Gust Load Alleviation of Flexible Aircraft

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ABSTRACT

Concerns about aircraft gust disturbance have increased not only because of the design cases that are not primarily structural but also because of gust influence on aircraft handling qualities and flight controllability. Load alleviation system duty is reducing loads caused by gust on aircraft. Using active control when crossing gust causes alleviation of loads on aircraft and improving ride quality. In this paper gust response of a flexible aircraft has been simulated by using Lagrange equation and quasi steady aerodynamics. Wing has been considered as flexible and other parts have been considered rigid. Two degrees of freedom in pitch and plunge of rigid mode has been considered and elastic wing has been modeled as beam with torsion and bending. Gust responses with different profiles has been analyzed. Then by using elevators and aileron gust loads has been reduced. Feedback control has been used to decrease pitch and heave acceleration of the aircraft. Closed and open loop response to gust has been compared and it has been shown that pitch oscillations has been damped very well by elevator. Then by using elevators and flaperon gust loads has been reduced by using neural networks adaptive controller and classic controller. Comparison has been made between closed loop and open loop response to gust.

KEYWORDS

Flexible aircraft, quasi-steady aerodynamics, gust load alleviation

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1. Introduction

Gust is one of the sources of critical design and fatigue loads. The gusts cause structural elastic vibrations and rigid-body motions which can result in a significant reduction of the airframe structure's life. It is due to the high level of dynamic stresses that occur during these events. However, vibrations caused by gusts may have an adverse effect on passenger comfort, pilot workload, and aircraft handling quality [1]. An active control technique called gust load alleviation (GLA) can be used to minimize the adverse effects induced by the gust. This paper investigates dynamic response of flexible aircraft to gust. Then by using control surfaces tries to alleviate gut loads on aircraft. It uses elevator and flaepron to decrease gust effects on aircraft.

2. Methodology

A flexible aircraft (figure 1) has been modelled with considering pitch and plunge of rigid body, z and θ and bending and torsion of elastic wing h and α.

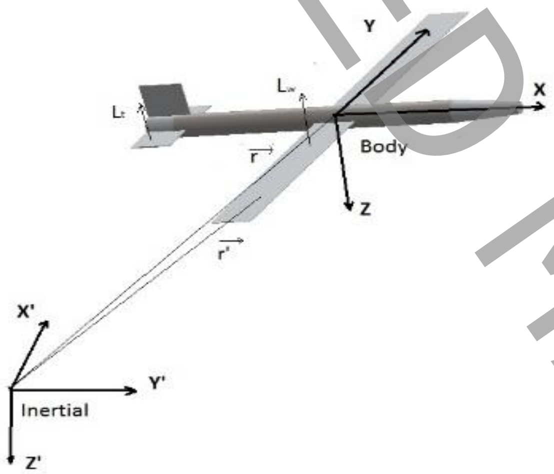

Fig.1- Aircraft with flexible wings

Quasi steady aerodynamic model has been used. By using Lagrange equation, it is possible to obtain generalized forces Q_h and Q_α [2]:

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}_i}\right)-\frac{\partial T}{\partial q_i}+\frac{\partial \bar{U}}{\partial q_i}=Q_i\ ,\ i=1,2,3,4 \qquad (1)$$

$$q_1=z,\quad q_2=\theta,\quad q_3=h,\quad q_4=\alpha$$

The generalized forces of Q_i are calculated by virtual work:

$$\begin{aligned} Q_z &= -L_w + W - L_T \\ Q_\theta &= \ell_w L_w + M_{E.A} - \ell_T L_T \\ Q_h &= -L_w \\ Q_\alpha &= M_{E.A} \end{aligned} \qquad (2)$$

L_w and L_t are lift forces of wing and tail, l_w and l_t distance from wing and tail elastic axes to aircraft C.G respectively. $M_{E.A}$ is moment around elastic axis of wing. Now by putting Q_i and arranging aerodynamic and structural forces it is possible to write:

$$(M_s+M_a)\ddot{q}+(C_s+C_a)\dot{q}+(K_a+K_s)q=F \qquad (3)$$

$$q_1=z,\quad q_2=\theta,\quad q_3=h,\quad q_4=\alpha$$

In above equation z and θ are rigid modes, h is bending modes of wing, and α is torsional modes of wing. F is composed of two elements gust and control forces:

$$F = F_{Gust} + F_{control} \qquad (4)$$

$$F_{control} = BU \qquad (5)$$

$$U = \left[\delta_{elevator} \quad \delta_{flapeleron}\right]$$

In the above equation U denotes control command, $\delta_{elevator}$, elevator rotation, and $\delta_{flapeleron}$ fapron rotation.

3. Results

The 1-cosine gust [3] with a vertical velocity of 20 m/s and a gust length of 110 m has been applied to the flexible airplane with a velocity of 150 m/s. The wing has been considered flexible. Pitch response to gust has been shown for closed and open loop in figure 2.

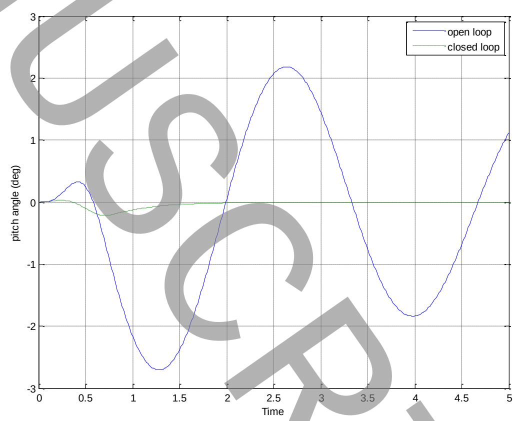

Fig. 2- Comparison of pitch response of aircraft in closed and open loop

Gust causes aircraft pitch nose down then nose up and this behavior repeats with lower amplitude. But with controller after nose down aircraft slightly begins to nose up and reaches to zero attitude. As it is seen controller has been able to damp and control oscillations of aircraft and brings back vehicles to its stable position in a short time. Figure 3 shows heave acceleration. Controller reduces heave acceleration and damps oscillations.

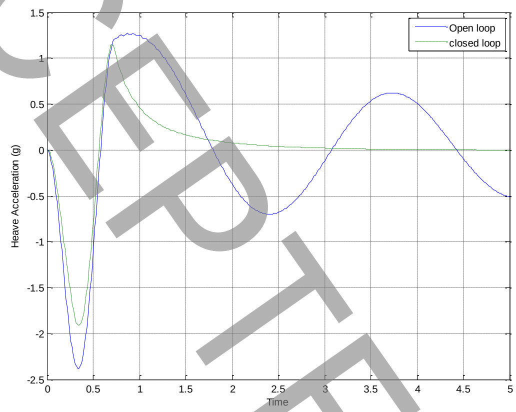

Fig. 3- Comparison of heave acceleration of aircraft in closed and open loop

In order to alleviate gust load on aircraft, PID[2] and adaptive neural network controllers has been used. In figure 4 pitch response of adaptive neural network and PID control methods has been compared. As it is seen adaptive neural network method shows better results than PID. Figure 5 shows heave acceleration results for these controllers. Both have similar trends but as before adaptive neural network methods damps acceleration faster than PID method.

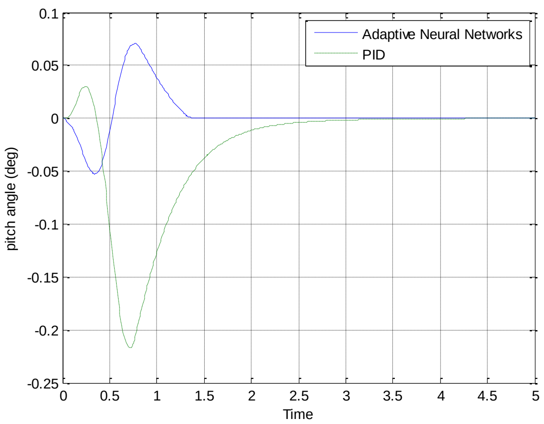

Fig. 4-Pitch angle versus time

[2] Proportional Integral Derivative

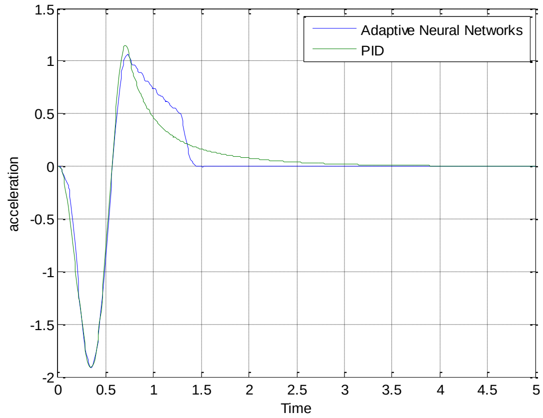

Fig. 5-Heave acceleration (g) versus time

Figure 6 shows wing bending due to gust. Adaptive neural network methods damps wing bending faster than PID method.

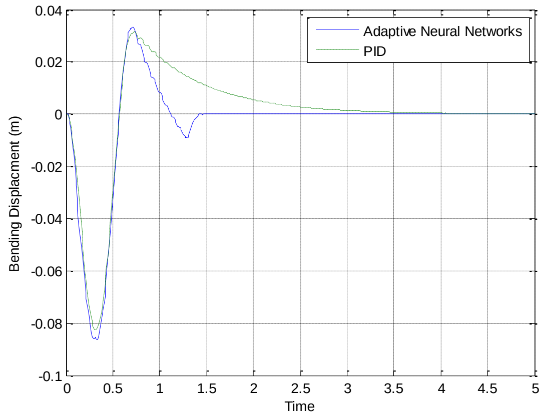

Fig. 6-Wing bending versus time

4. Conclusions

In this paper, dynamic response of a flexible aircraft to "1-cosine" gust has been studied. Then by using neural adaptive controller gust loads gust loads has been reduced. Elevator has been used to control pitch oscillations and alleviate heave acceleration of the aircraft. A comparison has been made between PID, and neural adaptive controller, which shows neural adaptive controller has better results than PID.

5. Reference

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