Dynamic Analysis of Horizontal Stabilizer and Vertical Fin Of Light Utility Helicopter (HAL LUH)

Submitted by

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INTRODUCTION
COMPANY BACKGROUND

- Hindustan Aeronautics Limited is an Indian state-owned aerospace and defence company based in Bangalore, Karnataka. It is governed under the management of the Indian Ministry of Defence.
- The government-owned corporation is primarily involved in the operations of the aerospace industry. These include manufacturing and assembly of aircraft, navigation and related communication equipment and airports operation.
- Hindustan Aeronautics has a long history of collaboration with several other international and domestic aerospace agencies such as Airbus, Boeing, Lockheed Martin, Sukhoi Aviation Corporation the Indian Aeronautical Development Agency and the Indian Space Research Organisation.
- HAL Aerospace Museum is India's first aerospace museum located at Hindustan Aeronautics Limited premises, in Bangalore. Established in 2001, the Museum is part of the HAL Heritage Centre and Aero Space Museum, and showcases the growth of the Indian aviation industry and HAL for six decades.
- HAL built the first military aircraft in South Asia. It is currently involved in the design, fabrication and assembly of aircraft, jet engines, helicopters and their spare parts. It has several facilities spread across India. The locations where the manufacturing plants are operated by HAL include Nasik, Korwa, Kanpur, Koraput, Lucknow, Bangalore and Hyderabad.

INTRODUCTION

AIM

- The aim of Dynamic analysis of a helicopter component is to find the values of natural frequencies using Finite Element Analysis of model.

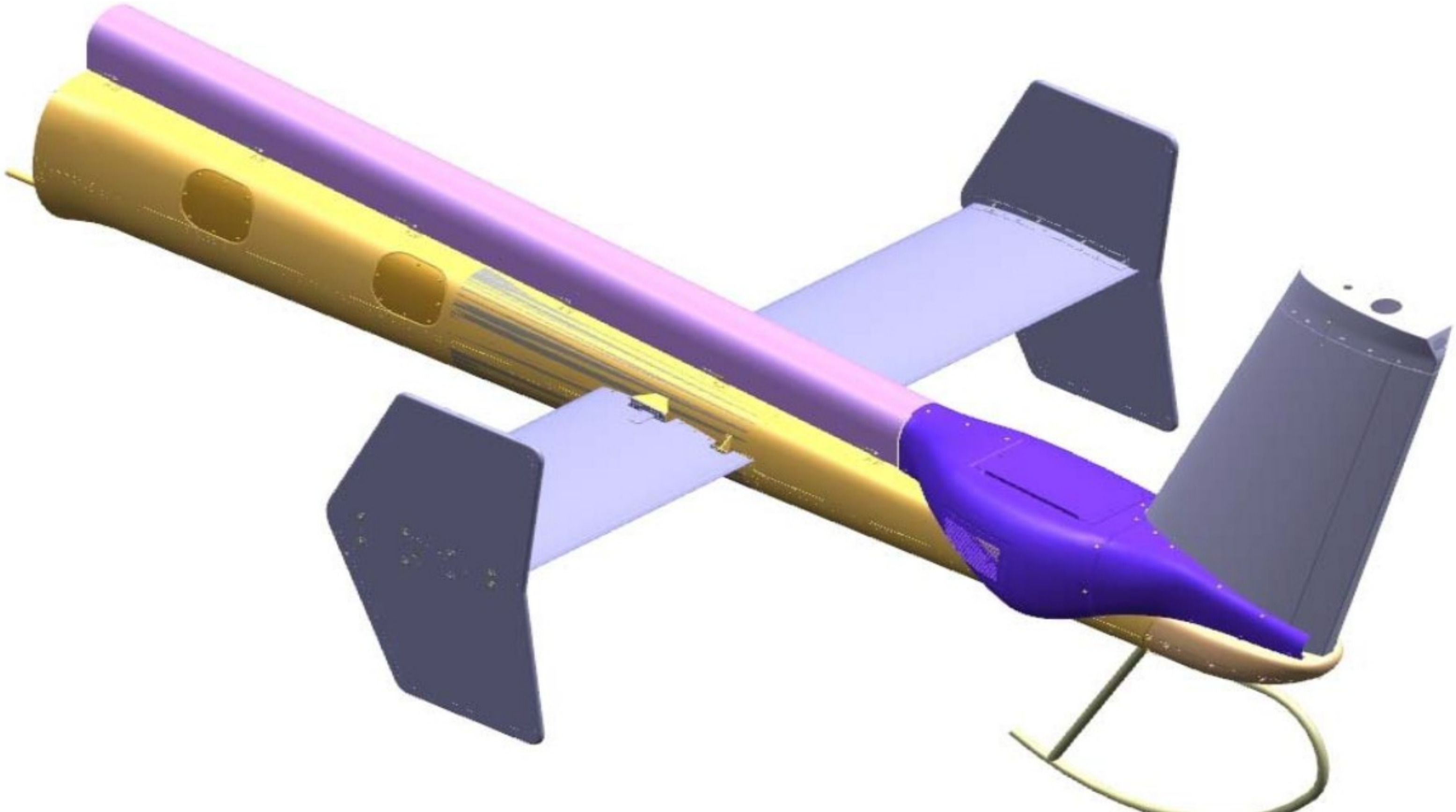
INTRODUCTION

Q. Why to find out natural frequency?

- Natural frequencies or resonant frequencies of helicopter components are found out in order to see if they match with the values of natural frequencies of rotor. Because if they match, the *structure of helicopter would be unstable and unsafe for flight*.

LOCATION

- LUH is modeled with low weight fiber composite for horizontal stabilizer and vertical fin.
- The Horizontal stabilizer is positioned on the tail boom ahead of the tail rotor
- Vertical fin is positioned vertically at the end of tail boom to off load the tail rotor and for yaw control.
- The Equipment Panel is positioned inside the cockpit



ABBREVIATIONS

- HT - Horizontal Stabilizer
- VT - Vertical Fin
- ET- Equipment Panel
- LUH – HAL Light Utility Helicopter
- MATLAB – Matrix Laboratory
- XM – Mass Centre
- XSM – Shear Centre

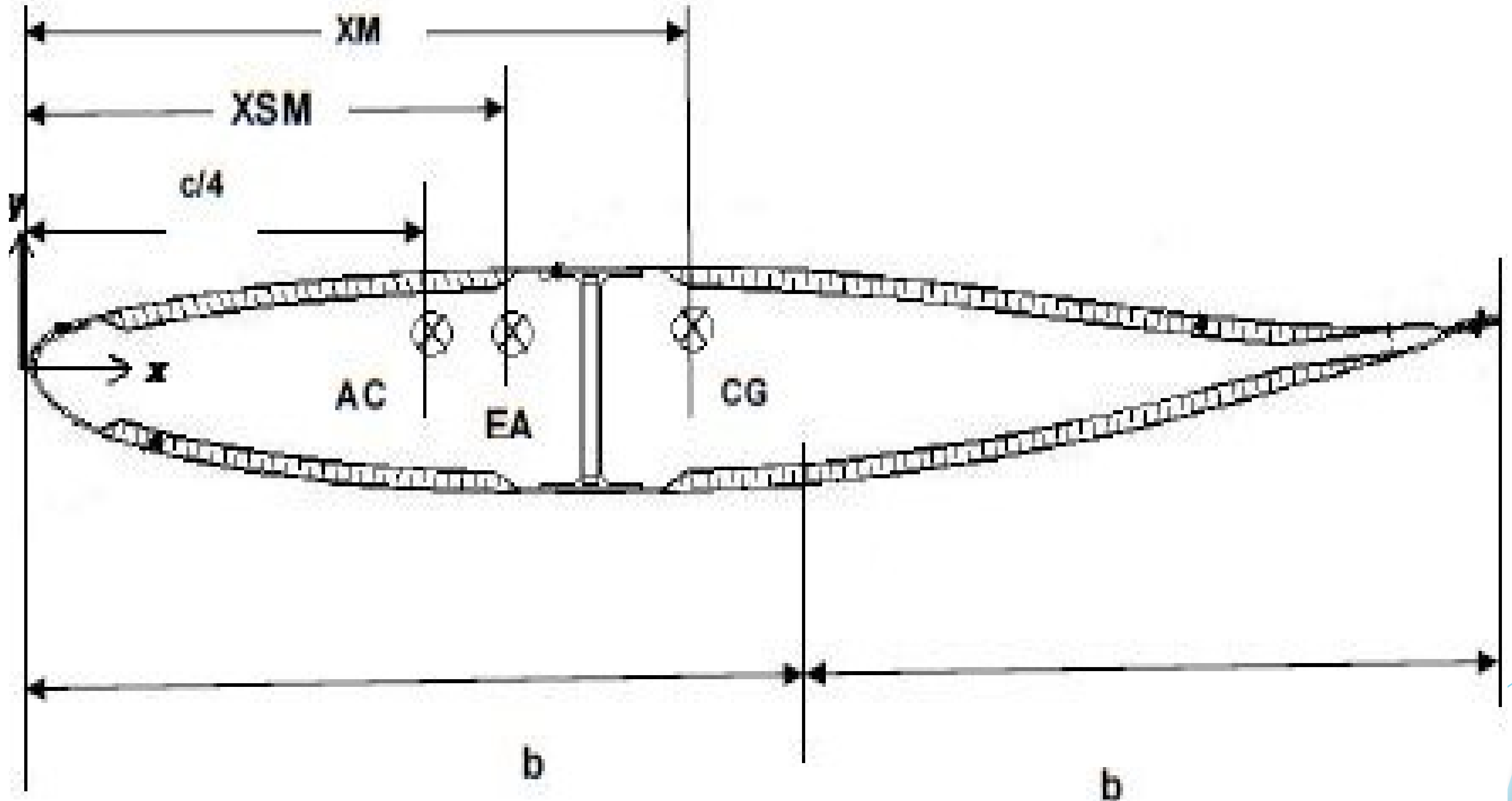
DYNAMIC ANALYSIS: LUH HORIZONTAL STABILIZER (HT)

- **Method Used: FE method**
- The FE method was used to model the HT using ALTAIR HYPERMESH and the natural frequencies were obtained through modal analysis using NASTRAN.

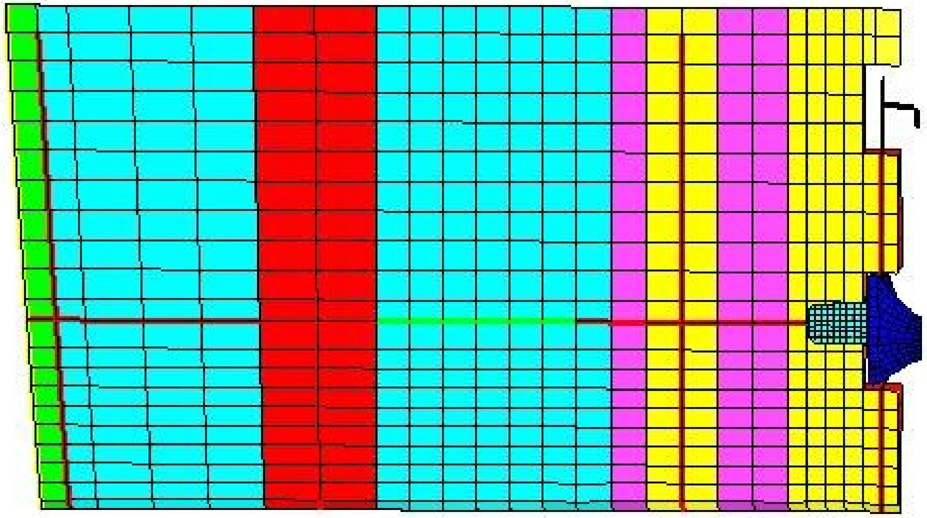
Horizontal Stabilizer (HT)

- The LUH Horizontal stabilizer has a uniform airfoil GAW2 (inverted) profile which is rigidly fixed to the helicopter tail boom with end plates
- In addition to torsional motion, bending motion is included in the model and there is a phase shift between torsion and bending motion due to aerodynamic loads.
- The first bending mode and the first torsion mode of LUH HT are given below.
- **The HT 1st Flap bending mode frequency =19.00Hz**
- **The HT 1st Torsional mode frequency =54.74Hz**

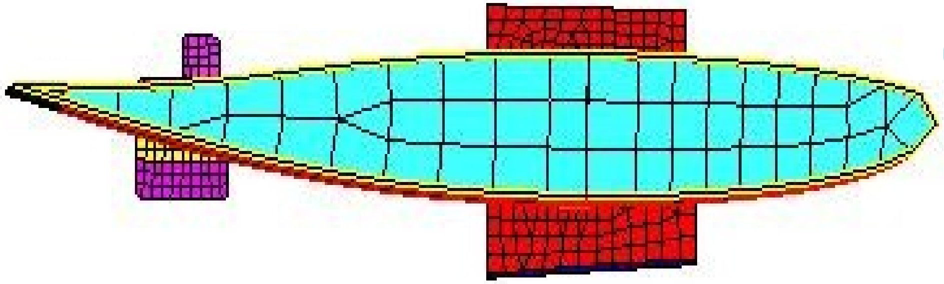
Cross-Section of HT



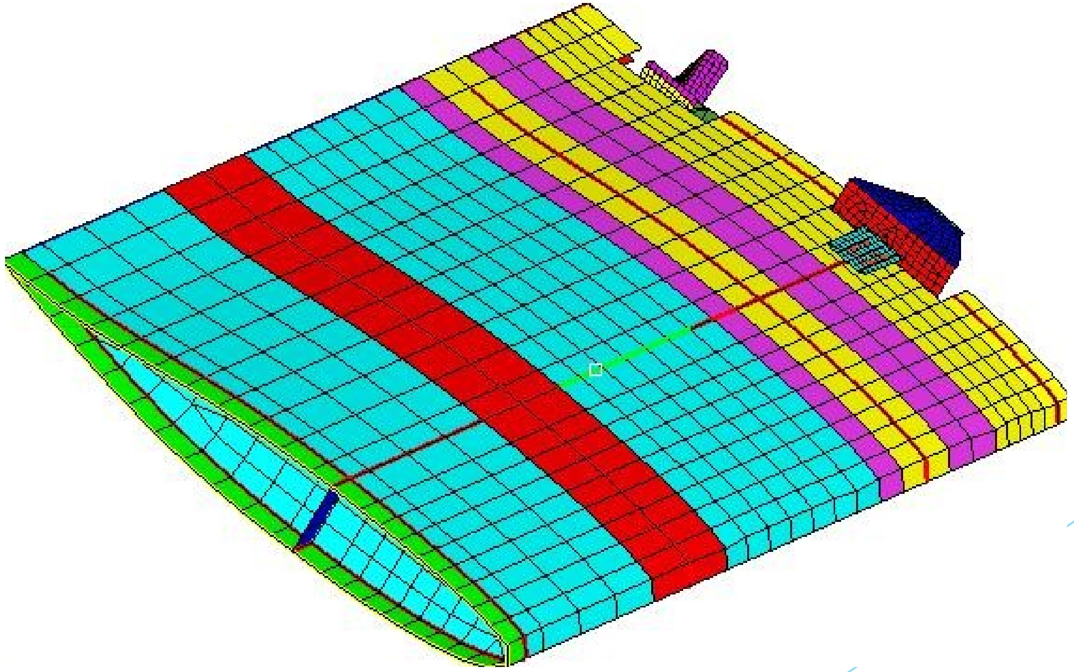
FE MODEL OF HT



TOP VIEW

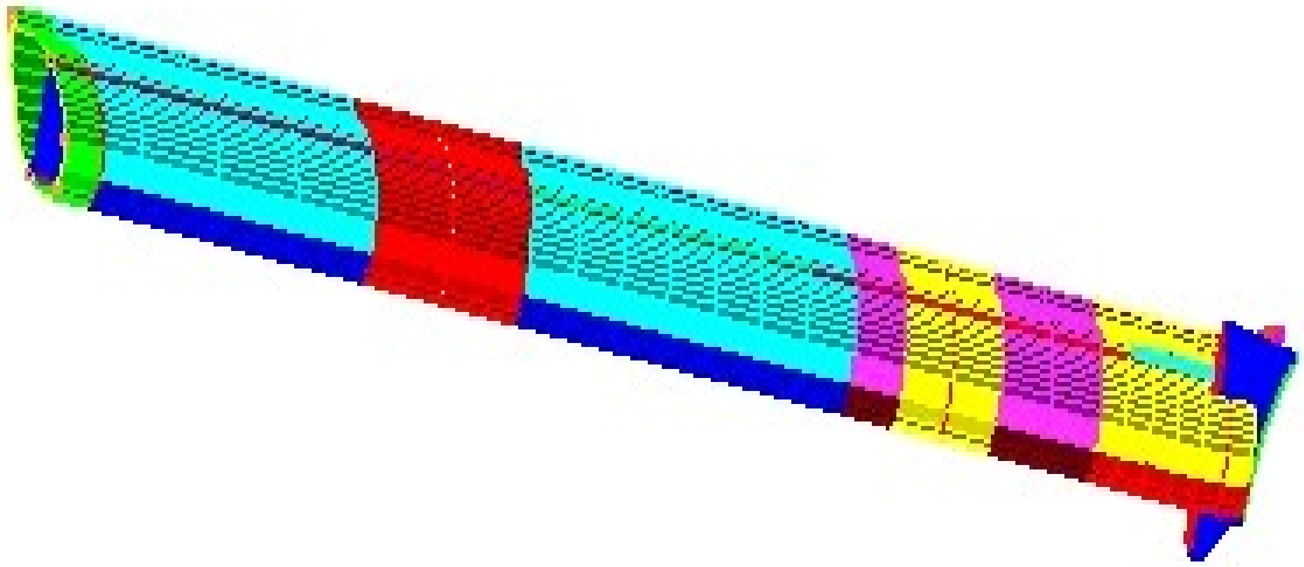


SIDE VIEW

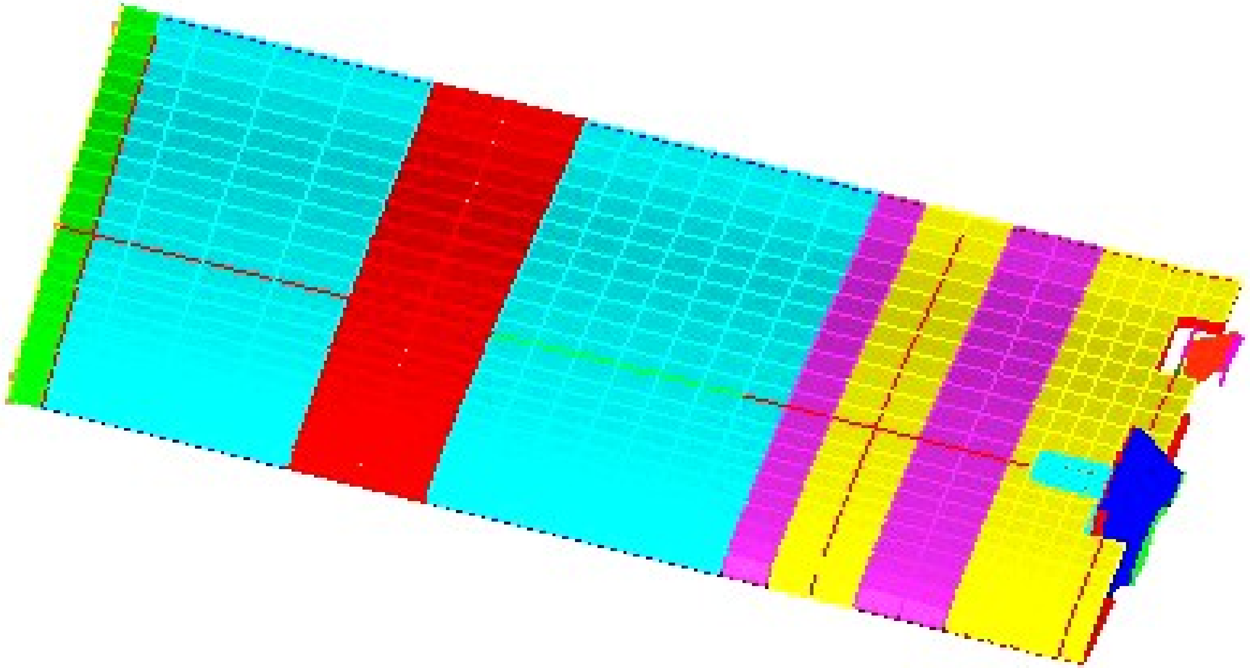


ISOMETRIC VIEW

Fundamental Bending Mode= 23.61 Hz



Fundamental Torsion Mode = 55.74 Hz



DYNAMIC ANALYSIS: LUH VERTICAL FIN (VT)

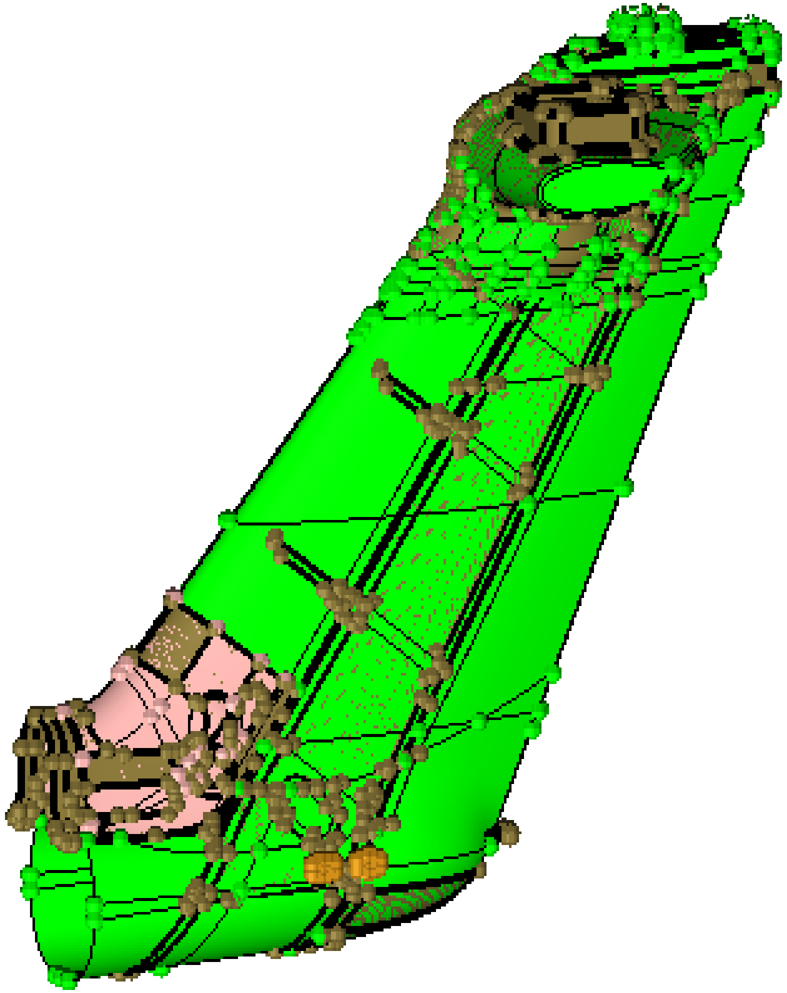
- **Method Used: FE method**
- The FE method was used to model the VT using ALTAIR HYPERMESH and the natural frequencies were obtained through modal analysis using NASTRAN.

Vertical Fin (VT)

- The LUH Vertical Fin has a NACA0017 truncated airfoil profile
- In addition to torsional motion, bending motion is included in the model and there is a phase shift between torsion and bending motion due to aerodynamic loads.
- The first bending mode and the first torsion mode of LUH VT are given below.
- **The VT 1st Flap bending mode frequency = 19.00 Hz**
- **The VT 1st Torsional mode frequency = 54.74 Hz**

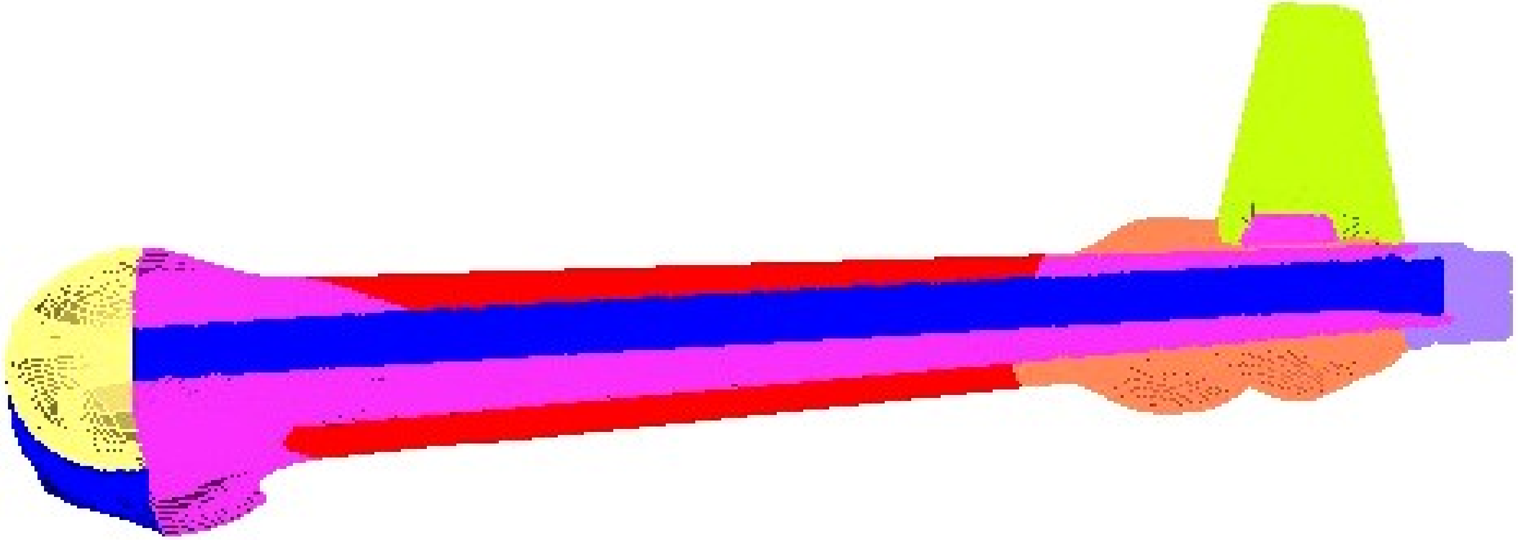
FE Model of LUH VT

Original Geometry

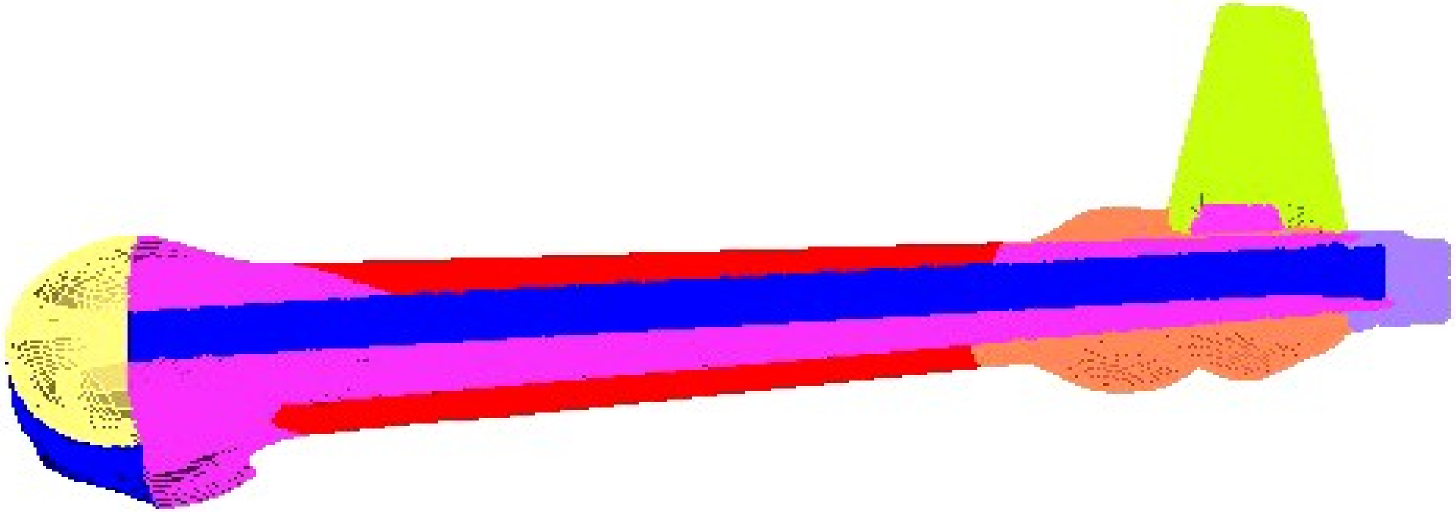


CORRECTED AND MESHED GEOMETRY WITH ASSIGNED MASS (CONM2)

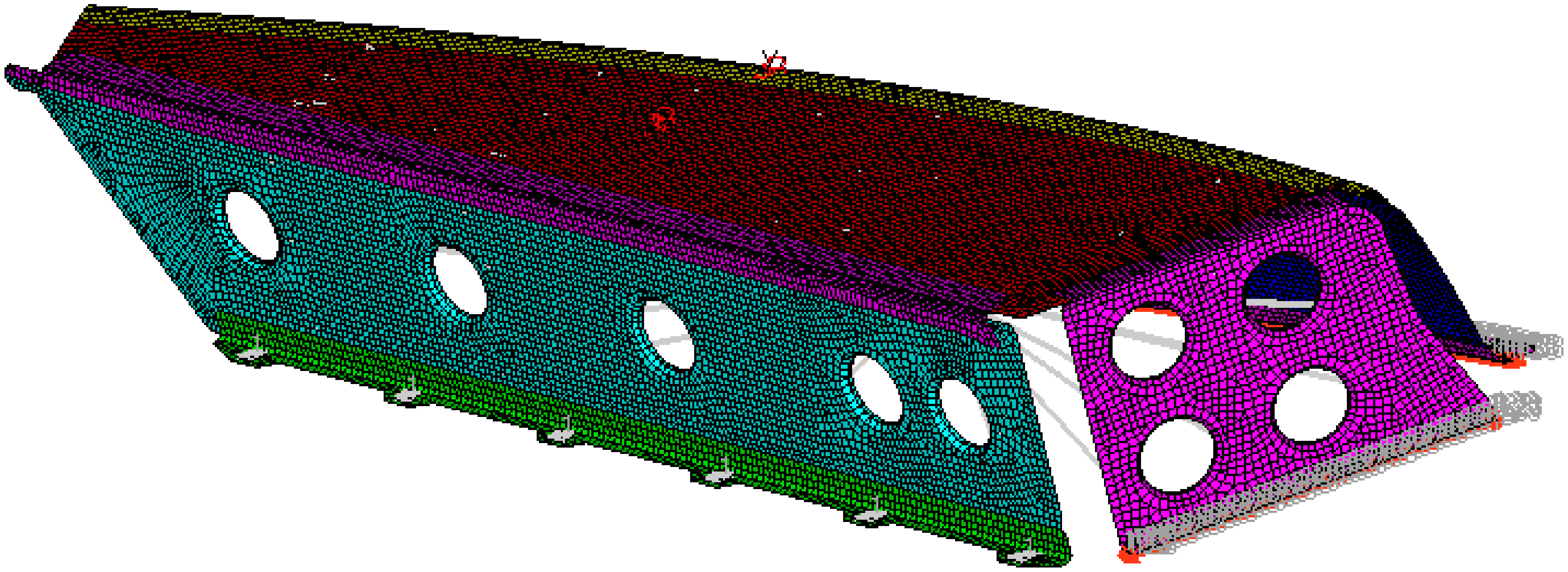
Fundamental Bending Mode= 39.32 Hz



Fundamental Torsion Mode = 60.15 Hz

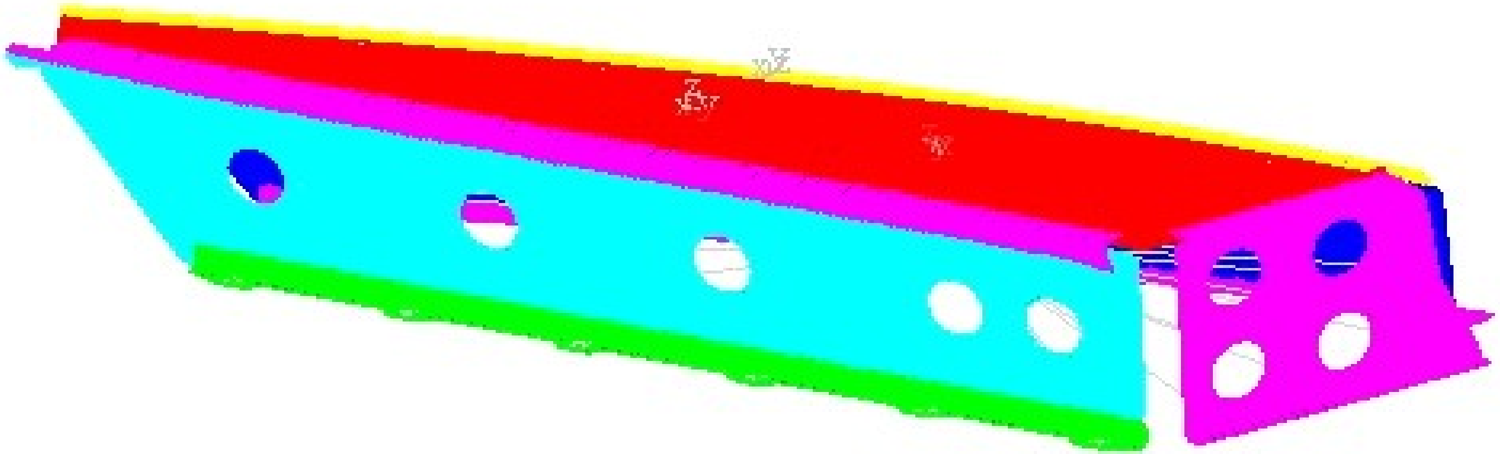


DYNAMIC ANALYSIS: LUH EQUIPMENT PANEL (ET)

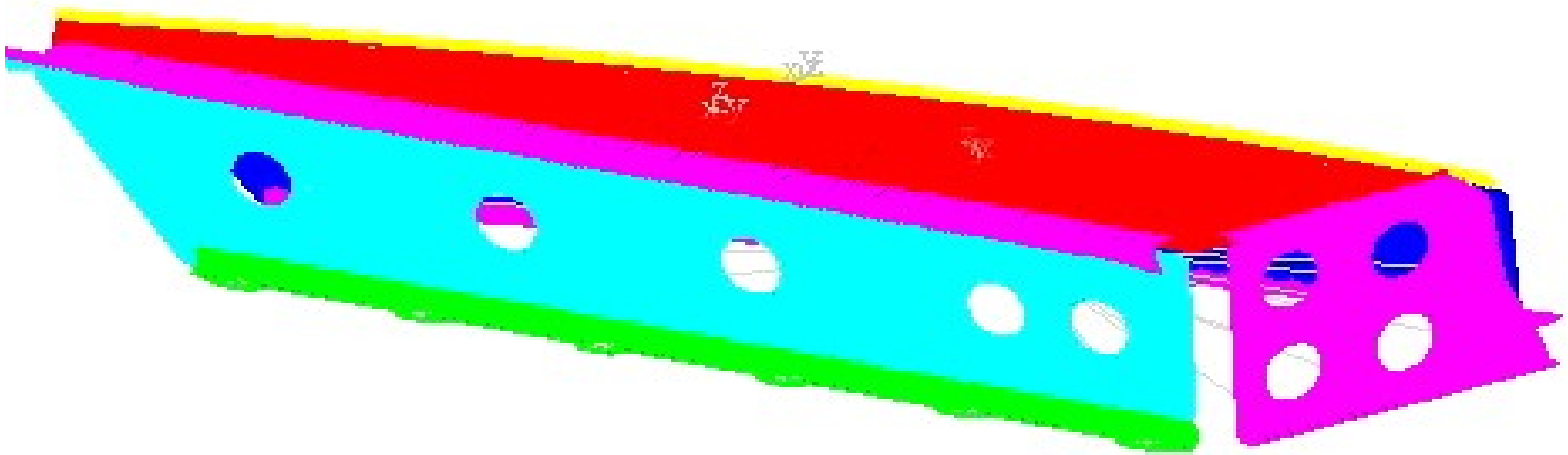


- FE Model of LUH ET

Fundamental Bending Mode= 13.35 Hz



Fundamental Torsion Mode= 17.32 Hz



Procedure for creation of FE Model:

I. Obtained Original Geometry (CAD Parasolid File of extension .x_t)
II. Geometry Cleanup: Removal of Red Lines- Free edges (only corrected where required)
III. Removal of Yellow Lines-Surfaces which are shared by 3 or more surfaces
IV. Green Lines –Required lines / Shared edges
V. Creation of nodes at the area which is to be attached to the Tail Boom
VI. Meshing: Command AUTOMESH used surface-by-surface

MATLAB code for finding out Natural Frequency

- Natural Frequency as obtained by Free Dynamic Analysis is given by:
- $\omega_n = \sqrt{\frac{k}{m}}$
- Where k = Stiffness (in N/m)

  m = Mass of Material (in kg)
- Created two files natfreq.m and matlist.m. natfreq.m file contains the MATLAB code and matlist.m contains the function matlist() which consists of the values of Young's Modulus of different types of Materials.

natfreq.m

```
%File name: natfreq.m

%Calculation of Natural Frequency


disp('*** Finding out the Natural Frequency ***');

fprintf('\n All parameters should be entered in SI units');

l=input('\nEnter length (in m)= ');

p=input('\nEnter Force (in N)= ');


%Calling function matlist
matlist();


E=input('\nEnter E of material ');

I=input('\nEnter Moment of Inertia= ');
```

natfreq.m

```
I=input('\nEnter Moment of Inertia= ');

%Displacement value for cantilever beam
%Horizontal Stabilizer acts as Cantilever beam

displacement=(p*(l^3))/(3*E*I);


%Stiffness
stiffness=p/displacement;
fprintf('\nStiffness  ');
disp(stiffness);

%Natural Frequency
natfreq=sqrt(stiffness/mass);
fprintf('\nNatural Frequency');
disp(natfreq);
```

Material Library

```
%File name: matlist.m

function matlist()

disp('Material List');
disp('For Aluminium E=72*10^9');
disp('For Glass-Polyester E=38*10^9');
disp('For Carbon-Epoxy E=220*10^9');
disp('For Steel E=200*10^9');
disp('For Boron-Epoxy E=200*10^9');



end
```

MATLAB code for finding out Time Response Curve

```
%File name: timeresponsecurve.m
%Time Response curve


clear all;close all;clc;
disp('  Time response curve ');

mass=input('\nEnter mass (Default 5 kg) =  ');
if isempty(mass)
          mass = 5;
end

k=input('\nEnter Stiffness (Default 10 N/m)= ');
if isempty(k)
          k = 10;
end

x0=input('\nEnter Initial Displacement (Default 5 m) = ');
if isempty(x0)
          x0 = 5;
end

w=sqrt(k/mass); %Natural Frequency

i=1;

%Loop for response at each time from t=0 to t=10
for t=0:0.1:10
y(i)=x0*sin(w*t);
i=i+1;
end

t=linspace(0,10,101);
```

MATLAB code for finding out Time Response Curve

```
t=linspace(0,10,101);

%Graph
disp('Time Response Curve');
plot(t,y,'or');
% Create xlabel
xlabel({'Time'});
% Create ylabel
ylabel({'Displacement'});
% Create title
title({'Time Response Curve'});
```

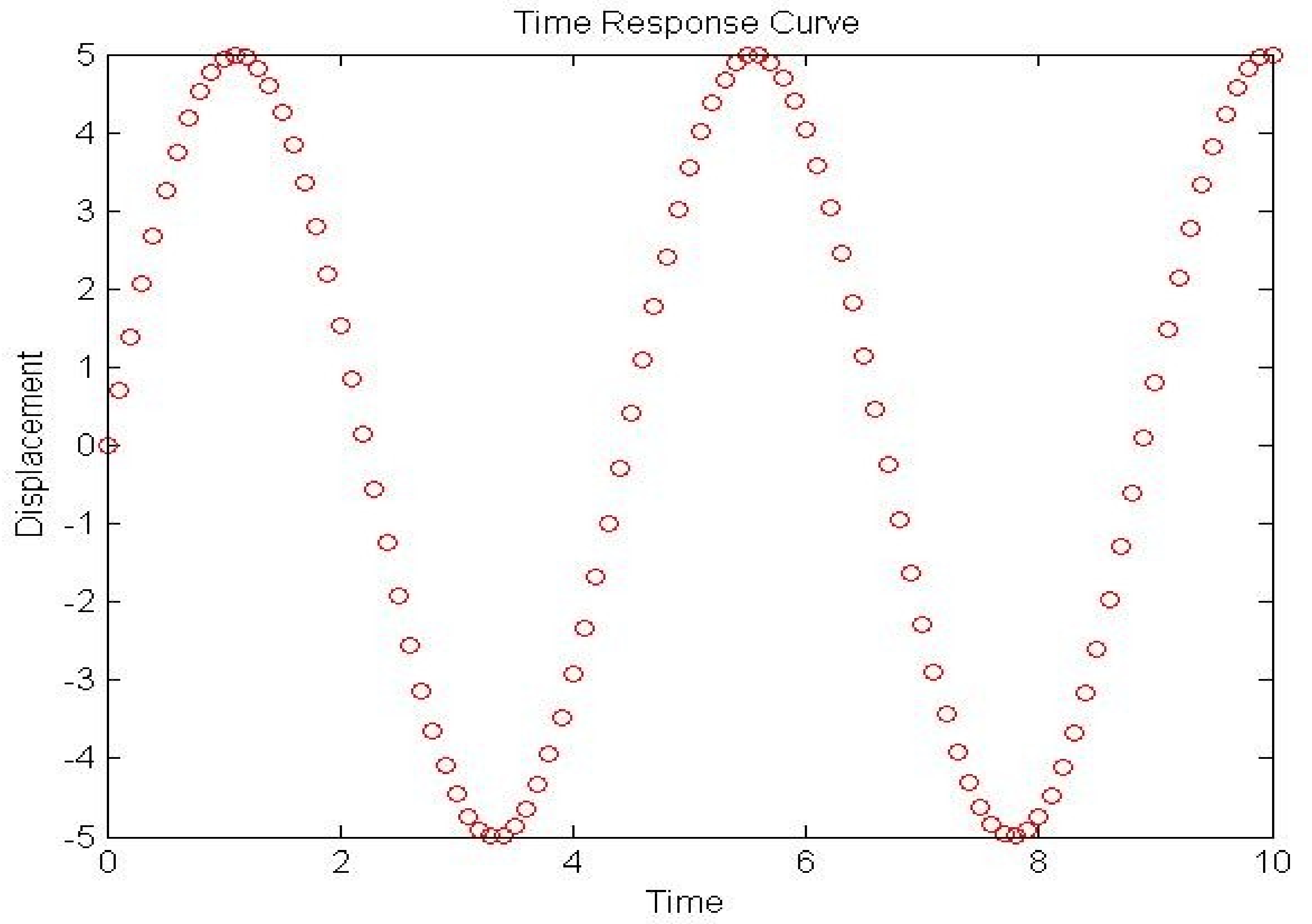
```
Output
Time response curve

Enter mass (Default 5 kg) =

Enter Stiffness (Default 10 N/m)=

Enter Initial Displacement (Default 5 m) =
Time Response Curve
```

Time Response Curve: Graph generated by Displacement vs Time



CHEETAH & CHEETAK

- Cheetah helicopter is a single-engine multi mission helicopter in 2-tonne class with a modern fuel efficient high performance engine TM 333 2M2 fully controlled by Full Authority Digital Electronic Control (FADEC) System in place of ARTOUSTE IIIB engine.
- Cheetal is manufactured by Helicopter Division of the Hindustan Aeronautics Limited (HAL).
- This is also called as HAL SA216 Alouette III

- The Chetak helicopter is a two ton class helicopter operated by several military and civil operators all over the world.
- Chetak is manufactured by Helicopter Division of the Hindustan Aeronautics Limited (HAL).
- This is also called as HAL SA315B Lamas

Salient Features of Chetak

- The Chetak helicopter is utilized for the following roles:
- Communication Duties (Passenger transport)
- Cargo/ Material Transport
- Casualty Evacuation (CASEVAC)
- Search and Rescue (SAR)
- Aerial Survey and Patrolling
- Emergency Medical Service (EMS)
- Electronic News Gathering
- Anti- Hijacking
- Off shore Operations

Salient Features of Cheetah

- Some of the salient features of Cheetal are:
- Elimination of clutch due to free turbine engine.
- Introduction of Inversion Gear Box
- Modified electrical system/instrument panels by adding DC master box, new engine instruments with modular warning lights.
- Introduction of Master warning flasher light in the cockpit, which flashes in the event of any warn, comes ON in cockpit.
- Automatic takeover of engine control by Electronic Backup Control Box system (EBCB) in the event of FADEC failure

ALOUETTE III TRANSMISSION SYSTEM

Q. Why use a transmission system in Helicopter?

A. The angular velocity (in rpm) generated from the engine is very high and therefore it needs to be reduced by a significant margin, so transmission system is used in helicopter.

Features of the ALLOUETTE III Transmission system

- Used in both Cheetah and Chetak helicopters
- Consists of the following components:
- Turbine
- Main Gear Box (MGB)
- Tail Gear Box (TGB)
- Main Rotor Head (MRH)
- Vent Gear Shaft (VGS)
- Tail Rotor Head
- Clutch Unit
- Free wheel (similar to Flywheel)
- Inclined Drive Shaft
- Coupling Shaft
- Tail Drive Shaft
- Angular Velocities of the transmission components are as follows :

Components	Angular Velocity (in rpm)
Engine (Turbine)	33500
Main Gear box (MGB)	5770
Vent Gear Shaft (VGS)	2820
First Stage Planetary Gear	999
Main Rotor Head (MRH)	353
Tail Rotor Head (TRH)	1940
MGB Reduction Ratio	16.253:1

Conclusion

- The dynamic analysis of the horizontal stabilizer and vertical fin of the LUH helicopter is determined. The helicopter is expected to have a maximum speed of 280 Km/h.
- Since the natural frequencies do not match the frequencies of rotor, the helicopter is stable and safe for flight.

THANK YOU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