ON THE DEVELOPMENT OF COMPUTER CODE FOR AIRCRAFT FLIGHT DYNAMICS ANALYSIS

OUTMAN MOHAMED ALAZOMUI

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

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.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

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 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].

Type equation here.

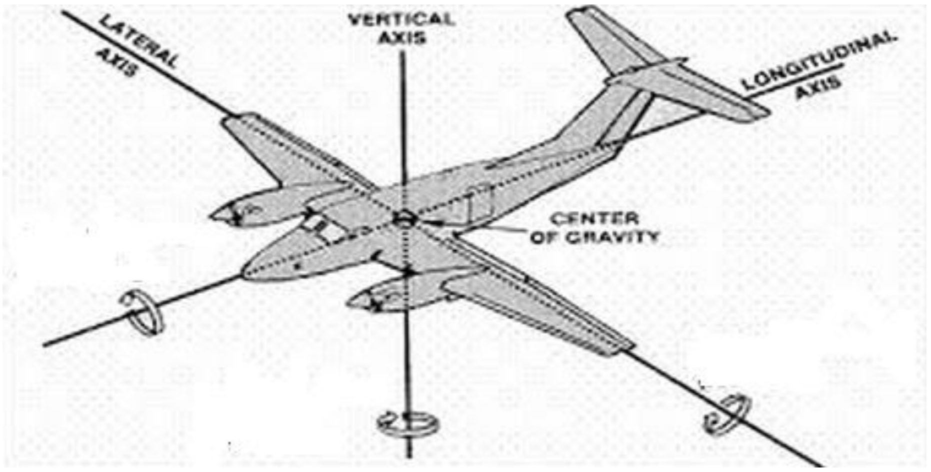


Figure 1.1 Stability the longitudinal flight mode and lateral flight mode [3]

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.

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:

(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;

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 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.

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

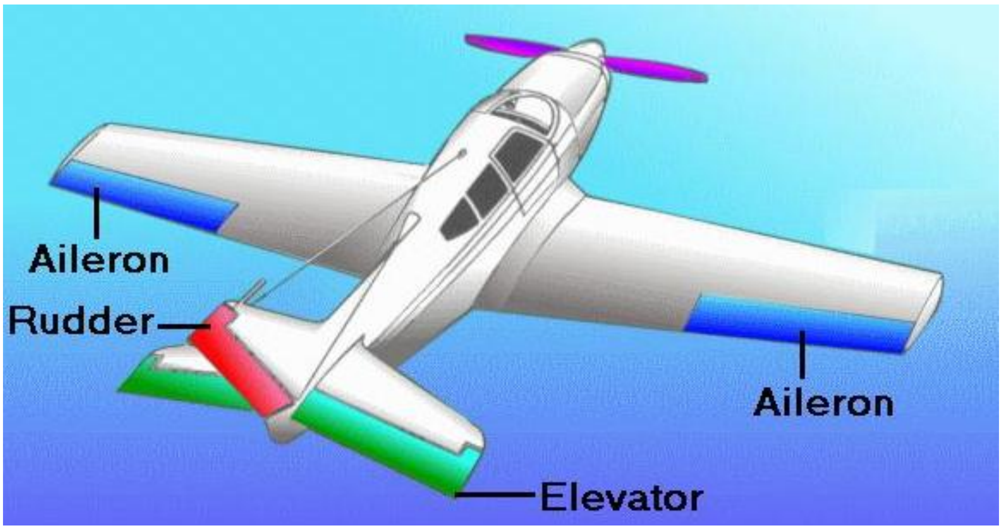
To control the airplane’s trajectory, it can be done by changing the external surfaces of the aircraft. Such external surfaces are elevators, stabilators, canards, elevons, tailerons, ailerons, rudders, and thrust vectoring nozzles. These external surfaces are often called as primary surfaces. Any operation 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

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].

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].

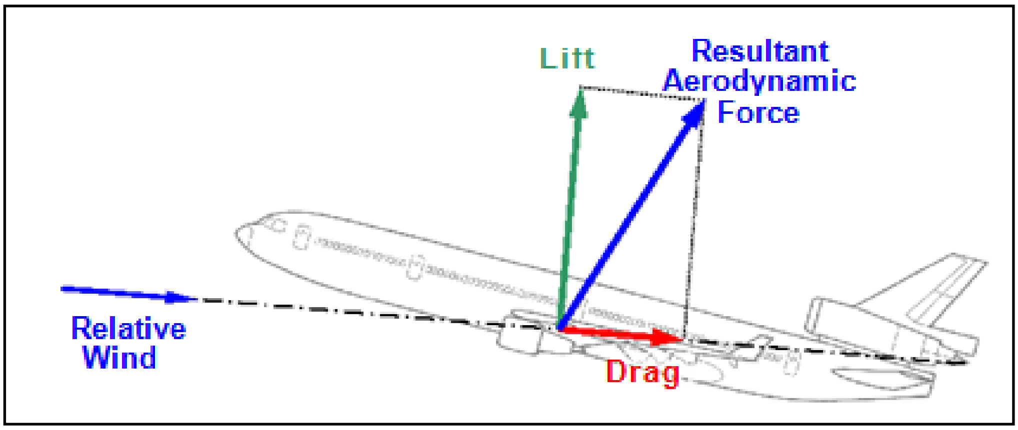


Figure 2.2 aerodynamic forces acting on an aircraft[6]

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].

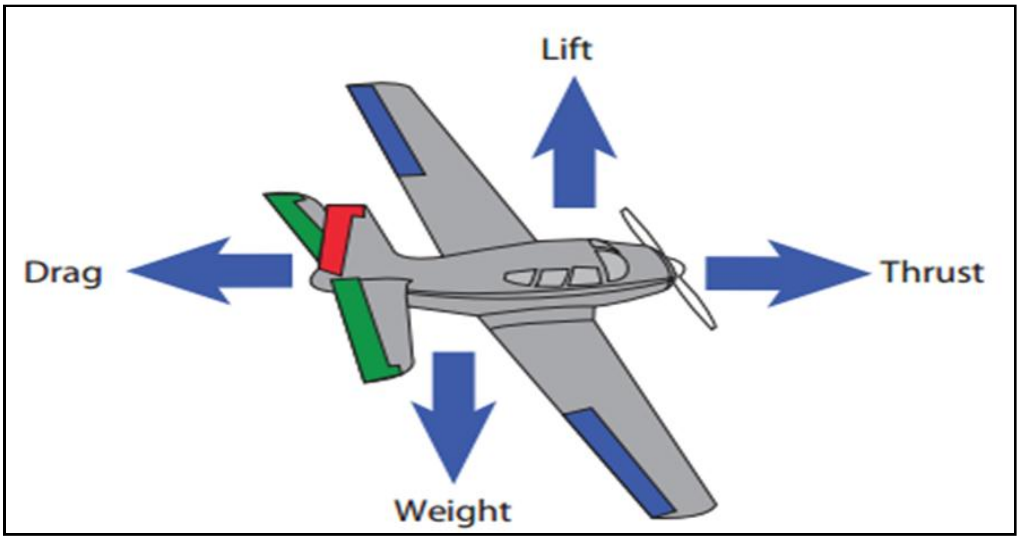


Figure. 2.3 four forces of flight [6]

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].

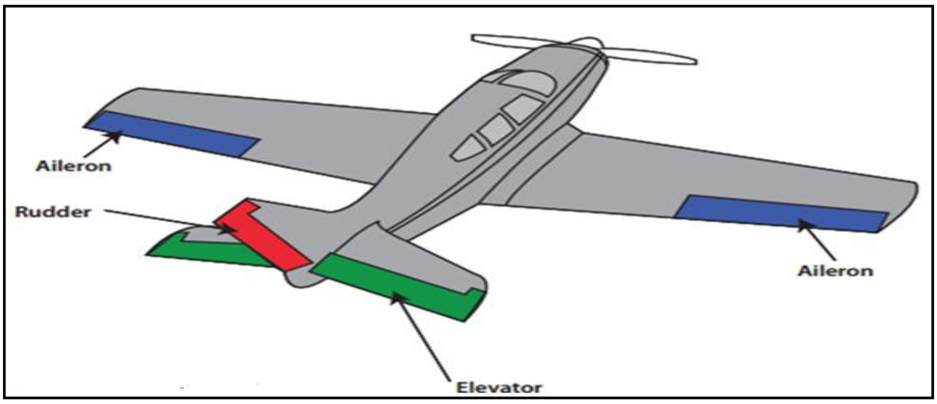


Figure. 2.4 aircraft control surfaces[6]

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].

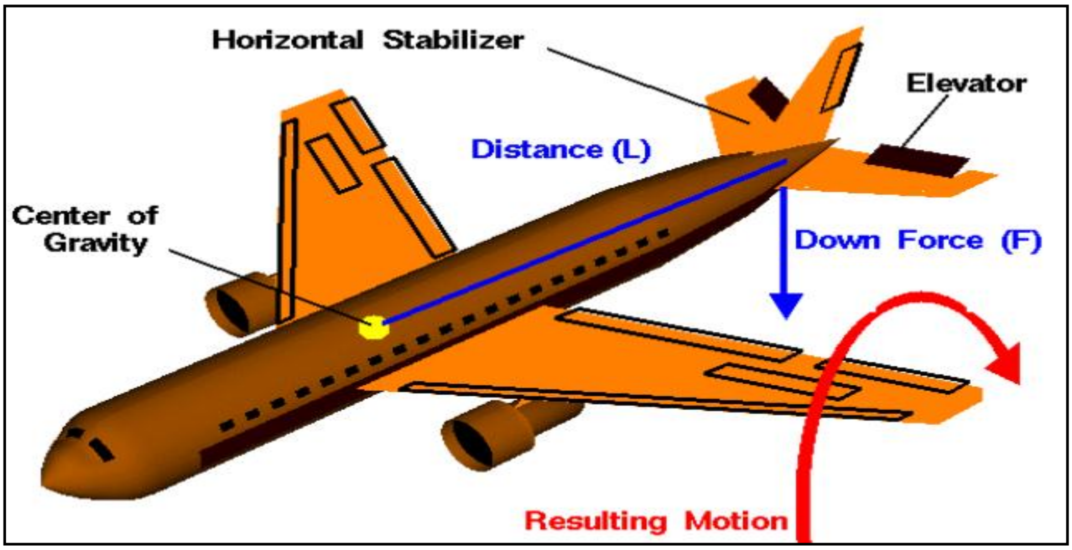


Figure 2.5 elevator and pitch moveent[6]

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].

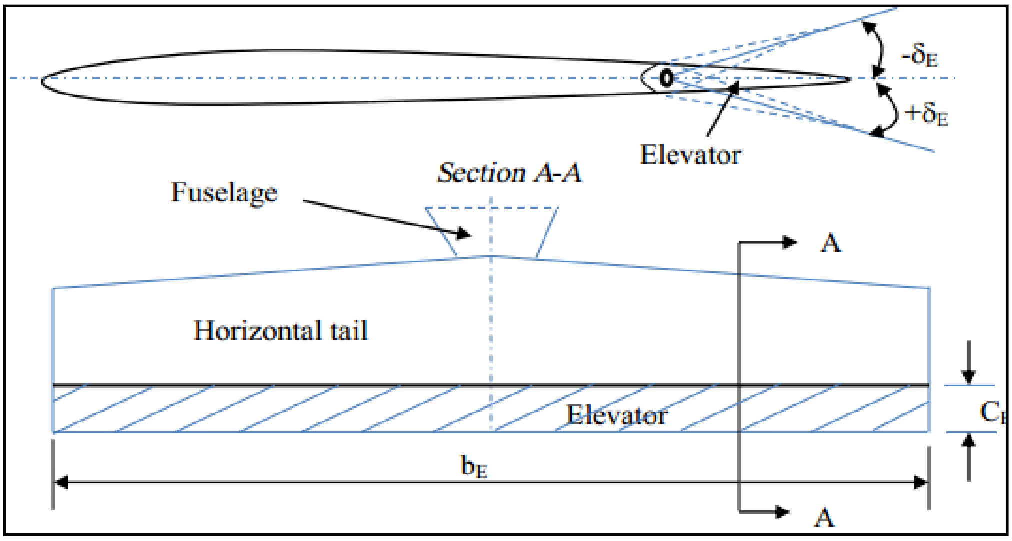


Figure 2.6 Top-view of the horizontal tail and elevator.

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.

Table 2.2 Elevator size of different aircraft[6][12]

NO	**Aircraft**	**Type**	**MTo(g)**	**SE/SH**	**CEH**	**δ maxdeg**	
						dow	**up**
1	Cessna 182	Light GA	1.406	0.38	0.44	22	25
2	Cessna Citation III	Business	9.979	0.37	0,37	15	15.5
3	Gulfstream200	Business	16.080	0.28	0.31	20	27.5
4	AT- 802	Agriculture	7.257	0.36	0.38	15	29
5	Atr 42-320	RegionalAirliner	18.600	0.35	0.33	16	26
6	Lockheed c-130 Hercules	MilitaryCaro	70.305	0.232	0.35	15	40
7	Fokker F-28-4000	Transport	33.000	0.197	0.22	15	25
8	Fokker F-100B	Airliner	44.450	0.223	0.32	22	25
9	McDonnell Douglas DC- 8	Transport	140.600	0.225	0.25	10	25
10	McDonnell Douglas DC 9-40	Transport	51.700	0.28	0.30	15	25
11	McDonnell Douglas DC 10-40	Transport	251.700	0.225	0.25	16.5	27
12	McDonnell DouglasMD-11	Transport	273.300	0.31	0.35	20	37.5
13	Boeing 727-100	Transport	76.820	0.23	0.25	16	26
14	Boeing 727-100	Transport	50.300	0.224	0.25	20	20
15	Boeing 727-200	Transport	247.20	0.30	0.32	25	30
16	Boeing 727-200	Transport	377.842	0.185	0.23	17	22
17	Airbus A-300B	Transport	165.000	0.295	0.30	-	-
18	Airbus 320	Transport	78.000	0.31	0.32	17	30
19	Airbus A340-600	Airliner	368,000			15	30
20	lOckheed L-1011 Tristar	Transport	231.000	0.215	0.23	0	25
21	Lockheed c-5A	Cargo	381,000	0.268	0.35	10	20

Table 2.2 (continued)

2.5.2 Ailerons

The aileron is introduced as part of the aircraft configuration is to make the aircraft can roll. This devices are located at the rear of the wing, one on each side. They work opposite to each other, so when one is raised, the other is lowered. Their job is to increase the lift on one wing, while reducing the lift on the other. By doing this, they roll the aircraft sideways, which allows the aircraft to turn. This is the primary method of steering a fixed-wing aircraft figuer(2.7)[7].

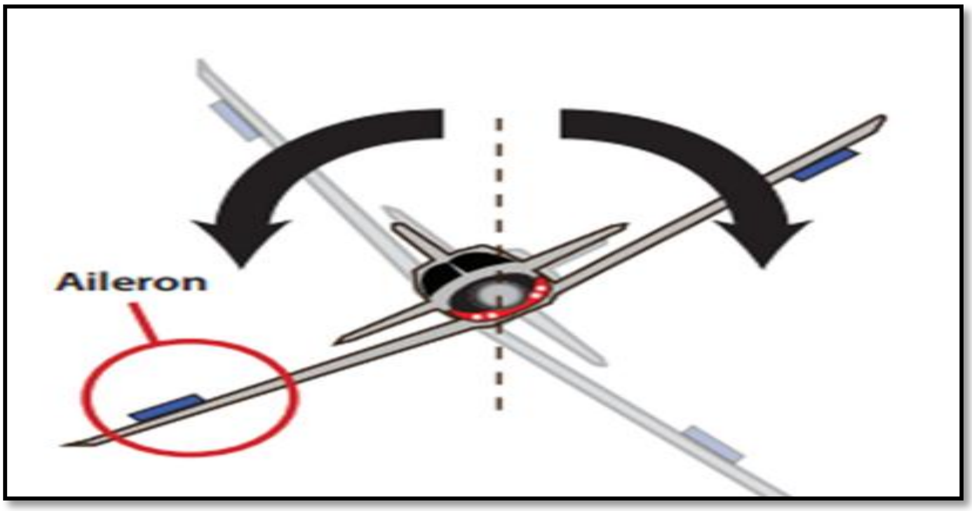


Figure 2.7 ailerons and roll movement[6]

A basic item in the list of aircraft performance requirements is the manoeuvre ability. Aircraft manoeuvre ability is a function of engine thrust, aircraft mass moment of inertia, and control power. One of the primary control surfaces which cause the aircraft to be steered along its three-dimensional flight path (i.e. manoeuvre) to its specified destination is aileron. Ailerons are like plain flaps placed at outboard of the trailing edge of the wing. Right aileron and left aileron are deflected differentially and simultaneously to produce a rolling moment about x-axis. therefore, the main role of aileron is the roll control; however it will affect yaw control as well. Roll control is the fundamental basis for the design of aileron[14] .Figure show the wing top view drawing which indicate the location of the aileron on the wing. While Figure … shows the aileron deflection angle which allow it can be done up and down deflection. Table … shows typical dimension of aileron size for various type of aircraft.

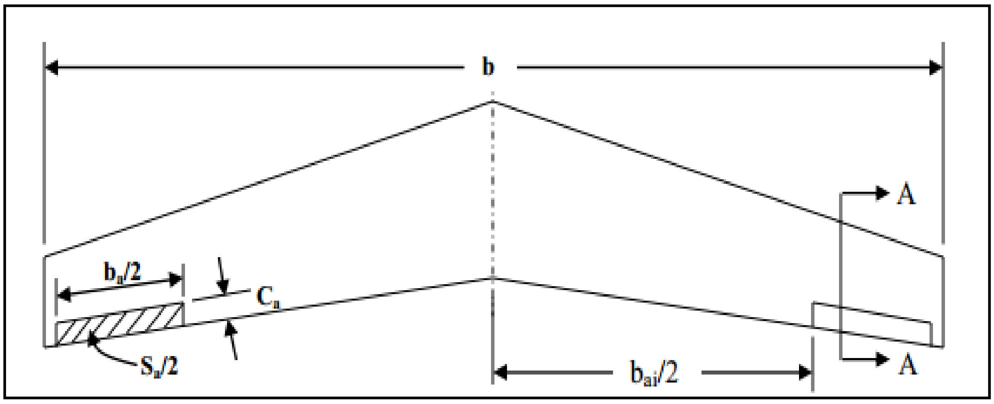


Figure … A-Top-view of the wing and aileron[14]

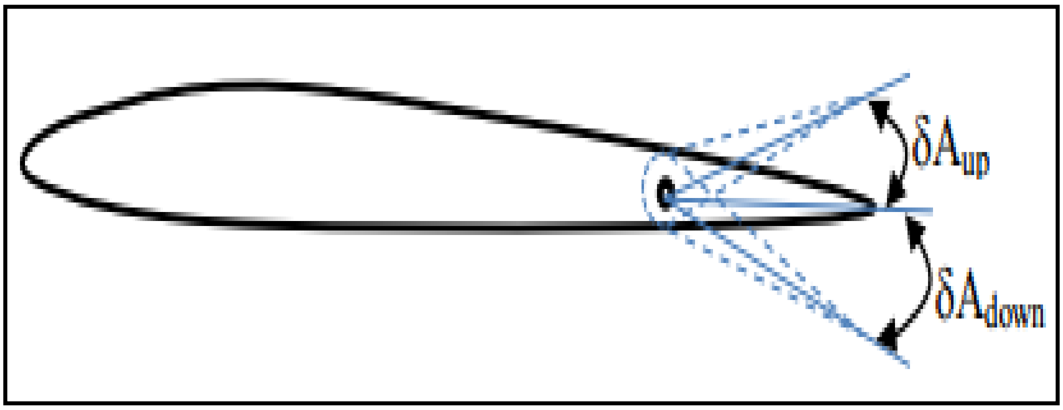


Figure 2. Aileron deflection can deflect in up and down direction.

Table 2.3. aileron size for different aircrafs[14]

NO	Aircraft	Type	m_{To} (kg)	B (m)	C_A/ C	Span ratio		δ_{max}(deg)	
						b_i/b/2	b_0/b/2	up	Dow
1	Cessna 182	Light GA	1.406	11	0.2	0.46	0.95	20	14
2	CessnaCitation III	Business jet	9.979	16.31	0.3	0.56	0.89	12	12.5
3	AirTractorAT 802	Agriculture	7.252	18	0.36	0.4	0.95	17	13
4	Gulfstream 200	Business jet	16.080	17.7	0.22	0.6	0.,86	15	15
5	Fokker 100A	Airliner	44.450	28.08	0.24	0.6	0.94	25	20
6	Boeing 777-200	Airliner	247.200	60.9	0.22	0.32	0.76[28]	30	10
7	Airbus 340-600	Airliner	368.000	63.45	0.3	0.64	0.92	25	20
8	Airbus A340-600	Airliner	368.000	63.45	0.25	0.67	0.92	25	25

2.5.3 Rudder | yaw

A rudder is located on the plane’s vertical tail and is used to steer the plane left or right. some aircraft have more than one vertical tail, like the fa-18 fighter jet, and each tail has its own rudder. The vertical tail on a plane is also an airfoil shape, but the airfoil is not curved. As a result, the vertical tail does not normally generate lift. When the rudder is moved in one direction, the vertical tail is effectively curved, and produces lift. However, this lift does not act vertically, as the vertical tail is not horizontal like the wing. Lift always acts perpendicular to the wing or tail that generates it, so the lift generated by the vertical tail will act horizontally. This lift will cause the plane to rotate left or right. If therudder is moved to the left, it will generate lift to the right, which will move the nose of the plane to the left. Rudders are often slower at turning an aircraft than the ailerons, but they can turn the aircraft without rolling it and are useful for small adjustments during takeoff, landing and other flights. Sometimes a pilot uses both the rudder and the ailerons together while turning in order to produce a smoother flight. As shown in the Figure 2.9 [14].

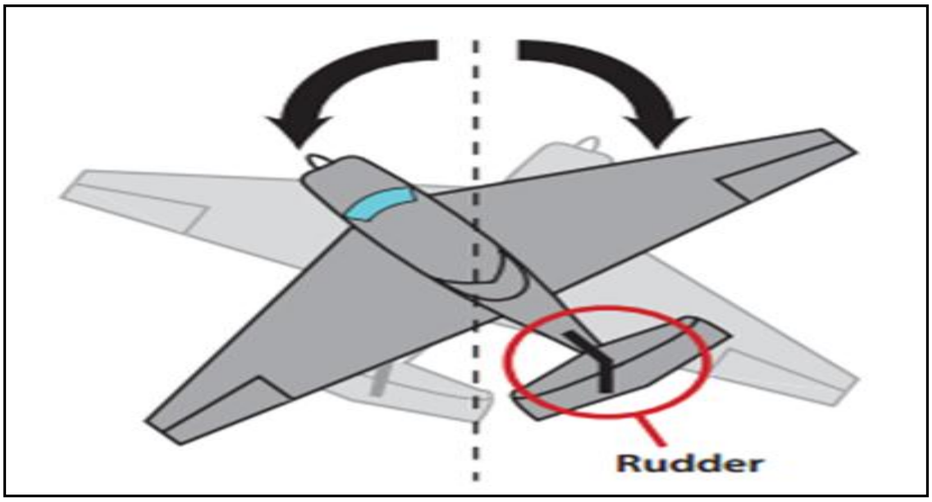


Figure. 2.9 rudder and yaw movement the[14]

Rudder is a primary control when it is rotated (i.e. deflected δ_r), a lift force (i.e. side force, L_v) is created figure (2.13). As result, a yawing moment (n) about aircraft center of gravity (about aircraft z-axis) is generated. thus, control of the yawing moment about the center of gravity is primarily provided by means of the rudder. The unintended production of the rudder is a rolling moment. This is due to the fact that the vertical tail (i.e. rudder) is usually placed above the aircraft cg. Two fundamental roles of rudder are directional control and directional trim. therefore, parameters of the rudder are determined by the directional trim and control requirements. The rudder control power must be sufficient to accomplish these two requirements in various flight conditions. The aircraft heading angle is mainly determined through a directional control process.

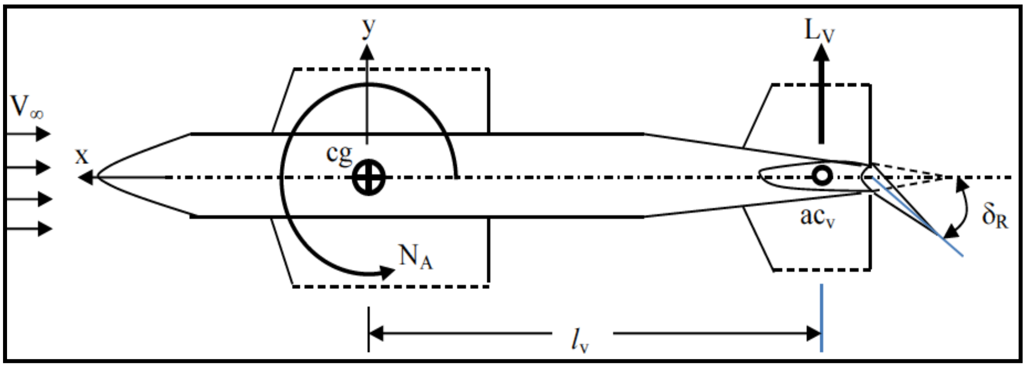
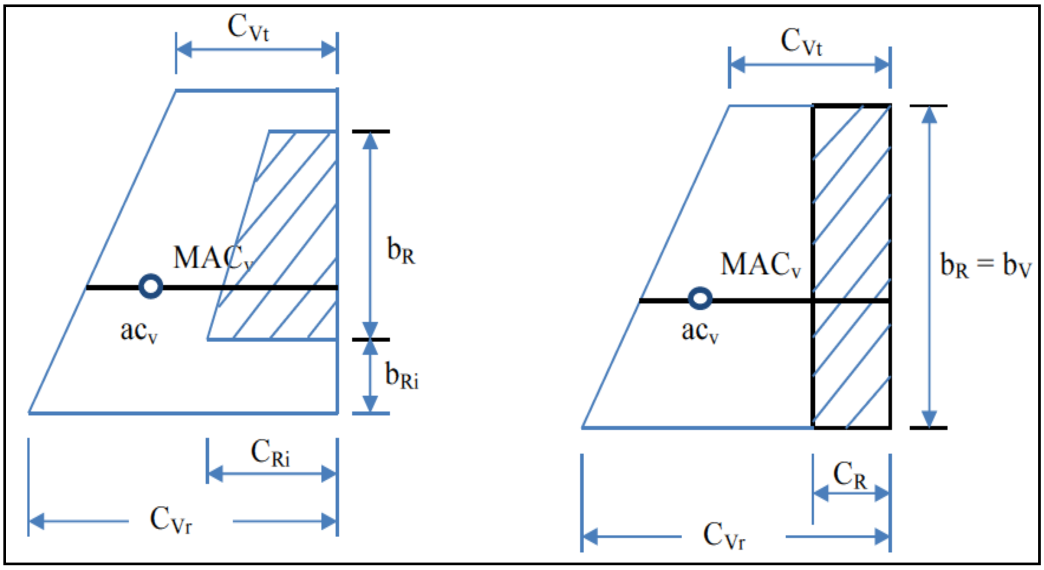


Figure 2.10 Directional control via rudder deflection (top view)[13]

there are interferences between rudder and aileron, and they are often applied simultaneously. Thus, the lateral and directional dynamics are frequently coupled. thus, it is a good practice to design aileron and rudder concurrently. Rudder, similar to elevator, is a displacement control device, while the aileron is a rate control device. The fundamentals of design of elevator and rudder are similar, but since their applications are different, the design of rudder is generally more complicated. However rudder deflections to the right and to the left are the same, but up and down elevator deflections are different



1 . a swept rudder 2. a rectangular rudder

Figure 2.11 Vertical tail and rudder geometry[13]

In the design of the rudder, four parameters must be determined. they are:

- **(i)** Rudder area (s_r);
- **(ii)** Rudder chord (c_r);
- **(iii)** Rudder span (b_r);
- **(iv)** Maximum rudder deflection (δ_{rmax}); and
- (iv) Location of inboard edge of the rudder (b_{ri});

Table 2.4 show the typical size rudder for differents type of aircraft[14].

NO	Aircraft	Type	m_{TO}(kg)	s_{R/S_V}	C_{R/C_V}	C_{Rmax}(deg)
1	Cesna 182	Light GA	1.406	0.38	0.42	±24
2	Cesna 650	Business jet	9.979	0.26	0.27	±25
3	Gulfstream 200	Business jet	16.080	0.3	0.32	±20
4	Air tractor AT-802	Regional airlines	18.600	0.61	0.62	±24
5	LockheedC-130E Hercules	Minitary cargo	70.305	0.239	0.25	35
6	DC-8	Transport	140.600	0.269	35	±32.5
7	DC-10	Transport	251.700	0.145	38	±23/±46
8	Boeing 737-100	Transport	50.300	0.25	0.26	
9	Boeing 777-200	Transport	247.200	0.26	0.28	±27.3
10	Boeing 747-200	Transport	377.842	0.173	0.22	±25
11	Lockheed C-5A	Cargo	381.000	0.191	0.2	-
12	Fokker 100A	Airliner	44.450	0.23	0.28	±20
13	Embraer ERJ 145	Regional jet	22.000	0.29	0.31	±15
14	Airbus A340-600	Airliner	368.000	0.31	0.32	±31.6

2.5.4 Rudder design requirements

The design requirements of rudder are primarily driven by directional control and directional trim. directional control is governed mainly through yaw rate (r); While directional trim is often governed by maximum rudder deflection. Faa has a number of regulations for directional control; All of which must be addressed by a rudder designer.

2.6 Center of gravity

The center of gravity, also known as cg, is the effective point whereby all weight is considered to be. The cg is also the same point where the axes of flight meet figure 2. 11 This point isn’t fixed on any aircraft, but moves forwards or backwards along the longitudinal axis, depending on how the aircraft is loaded. It is vital that its center of gravity remain within certain limits however, as an aircraft that is too nose- or tail-heavy will either not fly, or be so difficult to control that it becomes too dangerous to try. These limits are referred to as its operational envelope[4]**.**

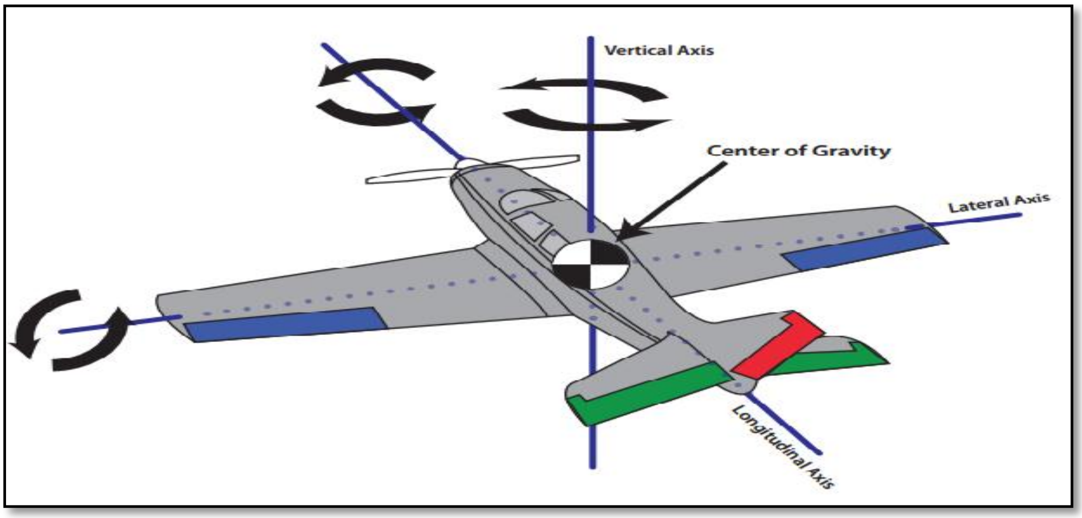


Figure 2. 12 center of gravity [14]

2.7 Coordinate systems and equations of' motion:

In order to describe the motion of a dynamic system it is n ary to define a suitable coordinate system and formulate equations for the motion in accordance with the physical laws governing the system. The diagrams and discussion that follow consider the motion of a particle (point mass) and the more complicated motion of a rigid body.

2.7.1 particle motion

Coordinate systems and equations that conveniently describe the motion of a point mass are presented in the following pages. rectangular, spherical, and cylindrical coordinate systems are presented. Preferred axis orientation and notation indicated and used are consistent, insofar as possible, with the reference literature.

2.7.2 COORDINATE SYSTEM (FLAT NONROTATING EARTH)

The familiar cartesian or rectangular coordinate system has many applications in the analysis of vehicle motion. for instance, it may be used to describe the flight path (trajectory) of a body with respect to a given starting point on the earth's surface. a typical case is suggested in the description of the coordinate system below. Generalization to any specific problem is self-evident and requires no further discussion.

2.7.3 Description of coordinate system

In defining the coordinate system applied in the Flight Dynamic study is normally use a rule as follows:

(i) Origin of rectangular coordinates x, y, z: arbitrary, often a point on the surface of the earth;

(ii) Fundamental plane: usually the xy-plane; tangent to the surface of the earth at the origin;

(iii) Positive x•axis: arbitrary, often selected along initial heading or direction of motion.

(iv) Positive z-axis: arbitrary, often oriented in sense to denote altitude above the surface of earth or the xy-plane;

(v) Positive rotation in fundamental plane: from x-axis to y-axis; i.e., right-hand system as depicted in the Figure 2.13;

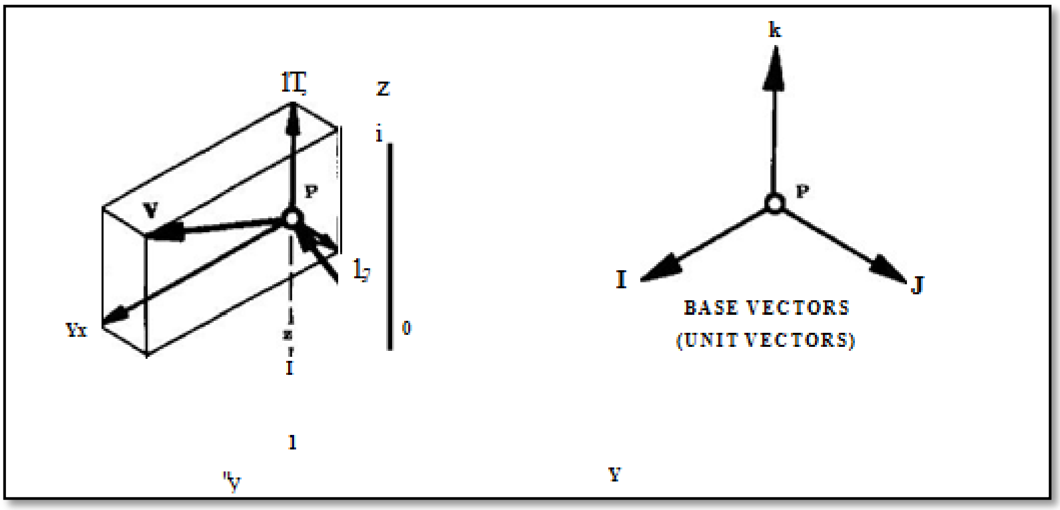


Figure 2.13 General rectangular-coordinate system[16].

2.8 Flight dynamics.

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 [17][18].

Flight dynamics: It's a branch of dynamics dealing with the motion of an object moving in the earth's atmosphere. The study of flight dynamics will enable us to (a) obtain the performance of the airplane which is described by items like maximum speed, minimum speed, maximum rate of climb, distance covered with a given amount of fuel, radius of turn, take-off distance, landing distance etc., (b) estimate the loads on the airplane, (c) estimate the power required or thrust required for desired performance, (d) determine the stability of the airplane i.e. whether the airplane returns to steady flight conditions after being disturbed and (e) examine the control of the airplane. Flight dynamics is a basic subject for an aerospace engineer and its knowledge is essential for proper design of an airplane [18].

2.8.1 Stability and control analyses

Roughly speaking, the stability analysis is concerned with the motion of the airplane, from the equilibrium position, following a disturbance. Stability analysis tells us whether an airplane, after being disturbed, will return to its original flight path or not. Control analysis deals with the forces that the deflection of the controls must produce to bring to zero the three moments (rolling, pitching and yawing) and achieve a desired flight condition. It also deals with design of control surfaces and the force control wheel/stick /pedals. While aircraft performance analysis deals with obtaining a maximum level speed, minimum level speed, rate of climb, angle of climb, distance covered with a given amount of fuel called 'Range', time elapsed during flight called 'Endurance', minimum radius of turn, maximum rate of turn, take-off distance, landing distance etc. These aircraft performance analysis carried out analysis for

REFERENCES

1. Air craft dynamics from modeling to simulation, Professor Marcello R. Napolitano - 2012
2. Airplane flight dynamics and automatic flight controls - Jan Roskam – part I - 2009
3. Anderson, Jr. J.D. “Introduction to flight” McGraw Hill 2005.
4. Bandu N. pamadi Performance stability, Dynamics,and control of Airplanes second edition (2008)
5. CF-104 Starfighter, 1961-1986, CFB Baden-Soellingen, 1986.
6. Chetayev, N.G. “The stability of motion”, Pergamon 1961.
7. Clearwater, John, Canadian Nuclear Weapons, Dundurn Press, Toronto, 1998.
8. Dianwei, Q., Jianqiang, Y., Dongbin, Z. & Hua, X. Dynamic Analysis and Model Transformations of Longitudinal Flight of Hypersonic Aircrafts, at. Paper read at Innovative Computing Information and Control, 2008. ICICIC '08. 3rd International Conference on: 487-487. 18-20 June 2008.
9. Dommasch, D.O. Sherby, S.S. and Connolly, T.F. “Airplane aerodynamics” Pitman (1967).
10. Engineering Flight Simulator Using MATLAB, Python and FLIGHTGEAR Istas F. Nusyirwan Department of Aeronautical Engineering, Faculty of Mechanical Engineering Universiti Teknologi Malaysia istaz@utm.my.
11. Fairhall, David (25 January 2000). "John W R Taylo.
12. Fuller, John D., and Robert H. Tolson. "Program for the Estimation of Spacecraft Aerodynamic Properties." AIAA Paper 728 (2009).

13. Hall, W. Earl, and Narendra K. Gupta. "System identification for nonlinear aerodynamic flight regimes." Journal of Spacecraft and Rockets 14.2 (1977): 73-80.
14. Hansen, James R. The Bird is on the Wing: Aerodynamics and the Progress of the American Airplane. No. 34. Texas A & M University Press, 2004.
15. http://www.free-online-private-pilot-ground school.com/aircraft-ucture.html
16. http://www.wingsoverkansas.com/history/a199/
17. Jameson, Antony. "Aerodynamic design via control theory." Journal of scientific computing 3.3 (1988): 233-260.
18. Jaroszewicz, Adam, et al. "Biomimic sensors guided flight stability and control for flapping wings autonomous micro air vehicle (entomopter)." AIAA Paper 664 (2007)
19. Jump up to:[a] [b] Grady, Mary (22 July 2012). "Cessna Unveils Jet An Engine For Skylane". *AVweb*. Retrieved 24 July 2012.
20. Marcello Napolitano (Aircraft Dynamics: From Modeling to Simulation) October 2011, ©2012
21. Miele, A. “Flight mechanics Vol. I” Addison Wesley (1962).
22. Nasa “Principle of Flight, http://www.answers.com/topic/flight-controls
23. NAxes / Control Surfaces ASA. http://flight.nasa.gov/pdf/axes_control_surfaces_5-8.pdf
24. Pickler, R., and Milberry, L., Canadair - The First 50 Years, CANAV Books, Toronto, 1995.
25. R. K. Heffley & W. F. Jewell, Aircraft Handling Qualities Data, NASA CR-2144, December 1972
26. Reynerson, Charles. "Aerodynamic Disturbance Force and Torque Estimation for Spacecraft and Simple Shapes Using Finite Plate Elements–Part I: Drag Coefficient." 29th Annual AAS Guidance and Control Conference. 2007.
27. Sadraey, Mohammad. "Design of Control Surfaces." Aircraft Design: A Systems Engineering Approach: 631-753.(2012)
28. Salman, M. U. & Chang, B. Analysis of aircraft dynamics near the flight envelope boundary, at. Paper read at Control Conference (ASCC), 2011 8th Asian: 407-412. 15-18 May 2011.

29. See “MU-2B Series Airplane Safety Evaluation Report,” FAA, December 2005; page 20.
30. Shames, I.H. and Krishna Mohana Rao, G. “Engineering mechanics – statics and dynamics”, 4th Edition, Dorling Kindersley (India), licensees of Pearson Education (2006).O LONG BEACH CA, 1965.
31. The lander, J. A. Aircraft Motion Analysis. DOUGLAS AIRCRAFT CMiele, A. “Flight mechanics Vol I” Addison Wesley (1962).
32. Thomas B Haines (October 2012). "Jet A for your Skylane". *AOPA pilot*.