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Static and Dynamic Analysis of Flight Control Circuit Mixing Unit in a Typical Light Helicopter

Anup Banakar K
Department of Mechanical Engineering
East Point College of Engineering And Technology
Bengaluru
India

Dinesh Kumar
Department of Mechanical Engineering
East Point College of Engineering And Technology
Bengaluru
India

Abstract: Conventional helicopter (single main rotor & tail rotor) has three flight control inputs called as the cyclic stick, collective stick and anti-torque / rudder pedals. The principle motivation behind the flight controls in helicopter is to change the pitch angles of main and tail rotor and enabling the pilots to control helicopter elevation, speed and direction. The contributions to the cyclic stick and collective stick control the main rotor pitch angles. The inputs to the pedals (rudder) control the tail rotor pitch angles. Main rotor controls comprise of Collective, Cyclic Longitudinal (Pitch) and Cyclic Lateral (Roll) channels, which together control the main rotor blade pitch angles. Cockpit controls for Pilot and Co-Pilot are cultivated utilizing torque tube/switches and control bars. The mixing of collective and cyclic is done at mixing unit. The main rotor mixing unit is required to guarantee that all control inputs are transmitted to the main rotor without loss of input or one influencing the other. A mixing unit keeps up the cyclic angle by mixing collective input with right lateral, left lateral, and fore/aft inputs into a summing bell crank. “The present work mainly focuses on the finite element idealization of the mixing unit, evaluation of the strength characteristics for the applied control loads and also estimation of free vibration characteristics of the mixing unit”.

1. INTRODUCTION

About Helicopters: A helicopter is an aircraft that is lifted and driven by one or more horizontal rotors, each rotor consisting of two or more rotor blades. Helicopters are classified as rotor craft or rotary-wing aircraft to distinguish them from fixed-wing aircraft because the helicopter derives its source of lift from the rotor blades rotating around a mast. "Helicopter" is derived from the French hélicoptère, instituted by Gustave de Ponton d'Amécourt in 1861. It is connected to the Greek words’ helix/helikos ("winding" or "turning") and pteron ("wing").

The helicopter utilizes rotating wings to give lift, drive, and control. The rotor blades rotate about a vertical axis, describing a disk in a horizontal or nearly horizontal plane. Aerodynamic forces are created by the relative motion of a wing surface with respect to the air. The helicopter with its rotational wings can produce these forces even when the velocity of the vehicle is zero, as opposed to fixed-wing airplane, which require a transnational motion to continue flight.

Helicopter controls: There are three noteworthy controls in a helicopter that the pilot must use amid flight. They are the collective pitch control, the cyclic pitch control, and the anti-torque pedals or tail rotor control. In addition to these main controls, the pilot must also use the throttle control, which is usually mounted directly to the collective pitch control to fly the helicopter. The collective is utilized to make changes angle of the main rotor blades and does this at the same time, or on the collectively, as the name implies.

The cyclic pitch control is generally anticipated upward from the cockpit floor, between the pilot's legs or between the two pilot seats in certain models. This essential flight control enables the pilot to fly the helicopter toward any path of movement: forward, rearward, left, and right.

2. OBJECTIVES

The objectives of the present study are

1. Finite element idealization of the mixing unit assembly of a typical light helicopter flight control system.
2. Evaluation of strength characteristics of mixing unit for the applied control loads which were being felt during the jammed condition of controls.
3. Finding the free vibration characteristics (natural frequencies, mode shapes) of mixing unit.

3. DESCRIPTION

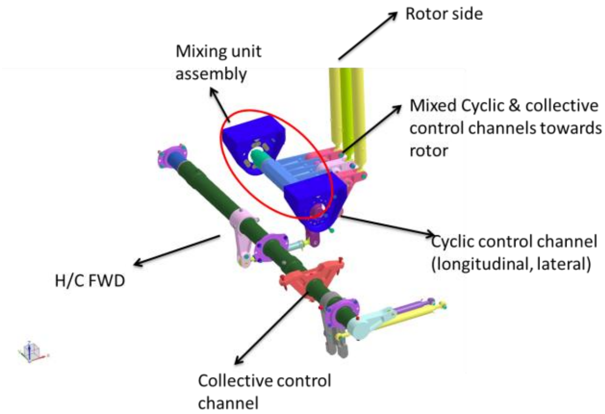
Finite element idealization of mixing unit assembly: The mixing unit assembly of a typical light helicopter is having the assembled parts of torque tube, lever input and brackets.

HYPERMESH software is used as preprocessor for discretizing the geometry domain to the finite elements. Individual CAD part (torque tube, lever, and brackets) models are imported into HYPERMESH.

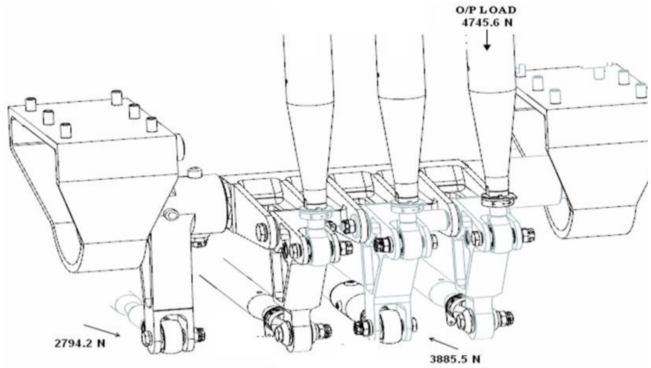
Static analysis of mixing unit assembly: In the present investigation MSC NASTRAN software utilized as finite element solver for taking care of static analysis problem. Figure 1 shows all components of Mixing circuit.

Details of the material used in the modeling

Part	MATERIAL	YOUNGS MODULUS (N/M2)	POISSON'S RATIO
Input lever	Al	7.00E+10	0.23
Torque tube assembly	SS	2.10E+11	0.23
Bracket LH-side	AL	7.00E+10	0.23
Bracket LH-side	Al	7.00E+10	0.23



Torque tube and lever assembly: The pilot limit loads during jamming conditions are shown in Figure2. A factor of safety of 1.5 is used over these loads and these loads are applied to the torque tube and lever assembly FE model.



Ultimate load on the input lever = 2794.2 x 1.5 = 4191.3 N
Ultimate load on the torque tube $F_{z\text{-ult}}$ = 4745.6 x 1.5 = 7118 N
Ultimate load on the torque tube $F_{x\text{-ult}}$ = 3885.5 x 1.5 = 5828 N

Bracket assembly: Loads on the brackets are estimated by idealizing the two support brackets at ends A and B with the torque tube AB of length L (296 mm) and a (92 mm) is being the distance of I/P and O/P levers as shown in the below figure. The reaction forces and moments which will come on to the bracket for the applied vertical and horizontal loads are calculated using standard empirical relations.

R_{AV} = 5498 N
M_{AV} = -310.87 NM
R_{AH} = 4501 N
M_{AH} = -254.5 NM

R_{BV} = 1620 N
M_{BV} = -139.1 NM
R_{BH} = 1326 N
M_{BH} = -113.9 NM

Free vibrations / Real Eigen value analysis: Free vibration analysis is utilized to decide the essential dynamic characteristics of the system.
In the case of damping is dismissed, the solution is known as undamped free vibration analysis. Real eigenvalue analysis is utilized to decide the basic dynamic characteristics of a structure.

Forced vibrations (Linear frequency response analysis): Forced vibrations frequency response analysis is an efficient strategy for finding the steady-state reaction to sinusoidal excitation.
Forced vibrations (Linear transient response analysis): Forced vibrations transient response analysis is the most general strategy for figuring the reaction to time-varying loads.

4. RESULT AND CONCLUSIONS

Finite Element idealization of mixing unit assembly (mixing collective input with right lateral, left lateral, and fore/aft inputs) of typical light helicopters main rotor flight control system is carried out. Static analysis of mixing unit is carried out for the applied pilot limit forces. Dynamic / Eigen analysis is carried out for evaluating the Eigen values of the mixing unit.

Based on the strength (static analysis) and stiffness (dynamics analysis) characteristics of the helicopter flight controls mixing unit assembly, it is concluded that

1) The strength margins of individual parts of the mixing unit assembly shows a good margin except the brackets where the safety margins are less.
2) The modified bracket where flange thickness is increased from 6mm to 8mm shows a significant increase in the strength margins.
3) The fundamental frequencies of the brackets, torque tube assembly, input lever is very high and above 2000 Hz which are well away from the dominant excitation frequencies of helicopter main rotor 1/rev and N/rev frequencies.

4) The fundamental frequencies of entire mixing unit assembly are above 500 Hz which are well away from the dominant excitation frequencies of helicopter main rotor 1/rev and N/rev frequencies and design is safe.
5) Design of the mixing unit is flight safe w.r.t the strength and stiffness characteristic as per the design limit pilot forces specified in Federal Aviation Regulations.

5. REFERENCES

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