NON LINEAR SIMULATION AIRCRAFT BEHAVIOUR SIMULINK

[1]AHMAD ESHTIWEY ALAIAN, [2]BAMBANG BASUNO, [3]ZAMRI BIN OMAR

[1,2,3]Mechanical Engineering
E-mail: [1]ahub2162008@yahoo.com, [2]bambangb@uthm.edu.my, [3]bzamri@uthm.edu.my

Abstract— The governing equations of flight motion in six degrees of freedom are well established [1] [2]. The flight dynamic behavior of the aircraft can be evaluated by solving that governing equation of flight motion. The present work focuses on evaluated the flight dynamics behavior of the flying vehicle in its linearized form. In this form, the governing equation of flight motion can separated in the form as governing equation for a longitudinal motion and the lateral direction flight motion. In this respect, the present work focuses on the solution of the governing equation of flight motion in both direction (longitudinal and the lateral direction). In addition to the present work also solve the governing equation of flight motion in its original form. The governing equation of flight motion whether they are in its original form or its linearized form related to the problem of solving an ordinary differential equation. s. The choice of which technique to use to solve such type equation are depended on the desired accuracy of the solution and the computational effort to be expended. Here one may use Euler's method, Second Order Runge-Kutta method, Fourth Order Runge-Kutta Method or Third Order Adams-Bashforth method [3]. In view of Matlab programming, the governing equation of flight motion in its linearized form can be solved by use of Laplace transform while in term of governing equation in its original form can be solved by use a Simulink. Both approaches had been to evaluate the flight dynamics behavior of a Piper Cherokee PA 28-161 Warrior airplane. The evaluation is carried at two flight conditions. The first flight condition is at trim condition if the aircraft is set at flight speed 147.00 ft/sec and at sea level. The second condition is set with starting point aircraft a trimmed flight conditions the control surfaces and thrust are changed simultaneously. The results show that for particular state variables of the flight behavior there are a significant different result between a linear and non-linear solution of the problem in hand.

Index Terms— Simulink, flight dynamic analysis, state variables and Piper Cherokee PA 28-161 airplane.

I. INTRODUCTION

Simulink is a software package for modeling, simulating, and analyzing of various dynamic systems [4] [5]. The dynamic system can be a linear, nonlinear, continuous-time, discrete-time, multivariable, and multirate dynamic systems. The manner how the Simulink works basically used a graphical, mouse-driven program that allows systems to be modeled by drawing a block diagram on the screen. Hence the Simulink consist of two major classes of items: blocks and lines. Blocks are used to generate, modify, combine, output, and display signals. While Lines, on the other hand, are used to transfer signals from one block to another [6]. Considering such ability, this software package, had been use to analysis the dynamics behavior of the Piper Cherokee PA 28-161 Warrior aircraft.

II. THE GEOMETRY DATA AND MASS OF THE PIPER CHEROKEE PA 28-161 AIRCRAFT

The three side views drawing of the Piper Cherokee PA 28-161 Warrior airplane model is shown in Fig.1. and the mass aircraft mass and moments of inertia adopted from Ref [7] are given in the Table1.

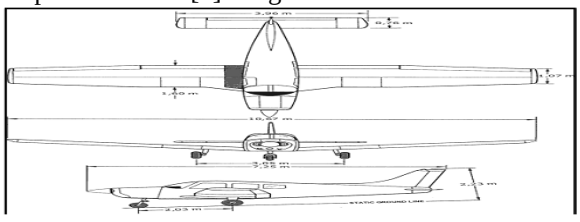


Fig. 1.Three side views of Piper Cherokee PA 28-161 aircraft [8]

Table1: Mass and the moment of inertia of Piper Cherokee 28-161 aircraft [7]

Symbol	Definition	Value	Unit
m	Aircraft mass	75.900	slug
I_{XX_B}	Moment of inertia x-axis	1087.8	slug ft^2
I_{YY_B}	Moment of inertia y-axis	1269.8	slug ft^2
I_{ZZ_B}	Moment of inertia z-axis	2350.5	slug ft^2
I_{XZ_B}	Moment of inertia xz-axis	0.0000	slug ft^2

However in order to allow the Simulink software to evaluate the dynamic behavior of this airplane, the user only needs to provide the characteristics of aerodynamic of the aircraft under consideration. The developed computer software in corresponding to the used of Simulink tool had been provided with the routine for calculating the aerodynamics characteristics of the airplane based on semi empirical aerodynamics method. With the flight conditions are set at the flight speed u = 147.0 Ft/sec. and the flight altitude at sea level. At this flight condition with the mass and inertia as given above and combined with the calculated aerodynamic characteristics give the trimmed flight condition for the aircraft under consideration is flying at the angle of attack $\alpha = 4.41^o$, angle of elevator $\delta_E = -5.417^o$,

velocity in x-direction u = 146.64 Ft/sec and the engine thrust T = 225.152 hp.

III. THE SIMULINK DIAGRAM FOR THE PIPER CHEROKEE PA 28-161

The Simulink can be though as software package for solving the differential equation by combining the block diagram. The governing equation of flight motion, in view of Simulink approach can be expressed in the form of block diagram as shown in the Fig.2.

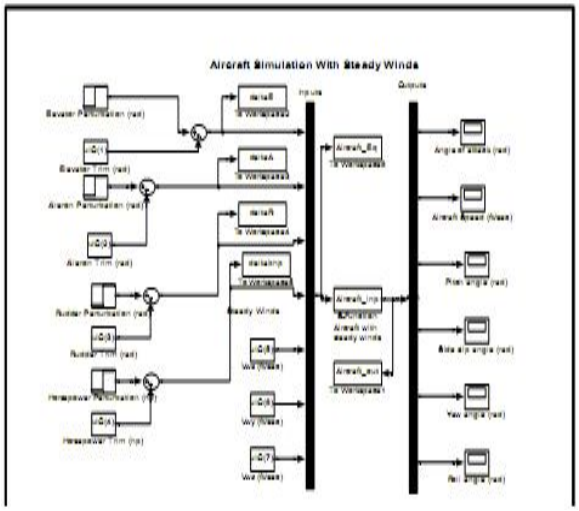


Fig.2. Aircraft simulation with steady state winds

Above figure shows the block diagram (Aircraft_Eq) represents the block diagram contains the governing equation of aircraft flight motion will be solved. While the block diagram (Aircraft_inp) represent the block diagram corresponding to the input and the block diagram the output (Aircraft_out) represents the output obtained from the solution of the governing equation of flight motion. Through this Simulink block diagram, the user can be carrying out the flight dynamic analysis at trim conditions only or at trim with as a small perturbation flight due to the operation of the control surfaces or change of its engine thrust. Here the control surfaces which consist of the elevator, aileron and rudder can be operated in an independent mode or in simultaneously mode. The output of this Simulink model will consists of 6 state variables, namely are, the state variable of a) angle of attack α, b) velocity in x-direction, c) pitch angle θ, d) side slip angle β, e) yaw angle ψ and f) roll angle Φ. All these flight parameters are plotted with respect to time.

IV. ANALYSIS SIMULINK RESULT

By setting at trim condition the sixth state variables [α, u, θ, β, Ψ, and ⍰) for the trim condition provided by Simulink approach for the Piper Cherokee PA 28-161 are shown by Figure 3, 5, 7, 9, 11 and Figure 13. While from the trim condition and suddenly all control surfaces for elevator, aileron and rudder are deflected by 5^o [$\delta_E = \delta_A = \delta_R = 5.0^o$)and the engine thrust is increasing by 5.0 %, gives the result of 6 state variables are shown in the Figure 4., 6, 8, 10, 12 and Figure 14. At trim conditions, the results show that all mentioned state variables go to steady state conditions. While if the control surface and engine thrust are varied some state variables behave to steady state solution while others tends to always change with respect to time.

Here the angle of attack α is faster increasing in the opposite direction and goes to steady state behavior while the velocity in x-direction u will be increasing to its maximum value and then tend back to steady state behavior in time more than 100 sec. For the pitch angle, the behavior of this variable will give a similar curve direction with a new value of the pitch angle and steady state behavior condition time. In the same case with operated the airplane control surfaces and engine thrust, this case will be produce a new curve behavior of the sideslip angle, yaw angle and roll angle. For side slip and roll angle, these flight parameters will be increasing to their maximum value and tend back to steady state behavior but for the yaw angle will be increasing and continues to increase.

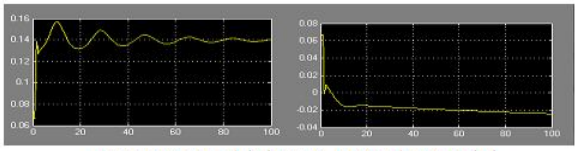


Fig.3.Trimmed (α)Fig.4. Perturbation (α)

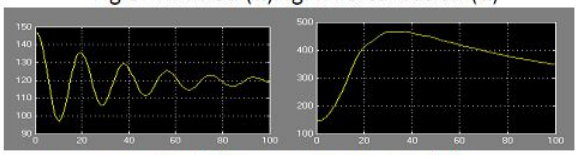


Fig. 5. Trimmed (u) Fig.6. Perturbation (u)

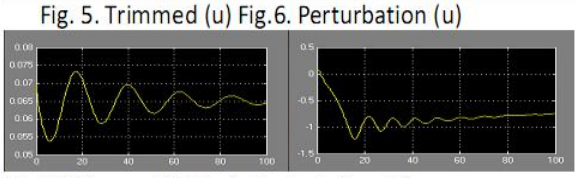


Fig.7. Trimmed (θ)Fig.8. Perturbation (θ)

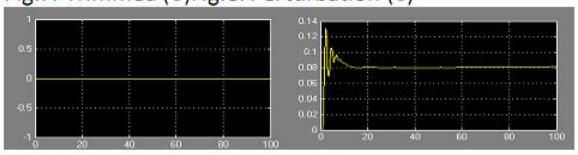


Fig.9 Trimmed(β)Fig.10. Perturbation (β)

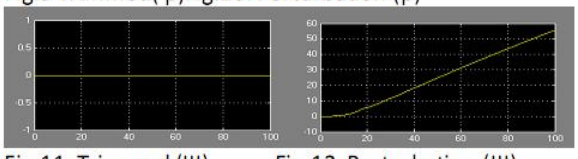


Fig.11. Trimmed (Ψ) Fig.12. Perturbation (Ψ)

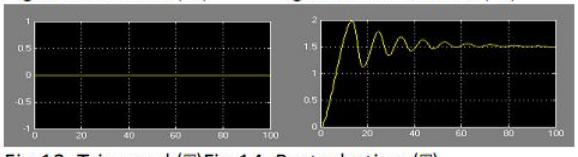
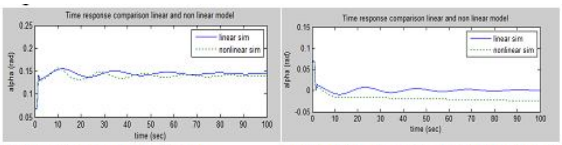


Fig.13. Trimmed (⍰)Fig.14. Perturbation (⍰)

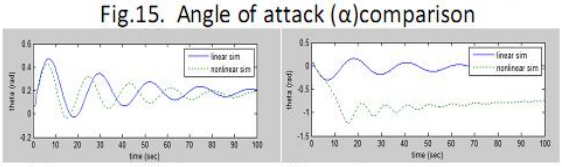
V. COMPARISON RESULT BETWEEN NONLINEAR AND LINEAR MODEL

The following results described the comparison result of the behavior of the Piper Cherokee 28-161 between linear and nonlinear solution for its governing equation of flight motion. The present work presented the comparison in term of view flight parameters, they are namely: angle of attack α, side slip angle β, pitch angle θ, yaw angle Ψ, and the roll angle ⍰. For the purpose of comparison, the flight setting had been chosen here are the flight setting at trim condition and the flight setting with all the control surfaces are deflected 5.0^{o}and the engine thrust is increased 5.0 %. The comparison of these above flight parameters are shown in Fig.15 to Fig.19.



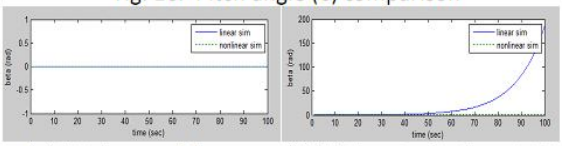
(a) At trim condition (b) With perturbation at trim

Fig.15. Angle of attack (α)comparison



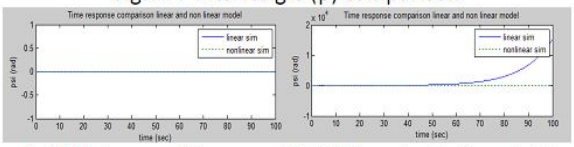
(a) At trim condition (b) With perturbation at trim

Fig. 16. Pitch angle (θ) comparison



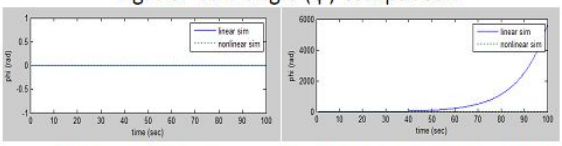
(a) At trim condition (b) With perturbation at trim

Fig. 17. Pitch angle (β) comparison



(a) At trim condition (b) With perturbation at trim

Fig. 18. Yaw angle (ψ) comparison



(a) At trim condition (b) With perturbation at trim

Fig. 19. Roll angle (⍰) comparison

Fig.15a, b and Fig.16a and b showed the comparison of the angle of attack and the pitch angle response between linear and nonlinear simulation model respectively. Considering Fig. 15, the responses of the angle of attack are given similar curves for both linear and non-linear model. While the responses of pitch angle in Fig. 16 for both linear and nonlinear model for the case trim flight in fig. 16a is given a similar solution. However in Fig. 16b of the case when all control surfaces are operated and the engine thrust is increased, there is some a significant difference although both produce a curve with different tend.Fig.17a and b showed the side slips angle response comparison between its linear and nonlinear simulation model. Considering Fig.17a, the responses of the side slip angle for both linear and nonlinear model for the case trim flight is given a similar solution with no change in the side slip angle β. However in the case when all control surfaces are operated and the engine thrust is increased as shown in Fig. 17b, there is some a significant difference results although both produce a nearly similar curve in the first 40.0 sec and completely differ afterward. The comparison between the linear and nonlinear simulation model shown in Fig.18a, and b for the yaw angle ψ, the responses of the yaw angle for both linear and nonlinear model for the case trim flight is given a similar solution with no change in the yaw angle ψ. However in the case when all control surfaces are operated and the engine thrust is increased, there is some a significant difference although both produce a curve with a similar behavior until 50.0 sec and then the behavior becomes slightly different in the case of linear simulation.For roll angle comparison between its linear and nonlinear simulation model is present in Fig.19a and b. The response of the roll angle ⍰ of these above cases is similar to case of the side slip β and the yaw angle ψ response (Fig. 17 and Fig. 19) respectively.

CONCLUSION

The Simulink as graphical mouse-driven program is a useful Matlab tool for flight dynamics analysis purposes. This Matlab tool ma Fig.17 and Fig.18 showed the comparison of pitch angle response between linear and nonlinear simulation model. Considering Fig.17 one can see the responses of the pitch angle for both linear and nonlinear model for the case trim flight is given a similar solutions. However in the case when all control surfaces are operated and the engine thrust is increased by 5.0 %, there is some a significant difference although both produce a curve with different tend.
kes one easier to present the state variable of aircraft under investigation in graphical form. For this type aircraft indicates that the linear and non-linear solution gives significant different results. Evaluating for different aircrafts are required in order to obtain a proper conclusion that the difference between linear and non-linear approach may just happen for particular aircraft only not for in any kind aircraft.

REFERENCES

[1] Nelson, Robert C. Flight stability and automatic control. Vol. 2. WCB/McGraw Hill, 1998.

[2] Roskam, Jan. Airplane flight dynamics and automatic flight controls. DAR Corporation, 1995.

[3] Garza, Frederico R., and Eugene A. Morelli. "A collection of nonlinear aircraft simulations in matlab." (2003).

[4] Messner, Bill, Dawn Tilbury, and Asst Prof Rick Hill. "Control Tutorials for MATLAB and Simulink." (1999).

[5] Prof. Dr. OttmarBeucher. University of Applied Sciences Karlsruhe. Germany. National Chung Hsing University, Taichung. Summer 2013.

[6] Bobál, V., and P. Chalupa. "Self-tuning controllers Simulink library."Department of Control Theory, Tomas Bata University in Zlin, Mostni 5139.760 (2002).

[7] https://solaflyklubb.files.wordpress.com/2013/09/ln-pal-pa28-161-poh.pdf.

[8] http://web2.airmail.net/jperkins/Piper/Piper_SEL_03.htm.

★★★