

# Development of a Longitudinal Control Model of an Aircraft with Gusty Environment

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## ABSTRACT

The humanity fascination about aerodynamic flight system and the fantasy of air flying have induced the hesitating understanding of elementary aerodynamic phenomena. The controller system considered the heart of aerodynamic motion since taking off till landing. The obvious compatibility between the output and the input is the aim of this study. This paper has contributed toward the development of a control system in aircrafts and has indicated especially how to design a longitudinal flight control for aircrafts. The stick commands of a pilot can be applied as the set level for the aircraft situation, angle of direction, and pitch rate to determine commands. The results displayed a good output corresponding to input (stick command) after a significant changes in model transfer functions. This mean it has been reached to design a controller model with an impact filters to get a best response of the aircraft motion depending on what a pilot commands. Finally, a modified Dryden wind gust structure has merged to destabilize the system and bring closer approach into a real environment.

## General Terms

Your general terms must be any term which can be used for general classification of the submitted material such as Pattern Recognition, Security, Algorithms et. al.

## Keywords

Flight control, Longitudinal, Aerodynamic, Dryden wind gust, Pilot stick

## 1. INTRODUCTION

The researchers interest about aerodynamic flight techniques have induced the hesitating understanding of elementary aerodynamic phenomena. Up till now, in spite of many studies on aerodynamics control, aircrafts dynamics are so far from being totally comprehensive [1,2,3]. For an aircraft flight simulation, the accurate description of the aircraft control characteristic is a definite problem. Quick prototyping systems allow the implementation and justification of real-time aerodynamic simulation and control strategies throughout the development procedure[4,5,6,7]. The aerodynamic control simulation is the important analysis of flight simulation, which can be properly describe the aerodynamic properties of the actual vehicle[8,9]. Generally, the control design is not easy to get exactly description of aerodynamic control characteristics[10,11,12].

This paper contributes to develop a model of aircraft control system by updating the impact filters and especially how to design a longitudinal flight control for aircrafts. The set instructions for the aircraft motion have been get by the stick

commands of a pilot. These commands can be applied for the aircraft situation, angle of direction, and pitch (area) rate to determine commands. The obvious compatibility between the output and the input is the aim of this study. So there is a need to reach a controller model with an impact filters to get a best response of the aircraft motion depending on what a pilot commands. Finally, to get an actual model, the simulation must be in real environment like windy weather to perturb the system and bring closer approach into a real environment.

The paper [1] illustrates the comprehension of longitudinal aerodynamics subject and the control of the aircraft towards steady aerodynamic forces. In [8] the longitudinal aerodynamic flight control identification using QAR (quick access recorder) data and linearization model is assumed in research. An adaptive approach is applied to design a feedback longitudinal aerodynamics control rule for the Unmanned Air Vehicle (UAV) as in paper [13]. The [14] presented a control law to choosing the gain factors for a longitudinal aerodynamics motion. This design included handling quality necessities like formal, time and frequency measures that were designed by the manufacturer. The paper [15] described an applicable aerodynamic control model to several types of UAVs with unstable environment scenarios. This model presented in this paper demonstrated height setting control in case of vertical gusty wind turbulences. The paper [16] presented a practical controlling movement in the existence of aerial turbulences at landing process of an (UAH) unmanned autonomous helicopters. The study in [17] proposed a fault-tolerant control (FTC) system for the (UAH) unmanned autonomous helicopters with flapping aerodynamic in windy environment as well as observation technique of actuator errors. The radiating neural networks are constructed to estimate the indefinite wind gusts. Paper [18] presented the feasibility of manipulating turbulence environment for a small UAV. Longitudinal aerodynamics results showed a significant benefits in sinusoidal wind environment. Finally this paper is organized as follows: In second section a simulation and discussion of results are described. Third section presents the details of Dryden wind gust model construction. Paper ended with conclusion and references.

## 1.1 Research Method

The simulation model represents the aircraft control that utilized an angular direction and pitch-area rate of aircraft to determine commands. The simulation model consists of an aircraft linear estimations and actuator actions. Both are merged to flight controller of aircraft. The stick commands of a pilot can be applied as the set level for the aircraft situation, angle of direction, and pitch rate to determine commands. Fig.1 shows the block diagram of the simulation system.

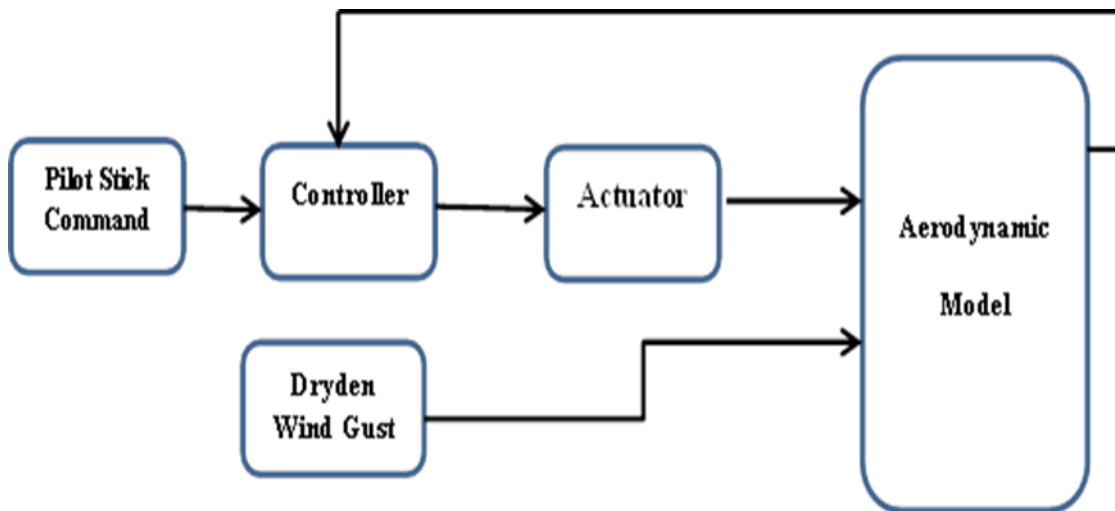


Fig.1 Simulation Diagram of Aerodynamic Control System

**2. RESULTS AND ANALYSIS**

In this section, the results of research explained and given the comprehensive discussion.

The aerodynamic model of aircraft has designed to receive one component from actuator model, and two components

from wind gust model:

1. Elevator deflection in (degree)
- 2.Linear velocity or vertical gust in (feet/second)
- 3.Angular velocity or Rotary gust in (rad/second)

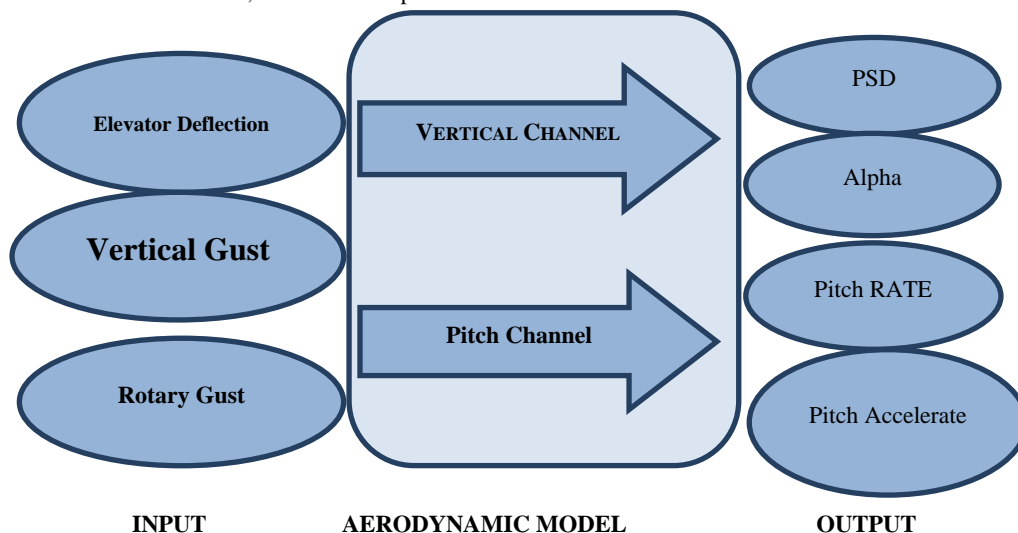


Fig.2 Aerodynamic Architecture

Then the aerodynamic model deals with above components by two channels: vertical channel and pitch channel. The output of these process will be produced in terms of power spectral density PSD (in feet/sec<sup>2</sup>), alpha(in deg), pitch rate (in rad/sec), and finally pitch accelerate (in rad/sec<sup>2</sup>). Fig 2 illustrates the architecture of aircraft aerodynamic model which consists of the three input components , processing channels, and four output components.

**2.1. Without Wind Gust Effect**

Fig.3 represents the effect of actuator model which can be achieved by the transfer function in Eq. (1):

$$T.F=1/(ta s+1) \dots\dots\dots(1)$$

ta =1.

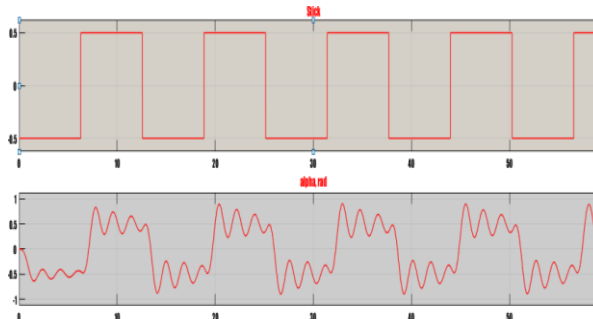
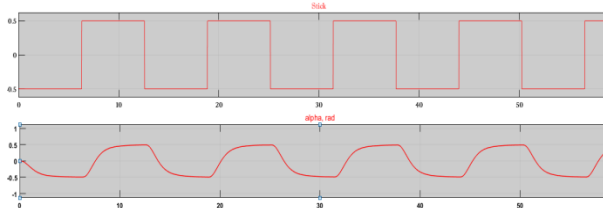


Fig. 3 Response to Stick Command - Effect of Actuator Model

Where the x-axis represents the simulation time (0-60 seconds) and y-axis is the representing of model output. The upper graph is the pilot stick and the lower is the output which

feed back to the input controller.

It's clear that the output is so far from the input which means there is a perturbation in the response to the input command. When the value of factor (ta) reduced to (0.05), the result is positively improved as shown in Fig.4



**Fig.4 Improvement of Response to Stick Command - Effect of Actuator Factor (ta)**

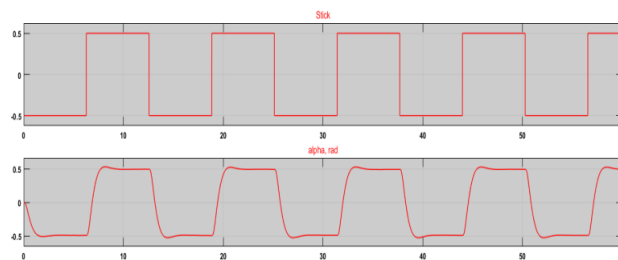
The second impact factor is denoted (Ts) in the stick prefilter transfer function as in Eq.2:

Stick prefilter T.F is :

$$T.F = \frac{1}{TsS + 1} \quad \dots \dots \dots (2)$$

Ts=1 in Fig. 4

In fact there is an undesirable delay in response. to overcome this delay , the factor Ts has been taken (0.1) which leads to a better response as shown in Fig. 5



**Fig. 5 Response to Stick Command-Effect of Stick Prefilter (Ts=0.1)**

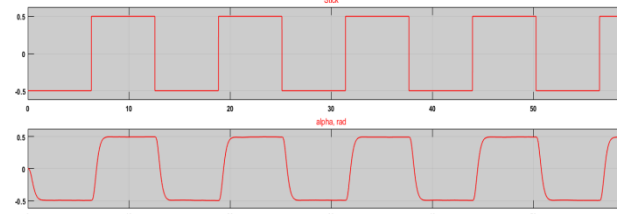
Fig.5 displays a good output corresponding to input (stick command) after a significant changes in model transfer functions. The aircraft has a complicated controller which depends on the pilot stick command as an input and a negative feedback as a radian per second from the output or represented by a pitch rate filter. This filter can be represented as:

Pitch rate lead filter T.F is :

$$T.F = \frac{Tp + W1}{S + W2} \quad \dots \dots \dots (3)$$

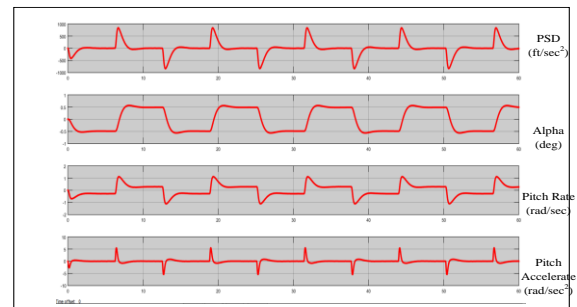
Tp=1, w1=3, w2=4 . Actually these factors factorized in fig 5. Fig 6 shows the best result obtained in this work by reduced the value of Tp in the numerator of the filter to 0.65 instead of 1.

It is obvious in Fig 6 the compatibility between the output and the input, that is the aim of this study. This mean it has been reached to design a controller model with an impact filters to get a best response of the aircraft motion depending on what a pilot commands.



**Fig.6 Response to Stick Command-Effect of Pitch Rate Filter(Tp=0.65)**

Going back to Fig.2 , representing the output of aerodynamic simulation model of aircraft is obtained as in Fig.7 when the noise power has taken 1 in band limited white noise.



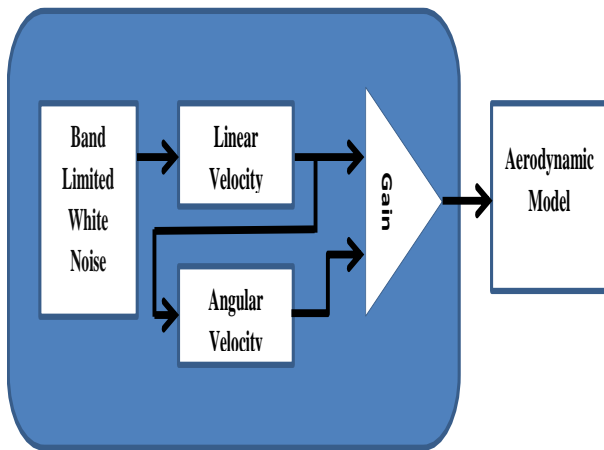
**Fig.7 Aerodynamic Output Without Gusty Environment**

Where the x-axis represents the simulation time (0-60 seconds) and y-axis is the four different outputs (PSD, Alpha, Pitch Rate, and Pitch Accelerate) .Its clear that no effect of gusty environment on the output of the aerodynamic model and they are smooth waves.

**2.2 With Wind Gust Effect:**

The design of aerodynamic control improved to be flying in a turbulent paths [19,7], which is classically attained from the steady-state environments formulas within preferred flights. However, the airplanes control is required to accommodate to a very diverse of weather ,which mean the airplane could be flying in large aeronautical envelopes. For example; fighter and unmanned aircraft in wind gust are large aeronautical envelopes aircrafts. Then it is necessary to ensure a good stability which is achievable by the use of nonlinear feedback models. The nonlinear effects of aeronautical envelopes on aerodynamics are potentially important in practice. In fact, these effects, increase an airplane loss-of-control (LOC), which considered the main responsible of incurable accidents.[1][20,21,22][23,24].

A modified Dryden wind gust structure has merged to destabilize the system and bring closer approach into a real environment. Fig.8 illustrates the wind gust simulation model.

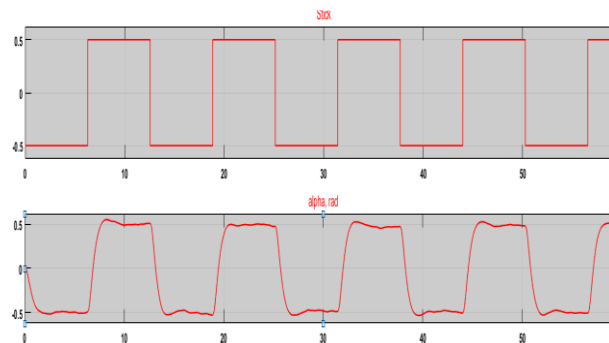


Dryden Wind Gust Model

**Fig.8 Block Diagram of Dryden Wind Gust Model**

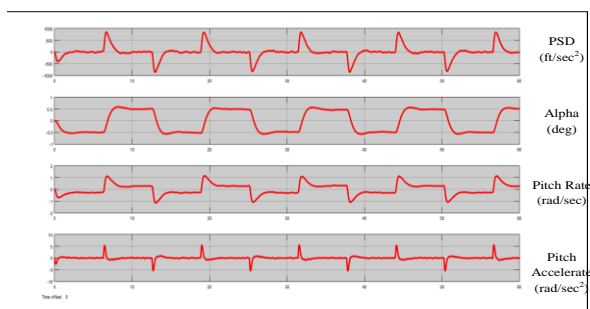
The Dryden wind gust model deals with the velocity elements (angular and linear wind gust elements) as illustrated in Fig.8 with spatially specifying every element PSD power spectral density. Exact filters (by rational power spectral densities) have been used in this model to treat white noise by the model power spectral densities. The combination of length and gust turbulence intensity parameters determines the shape of the power spectral densities (PSD).

Fig.9 displayed the response with the wind effect ,which clearly showed the noise perturb the longitudinal motion.



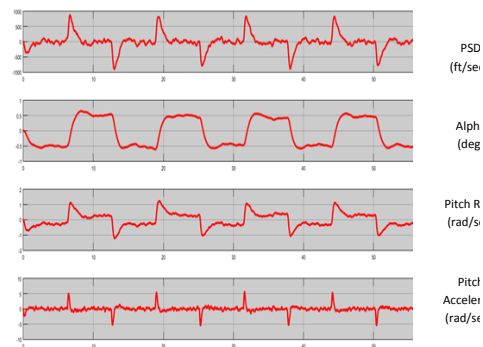
**Fig.9 Response to Stick Command-Dryden Wind Gust Effect**

Where the x-axis represents the simulation time (0-60 seconds) and y-axis is the representing of model output. The output of the aerodynamic model have been represented as in Fig 10, when the noise power has taken 100 in band limited white noise.



**Fig.10 Aerodynamic Output With Gusty Environment (100)**

However, in heavy gusty environment the different output of the aerodynamic model have been represented as in Fig.11 , when the noise power has taken 1000 in band limited white noise.



**Fig .11 Aerodynamic Output With Heavy Gusty Environment (1000)**

Where the x-axis represents the simulation time (0-60 seconds) and y-axis is the four different outputs (PSD, Alpha, Pitch Rate, and Pitch Accelerate) .It’s clear the effect of gusty environment on the output of aerodynamic model.

### 3. ACKNOWLEDGEMENT

The authors would like to express deepest appreciation to all those who provided them the possibility to complete this research. A special gratitude the authors give to their families, whose contribution in stimulating, suggestions and encouragement, helped us to coordinate the research. Furthermore they would also like to acknowledge with much appreciation the staff of Electrical Engineering Department-College of Engineering, who gave the all required equipment to complete the research.

### 4. CONCLUSION

As the controller system considered the heart of aerodynamic motion since taking off till landing, the paper has shown the improvement of a control system in aircraft and has indicated especially how to design a longitudinal flight control for aircrafts. The obvious compatibility between the output and the input is the aim of this study. This mean it has been reached to design a controller model with an impact filters to get a best response of the aircraft motion depending on what a pilot commands. A modified Dryden wind gust structure has merged to destabilize the system and bring closer approach into a real environment. The simulation results well represents the characteristics of actual longitudinal flight control.

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