ON THE DEVELOPMENT OF COMPUTER CODE FOR AIRCRAFT FLIGHT DYNAMICS ANALYSIS

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A thesis report submitted in partial fulfillment of the requirement for the award of the Degree of Master of Mechanical and Manufacturing Engineering

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ABSTRACT

The stability analysis of the aircraft can be evaluated in two flight modes: longitudinal stability analysis and the lateral – directional stability analysis. The present work focused on the second mode of flight. The stability analysis carried out by evaluates the behavior of three flight parameters if their aircraft control surfaces operated. These three flight parameters are the side slip angle β, the roll angle Φ and the yaw angle ψ. These three parameters describe the aptitude of the aircraft which can be obtained through solving the governing equation of flight motion. In this respect, the governing equation of flight motion is the Lateral-Directional Flight Equation. To solve this equation, the present work use a Matlab programming language which allow to solution of the governing equation of flight motion carried out by use of a Laplace transformation. The stability analysis of the aircraft carried out over four type aircraft. The first two type of aircraft belong to class of a propeller driven aircraft, while the rests are the turbojet aircraft type of aircraft. The developed computer code provide 2 option how the aileron are deflected, they are namely (1) a single double impulse aileron and (2) a multiple doublet impulse aileron. While from the point of view rudder is also having two type of deflection, namely (1) a single double impulse rudder and (2) a multiple double impulse rudder. These types of control surfaces deflection applied to case of Cessna – 182, Beech – 99, Lear Jet – M24 and The Lockheed F104. The results indicate that each of aircraft has different response in anticipating with the deflection of aileron as well as rudder.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The aircraft flight behavior can be split into two flight modes: longitudinal flight mode and lateral flight mode [1] [2] [3]. The longitudinal flight mode concern with the flight behavior in the vertical plane, namely with the aircraft movement in the horizontal and vertical direction with flight direction change due to the aircraft rotation with respect to the lateral axis. The lateral flight mode related to the aircraft behavior in the lateral plane. The heading, banking and sliding are part of flight behavior in the lateral flight mode [1].

These flight behaviors are presented in 12 variable states. The first three variable states described the aircraft position with respect to the inertia frame of reference, the other six variable states related to the translational and rotational aircraft speed , while other three variable states related to the aptitude of the airplane whether the airplane having certain pitch angle ,bank angle or yaw angle . The lateral behavior of flight motion is important part in understanding the aircraft behavior, especially in order to understanding whether the airplane can be a controllable airplane or not. The purposes of this research work are to investigation the lateral

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behavior of two class of aircraft model: propeller driven airplane and jet engine aircraft [1][2].

1.2 Back ground

There is a broad area of research behind using programming languages to calculate many different concepts and variables of flight dynamics in aircrafts. The programming language MATLAB is used in many cases, and has helped contribute to this vast field of research [1][2].

There is an incremental rate of success and many new observations have come to play after using matlab to find these different estimates within flight dynamics [2]. At the beginning of the study of any subject, it is helpful to know its definition, scope and special features. It is also useful to know the benefits of the study of the subject, background expected, approach, which also indicates the limitations, and the way the subject is being developed. In this chapter these aspects are dealt with [2].

Flight dynamics deals principally with the response of aerospace vehicles to perturbations in their flight environments and to control inputs. In order to understand this response, it is necessary to characterize the aerodynamic and propulsive forces and moments acting on the vehicle, and the dependence of these forces and moments on the flight variables, including airspeed and vehicle orientation. [3].

These notes provide an introduction to the engineering science of flight dynamics, focusing primarily of aspects of stability and control. The notes contain a simplified summary of important results from aerodynamics that can be used to characterize the forcing functions, a description of static stability for the longitudinal problem, and an introduction to the dynamics and control of both, longitudinal and lateral/directional problems, including some aspects of feedback control Figure (1.1). This plane is used for defining the longitudinal flight mode and lateral flight mode [2] [3].

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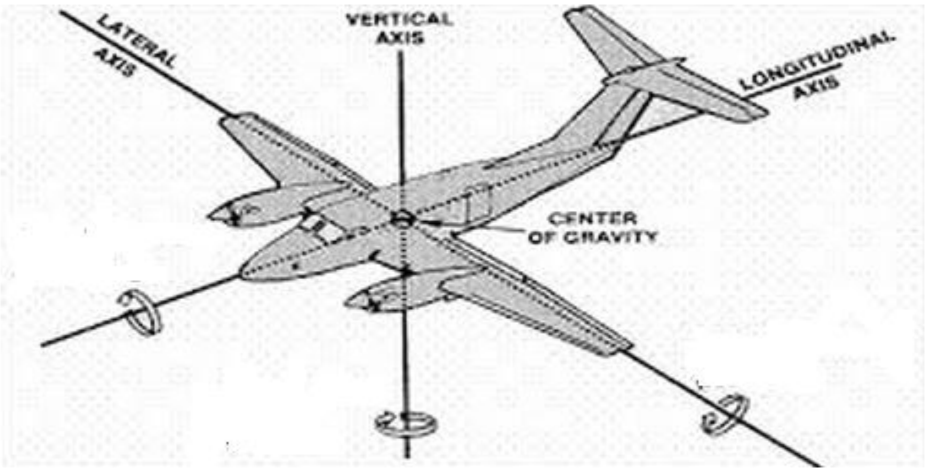

Figure 1.1 Stability the longitudinal flight mode and lateral flight mode [3]

1.3 Problem statements

There have been many previous studies on obtaining an estimated through computer code using the Matlab language for aircraft flight dynamic analysis [2][4]. It had been understood that the flight dynamics analysis plays an important role in the aircraft design. The flight dynamics analysis may in the form of aircraft performance analysis, static stability analysis, dynamics stability analysis or flight control analysis. The present work focusing on the dynamics stability analysis, namely in predicting the aircraft response due to control surface operation in the lateral and directional direction. It is true that for predicting the flight dynamic behavior can be used by help of any type of programming language. Here one may use FORTRAN, C++, Pascal or MATLAB Programming language. However considering the MATLAB programming language represent as the richest programming language in providing graphical representation result and also capability in solving time dependent derivative function by use of the Laplace transformation approach, it is therefore, the Matlab had been chosen as a computer programming language in use in the present work.

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The aircraft motion basically can be split in two form of motions: the longitudinal motion and the lateral- directional motion. In the second type of motion, the aircraft is controlled by the movement of the aileron, rudder and engine thrust. These three elements represent the driving force how the aircraft flies in the lateral-directional direction. The present work will carry out investigation the flight behavior in that two directions due to the operations of aileron and rudder independently or simultaneously combine with the change of engine thrust.

1.4 Thesis objective

The objectives of the research work are develop computer code written in MATLAB programming language in order to allow one to evaluate the dynamics stability behavior in the lateral- directional direction. This developed computer code will be used to evaluate the lateral and directional behavior over four type aircraft models.

The first two aircraft model belongs to the class of a propeller driven aircraft as (Beech 99 aircraft, Cessna 182 aircraft) and while the other two aircraft model are jet engine aircraft as (Learjet 24 aircraft, Lockheed F-104 aircraft). Here the aileron and rudder movement are modeled by introducing their movement in the form a single or multiple doublet impulses.

In combining with thrust, such aileron and rudder movement will determine the aircraft behavior in term of horizontal flight speed u, aircraft's yaw angle Ψ, bank angle ϕ, the rotational velocity in roll and yaw and aircraft position in respect to the prescribed inertial coordinate system.

1.5 Scope of study

Refer to the objectives of the research work as mentioned in the previous of paragraph, the scope of study will be conducted in the present work involves:

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(i) Understanding coordinate system applied to the airplane namely the earth coordinate system, aircraft body axis coordinate system and the aircraft stability coordinate system;

(ii) Derivation the governing equation of flight motion in general and in specific flight motion;

(iii) The implementation of the developed computer code for analyzing four types aircraft model;

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CHAPTER 2

LITERATUER REVIEW

2.1 Overview Flight Equation of Motion

The simulation of aircraft in flight is undoubtedly one of the most exciting and yet complicated fields in the engineering world today. As commercial off-the-shelf computers have become cheaper but more powerful, the opportunity to simulate the complex behaviour of aircraft motion in real time has become possible. Many flight simulation software have emerged such Microsoft Flight Simulator, X-Plane and Flight Gear. The implementation of 6DOF aircraft equations of motion, the quaternion transformation method, experimentally derived aerodynamic and stability coefficient implementation could simulate an aircraft with higher level of realism. Coupled with the actual propulsion model, atmospheric model and other system models, it gives many unique simulation features. Developing an aircraft simulator is an evolving process. It requires a continuous improvement on the model such as the equations of motion, the scenery and the level of the fidelity of the model. Unlike commercial flight simulators where the simulation engine is hard coded, an open source flight simulator provides the opportunity to customize the simulation engine

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to run various operating conditions. This will enable the study of the response and stability characteristics various aircraft parameters.

However to arrive on truly in developing flight simulator, one to follow certain steps, one have to be able to evaluate the aircraft behavior in linear as well as in nonlinear of the aircraft flight of motion. The linear form of the equation's aircraft flight of motion is derived from the nonlinear equation of flight motion by introducing small perturbation from flight equilibrium condition. The equation of flight motion in linear form can be defined to describe the flight motion in longitudinal direction or in the lateral – directional motion. It is necessary to be noted that aircraft in flight is free to rotate in three dimensions: *pitch*, nose up or down about an axis running from wing to wing, *yaw*, nose left or right about an axis running up and down; and *roll*, rotation about an axis running from nose to tail. These three axes are called as lateral, vertical, and longitudinal axis. These axes move with the vehicle, and rotate relative to the Earth along with the craft. The longitudinal motion is the motion of aircraft with respect to the vertical plane only and the rotation just occur only with respect to the lateral axis. While lateral motion is considered as the movement of the aircraft in horizontal plane with aircraft allow to rotate with respect the vertical or longitudinal axis. In this two types of motion, longitudinal and lateral motion, in respect to the rotation motion can be managed by aircraft control surfaces. These aircraft control surfaces combined with other devices generate a system a flight Control System.

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2.2 Flight Controls System

Devices the pilot uses to steer and control the trajectory of an airplane; also refers to the external surfaces responding to the pilot's flight control movements or inputs. The pilot's controls, the external surfaces, and all mechanical and electrical linkages, computers, and sensors in between make up the flight control system. Pilot's controls usually include center stick, control wheel, or side stick; flap lever; speed brake handle or actuation button; and nozzle angle position lever in the case of the Harrier.

2.3 Aircraft Control Surfaces

To control the airplane’s trajectory, it can be done by changing the external surfaces of the aircraft. Such external surfaces are elevators, stabilators, canards, elevons, tailerons, ailerons, rudders, and thrust vectoring nozzles. These external surfaces are often called as primary surfaces. Any operation applied to the primary surface will produce aircraft movement in pitch, roll, and yaw motion. Secondary flight control surfaces augment the primary surfaces by modifying the lift and drag characteristics of the wings and airplane. These secondary surfaces include wing flaps (usually on the trailing edge but sometimes used on the leading edge), wing slats, spoilers, and speed brakes. The recent terminology for primary flight controls is “flight control effectors,” as the effector may not be a conventional control surface. For example, NASA’s F-15 ACTIVE research aircraft is said to have nine flight control effectors: left and right canards, left and right ailerons, rudder (the two rudders move together and are treated as one effector), left and right stabililators, and pitch or yaw T_V (thrust vectoring) [2].

As it has been mentioned previously, the control surfaces on the aircraft divided can be be divided into two categories. The first category is called as a primary control surfaces and the other one is called as a secondary control surface. The primary control surface are aileron, elevator and rudder. For a simple light aircraft, the location of those three control surfaces as shown in the Figure 2.1[5], while their corresponding axis and movements are given in the Table 2.1

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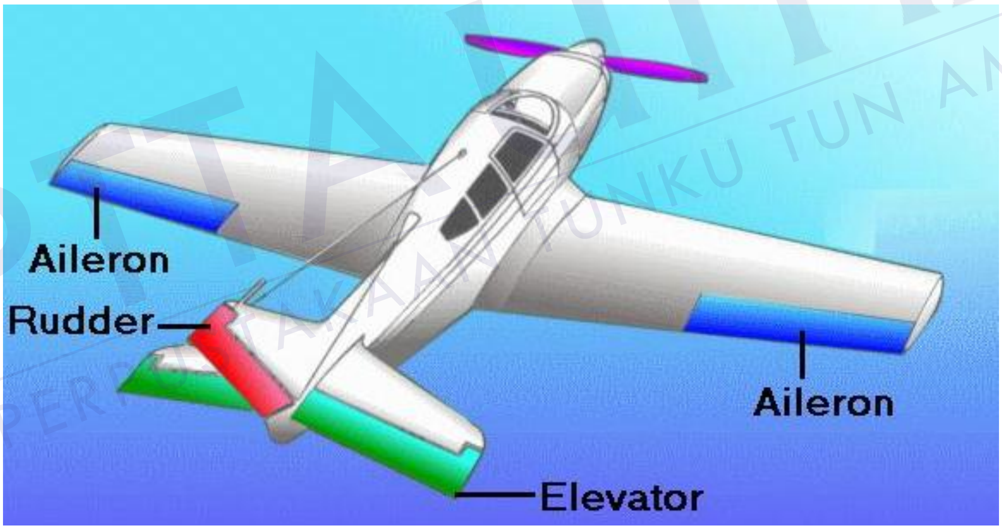
Figure 2.1: primary control surfaces on typical light aircraft [5]

Table 2.1 The function of controls surfaces[6].

	Control surface	Movement	Axis
Pitch	Elevator	Nose up /down	Lateral
Roll	Aileron	Wings up /down	Longitudinal
Yaw	Rudder	Nose left/right	Vertical



Consider above table, to control the aircraft in heading for climb or descent as forinstance, the aircraft will use elevator control surface. This device make the aircraft will pitch up or pitch down depended whether the elevator setting up or setting down [3].

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2.4 Aerodynamic forces and drag polar

The resultant or vector aerodynamic force is produced by the motion of the aircraft through the atmosphere. the resultant aerodynamic force is resolved into two components along the wind-axes as shown in figure 2.2. the component in the opposite direction to the aircraft’s velocity vector is called the drag and given the symbol D . the drag resists the motion of the aircraft. the component perpendicular to the aircraft velocity is called lift and given the symbol L . it is the lift that keeps the aircraft in the air [6][7].

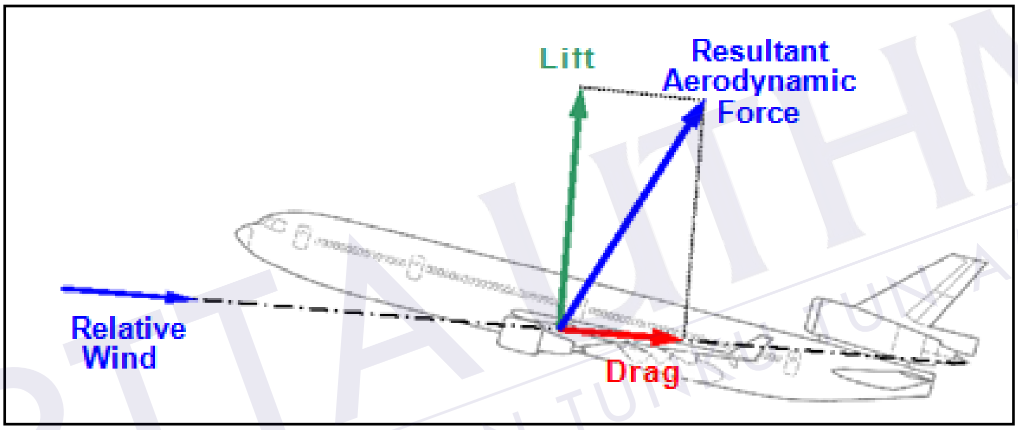

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Figure 2.2 aerodynamic forces acting on an aircraft[6]

Every aircraft, whether an airplane, helicopter or rocket, is affected by four opposing forces: thrust, lift, drag and weight figuer (2..3). control surfaces, such as the rudder or ailerons, adjust the direction of these forces, allowing the pilot to use them in the most advantageous way possible[8][9].

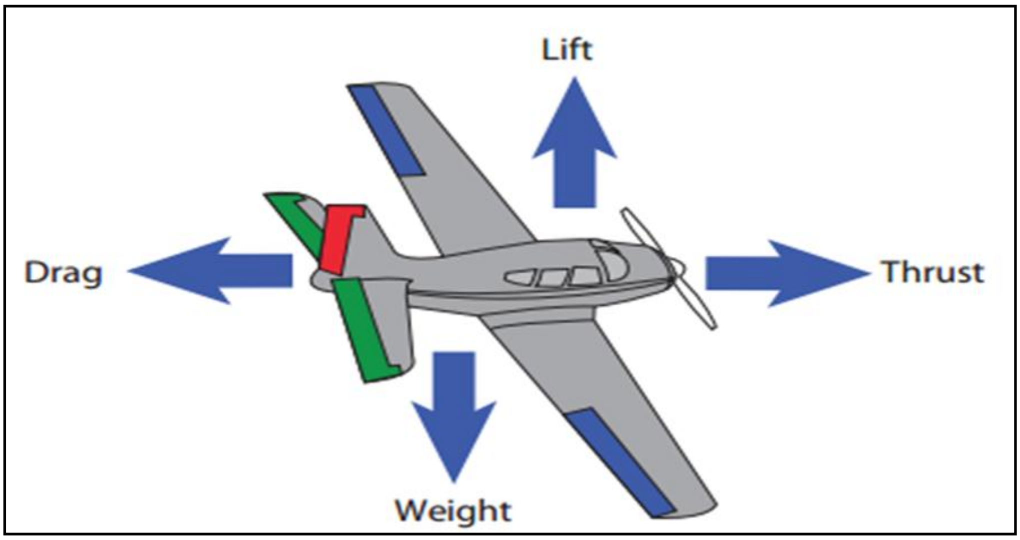

Figure. 2.3 four forces of flight [6]

A force can be thought of as a push or pull in a specific direction. it is a vector quantity, which means a force has both a magnitude (amount) and a direction for this lesson we will deal specifically with fixed-wing airplanes. other aircraft, such as hot air balloons and helicopters, use the same basic principles but the physics are very different [10][11].

2.5 Controlling the motion of flight

In order to reach the destination, the forces worked on the aircraft has to be precisely manipulated. This can be done through the control surfaces, which allowing to direct airflow in very specific ways [14].

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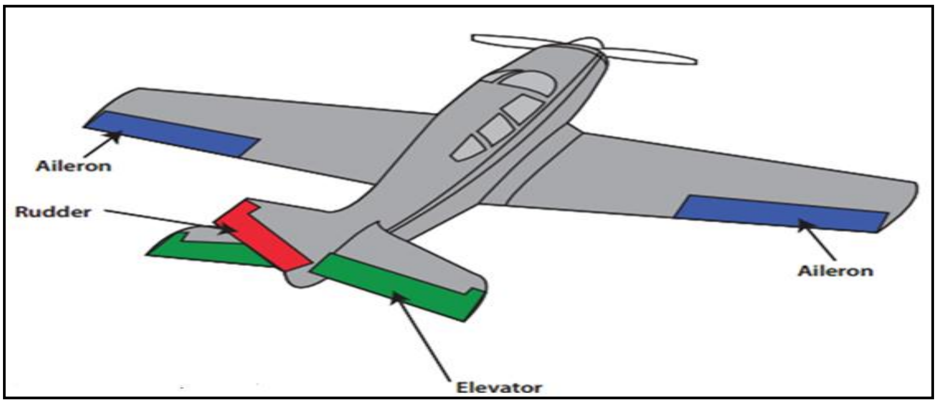

Figure. 2.4 aircraft control surfaces[6]

2.5.1. Elevator

Pitch as the name implies, the elevator helps “elevate” the aircraft. it is usually located on the tail of the aircraft and serves two purposes. the first is to provide stability by producing a downward force on the tail. airplanes are traditionally nose-heavy and this downward force is required to compensate for that. the second is to direct the nose of the aircraft either upwards or downwards, known as pitch, in order to make the airplane climb and descend figuer 2.5[14].

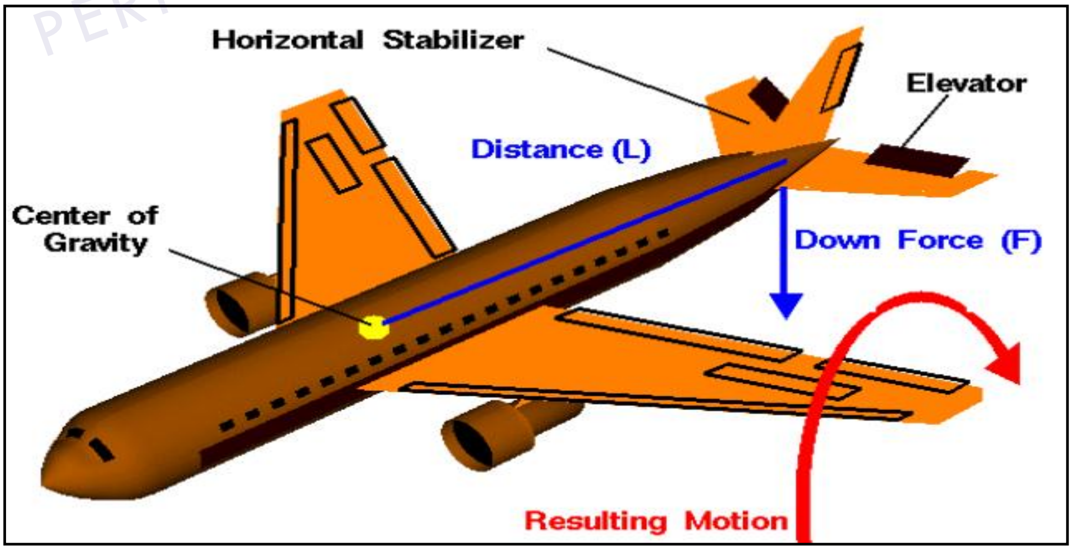

Figure 2.5 elevator and pitch moveent[6]

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Elevator is a primary control surface placed on the trailing edge of the horizontal tail or canard. longitudinal control and long itudinal trim are two main functions of the elevator; and it has minor influence on the longitudinal stability. elevator is flap-like and is deflected up and down. with this deflection, the camber of the air foil of the tail is changed, and consequently tail lift coefficient (clh) is changed. the main objective of elevator deflection is to increase or decrease tail plane lift and hence tail plane pitching moment [6].

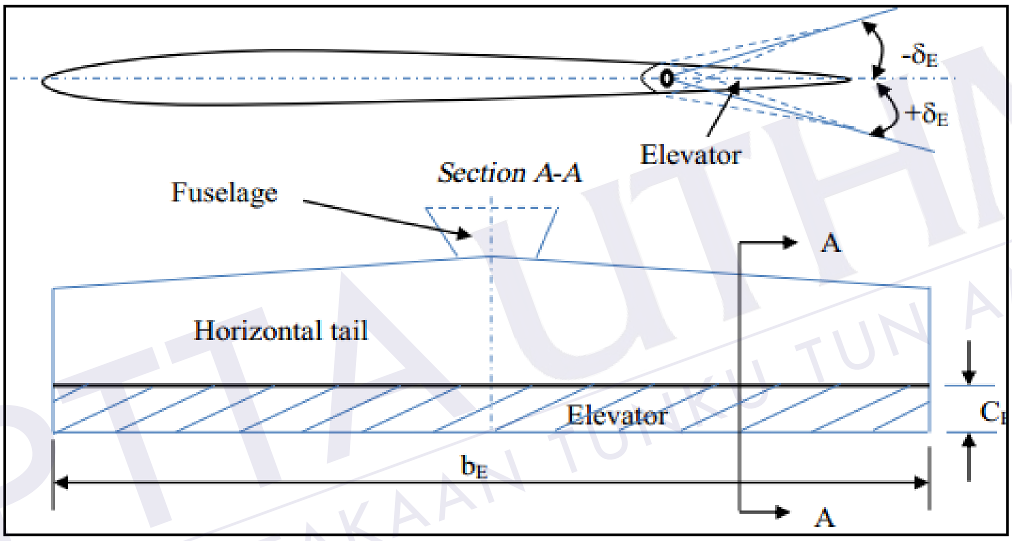

Figure 2.6 Top-view of the horizontal tail and elevator.

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Factors affecting the elevator performances are elevator effectiveness, elevator hinge moment, and elevator aerodynamic and mass balancing. the elevator effectiveness is a measure of how effective the elevator deflection is in producing the desired pitching moment. the elevator effectiveness is a function of elevator size and tail moment arm. hinge moment is also important because it is the aerodynamic moment that must be overcome to rotate the elevator. The hinge moment governs the magnitude of force required of the pilot to move the stick/yoke/wheel. Therefore, great care must be used in designing an elevator so that the stick force is within acceptable limits for the pilots. Aerodynamic and mass balancing deal with technique to vary the hinge moment so that the stick force stays within an acceptable range. Table 2.2 shows the comparison size of the elevator for different aircrafts.

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