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Influence of Friction in Collective Control System on the Pilot Induced Oscillation in Helicopter

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Abstract

Pilot induced oscillation (PIO) in helicopter is a random, low frequency pitching and heaving movement. It is a phenomenon wherein the amplitude of fuselage oscillations in the vertical direction at a specific frequency (4 to 5 Hz) becomes increasingly large with time. Mostly this tendency originates due to disturbing energy feedback into the main rotor through the control circuits. Pilot-induced oscillations have been an aviation problem for over 100 years now. A pilot induced oscillation is defined as "an inadvertent, sustained aircraft oscillation as a consequence of an abnormal joint enterprise between the aircraft and the pilot[1]". The control system connects the displacement of the controls to changes in the pitch of the main rotor blades. The collective friction is very important in helicopters, not just for comfort. It serves as a damper to attenuate Friction can be adjusted so that friction force is equal to or greater than any force in the control system tending to move the control from trim Pilot induced oscillation that can happen during flying condition. This paper deals with effect of friction on pilot induced oscillation and flight test were carried out by inducting friction based trim actuator in the collective circuit and its effects were studied towards vertical oscillation tendency

1. Introduction

Pilot induced oscillation (PIO) in helicopter is a random, low frequency pitching and heaving movement. It is a phenomenon wherein the amplitude of fuselage oscillations in the vertical direction at a specific frequency (4 to 5 Hz) becomes increasingly large with time. PIO is not a voluntary thing, it is the interaction between vertical g force and the pilot's mass, as well as the damping on the collective. Pilot will acts as sort of mechanical impedance between dynamically and aero elastically induced vibrations of the body, and the resulting inputs that are inadvertently transferred to control system. The main thing to know about PIO is that it is an undesired movement of the helicopter which makes it oscillates and looses its stability. As the control system of the aircraft uses a closed loop, these oscillations are amplified then they become bigger and the aircraft stability is much worse. This PIO behaviour appears through a variety of flight conditions and is very difficult to predict. Due to this complex behaviour, PIO is not easily eliminated [2].

In other cases, the pilot can interact with an airframe harmonic, and again, this oscillation can be quickly divergent in nature. The frequency of these oscillations is usually in the 4-5 Hz range. The research activity dealing with the PIO phenomenon is not as advanced as in the fixed wing aircraft case and very few published papers analyzing this subject can be found in literature [3]. The available literature mainly focuses on the investigation of problems that directly involve an active participation of the pilot: the so-called Pilot-Induced Oscillations (PIO). PIOs occurs more frequently, although test pilots, flight test engineers and handling qualities specialists have dealt with this phenomenon over the past decades, still it is very difficult to apprehend and all too often it catches pilots as well as engineers by surprise[4].

The control system connects the displacement of the controls to changes in the pitch of the main rotor blades. Here, only the collective control is considered, as it is assumed to be the one most influenced by vertical oscillatory motion of the pilot. The collective friction is very important in helicopters, not just for comfort also serves as a damper to attenuate PIO [4]. Very small helicopters are less likely to get into collective induced PIO because the natural vertical frequency of the airframe is higher than the frequency that a pilot's arm on the collective has but big helicopters tend to have lower frequencies [5].

1.1. Origin of PIO due to collective

The helicopter begins a gentle vertical vibration at such a frequency as to "bounce" the pilot up and down in his seat. The vibration is initially quite gentle and but because the pilot is beginning to bounce, his left arm moves the collective slightly up and down at a resonant frequency. This makes the vibration worse, so the helicopter bounces harder and the pilot bounces more so his arm moves more and the phenomena will be divergent. A vibration along the vertical axis may cause the involuntary introduction of collective control input. As a consequence, the collective rotor flapping (cone) dynamics may be excited, eventually resulting in sustained vertical oscillations of the airframe [6,7]. The resulting oscillations may endanger the safe execution of a mission task and, unless stopped, cause severe damage to the vehicle, or even its loss.

1.2. Effect of friction On PIO

From literature it was determined that the pilot did not have sufficient friction on the collective the weight of the flight control system would tune into the frequency of the helicopter movement moving up and down causing the servo valves to displace either in or out depending on the direction of movement of the control linkage. At very low friction, there is a real danger of either a pilot-induced vertical oscillation, wherein the pilot alone with the control system enters an oscillation that can be neutrally stable, or destructively divergent. Some helicopters will PIO in cyclic, as well, especially at high speed, where the longitudinal cyclic creates g.

2. Induction of friction based trim in collective control system

Typical way of attenuating the PIO is by increasing the collective friction, but pilots feel wise difference will be there to fix the frictional values. To resole these issues, by inducting a friction block directly in the control system. The present work deal with the installation of friction based trim actuator parallel to the collective control system as shown in figure 1, and flight tests were carried out with instrumentation on control and tail boom flap bending moment.

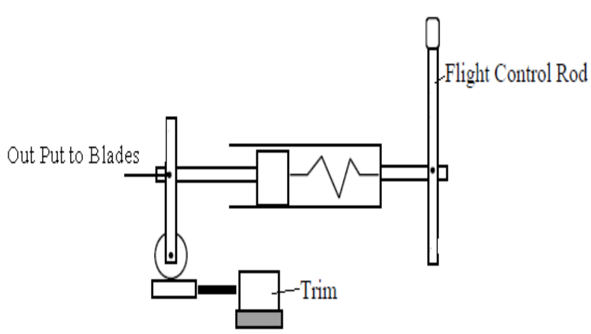

Fig.1 Induction of friction based trim

2.1. AFCS and trim actuator in flight control system

In modern helicopters, an Automatic Flight Control System (AFCS) would be part of the loop. Stability is improved by providing state feedback to the helicopters, so the automatic flight control system is also required to recognize pilot input and provide acceptable response to pilot inputs called augmentation. The trim actuator will have a force feel system embedded in it and allows the controls to be anchored at the desired position.

3. Flight test & data analysis

Flight test carried out with instrumentation on control and tail boom flap bending moment (MBTB). Based on dynamic component of MBTB, the severity of vertical oscillation tendency could be assessed. The dynamic value of MBTB measured was used for comparison of different schemes along with other parameters. Initially flight tests were carried out with no change in the collective channel time trace for base line data during never exceed speed is shown in figure 2 & time trace for base line data during 160kmph with 4 Hz input is shown in figure 3.

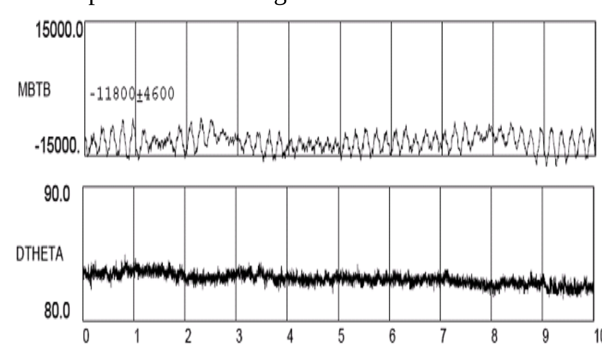

Fig.2 Time trace for Base line data during VNE

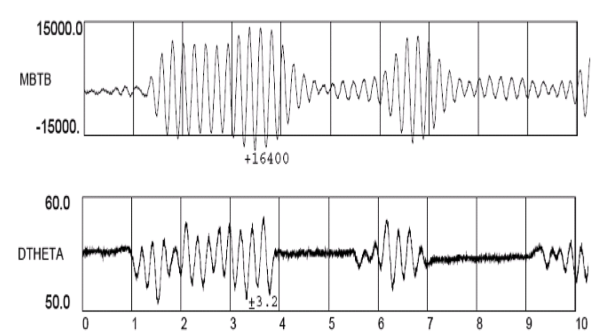

Fig.3 Time trace for Base line data during 160kmph with 4 Hz input

By introducing the friction based trim actuator in collective channel; Figure 4 shows the loads corresponding to sinusoidal input at 160kmph with automatic control system OFF with collective input of 4.3% dynamic had been given at 4Hz. Figure 5 gives the loads corresponding to sinusoidal input at 160kmph with automatic control system ON with collective input of 3% dynamic had been given at 4Hz.

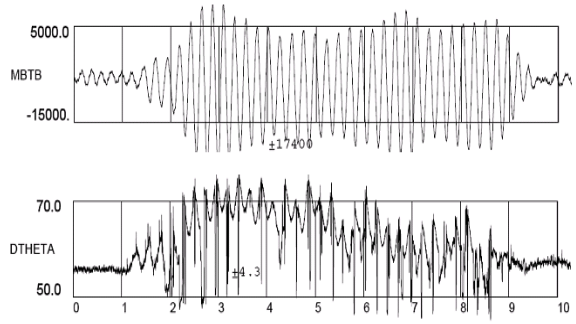

Fig.4 Time trace for Friction trim actuator at 160kmph and 4Hz input with AFCS OFF

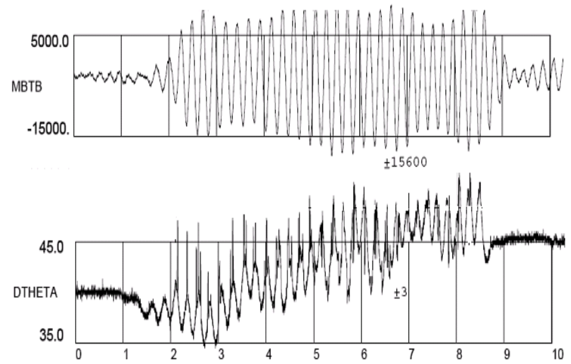

Fig.5 Time trace for friction trim actuator during 160kmph at 4Hz with AFCS ON

4. Conclusion

Flight test was carried out by inducting friction based trim actuator in the collective circuit. The table 1 shows the tail boom loads (dynamic) based on spectral analysis for the three configurations during VH, VNE and sinusoidal collective input of 4Hz at 160 kmph with friction based trim actuator; the dynamic loads are less compared to baseline data.

Table 1: Tail boom loads (dynamic) based on spectral analysis

Configuration	VNE	VH	MBTB/DTHETA
	MBTB AFCS OFF		Sinusoidal Collective input-4Hz(160Kmph)
Basic helicopter	1531	965	5664
Friction based trim actuator	661	648	4430
	MBTB AFCS ON		Sinusoidal Collective input-4Hz(160Kmph)
	800	500	3973

5. References

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