EXPERIMENTAL SETUP FOR GROUND RESONANCE

Introduction

Ground resonance is a phenomenon wherein a helicopter encounter violent vibrations during landing or take off, that is while it is in contact with the ground. It occurs due to frequency matching of a rotor mode and a fuselage mode. Our objective in designing this setup is to recreate ground resonance in laboratory and conduct experiments to control ground resonance. To this end, a setup is designed such that ground resonance will happen in a narrow range of RPM around 500. The basic design of the experimental setup is described in this document.

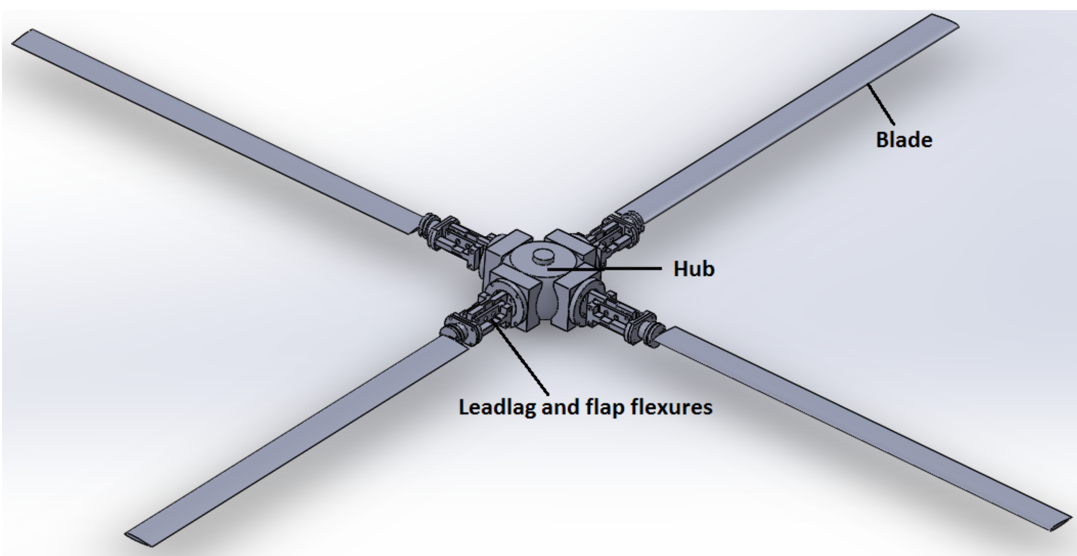
Scope

The scope of the work includes:

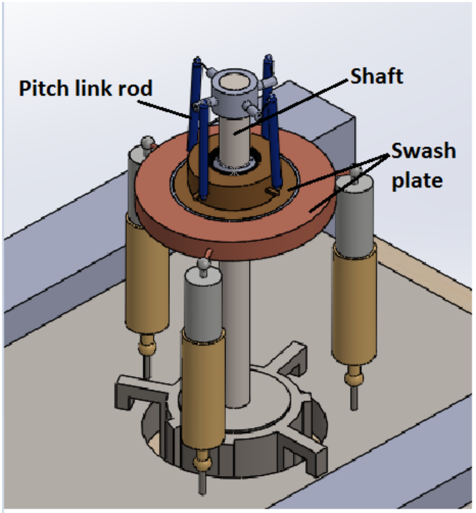
1. Fabrication of components and assembly
2. Selection of components like motor, actuators etc based on the available products in market
3. Testing of components and the complete setup
4. Minor design modifications.

EXPERIMENTAL SETUP

Rotor



The above rotor will be assembled with the shaft and the swash plate arrangement. These components are shown below. The motor, shaft, actuators are mounted on the fuselage which will be supported through laminas from the fixed support (this will explained later).

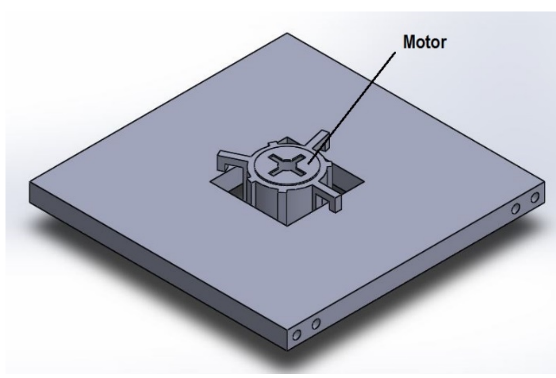


Isometric View

Individual Parts:-

The experimental setup primarily consists of a fuselage and a rotor with four blades attached to rotor hub through a flap and lag flexure as shown in Figure under rotor head section. The lead-lag flexures permit in-plane motion for the blade, and flap hinge allows blade to move out of plane. Detailed drawings of these hinges will be provided to the vendor. The fuselage is mounted on four thin plates that provide the translational degrees of freedom, that is allow the fuselage to move in a horizontal plane.

1. Fuselage

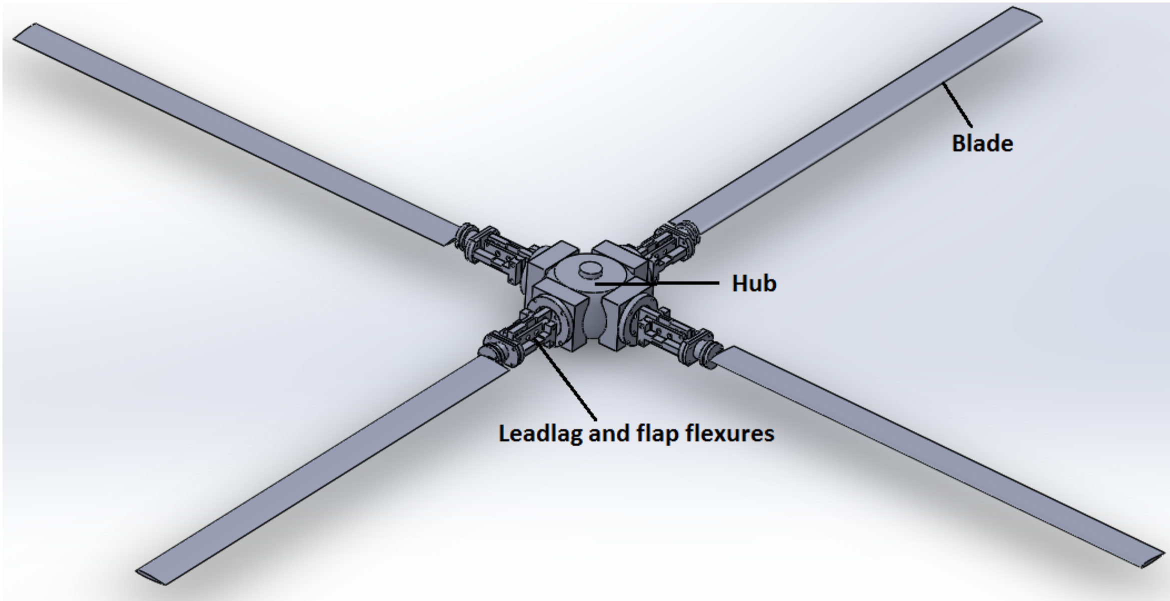


Isometric View

The fuselage is connected with the motor. The entire load of assembly comes on the fuselage and then to its laminas. It is made of stainless steel and mass is approximately 4 kg. It should be noted that there are holes drilled on the side (as shown in figure) in order to connect the laminas to it.

Material-Stainless steel (Grade 316)
Approximate Mass-4 kg

2. Rotor Head



Isometric View

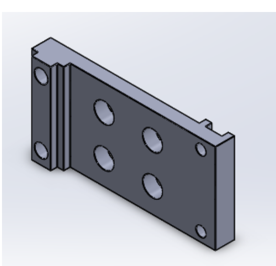
The rotor hub should have provision for mounting blades.

The blades are attached to a pitch bearing which in turn is connected to hinge (lead-lag and flap hinge) at distance of about 10cm from the hub. The hinges are in turn connected to the hub/shaft.

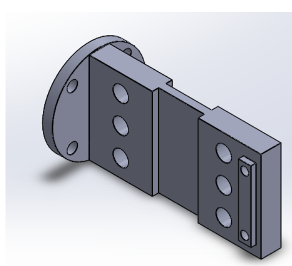
Material-Stainless steel grade 316

Hinges

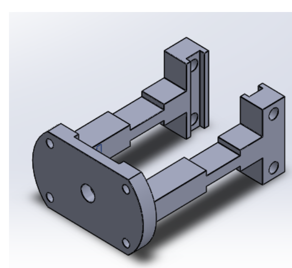
The setup consists of a lead lag and flapping hinge flexure. Lead lag hinge allows the blade to move back and forth (in-plane motion) while flapping hinge allows the blade to move up and down. Flapping flexure is connected to the pitch bearing. Lead lag flexure is connected to hub support. The total length of the hinge assembly will be approximately 8cm.



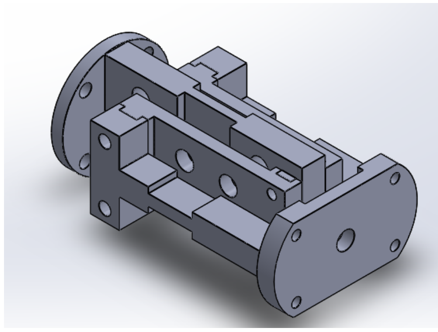
Lead lag plate (2)



Lead lag flexure



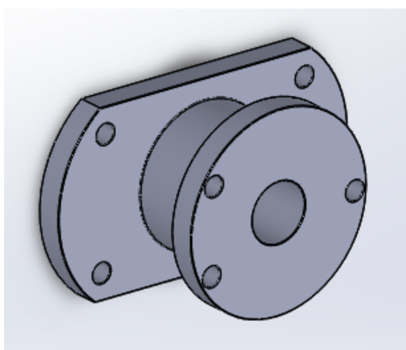
Flap flexure



Final hinge assembly

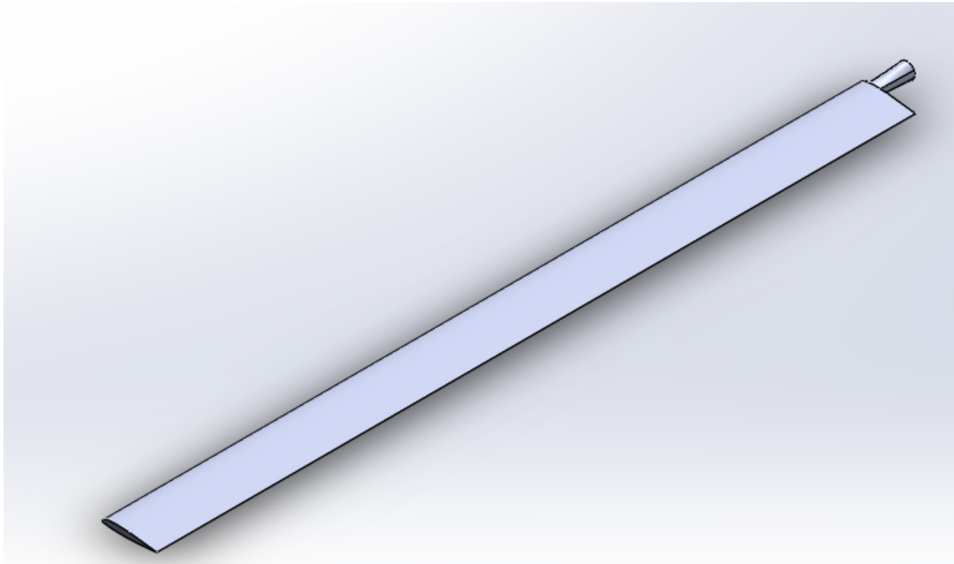
Pitch bearing

The pitch link horn (connected to pitch link rod) is connected to the pitch bearing. Movement of the swash plate translates to rotation of blade at pitch bearing. The inclination of the swash plate also gives rotation to blade/pitch bearing (through movement of pitch link rod and pitch horn) as the blade rotates about shaft, resulting in cyclic pitch inputs.



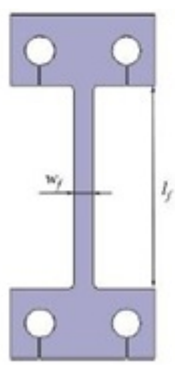
3. Blade

Airfoil: NACA23012
Chord: 41.9mm
Blade length: 750mm
Weight: 300g approx
The blade can be manufactured at IIT Madras. Nevertheless, it is requested that you may quote the price for blade (4 nos) manufacture separately, that is show the amount in the quote separately.



Isometric View

4. Laminas



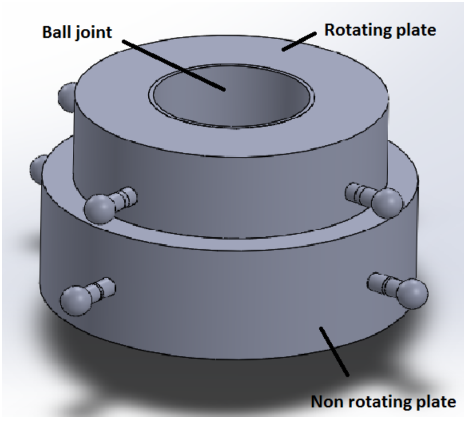
Laminas are used to attach fuselage to frame. The laminas can be made of spring steel. The frequency at which ground resonance occurs depends mainly on the laminas and hence it should be manufactured with precision. The thickness of the lamina is about 0.8mm and length and width are 70mm and 6.4 mm respectively.

Quantity of fuselage laminas=4 (for supporting the fuselage)

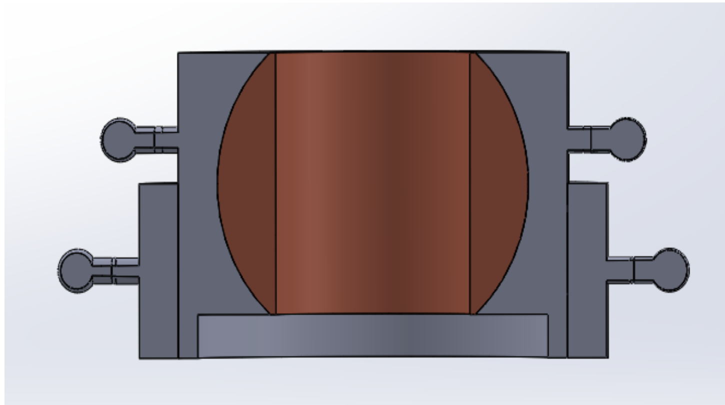
5. Shaft

Length-350 mm
Diameter-25 mm (may change based on design analysis)

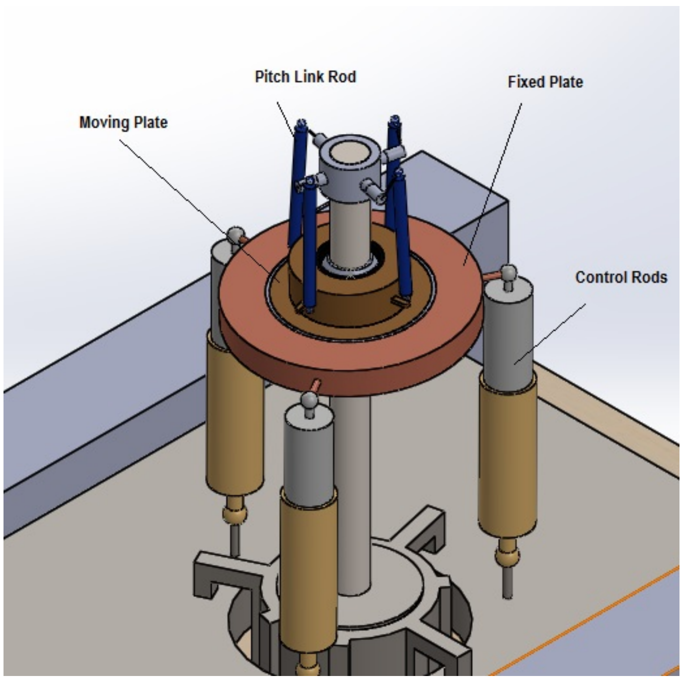
6. Swash Plate



Assembly view



Section view



Swash Plate Mechanism

An experiment needs to be performed to bring out the effects of collective pitch and Lock number on aeromechanical instabilities. Moreover, control augmentation is achieved by increasing the aerodynamic damping through control input given either as cyclic or collective pitch.

In order to perform this experiment, the following additional components needs to be included:-

1) A swashplate mechanism for providing the collective or cyclic input. Swashplate consist of a fixed plate through which input is given and a rotating plate that rotates along with the blade. The output from the rotating plate is provided as pitch to the hub
2) 3 servomotors with rigid links connected to it that serves as input to the fixed plate of swashplates.

3) Pitch link rods and pitch horns to connect the rotating plate to the blade pitch bearing
4) A scissor link that connects the rotating part of swashplate to shaft to reduce the load on pitch link rods

Actuators

Actuators for swash plate movement: (3 Nos)

Three actuators are required to move the fixed part of swash plate and provide both tilt as well as average movement for the plate. This will hence provide the blades with collective, and cyclic pitch inputs to the blade. The accuracy of the actuators will decide the accuracy with which the control inputs (pitch angle) can be provided to the blade. An accuracy of ~0.5 deg is required for swash plate which will require approximately an accuracy of .5 mm for actuator movement. The stroke of the actuator should be about 5 cm. The force exerted by the actuator should be such that it should be able to rotate the blade about its pitch axis counteracting the pitching moment acting on the blade. Approximate value of magnitude of force, the actuator should be able to produce is 100N or about 1 Nm. Frequency of operation of the actuator should be greater than 50 Hz.

Actuator for fuselage motion: (2 Nos)

Pneumatic or electrical Actuators that excite the fuselage and also act as safety mechanism (gets activated when fuselage displacement is greater than limit) need to be provided. Manual operation through switches also should be available.

Two actuators are required for exciting as well as arresting fuselage lateral motion. Arresting motion is mostly as a safety precaution and should have both manual and as automatic operation. That is if the displacement of fuselage is higher than a preset value, the actuators should operate and arrest the motion. The maximum force the actuator can exert should be about 40 N.

INSTRUMENTATION

Requirements:-

1. Measure angular speed (RPM) of shaft
2. Measurement of blade rotation about hinges. Wireless transmission arrangement will be done by IIT, however, required channels (4) should be provided for in the DAQ.
3. To measure the linear displacements of fuselage (LVDT preferred). Also, when the displacement exceeds the limit, a feedback system to cutoff the motor power.

<u>List of Instruments:-</u>

- ➢ RPM Sensor (Usually available along with Motor)
- ➢ Accelerometers (one on each blade) and two on fuselage
- ➢ LVDT (For x and y displacements) or any inductive sensors (2 Nos)

A control panel should also be provided for monitoring RPM, cutting off the motor, operating the actuators for arresting or exciting the fuselage. Wireless transmission of data from rotating blade will be done by IIT.

MOTOR SPECIFICATIONS

1. RPM Range:-0-1200 rpm continuous. Speed should be maintained within +/- 1 RPM
2. Shaft length (appx):-350 mm (may change based on design modifications)
3. Torque at 1000 RPM: >=12 Nm

Safety Measures

Ground resonance condition involves sudden increase in vibration levels and hence for safety a control system should be present that (when the vibration is too high) tries to dampen the vibration (possibly through pneumatic actuators) and also stop the motor. This can be achieved by taking feedback from LVDT and/or accelerometers and integrating the system with actuators (fuselage).

Other Requirements

1. A platform to keep the experimental setup
2. Data acquisition system (/card) that acquires data from LVDT and also a provision for other instrument channels (e.g. for accelerometers)

Summary

A brief list of important components is given below:

1. Rotor side (major components): Rotor hub, Swash plate mechanism, pitch link rod and pitch horn, flap and lead-lag hinges, pitch bearing, and motor
2. Fuselage side (major components): Lamina (4), fuselage
3. Instrumentation: LVDT (2), Accelerometers (6), RPM sensor
4. Actuators for swash plate (3)
5. Actuators for fuselage (2)
6. DAQ (/card)
7. A platform for the setup

Actual dimensions of the components will be provided to the vendor after award of the contract. Minor design modifications in future may be required both from functionality and safety issues.

If you need any clarification please contact :

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