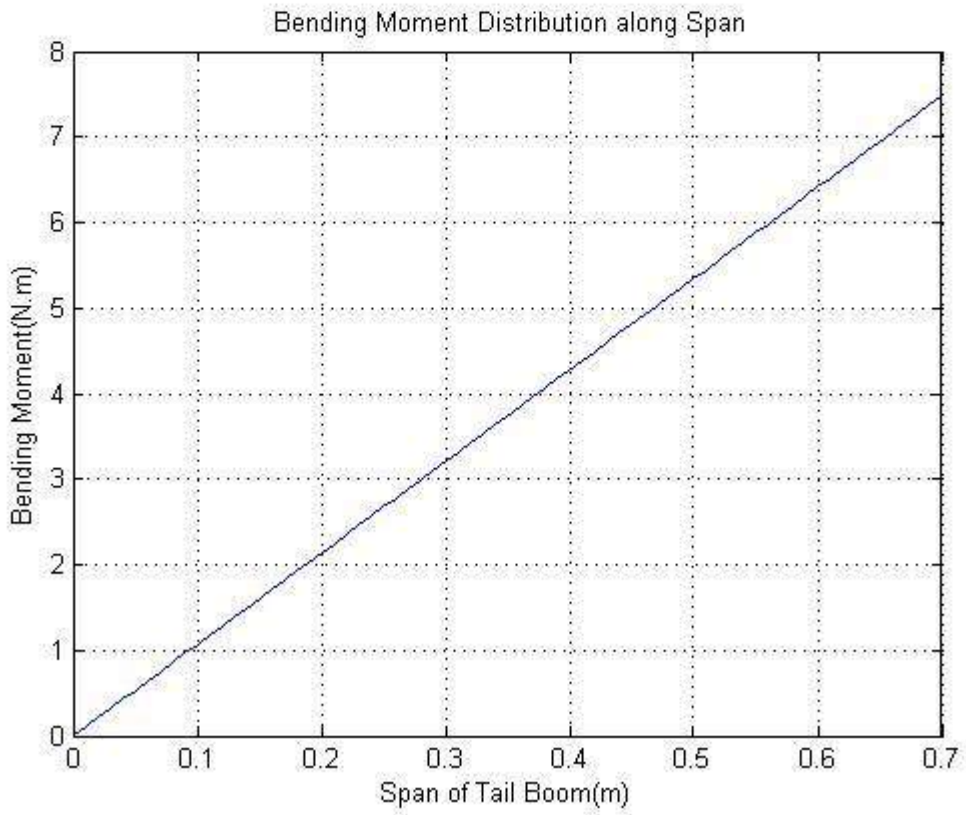
Drag Distribution along Span
Drag(N)
Span(m)
0.25
0.2
0.15
0.1
0.05
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


Lifts Bending Moment Distribution along Span
Bending Moment due to Lift(N.m)
Span(m)
0
5
10
15
20
25
30
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

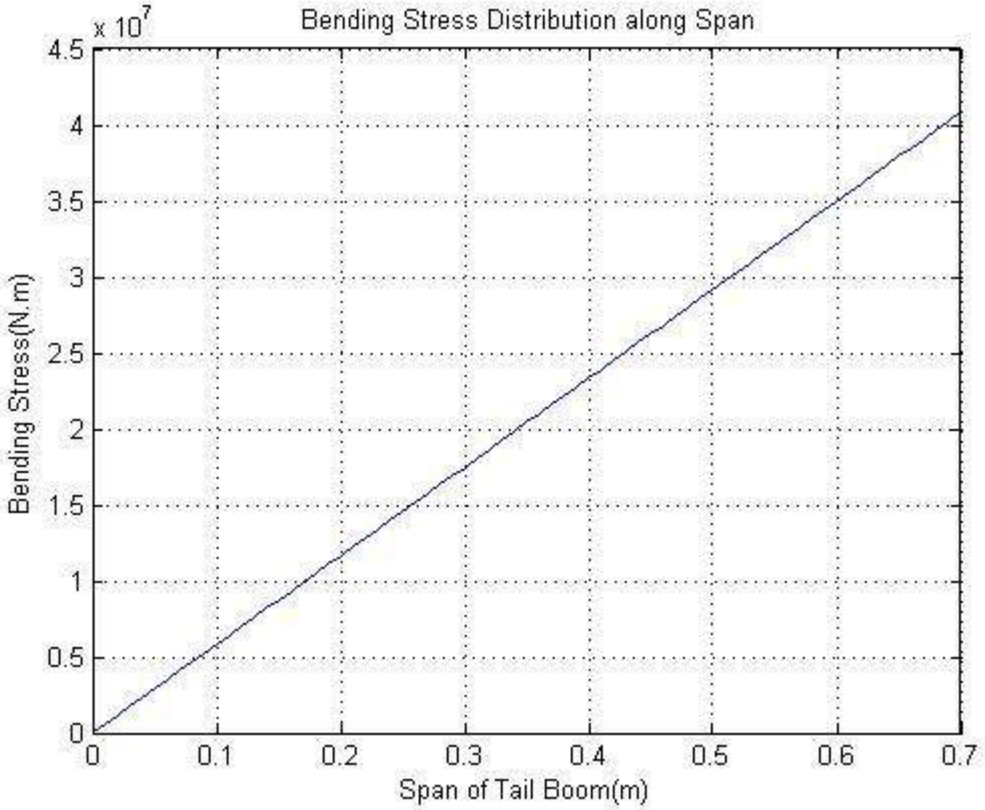

Drags Bending Moment Distribution along Span
Bending Moment due to Drag(N.m)
Span(m)
0
0.5
1
1.5
2
2.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


Lifts Bending Stress Distribution along Span
x 10^6
Bending Stress due to Lift(N/m^2)
Span(m)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.5
1
1.5
2
2.5
3
3.5
4
4.5


Drags Bending Stress Distribution along Span
Bending Stress due to Drag(N/m^2)
Span(m)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
1000
2000
3000
4000
5000
6000
7000

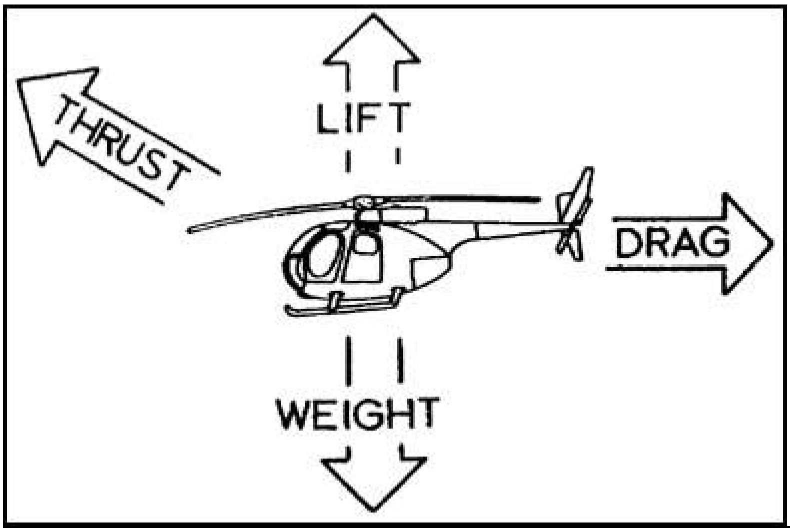


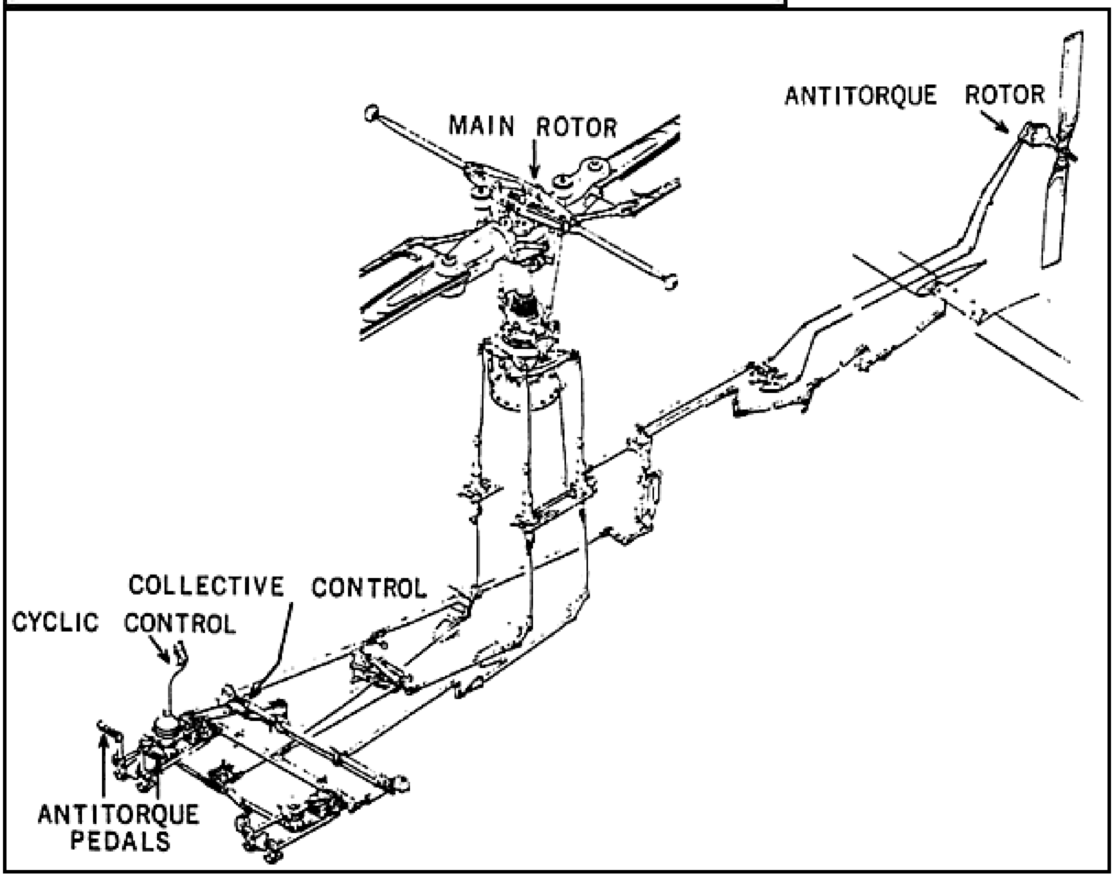
Bending Moment Distribution along Span
Bending Moment(N.m)
Span of Tail Boom(m)
0
1
2
3
4
5
6
7
8
0.1
0.2
0.3
0.4
0.5
0.6
0.7

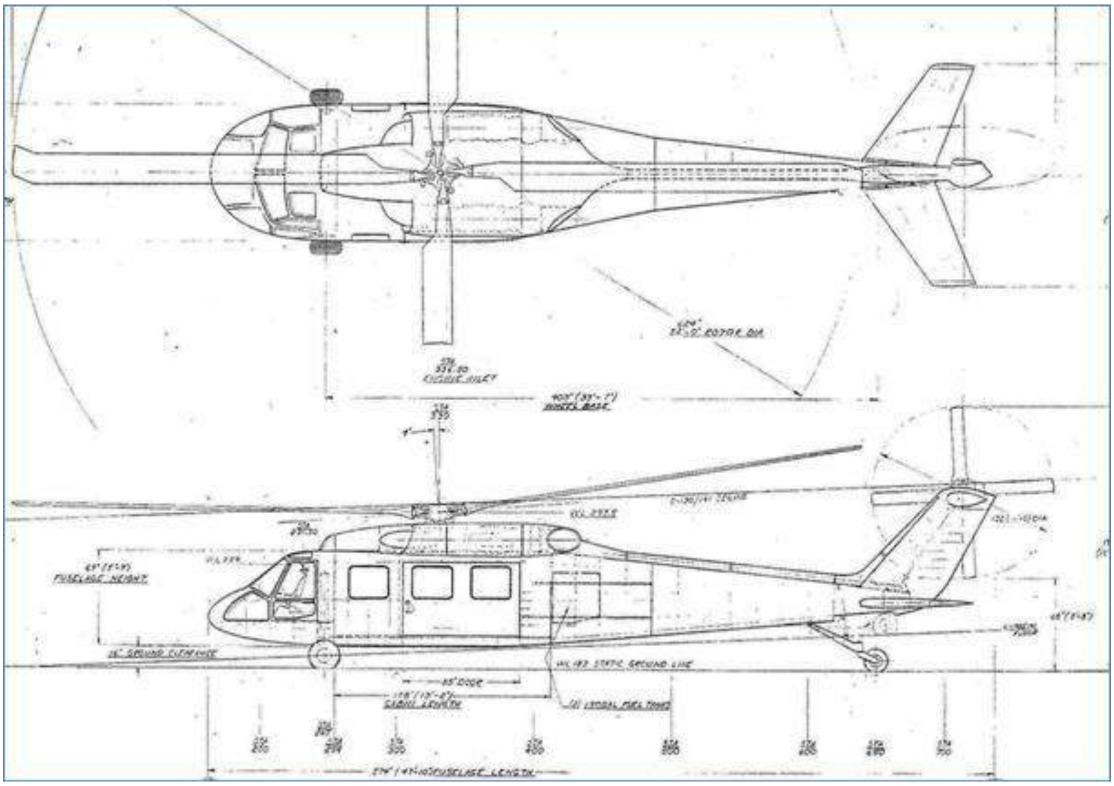


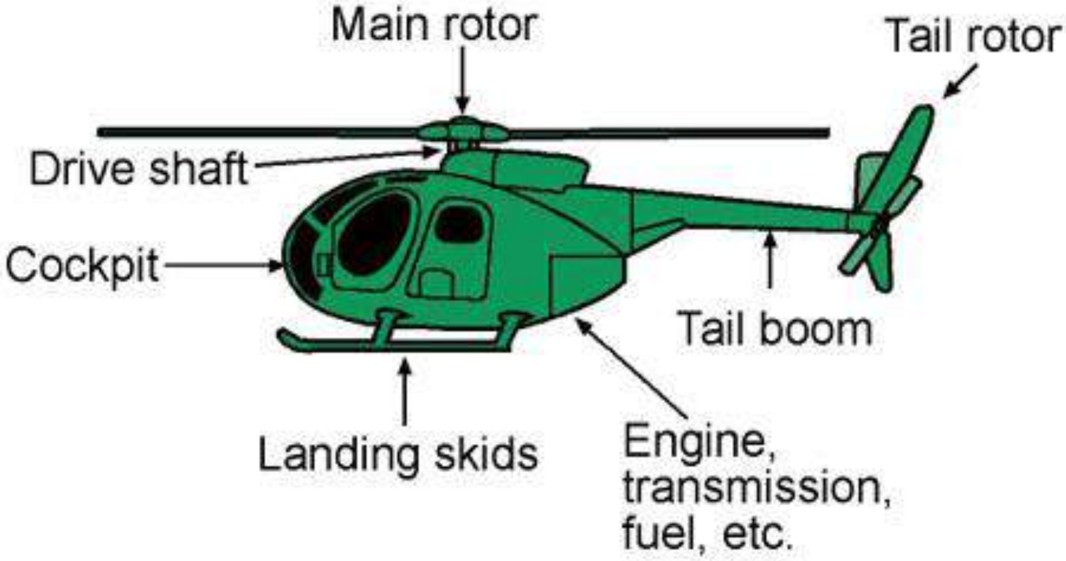
Bending Stress Distribution along Span
x 10^7
Bending Stress(N.m)
Span of Tail Boom(m)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0.1
0.2
0.3
0.4
0.5
0.6
0.7

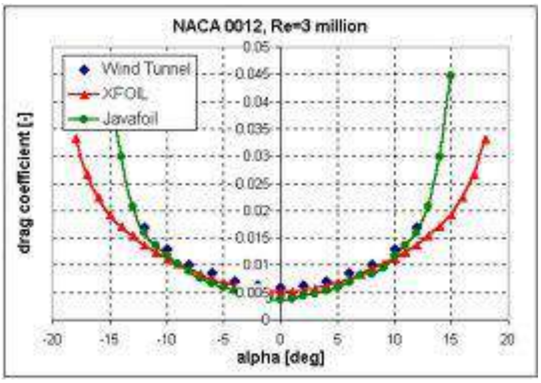
APPENDIX-(B)

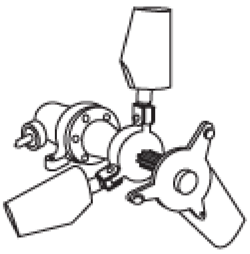

THRUST
LIFT
DRAG
WEIGHT

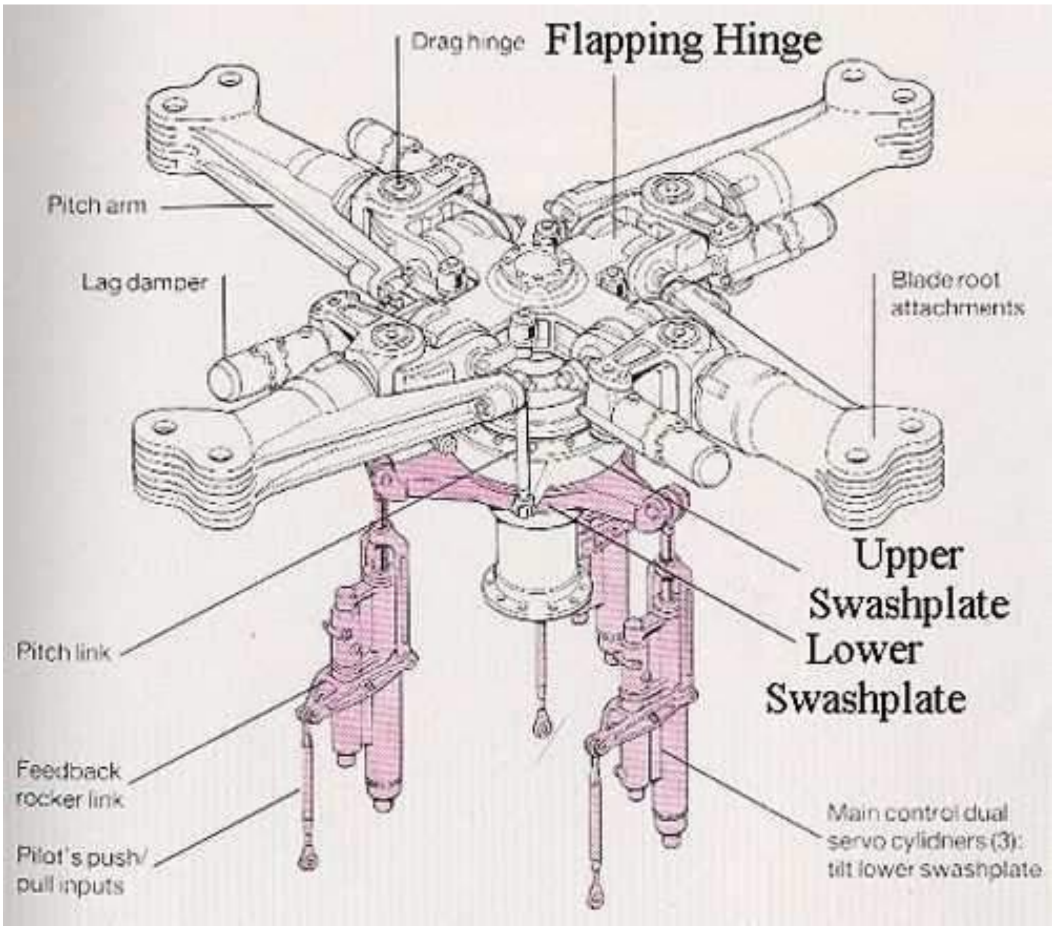

MAIN ROTOR
ANTITORQUE ROTOR
COLLECTIVE CONTROL
CYCLIC CONTROL
ANTITORQUE PEDALS

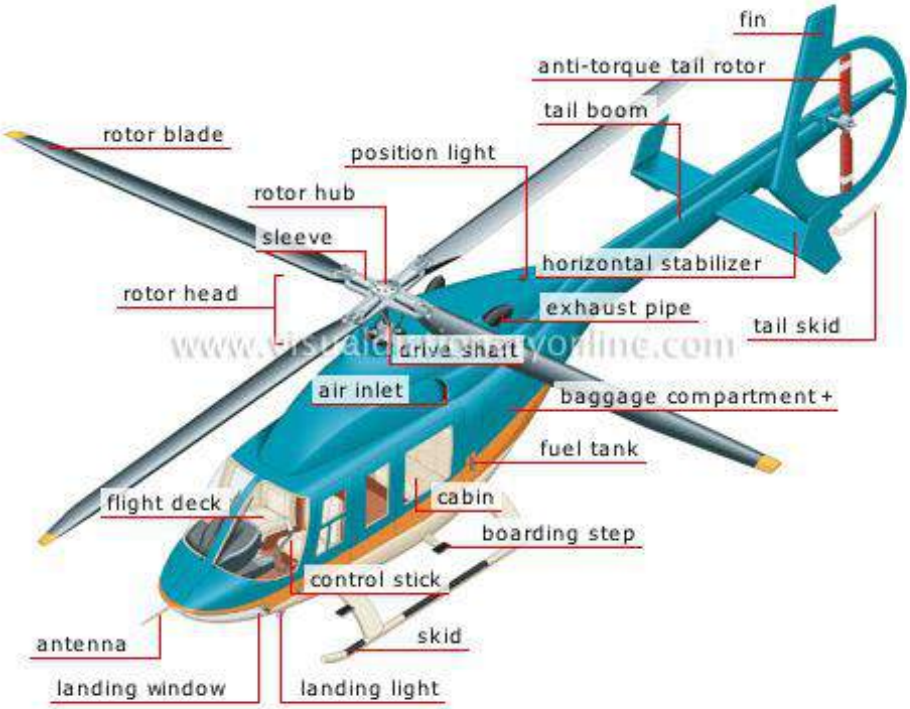



Main rotor
Tail rotor
Drive shaft
Cockpit
Tail boom
Landing skids
Engine,
transmission,
fuel, etc.


NACA 0012, Re=3 million
Wind Tunnel
XFOIL
Javafoil
drag coefficient [-]
alpha [deg]




Drag hinge
Flapping Hinge
Pitch arm
Lag damper
Blade root attachments
Upper Swashplate
Lower Swashplate
Pitch link
Feedback rocker link
Pilot's push/ pull inputs
Main control dual servo cylidners (3): tilt lower swashplate


fin
anti-torque tail rotor
tail boom
rotor blade
position light
rotor hub
sleeve
horizontal stabilizer
rotor head
exhaust pipe
tail skid
drive shaft
air inlet
baggage compartment +
fuel tank
cabin
flight deck
boarding step
control stick
antenna
skid
landing window
landing light

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8. "The Helicopter" by John Fay
9. "Aerodynamics" by Clancy
10. "Basic Helicopter Handbook" by United States Flying School
11. "Flight Without Formulae" by A.C. Kermode