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Research Article
The Lateral Directional Controller Design of Cessna–182 Aircraft Model

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Abstract

Background and Objective: The main objective of presented work focuses on the development of computer code for controlling the lateral motion of the propeller driven light aircraft model named Cessna 182 and verify the performance of proposed control methods. Through their transfer function the aircraft behavior in term of Yaw angle and the roll angle with respect to time due to the aileron deflection can be identified. It had been found that following the step function aileron deflection produces Yaw angle as well as roll angle behaves as transient function with large settling time. Particular response in both angles can be adjusted by introducing controller. **Methodology:** There are various method can be used for design the controller for aircraft .Present work used a PID conventional controller design and PID SISO controller design. These two controller design able to produce the behavior of the yaw angle and roll angle follows the aileron deflection. **Results:** As result the behavior of the original form of the aircraft transfer functions (before controller) and the behavior of the aircraft transfer functions after applying the control design technical allows one make an assessment the lateral controller design for the propeller driven light aircraft. **Conclusion:** From this research work it was concluded that PID controller is good choice and can be used to control the lateral behavior of the airplane for particular altitude.

Key words: Flight motion, lateral angle, PID controller design

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The aircraft control systems are developed to improve the performance of its specific tasks. The lateral equation of motion for this aircraft model had been defined by a famous author McLean[1] in which aircraft transfer function was explained. The requirements imposed on the control system were usually stated as performance specifications. Such specifications may be given in terms of transient response requirements (such as the maximum overshoot and settling time in step response) and of steady-state requirements (such as steady-state error in following ramp input) or may be given in frequency-response terms. In respect to the aircraft in motion, the mechanism of controlling that motion can be basically carried in two manners. The aircraft motion controlled in the longitudinal flight direction or in the lateral-directional direction. The presented work focused on the PID controller which was applied to the lateral directional motion of the propeller driven light aircraft Cessna 182[2]. The governing equation of flight motion in the lateral direction gave the relationship between flight aptitude angle with respect to the aerodynamic force, thrust and control surface deflection angle. The flight aptitude angle which influence by control surface deflection are the yaw angle Ψ, the side slip angle β and the roll angle Φ. Using Laplace transform one can convert the lateral equation in the form of transfer function which give the relationship directly between these three aptitude angles with control surface deflection angle[3]. For a given Cessna 182 as mentioned above, a sufficient data related to the aerodynamics data, mass and inertia of that airplane are available[4]. This allows one can define the transfer function related to the lateral directional motion. Direct implementation a unit step impulse gives response in the roll angle Φ tends to blow up. To avoid such phenomena a controller need to introduce into the control surface system. PID is common devices had been used to make a response to follow a particular performance. This device consists three parameters need to be adjusted. In manner how to adjust these three parameters are not unique, as result there were two approaches had been purposed in defining a suitable parameter for PID. They were namely: (1) the PID conventional control design approach, (2) the PID SISO control design approach. The first approach allows one uses different in implementing the conventional design approach. The main objective of this research work is to suggest a suitable control method for controlling the lateral motion of the propeller driven light aircraft model named Cessna 182 and also verify the performance of proposed controller.

METHODOLOGY

One of the techniques that used for solving control design problems is called the proportional integral derivative control (PID)[5]. This control has a simple feedback compensator structure but versatile. The PID controller as a unity feedback system in its block diagram representation as a given in the Fig. 1.

The control law for PID control u (t) can be defined as:

$$(t) = K_p e(t) + K_i \int e(t)dt + K_d \frac{de}{dt} \tag{1}$$

In above equation, the variable (e) represents the tracking error, it represents the difference between the desired input value (r) and the actual output (y). This error signal (e) will be sent to the PID controller and the controller computes both the derivative and the integral of this error signal. The control signal (u) goes to the plant is equal to the proportional gain (Kp) times the magnitude of the error plus the integral gain (Ki) times the integral of the error plus the derivative gain (Kd) times the derivative of the error. This control signal (u) is sent to the plant and the new output (y) is obtained. The new output (y) is then feedback and compared to the reference to find the new error signal (e). The controller takes this new error signal and computes its derivative and it's integral again, ad infinitum. The transfer function equation of Eq. 1 obtained by taking the Laplace transform in the form as given by (2).

$$K_p + \frac{K_i}{s} + K_d s = \frac{K_d s^2 + K_p s + K_i}{s} \tag{2}$$

The actual output y can be adjusted as the desired input r, if one able to define the value of parameters Kp, Ki and Kd appropriately. In order to obtain these three parameters, present work uses three following method. The first method called Method I is starting by enforcing an initial value of the gains Kp = 1, Ki = 0, Kd = 0 and s = small value and MATLAB script. The second method called as Method II is basically similar to the first one but in determining the appropriate PID parameter carried out manually. For a given a unit step

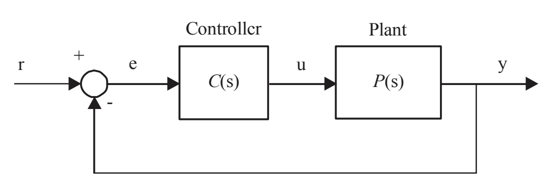

Fig. 1: The unity feedback system

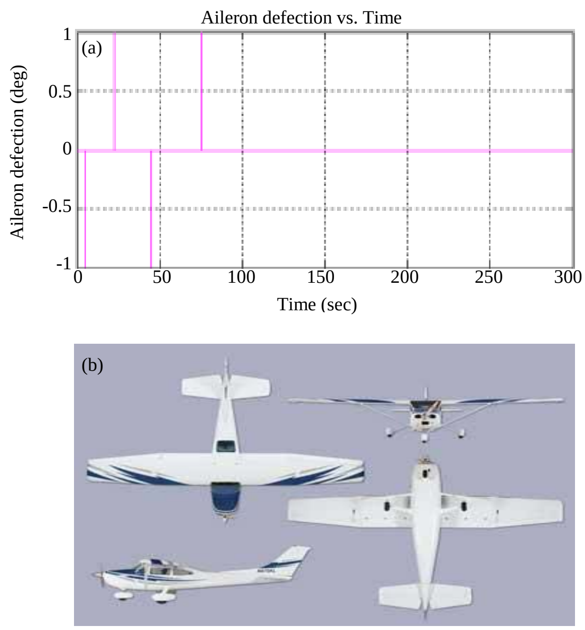

Fig. 2(a-b): Three side views of the aircraft model Cessna 182, (b) Control surfaces deflected as multiple doublet impulses

response, the value Kp is adjusted by increasing or decreasing that value until reach the steady state of the response is equal to one. While Ki and Kd are adjusted in order reach a specified setting time and the rise time. The third method is the PID SISO approach. This method uses the facility in adjusting the parameter PID provided by MATLAB.

The governing equation of lateral small perturbation equation: The lateral-directional direction of aircraft motion presented in Laplace transform can be given as[6]:

$$\frac{(s)}{\delta_A(s)} = \frac{s(A_A s^3 + B_A s^2 + C_A s + D_A)}{s(A_2 s^4 + B_2 s^3 + C_2 s^2 + D_2 s + E_2)} \tag{3}$$

$$\frac{\psi(s)}{\delta_A(s)} = \frac{s(A_{\psi A} s^3 + B_{\psi A} s^2 + C_{\psi A} s + D_{\psi A})}{s(A_2 s^4 + B_2 s^3 + C_2 s^2 + D_2 s + E_2)} \tag{4}$$

The first equation in above represents the transfer function of roll angle Φ and the second one is the Yaw angle ψ. Both transfer functions related the aileron deflection (δ).

RESULT

The test was performed on the aircraft model Cessna 182, which shows that the control surfaces deflected as multiple doublet impulses, Fig. 2a and b shown a three side views of the aircraft model Cessna 182, the aileron control surface is deflected twice times from (0o to -1.0o) and from (0o-1.0o).

Figure 2a: Three side views of the aircraft model Cessna 182, (b) the control surfaces deflected as multiple doublet impulses.

The transfer functions in the lateral direction due to aileron control surface for this aircraft are presented[7] in (5) and (6)

$$\frac{j(s)}{\delta_A(s)} = \frac{16527.837s^2 + 21475.723s + 132749.716}{220.016s^4 + 3164.994s^3 + 6302.816s^2 + 30261.902s + 540.019} \tag{5}$$

$$\frac{\psi(s)}{\delta_A(s)} = \frac{-975.051s^3 - 15850.178s^2 - 3314.765s - 19069.915}{220.016s^4 + 3164.994s^3 + 6302.816s^2 + 30261.902s + 540.019} \tag{6}$$

If the PID controller implemented, gives the controller transfers function of the aircraft defining roll and yaw controller according to Method I, II and PID SISO approach as given in Table 1.

Figure 3 describes the step response of the roll angle deflection plotted with respect to time due to aileron deflection in a unit step impulse.

If the controller transfer function in term of Yaw angle as given in Table 1 are applied due to a aileron deflection in unit tep impulse give the result as depicted in the Fig. 4. The method I seems not useful, since at a later time, the

Yaw angle response oscillate and tend to diverge. The method II produce an appropriate behavior for the yaw angle while the PID SISO approach give a better solution since there is no oscillation phenomena.

DISCUSSION

The PID and SISI PID was implemented and found fruitful results from the experiment work. To validate the

Table 1: Euler roll controller transfer function

Conventional control design approach	
Euler Roll controller transfer function:	$\frac{j(s)}{\delta_A(s)} =$
Method I	$\frac{(114.08033s^2 + 148.19035s + 916.29321)}{(s^4 + 14.391s^3 + 143.507s^2 + 286.86997s + 924.945)}$
Method II	$\frac{16.03\, s^4 + 913.3\, s^3 + 1305\, s^2 + 7190\, s + 132.7}{220\, s^5 + 3181\, s^4 + 7216\, s^3 + 3.157e4\, s^2 + 7730\, s + 132.7}$
SISO control design approach	$\frac{3.0785\, s + 0.04359156}{s^2 + 56.8\, s}$
Conventional control design approach	
Euler yaw controller transfer function	$\frac{\psi(s)}{\delta_A(s)} =$
Method I	$\frac{-2257.544s^3 - 29691.547s^2 - 2775.865s - 2775.865}{220.016s^4 + 3164.994s^3 + 6302.816s^2 + 30261.902s + 540.019}$
Method II	$\frac{1.172s^5 + 2.07\, s^4 + 4.351\, s^3 + 2.203s^2 + 5.718\, s + 1.094}{1.194s^5 + 2.102\, s^4 + 4.414\, s^3 + 2.233s^2 + 5.723\, s + 1.094}$
PID SISO	$\frac{-0.053242\, s - 0.000811941}{s^2 + 0.1863\, s}$

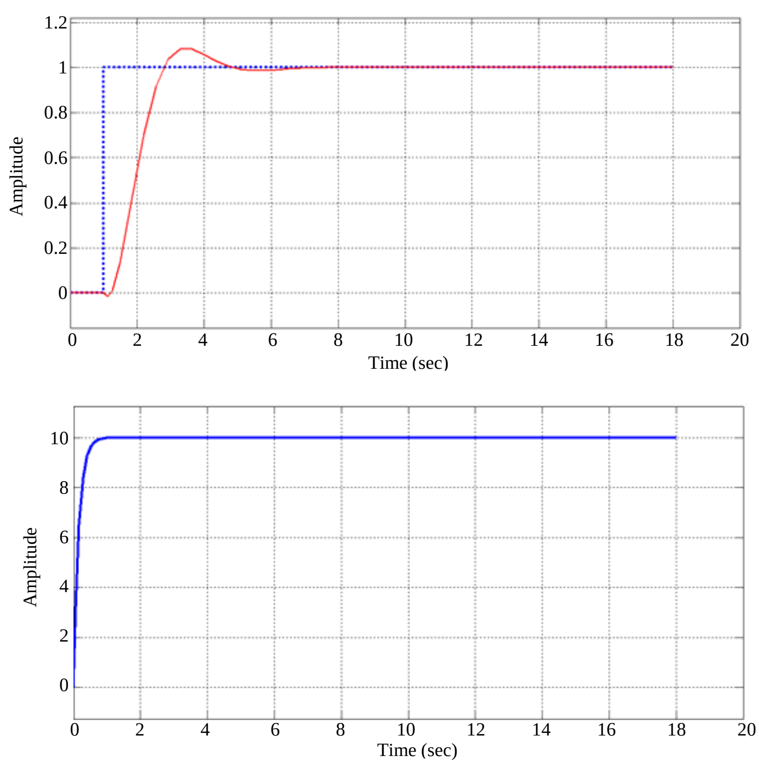

Fig. 3: Aileron roll step response

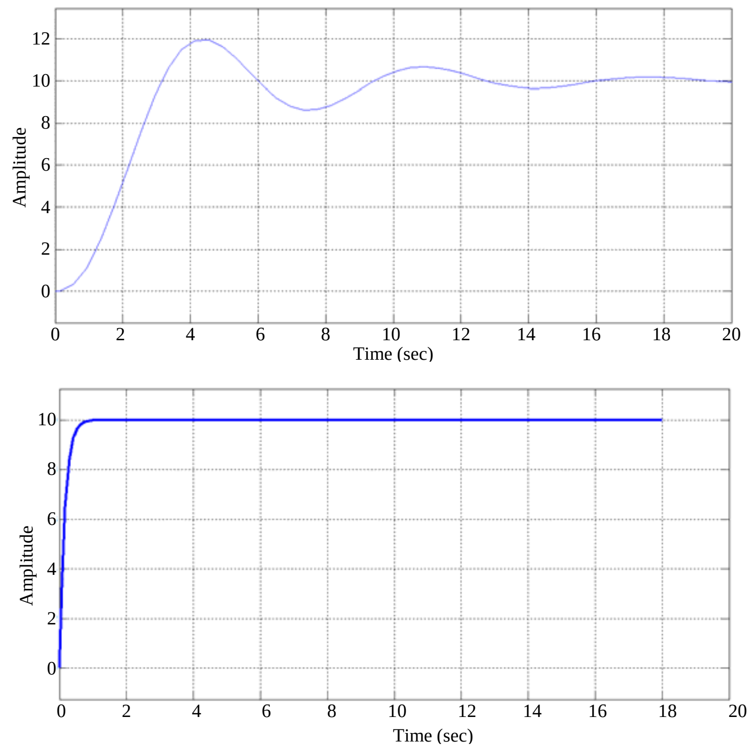

Fig. 4: Aileron yaw step response

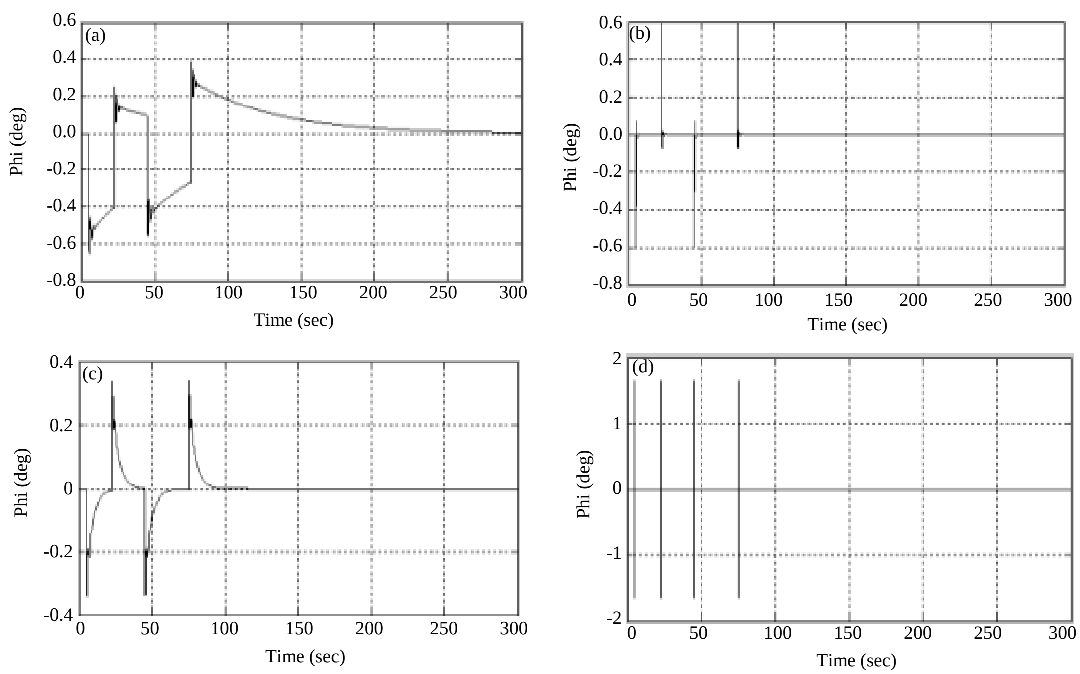

Fig. 5(a-d): Roll angle stability behavior for Cessna 182 (a) Before controller (b) Method I (c) Method II (d) PID SISO

performance of the implemented control it was compared with the time history and stability behavior as plots of the roll angle Fig. 5 and yaw angle Fig. 6 related to the aileron control surface deflections without controller[6,7] and after applying the control design approaches.

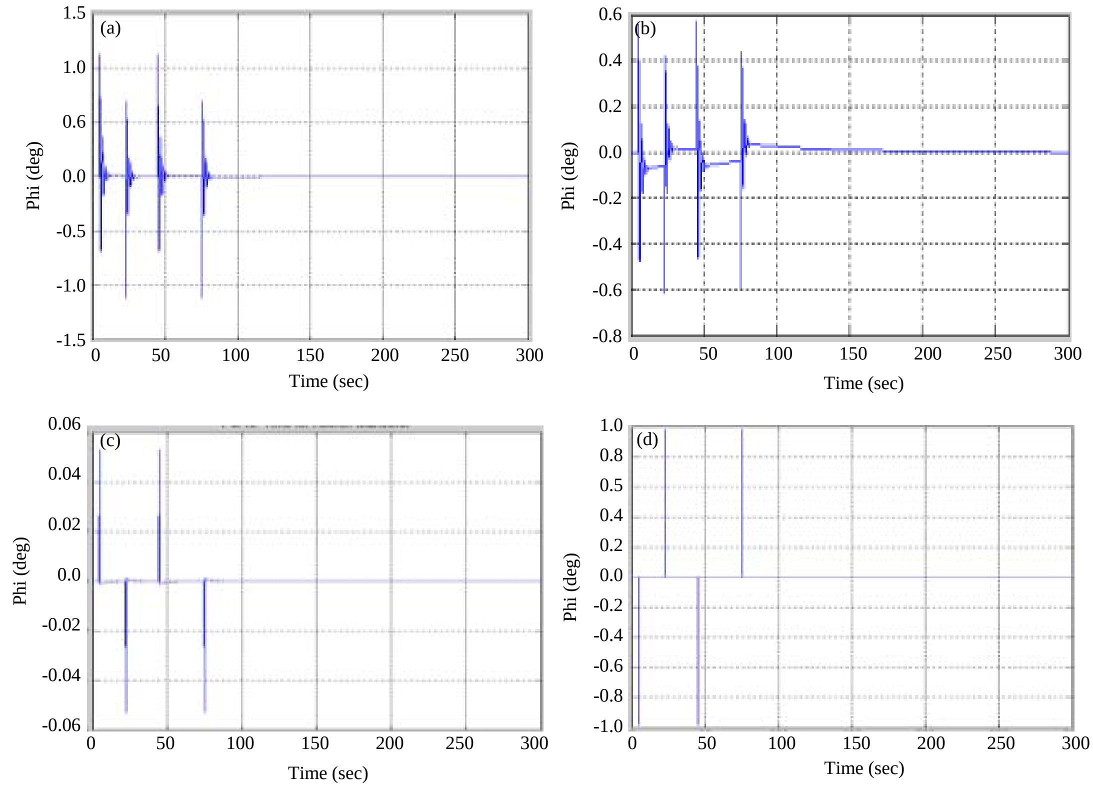

Fig. 6(a-d): Yaw angle stability behavior for Cessna 182

Figure 5 (b, c, d) and Fig. 6 (b, c, d) shows the time history of roll and yaw angle controller with respect to time respectively. From Fig. 5, it can be conclude that the method I produce the movement of the Roll angle is similar to the manner aileron deflected[8]. While in term of Yaw angle, amongst these three method only the method II which able to produce response exactly the as the aileron deflection.

CONCLUSION

From this research work it can be concluded that PID controller is good enough and can be used to control the lateral behavior of the airplane for particular altitude. It can be further concluded that, if the design emphasized on controlling the Roll angle it was better to used method I, while for Yaw angle method II was good choice respectively. The result showed that it can only be used for one flight altitude variable either the yaw angle or roll angle at a time.

SIGNIFICANCE STATEMENTS

In this research work PID conventional and PID SISO controller design were used which can produce the behavior of the yaw angle and roll angle with respect to the aileron deflection of aircraft.

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