DESIGN OF HEAVY WEIGHT SUPERSONIC FIGHTER AIRCRAFT

AEB4341 AIRCRAFT DESIGN PROJECT REPORT-I

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Certified that this project report titled "**DESIGN OF HEAVY WEIGHT SUPERSONIC FIGHTER AIRCRAFT"** is the bonafide work of "**Prasanth M (19101032),Ashwin A (19101038), Pratyush N (19101058)"** who carried out the project under authorized supervision. Certified further to the best of my knowledge that the work reported here does not form a part of any other project/research work on the basis of which a degree or reward was conferred on an earlier occasion on this or any other candidate.

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ABSTRACT

The aim of this design is to optimize a set of existing data available from aircrafts operating as Supersonic Fighter Aircraft with a Max. Take-Off value range in between 11000-19000 kg. The new design will focus on a Supersonic Fighter aircraft which will have a lesser maximum take-off weight and increased cruise speed. The new design will be more cost effective and produce higher thrust with less fuel consumption. The new design will be capable of easier in aerodrome operations and can have better manoeuvring.

Keywords: Fighter aircraft, single engine, turbojet engine.

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LIST OF SYMBOLS AND ABBREVIATIONS

A.R	- Aspect Ratio
B	- Wing span(m)
C	- Chord of the Aerofoil (m)
Croot	- Chord at Root (m)
Ctip	- Chord at Tip (m)
C_d	- Drag Co-efficient
Cdo	- Zero lift Drag co-efficient
CP	- Specific fuel consumption (lbs / hp / hr)
CL	- Lift Co-efficient
D	- Drag(N)
E	- Endurance (hr)
E	- Oswald efficiency factor
L	- Lift (N)
(L/D)Loiter	- Lift-to-drag ratio at loiter
(L/D)Cruise	- Lift-to-drag ratio at cruise
M	- Mach number of aircraft
Mff	- Mission fuel fraction
R	- Range (km)
Re	- Reynolds number
S	- Wing area (m^2)
Sref	- Reference surface area
Swet	- Wetted surface area
Sa	- Approach distance (m)
Sf	- Flare distance (m)
Sfr	- Freeroll distance (m)
S.C	- Service ceiling

(T/W)Loiter	- The thrust-to-weight ratio at Loiter
(T/W)Cruise	- The thrust-to-weight ratio at cruise
(T/W)Take-off	- The thrust-to-weight ratio at take-off
vCruise	- velocity at cruise (m/s)
vStall	- velocity at stall (m/s)
vt	- Velocity at touch down (m/s)
WCrew	- Crew weight (kg)
Wempty	- Empty weight of the aircraft (kg)
WFuel	- Weight of fuel (kg)
WPayload	- Payload of the aircraft (kg)
W0	- Overall weight (kg)
W/S	- Wing loading (kg/m^2)
ρ	- Density of air (kg/m^3)
μ	- Dynamic viscosity (Ns/m^2)
λ	- Tapered ratio
R/C	- Rate of Climb
η	- Kinematic viscosity (m^2/s)

CHAPTER 1

INTRODUCTION TO DESIGN

1.1 DESIGN METHODOLOGY

The design method to be followed from the start of the project to the nominal end can be considered to fall into three main phases. These phases are illustrated in Figure. The preliminary phase (sometimes called the conceptual design stage) starts with the project brief and ends when the designers have found and refined a feasible baseline design layout. In some industrial organizations, this phase is referred to as the 'feasibility study'. At the end of the preliminary design phase, a document is produced which contains a summary of the technical and geometric details known about the baseline design. This forms the initial draft of a document that will be subsequently revised to contain a thorough description of the aircraft. This is known as the aircraft 'Type Specification'.

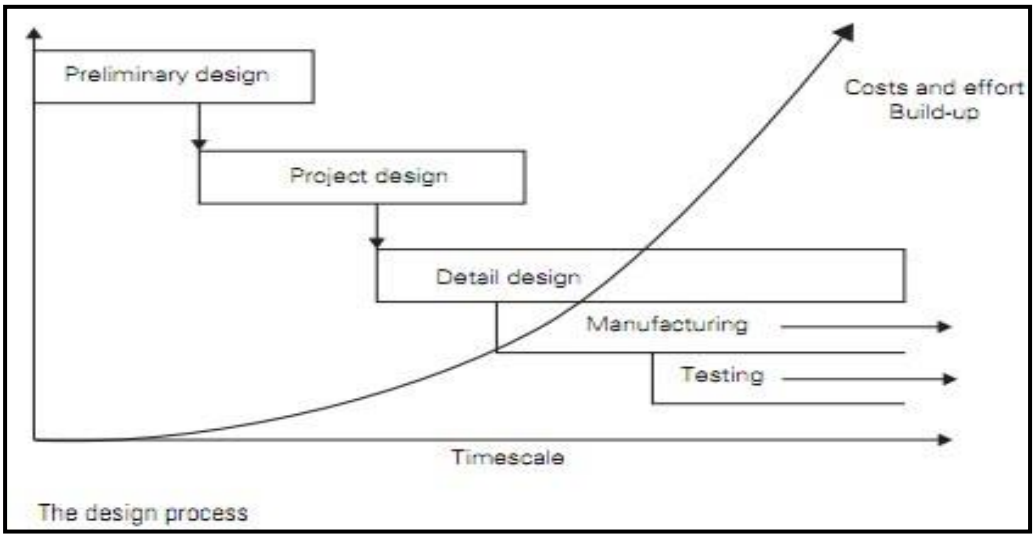


Figure 1.1 Design Methodology

The next phase (project design) takes the aircraft configuration defined towards the end of the preliminary design phase and involves conducting detailed analysis to improve the technical confidence in the design. Wind tunnel tests and computational fluid dynamic analysis are used to refine the aerodynamic shape of the aircraft. Finite element analysis is used to understand the structural integrity. Stability and control analysis and simulations will be

used to appreciate the flying characteristics. Mass and balance estimations will be performed in increasingly fine detail. Operational factors (cost, maintenance and marketing) and manufacturing processes will be investigated to determine what effects these may have on the final design layout. All these investigations will be done so that the company will be able to take a decision to proceed to manufacture'

1.1 Defining a new design

The preliminary design also involves a more detailed analysis of the aerodynamic loads and component weights. Based on this, the structural design is further refined. Aero elastic motion, fatigue and flutter are considered at this stage. Additional confirmation of estimates may require building and testing some of the proposed structural components. At the completion of this stage, the manufacturing of the aircraft is given serious consideration and the cost estimates are further refined. At the end of this step, the decision is made whether to build the aircraft.

With the decision to build the aircraft, the design is "frozen." The detailed design involves generating the detailed structural design of the aircraft. This involves every detail needed to build the aircraft. Sometimes component mock-ups are built to aid in the interior layout. However, the present use of computer aided design (CAD) software can substantially minimize the need for mock-ups by providing realistic 3-D views.

1.1.1 Aircraft Purpose

The starting point of any new aircraft is to clearly identify its purpose. With this, it is often possible to place a design into a general category. Such categories include combat aircraft, passenger or cargo transports, and general aviation aircraft. These may also be further refined into subcategories based on particular design objectives such as range (short or long), take-off or landing distances, maximum speed, etc. The process of categorizing is useful in identifying any existing aircraft that might be used in making comparisons to a proposed design.

With modern military aircraft, the purpose for a new aircraft generally comes from a military program office. For example, the mission specifications for the X-29 pictured in figure 1.1 came from a 1977 request for proposals from the U.S. Air Force Flight Dynamics Laboratory in which they were seeking a research aircraft that would explore the forward swept wing concept and

validate studies that indicated such a design could provide better control and lift qualities in extreme manoeuvres. With modern commercial aircraft, a proposal for a new design usually comes as the response to internal studies that aim to project future market needs. For example, the specifications for the most recent Boeing commercial aircraft (B-777) were based on the interest of commercial airlines to have a twin-engine aircraft with a payload and range in between those of the existing B-767 and B-747 aircraft.

1.1.2 Payload

The payload is what is carried on board and delivered as part of the aircraft's mission. Standard payloads are passengers, cargo or ordnance. The first two are considered nonexpendable payload because they are expected to be transported for the complete duration of the flight plan. Military ordnance is expendable payload since at some point in the flight plan it permanently leaves the aircraft. This includes bombs, rockets, missiles and ammunition for on-board guns. For personal or small general aviation aircraft, the payload includes the pilot as well as passengers and baggage. For business, commuter and commercial aircraft, the payload does not include the flight or cabin crew, only the passengers, baggage and cargo.

1.1.3 Cruise and Maximum Speeds

The mission of an aircraft usually dictates its speed range. Propeller-driven aircraft are usually designed to cruise at speeds between 150 to 300 knots. Jet powered aircraft have higher cruise speeds that are normally specified in terms of Mach number. The typical cruise Mach number for business and commercial jet aircraft is from 0.8 to 0.85.

This range of cruise speeds is close to optimum for maximizing the combination of payload weight, range and speed. The few supersonic commercial aircraft designs (1) have supersonic cruise speed as their principle design driver and (2) sacrifice range and payload. The cruise Mach number of the Concorde is 2.02. It will carry 100 passengers with a range of 3740 miles, which is considerably less than the aircraft of normal class, which have high subsonic cruise speeds. Modern military jet combat and attack aircraft usually have a flight plan that involves efficient cruise at high subsonic Mach numbers. This is usually in the range from Mach 0.85 to 0.90. The maximum speed is usually specified in the context of an intercept portion of the flight plan. This has a Mach number that is typically in the range of 2.0.

1.1.4 Normal Cruise Altitude

The cruise altitude is generally dictated by the cruise speed, propulsion system and cabin pressurization. An aircraft with an un-pressurized cabin would cruise no higher than 10,000 feet. With propeller-driven aircraft, turbo-charged piston engines can maintain a constant horsepower up to an altitude of approximately 20,000 feet. Higher altitudes are possible with turboprop aircraft, such as the Piper Cheyenne, which have a maximum ceiling from 35,000 to 41,000 feet. The decrease in air density with higher altitude lowers the drag, so that for these aircraft, the cruise range increases with altitude. At higher subsonic Mach numbers, the turbo-jet engine gives the higher efficiency. For subsonic turbo-jet aircraft, there is an optimum altitude where the fuel consumption is a minimum. This occurs at approximately 36,000 feet. Therefore, it is the best altitude for the most efficient, long range cruise of turbo-jet-powered aircraft.

1.1.5 Range

The range is the furthest distance the aircraft can fly without refuelling. In a flight plan, range refers to the distance travelled during the cruise phase. The choice of the range is one of the most important decisions because it has a large (exponential) effect on the aircraft take-off weight. An aircraft that is intended to fly across the United States (New York to Seattle) should have a minimum range of 2500 nautical miles. A range of 3500 nautical miles would be necessary for transatlantic flights from East coast U.S. cities to coastal cities in Western Europe. Shorter range transports that are designed to fly between major cities in a regional area (e.g., Los Angeles to San Francisco) should have a minimum range of 500 nautical miles. Twice that range would allow an aircraft to fly non-stop between most of the major cities along either coast of the United States.

1.1.6 Endurance

Endurance is the amount of time an aircraft can fly without refuelling. With a reconnaissance aircraft, endurance is one of the main design drivers. For a commercial aircraft, a flight plan will include an endurance phase to allow for time that night is spent in a holding pattern prior to landing. For operation within the continental United States commercial aircraft are required to be able

to hold for 45 minutes at normal cruise fuel consumption. For international operation, the required hold time is 30 minutes.

1.1.7 Take-off Distance

The total take-off distance of the length of a runway needed to accelerate, lift off, and climb to prescribe obstacle height. The obstacle height is 50 feet for military and small civil aircraft, and 35 feet for commercial aircraft.The take-off distance that is required to accomplish this depends on different factors in the design such as the thrust to weight ratio, the maximum lift to weight ratio and the surface of the air field that affects the rolling friction of the landing-gear wheels.

1.2 PHASES OF AIRPLANE DESIGN

The complete design process has gone through three distinct phases that are carried out in sequence. They are

- Conceptual design
- Preliminary design
- Detailed design

CONCEPTUAL DESIGN

The design process starts with a set of specifications (requirements)for a new aeroplane, or much less frequently as the response to the desire to implement some pioneering, innovative new ideas and technology. In either case, there is a rather concrete good towards which the designers are aiming. The first steps towards achieving that goal constitute the conceptual design phase. Here, within a certain somewhat fuzzy latitude, the overall shape, size, weight and performance of the new design are determined.

During the conceptual design phase, the designer is influenced by such qualitative as the increased structural loads imposed by a high horizontal tail location through the fuselage, and the difficulties associated with cut-outs in the wing structure if the landing gear are to be retracted into the wing rather than the fuselage or engine nacelle.

PRELIMINARY DESIGN

In the preliminary design phase, only minor changes are made to the configuration layout (indeed, if major changes were demanded during this phase, the conceptual design process have been actually flawed, to begin with. It is in the preliminary design phase that serious structural and control system analysis and design take place.

DETAIL DESIGN

The detail design phase is literally the nuts and bolts phase of aeroplane design. The aerodynamic, propulsion, structures performance and flight control analysis have all been finished with the preliminary design phase. The aeroplane is now simply a machine to be fabricated. The pressure design of each individual rib, spar and section of skin now take place.

1.2.1 Design Process

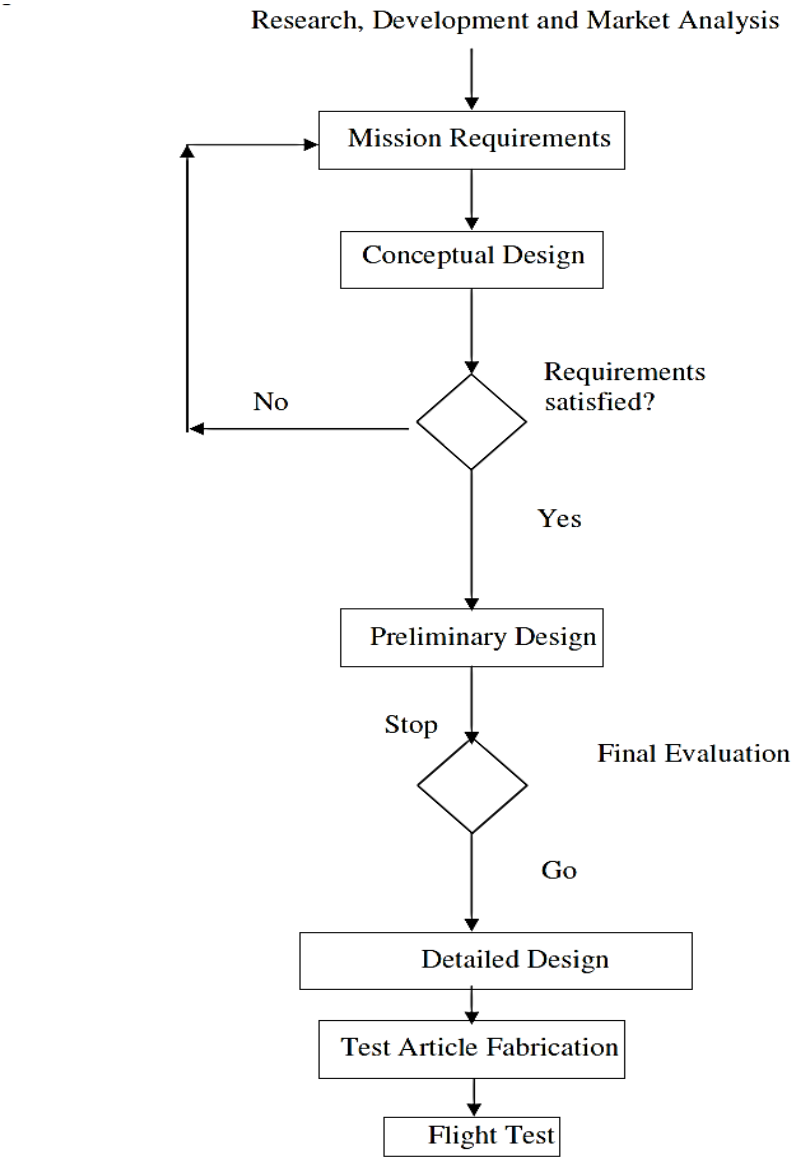


Figure 1.2 Conceptual design

1.3 Conceptual Design

This article deals with the steps involved in the conceptual design of an aircraft. It is broken down in to several elements, which are followed in order. These consist of,

1. Literature survey
2. Preliminary data acquisition
3. Estimation of aircraft weight

a. Maximum take-off weight

b. Empty weight of the aircraft

c. Weight of the fuel

d. Fuel tank capacity

4. Estimation of critical performance parameters

a. Wing area

b. Lift and drag coefficients

c. Wing loading

d. Power loading

e. Thrust to weight ratio

5. Engine selection

6. Performance curves

7. 3-view diagram

Engineering units of measurement

Many different systems of measurement are used throughout the world but two have become most common in aeronautical engineering. In the US the now inappropriately named ‘British’ system (foot, pound and second) is widely used. In the UK and over most of Europe, System International (SI) (metres, newton and second) units are standard. It is advised that students only work in one system. Confusion (and disaster) can occur if they are mixed.

The results of the design analysis can be quoted in both types of unit by applying standard conversions. The conversions below are typical:

1 inch = 25.4 mm

1 sq. ft = 0.0929 sq. m

1USgal = 3.785 litres

1USgal = 0.833 Imp. gal

1 statute mile = 1.609 km

1 ft/s = 0.305 m/s

1 knot = 1.69 ft/s

1poundforce=4.448 Newton

1 horsepower= 745.7 watts

1 foot = 0.305 meters

1 cu. ft = 28.32 litres

1 Imp. Gal = 4.546 litres

1 litre = 0.001 cubic meters

1 nautical mile = 1.852 km

1 knot = 0.516 m/s

1 knot = 1.151 mph

1 pound mass = 0.454 kilogram

1 horsepower = 550 ft lb/s

To avoid confusing pilots and air traffic control, some international standardization of a unit has had to be accepted. These include:

Aircraft altitude – feet Aircraft forward speed – knots∗

Aircraft range – nautical miles Climb rate – feet per minute

1.4 BLOCK ARRAY FOR CONCEPTUAL DESIGN

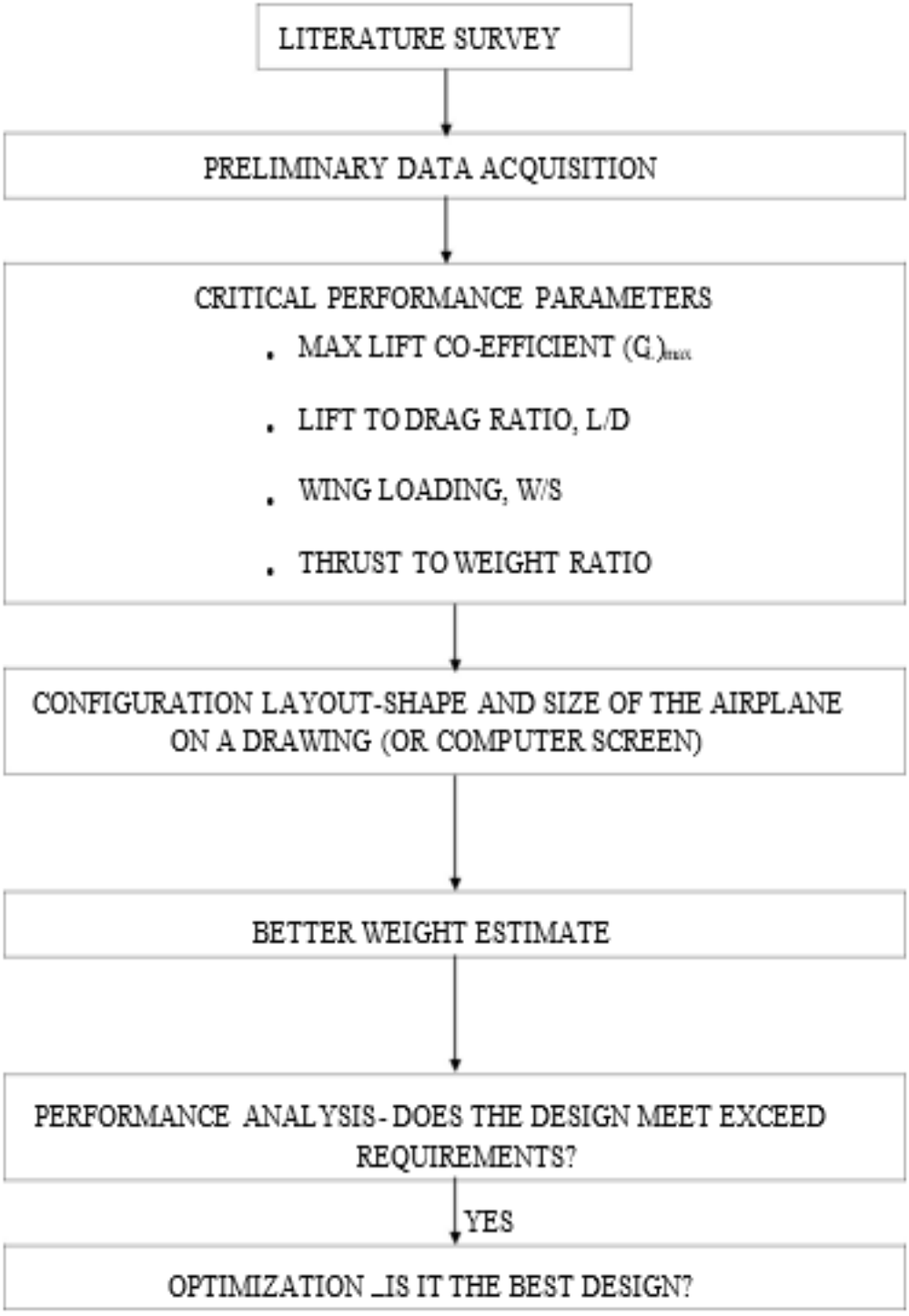


Figure 1.3 Conceptual design

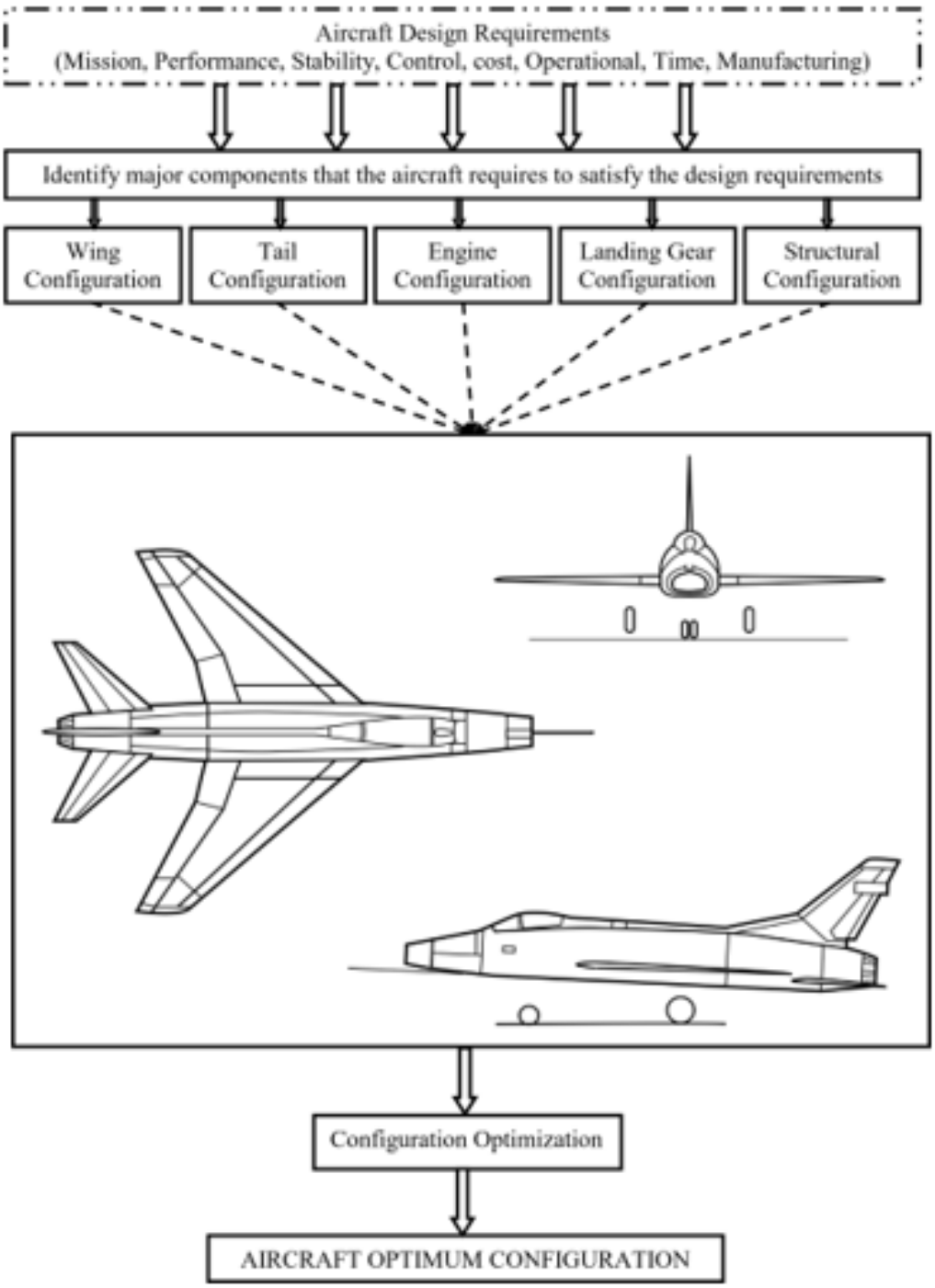


Figure 1.4 Aircraft design configuration

CHAPTER 2

COMPARATIVE STUDY OF DIFFERENT TYPES OF AIRPLANES

The following types of aircraft are taken for the study

- HOMEBUILT PROPELLER DRIVEN
- SINGLE ENGINE PROPELLER DRIVEN
- TWIN ENGINE PROPELLER DRIVEN
- AGRICULTURAL AIRPLANES
- BUSINESS JETS
- REGIONAL TURBO PROPELLER DRIVEN AIRPLANE
- TRANSPORT JETS
- MILITARY TRAINERS
- FIGHTERS
- MILITARY PATROL BOMB AND TRANSPORT AIRPLANES
- FLYING BOATS, AMPHIBIANS AND FLOAT AIRPLANES
- SUPERSONIC CRUISE AIRPLANES

Among this one aircraft is chosen for the study on its specification and performance.

2.1 HOMEBUILT AIRCRAFT

Homebuilt aircraft, also known as amateur-built aircraft or kit planes, are constructed by persons for whom this is not a professional activity. These aircraft may be constructed from "scratch," from plans, or from assembly kits.

Homebuilt aircraft are generally small, one to four- seat sports planes which employ simple methods of construction. Fabric-covered wood or metal frames and plywood are common in the aircraft structure. Fiberglass and other composites as well as full aluminium construction techniques are also being used.

2.2 SINGLE ENGINE PROPELLER DRIVEN AIRCRAFT

Single engine propeller aircraft are well-suited for short missions under 300 miles. They can easily access smaller airports with shorter runways, increasing the number of airstrips they’re able to reach within their ranges. They are also known as light aircrafts. They are mainly used for freight transport, sightseeing, photography, and other similar roles as well as personal use.

These aircrafts are nowadays used for training of pilots for the commercial passenger aircrafts. Using these aircrafts these aircrafts they acquire their pilot license

2.3 TWIN ENGINE PROPELLER DRIVEN AIRCRAFT

Causal observation of twin-engine propeller aircraft reveals that most configurations consist of a forward wing with nacelle-mounted engines on each side and a single tail empennage. However, about a third of the aircraft are of various engine and airframe arrangements. The alternative ways in which a twin-engine propeller-driven aircraft can be put together (excluding bi-planes and helicopters.). Aircraft are arranged in nine categories, as much as possible, with similar configuration traits. Each configuration category is identified with a sample aircraft.

2.4 AGRICULTURAL AIRPLANES

An agricultural aircraft is an aircraft that was built for agricultural use usually the aerial application of pesticides (crop-dusting) or fertilizer in these roles they are referred to as "crop dusters" or "top dressers". Agricultural aircraft are also used for hydroseeding. Agricultural aircraft are typically small,

simple, and rugged. Most have spraying systems attached to the trailing edges of their wings, and pumps are usually driven by wind turbines.

2.5 BUSINESS JETS

A business jet, private jet or bizjet is a jet aircraft designed for transporting small groups of people. Business jets may be adapted for other roles, such as evacuation of causalities or express parcel deliveries, and some are used by public bodies, government officials or the armed forces.

2.6 REGIONAL TURBO PROPELLER DRIVEN AIRPLANE

A regional airliner or a feederliner is a small airliner that is designed to fly up to 100 passengers on short-haul flights, usually feeding larger carriers' airline hubs from small markets. This class of airliners are typically flown by the regional airlines that are either contracted by or subsidiaries of the larger airlines. Regional airliners are used for short trips between smaller towns or from a larger city to a smaller city. Feeder line, commuter, and local service are all alternative terms for the same class of flight operations.

2.7 COMMERCIAL TRANSPORT AIRPLANE

An airliner is a type of aircraft for transporting passenger and air cargo. Such aircraft are most often operated by airlines. An airliner is typically defined as an aeroplane intended for carrying multiple passengers or cargo in commercial service. The largest of them are wide-body jets which are called also twin-aisle. These are usually used for long-haul flights between airline hubs and major cities. A smaller, more common class of airliners is the narrow-body or single-aisle used for short to medium-distance flights with fewer passengers than their wide-body counterparts.

2.8 MILITARY TRAINER

A trainer is a class of aircraft designed specifically to facilitate flight training of pilot and aircrews. The use of a dedicated trainer aircraft with additional safety features—such as tandem flight controls, forgiving flight characteristics and a simplified cockpit arrangement—allows pilots-in-training to safely advance their real-time piloting, navigation and warfighting skills

without the danger of overextending their abilities alone in a fully featured aircraft.

2.9 MILITARY PATROL BOMB AND TRANSPORT AIRPLANES

Military transport aircraft or military cargo aircraft are typically fixed wing and rotary wing cargo aircraft which are used to airlift troops, weapons and other military equipment by a variety of methods to any area of military operations around the surface of the planet, usually outside the commercial flight routes in uncontrolled airspace.

Originally derived from bombers, military transport aircraft were used for delivering airborne forces during World War II and towing military gliders. Some military transport aircraft are tasked to perform multi-role duties such as aerial refuelling and, rescue missions, tactical, operational and strategic airlifts onto unprepared runways, or those constructed by engineers.

2.10 FLYING BOATS, AMPHIBIANS AND FLOAT AIRPLANES

A flying boat is a fixed-winged seaplane with a hull, allowing it to land on water, that usually has no type of landing gear to allow operation on land. It differs from a floatplane as it uses a purpose-designed fuselage which can float, granting the aircraft buoyancy. Flying boats may be stabilized by underwing floats or by wing-like projections (called sponsons) from the fuselage. Their advantage lay in using water instead of expensive land-based runways, making them the basis for international airlines in the interwar period. They were also commonly used for maritime patrol and air-sea rescue.

2.11 SUPER CRUISE AIRCRAFT

Super cruise is sustained supersonic flight of a supersonic aircraft with a useful cargo, passenger, or weapons load performed efficiently, which typically precludes the use of highly inefficient afterburners or "reheat". Many well-known supersonic military aircraft not capable of super cruise must maintain supersonic flight in short bursts typically with afterburners. Aircraft such as the SR-71 Blackbird is designed to cruise at supersonic speed with afterburners enabled. Before discussing further about airplane design, it is helpful to know about different types of airplanes. These are classified according to (a) purpose (b) configuration.

2.12 FIGHTER AIRCRAFT

A fighter aircraft is a military aircraft designed primarily for air-to-air combat against other aircraft, as opposed to bombers and attack aircraft, whose main mission is to attack ground targets. The hallmarks of a fighter are its speed, maneuvrebility, and small size relative to other combat aircraft. Fighter airplanes have been described by a variety of labels. Early in World War I they were used as scout planes for artillery spotting, but it was quickly discovered that they could be armed and do combat with one another, shoot down enemy bombers, and conduct other tactical missions. Since that time fighters have assumed various specialized combat roles.
An interceptor is a fighter whose design and armament best fit it for intercepting and defeating or routing invading fighters. A night fighter is one equipped with sophisticated radar and other instruments for navigating in unfamiliar or hostile territory at night. A day fighter is an airplane in which weight and space are saved by eliminating the special navigational equipment of the night fighter. The air supremacy, or air superiority, fighter must have long-range capability, to enable it to travel deep into enemy territory to seek out and destroy enemy fighters. Fighter-bombers fill the dual role suggested by their name.

In the days of aerial “dogfights” during World War I, light machine guns were synchronized to fire through the airplane’s propeller, and by the end of the war, fighters such as the German Fokker D.VII and the French Spad were attaining speeds of 135 miles (215 km) per hour. Most of these were biplanes made of wooden frames and cloth skins, as were many of the standard interwar fighters.

The fighter's main tactical purpose is to establish air superiority over the battlefield. The success or failure of a combatant's efforts to gain air

superiority hinges on several factors including the skill of its pilots, the tactical soundness of its doctrine for deploying its fighters, and the numbers and performance of those fighters. Many fighters have secondary capabilities such as ground attack and some types, such as fighter-bombers, are designed from the outset for dual roles. Other fighter designs are highly specialized while still filling the main air superiority role, these include the interceptor, heavy fighter, and night fighter.

A fighter aircraft is primarily designed for air-to-air combat. A given type may be designed for specific combat conditions, and in some cases for additional roles such as air-to-ground fighting. Historically the British Royal Flying Corps and Royal Air Force referred to them as "scouts" until the early 1920s, while the U.S. Army called them "pursuit" aircraft until the late 1940s. The UK changed to calling them fighters in the 1920s, while the US Army did so in the 1940s. A short-range fighter designed to defend against incoming enemy aircraft is known as an interceptor.



Figure 2.1 Miraj 2000

Classification of airplane according to purpose:

There are two main types of airplanes viz. civil and military.

The category of civil airplanes includes passenger, cargo, agricultural, sports and ambulance. The category of military airplanes includes fighter, bomber, interceptor, reconnaissance, and aircraft for logistic support like troop-carriers and rescue aircraft Military aircraft are often designed to cater to more than one role e.g. fighter bomber or intercept or fighter. The purpose of an airplane dictates its specifications.

For example, a passenger airplane should have

(a) high level of safety,

(b) high payload carrying capacity,

(c) economy in operation,

(d) comforts,

(e) ability to fly in any weather and

(f) ability to use aerodromes of respective classes.

A bomber should have

(a) long range,

(b) high load carrying capacity,

(c) high speed,

(d) high endurance,

(e) high ceiling and

An interceptor should have

(a) high rate of climb,

(b) high ceiling (3 to 4 km above contemporary bombers),

(c) high speed,

(d) high manoeuvrability,

(e) ability to fly in any weather and

(f) appropriate armament.

Classification according to configuration:

a) Shape, number and position of wing.

b) Type of fuselage.

c) Location of horizontal tail.

d) Location and number of engines.

The different types of configurations are shown in figure

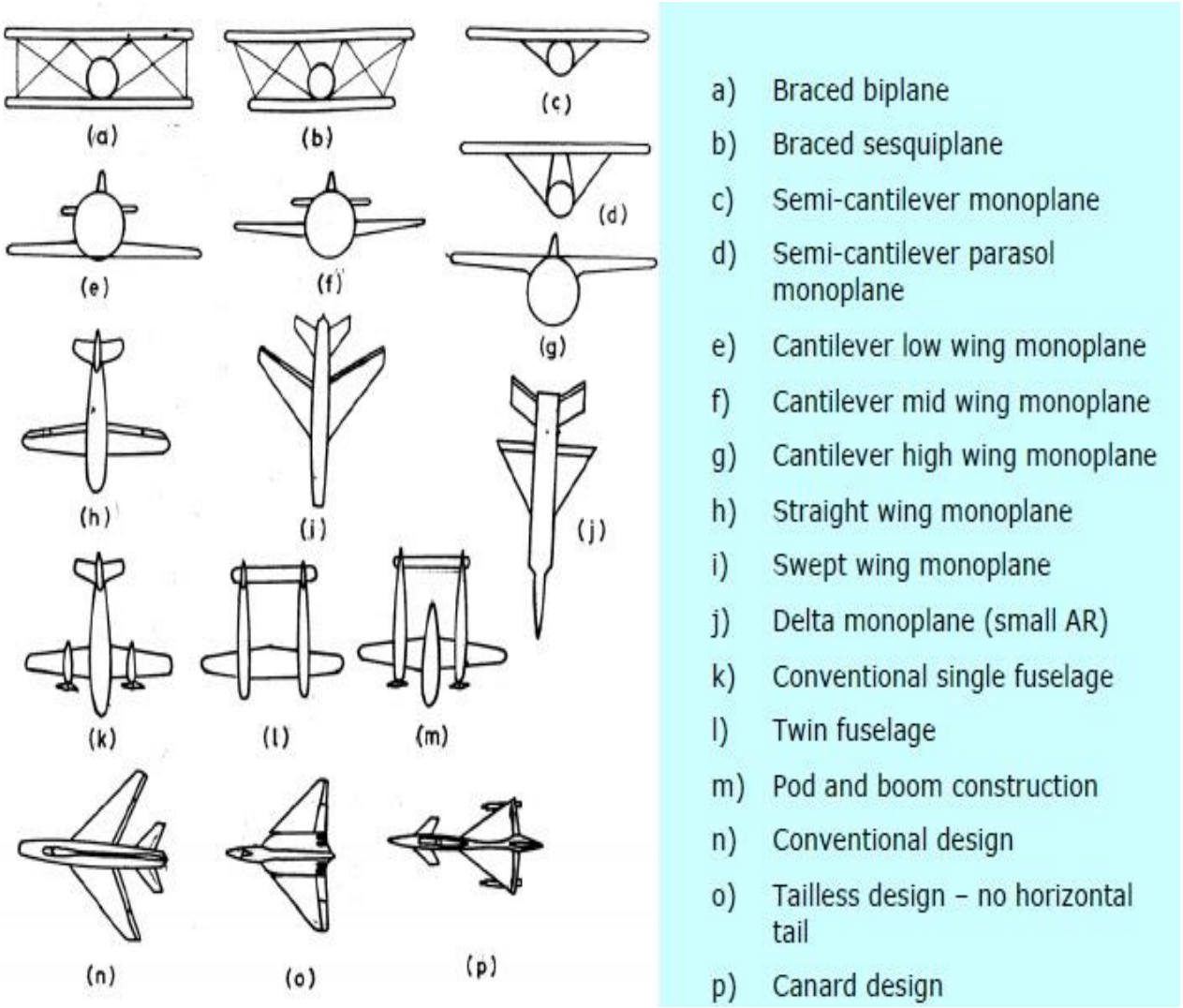


Figure 2.2 Different Types of Aircraft

CHAPTER 3

COMPARATIVE STUDY ON SPECIFICATIONS AND PERFORMANCE

CREW

A group of people who work on and operate an aircraft.

PASSENGERS

A traveller on a public or private conveyance other than the pilot and crew.

EMPTY WEIGHT

The empty weight of an aircraft is the weight of the aircraft without including passengers, baggage, or fuel.

PAYLOAD

The payload is what the airplane is intended to transport – passengers, baggage, freight etc.

TAKE OFF WEIGHT

It is the maximum weight at which the pilot is allowed to attempt to take off due to structural or other limits.

LANDING WEIGHT

It is the maximum aircraft gross weight due to design or operational limitations at which an aircraft is permitted to land.

WING LOADING

It is the total weight of an aircraft divided by the area of its wing.

$$\frac{W}{S} = \frac{1}{2}\rho_\infty V_{\text{stall}}^2 (C_L)_{\max}$$

WING AREA

It is the projected area of the wing planform and is bounded by the leading trailing edges and the wing tips.

WING SPAN

The maximum distance between the two wing tips and id denoted by b.

THRUST TO WEIGHT RATIO

It is a dimensionless ratio of thrust to weight or a vehicle propelled by such an engine that indicates the performance of the engine or vehicle.

WING SWEEP BACK ANGLE

The angle at which a wing is either swept backward or occasionally forward from its root.

ASPECT RATIO

It is the ratio of wing span to its mean chord. It is also equal to the square of the wing span divided by the wing area.

$$\text{Aspect ratio} = b^2/s$$

THRUST

It is the force exerted by the engines on the airframe to overcome drag and is measured in Newton (N)**.**

POWER

It is the rate at which work is done.

WET THRUST

It is the augmented thrust with the usage of afterburners or liquid injection.

CRUISE SPEED

The speed at which combustion engines have an optimum efficiency level for fuel consumption and power output.

RATE OF ASCENT (CLIMB)

The rate of positive altitude changes with respect to time or distance.

RATE OF DESCENT (SINK)

The rate of negative altitude changes with respect to time or distance.

ABSOLUTE CEILING

It is the altitude where maximum rate of climb is zero is the highest altitude achievable in steady, level flight.

SERVICE CEILING

It is the altitude where the maximum rate of climb is 100 ft/min and it's represented the practical upper limit for steady, level flight.

RANGE

It is the maximum distance an aircraft can fly between take-off and landing, as limited by fuel capacity in powered aircraft.

ENDURANCE

It is the maximum length of time that an aircraft can spend in cruising flight as long as the fuel is available.

STALLING VELOCITY

It is the velocity below which an aircraft will descend, or 'stall', regardless of its angle of attack.

TAKE-OFF DISTANCE

It consists of two parts, the ground run and the distance from where the vehicle leaves the ground until it reaches 50 ft or 15 m. The sum of these two distances is considered the take-off distance.

LANDING DISTANCE

It is the distance required to bring the aircraft to a stop under ideal conditions, assuming the aircraft crosses the runway threshold at a height of 50 ft, at the correct speed.

In the designer's perspective it is necessary to compare the existing airplanes that are of same type as that of our desired airplanes. Their important parameters, positive aspects and pitfalls to be overcome are taken into consideration. The data has been collected for supersonic fighter aircrafts. Several parameters are compared for 19 aircrafts and different parameters are plotted on the graph. The parameters compared are:

PARAMETER	**UNITS**
Length	m
Height	m
Wing Span	m
Wing Area	m^2
Wing Loading	kg/m^2
Aspect Ratio	-
Service Ceiling	m
Rate of Climb	m/s
Max Cruise Speed	kmph
No of Engines, Types	-
Empty Weight	kg
Max Take-Off Weight (MTOW)	kg
Thrust	kn
Crew	-
Range	km

Table-3.1 Notations for different parameters

CHAPTER 4

PREPARATION OF COMPARATIVE DATA SHEETS

INTRODUCTION

It's the collection of data of various aeroplanes to consolidate the data for the aeroplane that I design. Around 9 aeroplanes with their design parameters are compared.

AIRCRAFT FOR REFERENCE

1	Sukhoi Su-27
2	Chengdu J-20
3	Sukhoi Su-30
4	Sukhoi Su-33
5	Sukhoi Su-34
6	Sukhoi Su-37
7	Shenyang J-11
8	Sukhoi Su-35
9	Sukhoi Su-30 MKI
10	McDonnell Douglas F-15C
11	Shenyang J-15
12	General Dynamics F-111 Aardvark
13	Grumman F-14 Tomcat
14	Lockheed Martin F-22 Raptor
15	Sukhoi Su-57
16	Mikoyan-Gurevich MiG-25
17	Mikoyan-Gurevich MiG-31
18	McDonnell Douglas F-15E
19	Sukhoi Su-24MK
20	Lockheed Martin F-35 Lightning II
21	Tupolev Tu-128
22	Xi'an JH-7
23	Boeing F/A 18 Superhornet
24	Panavia Tornado F3
26	McDonnell Douglas F-4 Phantom
27	Sukhoi Su-47
28	Shenyang FC-31

1. Sukhoi Su-27



Table-4.1 Sukhoi Su- 27specifications

PARAMETER	**VALUES**
Length(m)	21.93
Wing Span(m)	14.70
Wing Area(m^2)	62
Rate of Climb(m/s)	300
Max Cruise Speed(kmph)	1350
No of Engines	2
Empty Weight(kg)	22500
Max Take-Off Weight (kg)	30000
Crew	1
Range(km)	4000
Maximum Thrust (kn)	245.2

2. Chengdu J-20



Table-4.2 Chengdu J-20 specifications

PARAMETER	VALUES
Length(m)	21.2
Wing Span(m)	13.01
Wing Area(m^2)	73
Rate of Climb(m/s)	304
Max Cruise Speed(kmph)	2100
No of Engines	2
Empty Weight(kg)	17000
Max Take-Off Weight (kg)	37000
Crew	1
Range(km)	5500
Maximum Thrust (kn)	294

3. Sukhoi Su-30



Table-4.3 Sukhoi 30 specifications

PARAMETER	VALUES
Length(m)	21.935
Wing Span(m)	14.7
Wing Area(m^2)	62
Rate of Climb(m/s)	230
Max Cruise Speed(kmph)	1350
No of Engines	2
Empty Weight(kg)	17700
Max Take-Off Weight (kg)	34500
Crew	2
Range(km)	3000
Maximum Thrust (kn)	245.16

4. Sukhoi Su-33



Table-4.4 Sukhoi 33 specifications

PARAMETER	VALUES
Length(m)	22.00
Wing Span(m)	14.7
Wing Area(m^2)	67.84
Rate of Climb(m/s)	325
Max Cruise Speed(kmph)	1350
No of Engines	2
Empty Weight(kg)	18,400
Max Take-Off Weight (kg)	33,000
Crew	2
Range(km)	3000
Maximum Thrust(kn)	251

5. ***Sukhoi Su-34***



Table-4.5 Sukhoi Su-34 specifications

PARAMETER	VALUES
Length(m)	23.34
Wing Span(m)	14.7
Wing Area(m^2)	62.04
Rate of Climb(m/s)	300
Max Cruise Speed(kmph)	1100
No of Engines	2
Empty Weight(kg)	22,500
Max Take-Off Weight (kg)	45,100
Crew	2
Range(km)	4500
Maximum Thrust (Kn)	264

6.Sukhoi SU-37



Table-4.6 Sukhoi SU-37 specifications

PARAMETER	VALUES
Length(m)	21.93
Wing Span(m)	14.7
Wing Area(m^2)	62
Rate of Climb(m/s)	230
Max Cruise Speed(kmph)	1350
No of Engines	2
Empty Weight(kg)	18,500
Max Take-Off Weight (kg)	34,000
Crew	2
Range(km)	3300
Maximum Thrust (Kn)	284

7.Shenyang J_11



Table-4.7 Shenyang J-11 specifications

PARAMETER	VALUES
Length(m)	21.90
Wing Span(m)	14.7
Wing Area(m^2)	52.84
Rate of Climb(m/s)	300
Max Cruise Speed(kmph)	1300
No of Engines	2
Empty Weight(kg)	16,380
Max Take-Off Weight (kg)	33,000
Crew	1
Range(km)	3530
Maximum Thrust (Kn)	264

8.Sukhoi SU-35



Table-4.8 Sukhoi SU-35 specifications

PARAMETER	VALUES
Length(m)	21.93
Wing Span(m)	15.3
Wing Area(m^2)	62
Rate of Climb(m/s)	280
Max Cruise Speed(kmph)	1170
No of Engines	1
Empty Weight(kg)	19000
Max Take-Off Weight (kg)	34,500
Crew	2
Range(km)	3600
Maximum Thrust (Kn)	274.6

9. Sukhoi SU-30 MKI



Table-4.9 Sukhoi SU-30 MKI Specifications

PARAMETER	VALUES
Length(m)	21.93
Wing Span(m)	14.70
Wing Area(m^2)	62
Rate of Climb(m/s)	300
Max Cruise Speed(kmph)	1170
No of Engines	2
Empty Weight(kg)	18400
Max Take-Off Weight (kg)	38,800
Crew	2
Range(km)	3000
Maximum Thrust (Kn)	246

10. McDonnell Douglas F-15 C



Table-4.10 **Mcdonnell Douglas F-15 C** ***specifications***

PARAMETER	VALUES
Length(m)	19.43
Wing Span(m)	13.06
Wing Area(m^2)	65.5
Rate of Climb(m/s)	340.6
Max Cruise Speed(kmph)	1055
No of Engines	2
Empty Weight(kg)	12701
Max Take-Off Weight (kg)	30,844
Crew	1
Range(km)	3862
Maximum Thrust (Kn)	211.4

11.Shengyang J-15



Table-4. **Shengyang J-15** ***specifications***

PARAMETER	VALUES
Length(m)	22.28
Wing Span(m)	15.00
Wing Area(m^2)	62.04
Rate of Climb(m/s)	325
Max Cruise Speed(kmph)	1270
No of Engines	2
Empty Weight(kg)	17500
Max Take-Off Weight (kg)	32,500
Crew	1
Range(km)	3500
Maximum Thrust (Kn)	245.2

12.Lockheed Martin F-22 Raptor



Table-4.12 **Lockheed Martin F-22 Raptor** ***specifications***

PARAMETER	VALUES
Length(m)	18.92
Wing Span(m)	13.56
Wing Area(m^2)	78.04
Rate of Climb(m/s)	350
Max Cruise Speed(kmph)	1963
No of Engines	2
Empty Weight(kg)	19700
Max Take-Off Weight (kg)	38,000
Crew	1
Range(km)	3000
Maximum Thrust (Kn)	312

13. Mikoyan-Gurevich MiG-25



Table-4.13 **Mikoyan-Gurevich MiG-25** ***specifications***

PARAMETER	VALUES
Length(m)	23.82
Wing Span(m)	14.01
Wing Area(m^2)	61.4
Rate of Climb(m/s)	208
Max Cruise Speed(kmph)	2500
No of Engines	2
Empty Weight(kg)	20000
Max Take-Off Weight (kg)	36,720
Crew	1
Range(km)	1730
Maximum Thrust (Kn)	220.2

14.Sukhoi Su-47



Table-4.14 Sukhoi Su-47 specifications

PARAMETER	VALUES
Length(m)	22.60
Wing Span(m)	16.70
Wing Area(m^2)	56
Rate of Climb(m/s)	233
Max Cruise Speed(kmph)	1800
No of Engines	2
Empty Weight(kg)	25,670
Max Take-Off Weight (kg)	34,000
Crew	1
Range(km)	3300
Maximum Thrust (Kn)	306

15.Lockheed Martin F-35 Lightning II



Table-4.15 **Lockheed Martin F-35 Lightning II** ***specifications***

PARAMETER	VALUES
Length(m)	15.70
Wing Span(m)	11.00
Wing Area(m^2)	43
Rate of Climb(m/s)	228.6
Max Cruise Speed(kmph)	1048.58
No of Engines	1
Empty Weight(kg)	13290
Max Take-Off Weight (kg)	31,751
Crew	1
Range(km)	1670
Maximum Thrust (Kn)	191

CHAPTER 5

COMPARATIVE GRAPHS PREPARATION AND SELECTION OF MAIN PARAMETERS FOR THE DESIGN

5.1 CONSOLIDATION OF DATA

In this section we will be comparing 19 different aircrafts that flew in supersonic regime with a purpose of military activity. Several parameters where compared so as to determine an optimized value of parameters that can be used in the process of designing an improvised Supersonic Fighter jet aircraft. The comparison is done by clearly differentiating the parameters based on various aspects as follows:

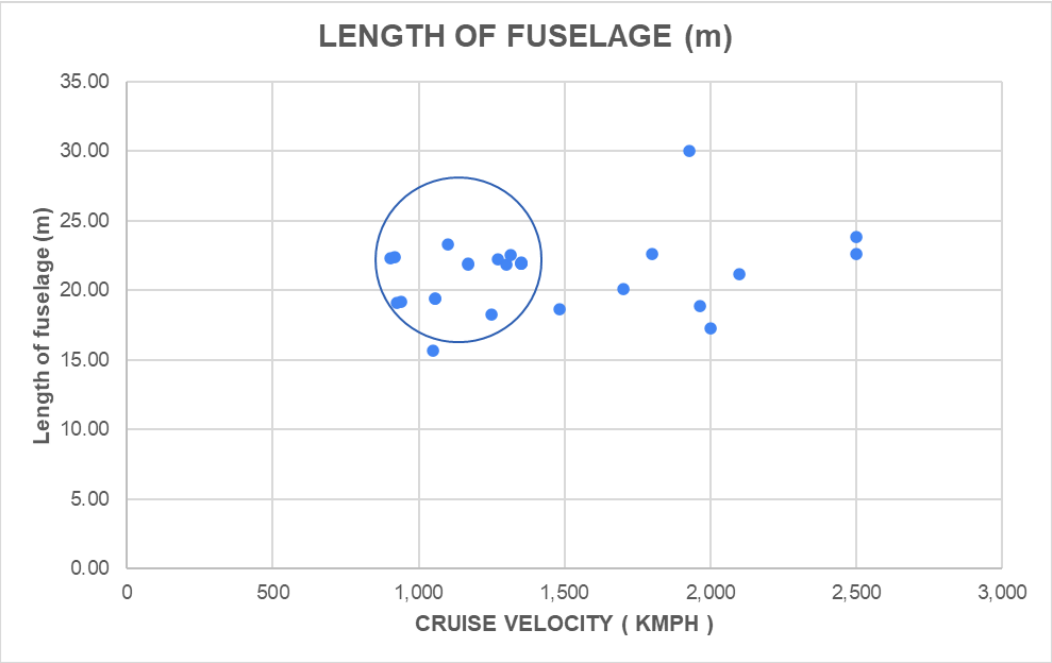
1. General Characteristics:
   - i) Crew
   - ii) Length
   - iii) Height
   - iv) Wing Area
   - v) Wing span
   - vi) Aspect Ration
2. Weight Configuration
   - i) Maximum Take-off Weight
   - ii) Empty Weight
   - iii) Payload Weight
   - iv) Thrust to Weight Ratio
3. Performance
   - i) Maximum Speed
   - ii) Service Ceiling
   - iii) Range
   - iv) Rate of climb
   - v) Wing loading
4. Engine Characteristics:
   - i) Dry Thrust
   - ii) Afterburner Thrust

Table-5.1 Consolidation of Data-1

S.NO	AIRCRAFT NAME/MODEL	MAXIMUM TAKE OF WEIGHT (kg)	LENGTH OF FUSELAGE (m)	WING SPAN (m)	WING AREA (m^2)	EMPTY WEIGHT (Kg)	CRUISE VELOCITY (Kmph)	MAXIMUM RANGE (KM)	RATE OF CLIMB (m/s)	MAXIMUM THRUST (KN)	NUMBER OF ENGINES	NUMBER OF CREW
1	Sukhoi Su-27	30,000	21.93	14.70	62	22,500	1,350	4,000	300	245.2	2	1
2	Chengdu J-20	37,000	21.20	13.01	73	17,000	2,100	5,500	304	294	2	1
3	Sukhoi Su-30	34,500	21.93	14.70	62	17,700	1,350	3,000	230	245.16	2	2
4	Sukhoi Su-33	33,000	22.00	14.70	67.84	18,400	1,350	3,000	325	251	2	2
5	Sukhoi Su-34	45,100	23.34	14.70	62.04	22,500	1,100	4,500	300	264	2	2
6	Sukhoi Su-37	34,000	21.93	14.70	62	18,500	1,350	3,300	230	284	2	2
7	Shenyang J-11	33,000	21.90	14.70	52.84	16,380	1,300	3,530	300	264	2	1
8	Sukhoi Su-35	34,500	21.90	15.3	62	19,000	1,170	3,600	280	274.6	2	1
9	Sukhoi Su-30 MKI	38,800	21.93	14.70	62	18,400	1,170	3,000	300	246	2	2
10	McDonnell Douglas F-15C	30,844	19.43	13.06	56.5	12,701	1,055.00	3862	340.6	211.4	2	1
11	Shenyang J-15	32,500	22.28	15.00	62.04	17,500	1,270	3500	325	245.2	2	1
12	General Dynamics F-111 Aardvark	45,359	22.40	19.00	61.07	21,410	919	2,140	131.5	224	2	2
13	Grumman F-14 Tomcat	33,725	19.13	19.55	52.5	19,838	927	3,000	230	250	2	2
14	Lockheed Martin F-22 Raptor	38,000	18.92	13.56	78.04	19,700	1,963	3,000	350	312	2	1
15	Sukhoi Su-57	35,000	20.10	14.10	78.8	18,000	1,700	3,500	325	284.4	2	1
16	Mikoyan-Gurevich MiG-25	36,720	23.82	14.01	61.4	20,000	2,500	1,730	208	220.2	2	1
17	Mikoyan-Gurevich MiG-31	46,200	22.62	13.46	61.6	21,820	2,500	2,240	288	304	2	2
18	McDonnell Douglas F-15E	36,741	19.45	13.05	56.5	14,379	1,055	3,750	250	211.4	2	2
19	Sukhoi Su-24MK	43,755	22.53	17.64	55.2	22,300	1,315	2,775	150	219.6	2	2
20	Lockheed Martin F-35 Lightning II	31,751	15.70	11.00	43	13,290	1,049.58	1,670	228.6	191	1	1
21	Tupolev Tu-128	43,700	30.06	17.53	96.94	24,500	1,926	2,565	127	198.2	2	2
22	Xi'an JH-7	28,475	22.32	12.80	42.2	14,500	903	907.48	155	182.52	2	2
23	Boeing F/A 18 Superhornet	29,937	18.31	13.62	46.5	14,552	1,250	2,346	228	196	2	1
24	Panavia Tornado F3	27,986	18.68	13.91	26.6	14,500	1,482	1,667	76.7	147	2	2
26	McDonnell Douglas F-4 Phantom	28,030	19.20	11.70	49.2	13,757	940	2816	210	158.76	2	2
27	Sukhoi Su-47	34,000	22.60	16.70	56	25,670	1,800	3,300	233	306	2	1
28	Shenyang FC-31	28,000	17.30	11.50	50	17237	2,000	1,200	330.2	220	2	1

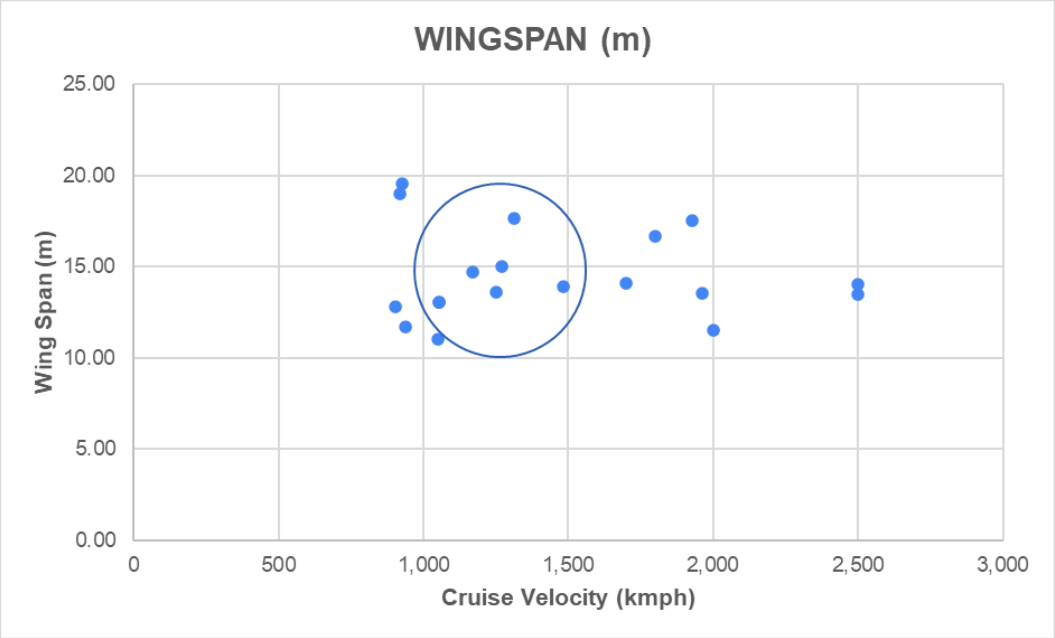
5.2 COMPARATIVE GRAPHS PREPARATION

Length – 21.2m



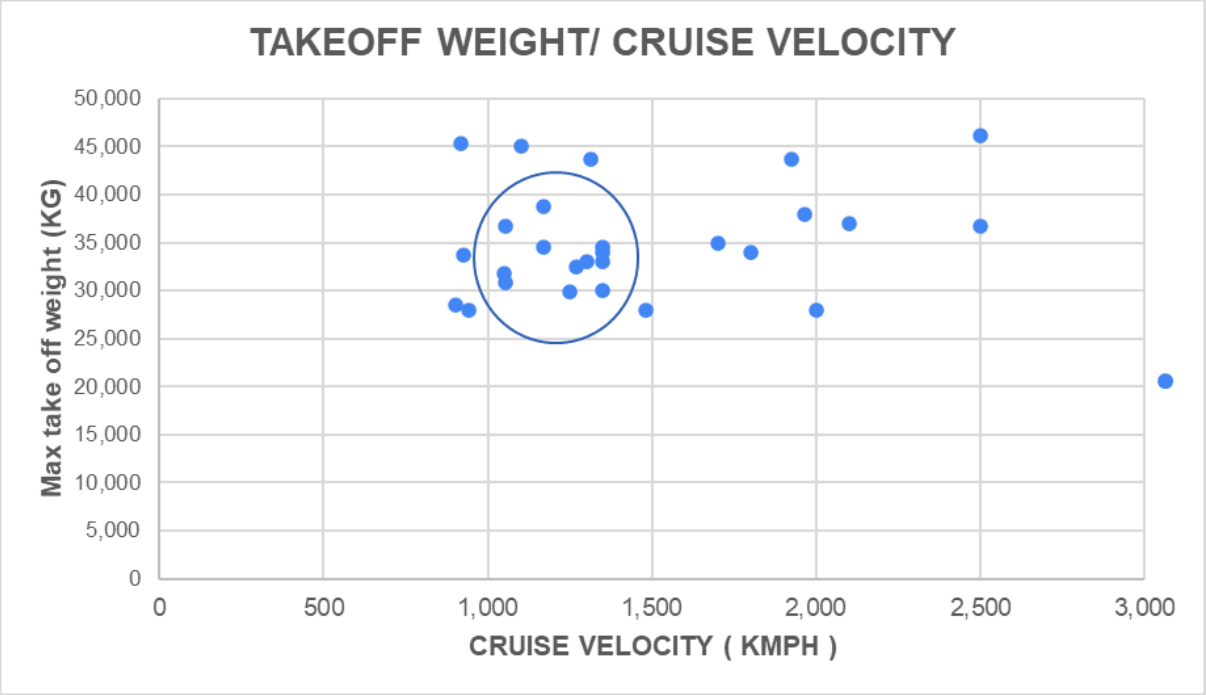
Graph-5.2.1 Max Cruise speed vs Length

Wing span – 14.50m



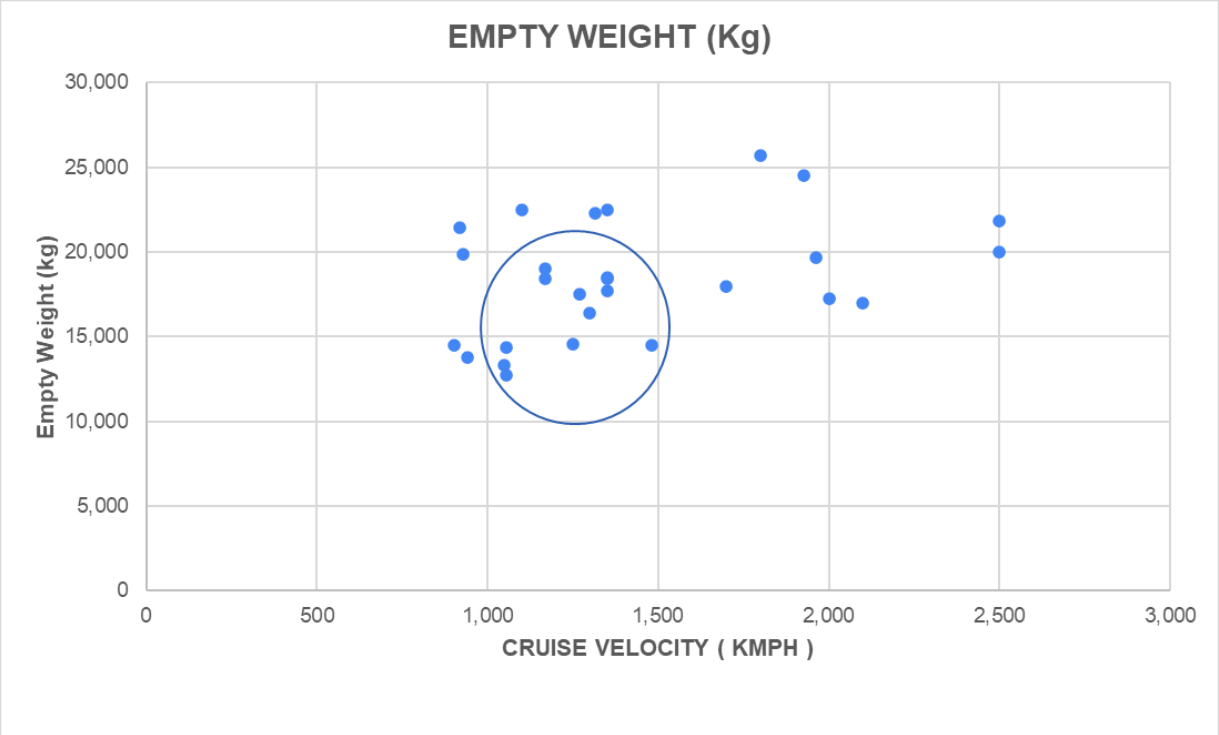
Graph Max-5.2.2 Cruise speed vs Wing Span

Take-off weight – 35,208 kg



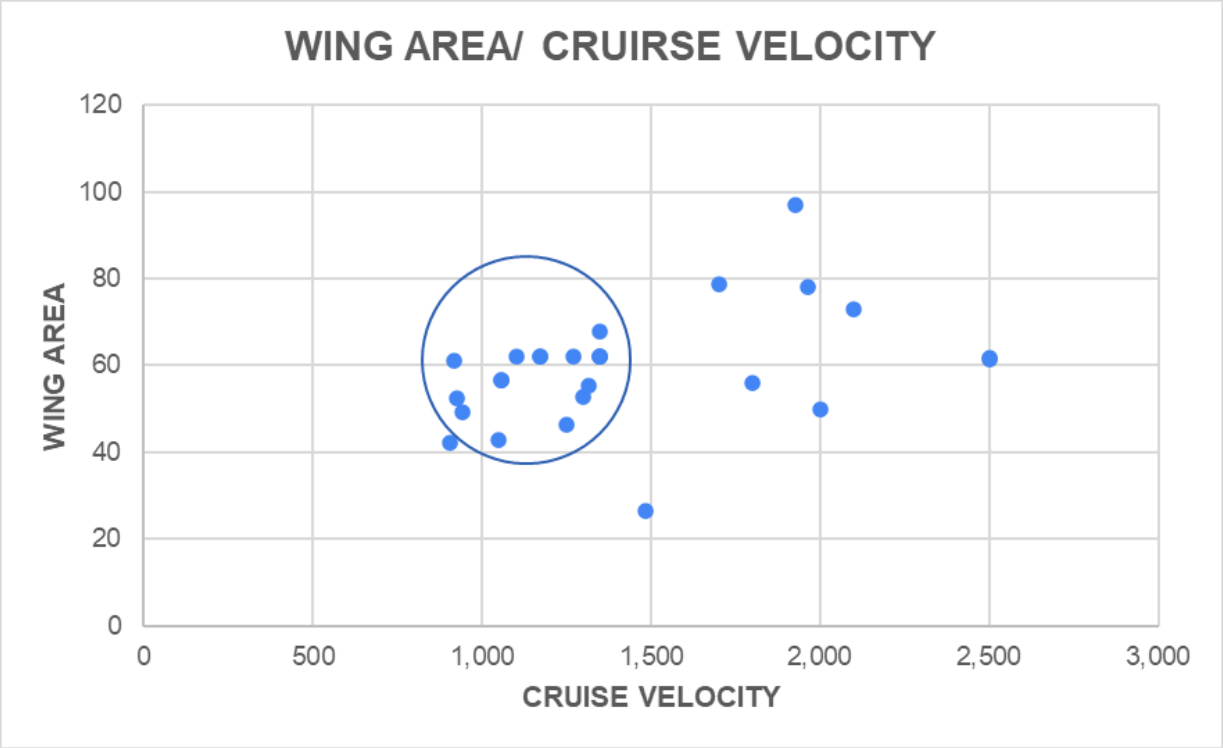
Graph Max-5.2.3 Cruise speed vs Take-off weight

Empty weight – 18,372 kg



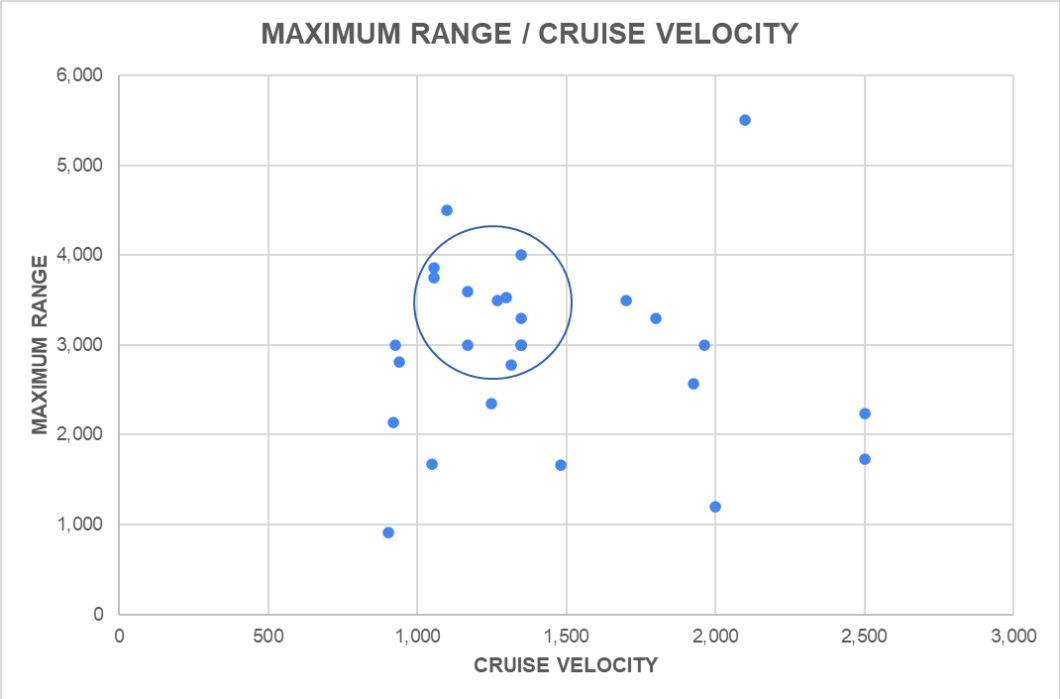
Graph Max-5.2.4 Cruise speed vs Empty Weight

Wing Area – 59.25 m^2



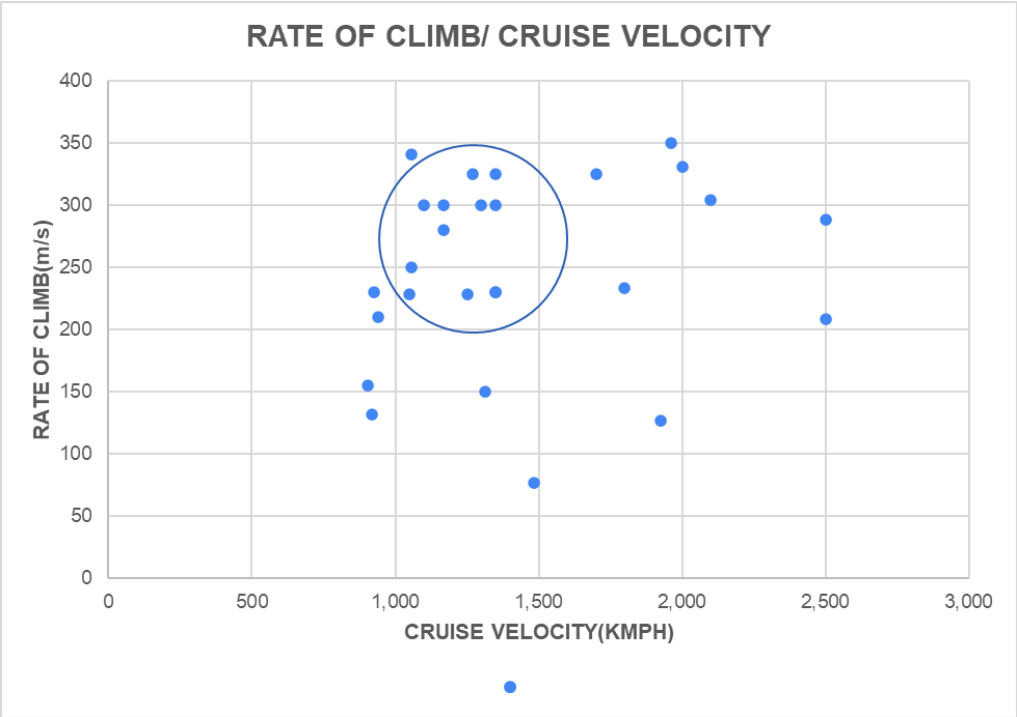
Graph Max-5.2.5 Cruise speed vs Wing Area

Maximum range – 2,941 km



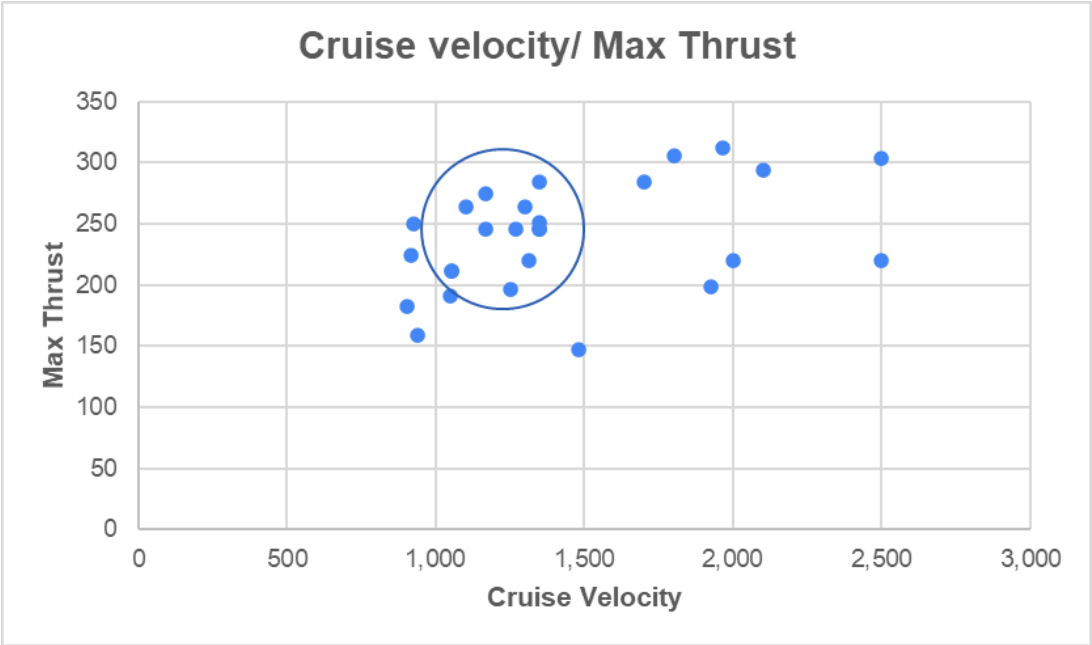
Graph Max-5.2.6 Cruise speed vs Maximum Range

Rate of Climb – 250.20 m/s



Graph-5.2.7 Max Cruise speed vs rate of Climb

Maximum Thrust – 238.87 kn



Graph-5.2.8 Max Cruise speed vs Maximum thrust

OPTIMISED VALUES

Table-5.6 Optimized Values

PARAMETER	VALUES
Length(m)	21.22
Wing Span(m)	14.5
Wing Area(m^2)	59.252
Rate of Climb(m/s)	250.2
Max Cruise Speed(kmph)	1437
No of Engines	2
Empty Weight(kg)	18372
Max Take-Off Weight (kg)	35208
Crew	1
Range(km)	2941
Maximum Thrust (Kn)	238.875

CHAPTER 6

WEIGHT ESTIMATION

6.1 INTRODUCTION

To find the weight of the following parameters of an aircraft.

- Take-off Weight (W_{TO})
- Fuel Weight (W_F)
- Empty Weight (W_E)

$$\mathbf{R_{CR} = R - [T.D + L.D + 2\ x\ (S.C)]}$$

6.2 MISSION PROFILE

Since we have chosen supersonic fighter aircraft it is expected to perform certain functions during its flight and is considered to perform subsequent manoeuvres before it lands back again. The mission profile gives an overview of all the functions an aircraft performs in its flight mission.

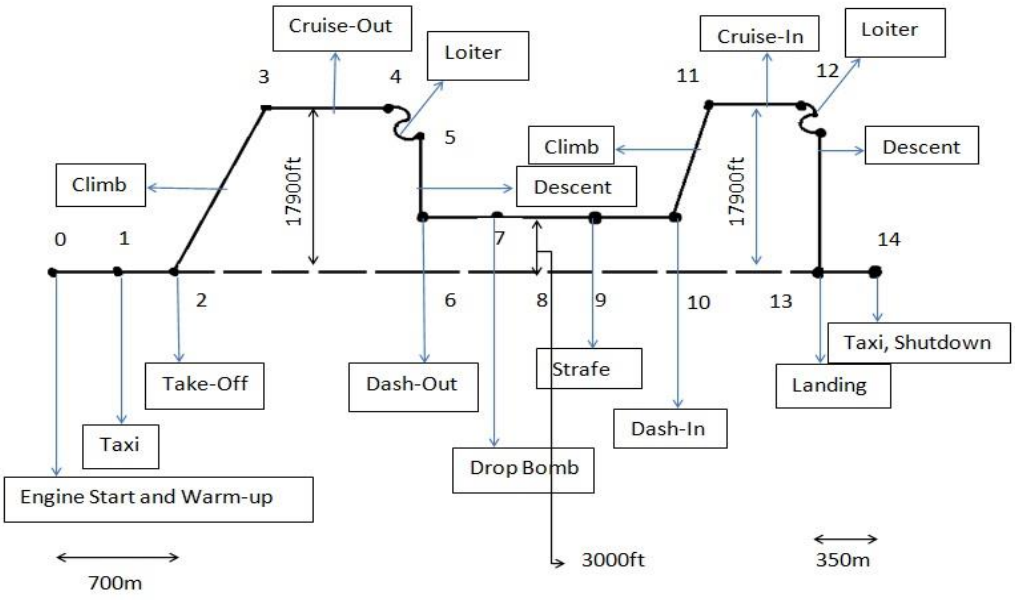


Figure 6.1 Mission Profile of a Supersonic Fighter Jet

6.3 Weight Estimation

1. **Payload ($W_{PL)}$ =** 7000 Kg
2. **Crew Weight (C_{rew}) =** 160 Kg
3. **Take-Off Weight (W_{TO})** = 35208 Kg
4. **Mission Profile**:

i) ***Phase I*: Start and Warmup**

$\frac{W_1}{W_{TO}}$ = 0.99

ii) ***Phase II*: Taxi**

$\frac{W_2}{W_1}$= 0.99

iii) ***Phase III*: Take-Off**

$\frac{W_3}{W_2}$ = 0.99

iv) ***Phase IV*: Climb and Accelerate to Cruise Speed**

$\frac{W_4}{W_5}$ = 0.971

v) ***Phase V*: Cruise Out**

$$R = \left(\frac{V}{C_j}\right)_{cr} \left(\frac{L}{D}\right)_{cr} \ln\frac{W_4}{W_5};$$

$$2941 = \left(\frac{1437}{0.6}\right)_{cr} (6)_{cr} \ln\frac{W_4}{W_5};$$

$\frac{W_5}{W_4}$ = 0.839

vi) ***Phase VI*: Loiter**

$$E = \left(\frac{1}{C_j}\right)_{cr} \left(\frac{L}{D}\right)_{cr} \ln\frac{W_5}{W_6};$$

$$\frac{2941}{1437} = \left(\frac{1}{0.6}\right)_{cr} (9)_{cr} \ln\frac{W_5}{W_6};$$

$\frac{W_6}{W_5}$ = 0.8728

vii) ***Phase VII*: Descent**

$\frac{W_7}{W_6}$ = 0.99

viii) ***Phase VIII*: Landing, Taxi and Shutdown**

$\frac{W_8}{W_7}$ = 0.995

5. Mission Fuel Fraction

MFF = $(\frac{W_1}{W_{TO}} * \frac{W_2}{W_1} * \frac{W_3}{W_2} * \frac{W_4}{W_3} * \frac{W_5}{W_4} * \frac{W_6}{W_5} * \frac{W_7}{W_6} * \frac{W_8}{W_7})$

= 0.99*0.99*0.99*0.971*0.839*0.8728*0.99*0.995 = 0.657

6. Iteration I

W_{fused} = (1-MFF) *$W_{TO\ Guess}$ = 12076.344 Kg

Weight of the fuel $W_f = 1.1 * W_{fused}$= 13283.97 Kg

Tentative Operating Empty Weight

$W_{OE\ TENT} = W_{TO\ Guess} - W_f - W_{PL}$

= 35208 – 12076 – 160 = 22972 Kg

Tentative Empty Weight

$W_{E\ TENT} = W_{OE\ TENT} - W_{TFO} - W_{Crew}$

= 22972 – 170.04 – 160

= 22642 Kg

Analytical Empty Weight

$W_E = inv \log_{10}\left(\frac{\log_{10} W_{TO\ Guess} - A}{B}\right)$

A = 0.509; B = 0.9505

= 22733.14 Kg

Error Percentage:

E% = $\frac{W_E - W_{E\ TENT}}{W_{E\ TENT}} * 100$ = 0.43%

Table-6.1 Optimized Phase Weight

Phase weight	**Kg**
Empty weight (W_E)	22733.14
Fuel Weight (W_F)	12076.344
Payload Weight (W_{PL})	7000
Take-off Weight (W_{TO})	35208
Crew Weight (W_{crew})	160

CHAPTER 7

POWERPLANT SELECTION

INTRODUCTION

A heavier-than-air aircraft requires a propulsion system to have a sustained flight. The contribution of a power plant to an aircraft is to generate the most influential force in aircraft performance; that is, the propulsive force or thrust. An aircraft engine produces thrust based on Newton's third law. An aircraft engine usually generates a backward force to displace (accelerate) the air flow, thus the aircraft, in reaction, is pushed forward. The primary function of an aero-engine is to generate propulsive force. This force is necessary to overcome the aircraft drag and provide the means (airspeed) for the wing to produce lift force.
The secondary function of the propulsion system is to provide power/energy to other subsystems such as the hydraulic system, electric system, pressure system, air conditioning system, and avionics. These subsystems rely on the engine power to operate. In most General Aviation (GA) as well as light transport aircraft, the power for internal consumption is extracted from the propulsion system.

There are many contributing functions, of which the majority are undesirable. Depending upon the engine locations, it may play a stabilizing or a destabilizing role in aircraft dynamics.

7.1 TYPES OF ENGINES

1. Piston engine
2. Turbofan
3. Turboprop
4. Turbojet
5. Ramjet
6. Scramjet

7.1.1 Piston Engine The reciprocating engine, also often known as a piston engine, is typically a heat engine (although there are also pneumatic and hydraulic reciprocating engines) that uses one or more reciprocating pistons to convert pressure into a rotating motion. Turbofan engines, which power the majority of Turbofan commercial aircraft, are turbine engines that have been fitted with a powerful front-end fan. The fan sends air into the combustor, similar to a turbojet engine. However, the fan also sends a second stream of air through a larger cylinder entirely outside (and around) the engine core. This second stream of air provides additional thrust, cools the engine, and also serves to reduce engine noise. Turbofans are interchangeably referred to as bypass engines, in reference to this airflow that bypasses the combustor.

7.1.2 Turbojet Turbojets are jet engines that depend exclusively on Turbojet the thrust of jet exhaust expelled by the engine for propulsion. Turbojet engines are extraordinarily powerful and only efficient at extremely high speeds. As such, they are more likely to be found in a missile, although the now defunct Concorde jet is an example of a turbojet powered commercial aircraft.

7.1.3 Turboprop Like turbojet and turbofan engines aircraft, Turboprop engines rely on a gas turbine for power. However, in the case of a turboprop aircraft, the turbine drives a rotating shaft, which in turn drives a reduction gear, which ultimately drives a propeller. The reduction gear is necessary to convert the high-speed shaft rotation into slower, functional propeller speed. Most of the power generated in a turboprop aircraft is used to drive the propeller

7.1.4 Ramjet The Ramjet uses the open Brayton cycle. No rotating machinery is used and compression is achieved by the intake and diffuser. As such they require speed to compress air enough that good efficiency can be achieved. Ramjets are inefficient at subsonic speeds and their efficiency improves at supersonic speeds.

7.1.5 Scramjet The scramjet ("supersonic combustion ramjet") is a variant of a ramjet air-breathing jet engine in which combustion takes place in supersonic airflow. As in ramjets, a scramjet relies on high vehicle speed to compress the incoming air forcefully before combustion (hence ramjet), but whereas a ramjet decelerates the air to subsonic velocities before combustion, the airflow in a scramjet is supersonic throughout the entire engine. That allows the scramjet to operate efficiently at extremely high speeds.

7.1.6 Pulsejet A pulsejet engine (or pulse jet) is a type of jet engine in which combustion occurs in pulses. A pulsejet engine can be made with few or no moving parts and is capable of running statically (i.e. it does not need to have air forced into its inlet typically by forward motion). Pulsejet engines are a lightweight form of jet propulsion, but usually have a poor compression ratio, and hence give a low specific impulse.

7.2 THRUST REQUIRED CALCULATION

• From the first weight estimate, we can have a rough idea of the weight of the power-plant that is to be used.
• The total weight of the power-plant to be calculated.
• Choice of engine is based on the higher operating fuel economy & efficiency for high payloads.
• Calculate Engines combination amount.
• Calculate enough thrust for Take-off.

Engine Thrust Requirement = $\frac{\boldsymbol{Totalthrust(FromGraph)+10\%}}{\boldsymbol{No.Ofengineused}}$

$= \frac{238875+(238875*10\%)}{2} = 131381025\text{kN}$

Table 7.1 Comparison of different engines

Sl. No.	**Engine Name**	**Engine Type**	**Dry Thrust(kN)**	**Total Thrust (kN)**
1	**Pratt & Whitney F135-PW 100**	Turbofan	128	191
2	**Saturn AL-31F**	Turbofan	107	180.6
3	**General electric YF 120**	Turbofan	105	156

We will be choosing **Pratt & Whitney F135** as our engine in this case as it is with more than **40,000 lbs**. of thrust, unmatched low-observable signature, world-class thermal management, and the most advanced integrated engine control system ever created, the F135 engine is the heartbeat of the F-35.

Not only is the **F135 the most powerful and most advanced fighter engine ever produced**, it's also the most dependable – demonstrating a step change in readiness and reliability over 4th generation fighter engines.

The F135 **delivers unrivaled performance to the warfighter, enabling operations in the most advanced threat environments and redefining what's possible for our customers and their missions. This engine enables to have super cruising ability.**

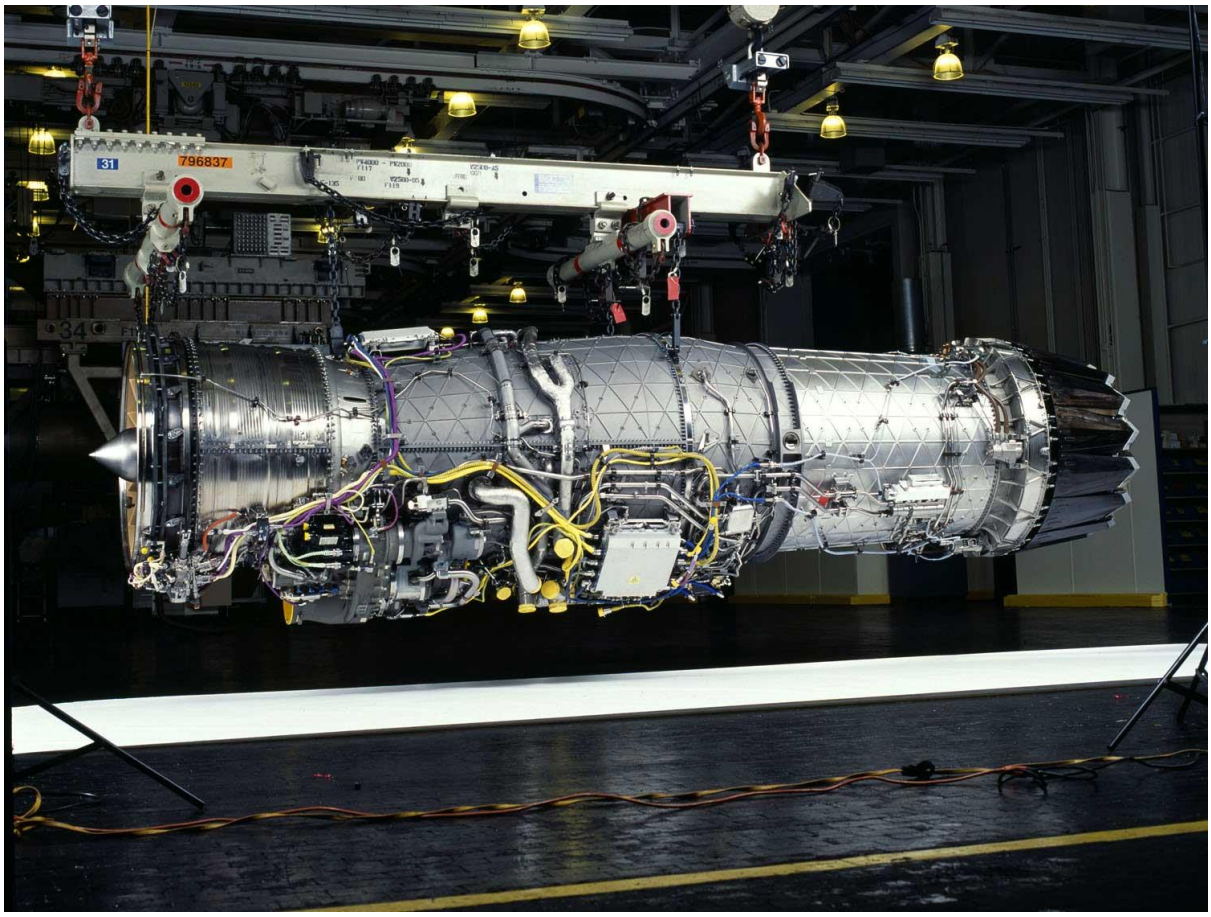


Figure 7.1: Pratt & Whitney F135

Conclusion

Engine Name: ***Pratt & Whitney F135*** Turbofan

Thrust: 191 kN

CHAPTER 8

WING, AIRFOIL AND TAIL SELECTION

8.1 INTRODUCTION

After the final weight estimation of the aircraft, the primary component of the aircraft to be designed is the wing. This chapter explain the selection of wing, types of wing and calculation of wing design parameter.

8.1.1 WING SELECTION

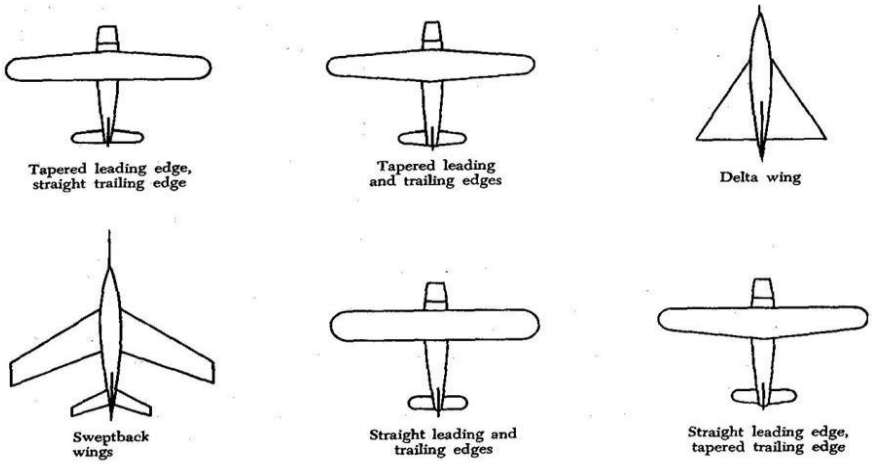
After the final weight estimation of the aircraft, the primary component of the aircraft to be designed is the wing. The wing weight and its lifting capabilities are in general, a function of the thickness of the aerofoil section that is used in the wing structure. The first step towards designing the wing is the thickness estimation. The thickness of the wing, in turn, depends on the critical Mach number of the aerofoil or rather, the drag divergence Mach number corresponding to the wing section

8.1.2 TYPES OF WING

Wings are differentiated from there wing configuration by the following

- Swept back wing
- Delta wing
- Tapered wing
- Based on the aspect ratio
- Based upon position

Figure 8.1 Wing Configurations



8.1.2 POSITION OF THE WING

The wing configuration of a fixed wing aircraft is mainly to generate the amount of lift required. There are different configurations of wing positions. The basic configurations are as follows:

- Low wing: mounted below the bottom of the fuselage.
- Mid wing: mounted approximately halfway up the fuselage.
- High wing: mounted on the upper part of the fuselage.

After the final weight estimation of the aircraft, the primary component of the aircraft to be designed is the wing. The wing weight and its lifting capabilities are in general, a function of the thickness of the air foil section that is used in the wing structure. The first step towards designing the wing is the thickness estimation. The thickness of the wing, in turn depends on the critical Mach number of the air foil or rather, the drag divergence Mach number corresponding to the wing section. The critical Mach number can well be delayed by the use of an appropriate Sweep-back angle to the wing structure. The natural choice of the standard series is the 65 series which is designed specifically for use in high-speeds

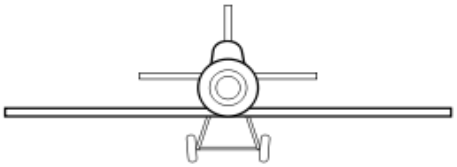


Figure 8.2: Low wing

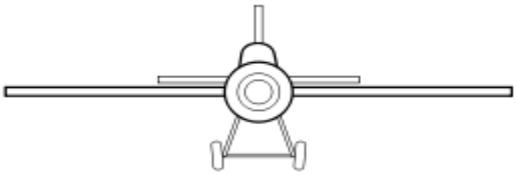


Figure 8.3: Mid wing

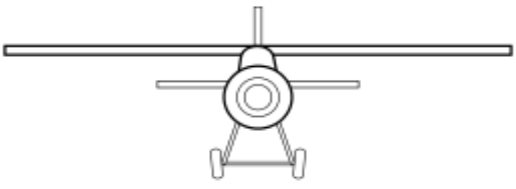


Figure 8.4: High wing

8.1.3 WING SELECTION

Based on the different applications such as operating altitude, operating Mach number, aspect ratio, tapper ratio and type of usage. There are different basic wing configurations are as follows and shown in (figure 9.1.3.1):

- Rectangular wing
- Tapered straight wing
- Elliptical wing
- Swept wing
- Delta wing

Since rectangular wing with low wing configuration will be the best possible configuration for an agricultural aircraft. Low wing helps is proper spraying and seeding.

8.1.4 WING DESIGN AND CALCULATIONS

- Aspect Ratio (AR) = $\frac{b^2}{S} = 3.548$
- Wing Area (S) = 59.252 m^2
- Wingspan (b) $= 14.5m$
- Chord Length (C) = $\frac{b}{AR} = \frac{14.5}{3.548} = 4.086m$
- C=C_r= Root chord = 4.086 m
- Taper Ratio, $\lambda = \frac{C_t}{C_r}$
- Tip chord, $C_t = \lambda X C_r$ = 0.25 x 4.086m = 1.0215 m
- (λ=0.5 because of tapered wing)
- Mean Aerodynamic Chord = $\hat{c} = \frac{2}{3} X C_r X \left\{\frac{1+\lambda+\lambda^2}{1+\lambda}\right\}^{1/2}$ = 2.8602 m
- Structural Weight for varying thickness of Air foil volume of fluid

$$\frac{Weightoffuel}{804} = \frac{12076.344}{804} = 15.002kg$$

- Thickness to Chord ratio $\left(\frac{t}{c}\right)$ = 20% of weight volume

$$0.2V = \left[\left(\frac{t}{c}\right) C_{mean} \left(\frac{b}{2}\right) \left(\frac{C_{root}}{2}\right) 0.75\right] = 0.047$$

$$= 4.7\ \%$$

8.1.5 CONCLUSION

Table 8.1: Optimised Wing Parameters values

PARAMETER	**VALUE**
Wing span(b)	14.5m
Wing area(S)	59.252m^2
Aspect ratio (AR)	3.548
Tapper ratio (λ)	0.25
Root chord (C_r)	4.086m
Tip chord (C_t)	1.0215m
Mean aerodynamic chord ($\bar{C}$)	2.8602m

8.2.1 AEROFOIL NOMENCLATURE The aerofoil is the main aspect and is the heart of the aeroplane. The aerofoil affects the cruise speed, landing distance and take off distance, stall speed and handling qualities and aerodynamic efficiency during all phases of flight. Aerofoil Selection is based on the factors of Geometry & definitions, design/selection, families/types, design lift coefficient, thickness/chord ratio, lift curve slope, characteristic curves.

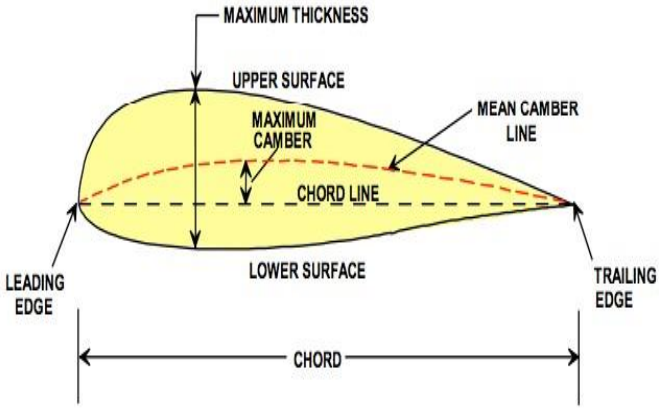


Figure 8.5: Airfoil

The following are the aerofoil geometry and definition:

Chord line: It is the straight line connecting leading edge (LE) and trailing edge (TE).

Chord (c): It is the length of chord line.

Thickness (t): measured perpendicular to chord line as a % of it (subsonic typically 12%).

Camber (d): It is the curvature of the section, perpendicular distance of section mid-points from chord line as a % of it (sub sonically typically 3%).

The angle of attack (α): It is the angular difference between the chord line and airflow direction.

The following are aerofoil categories:

1. Early it was based on trial & error.
2. NACA 4 digit is introduced during 1930's.
3. NACA 5-digit is aimed at pushing position of max camber forwards for increased C_{Lmax}.
4. NACA 6-digit is designed for lower drag by increasing region of laminar flow.
5. Modern it is mainly based on the need for improved aerodynamic characteristics at speeds just below the speed of sound.

a) **Camber**: The curvature of the profile view of an aerofoil is its chamber.

b) **Chord line**: The straight line joining the centre of curvature of the leading-edge radius and the trailing edge of an aerofoil is the chord line.

c) Chord: The distance between the leading edge and the trailing edge of an aerofoil measured along the chord line is the chord.

d) Maximum thickness: The maximum depth between the upper and lower surfaces of an aerofoil is its maximum thickness.

e) Angle of Attack: the angle subtended between the chord line of an aerofoil and the oncoming air flow.

f) Angle of Incidence: The angle subtended between the chord line and the longitudinal axis.

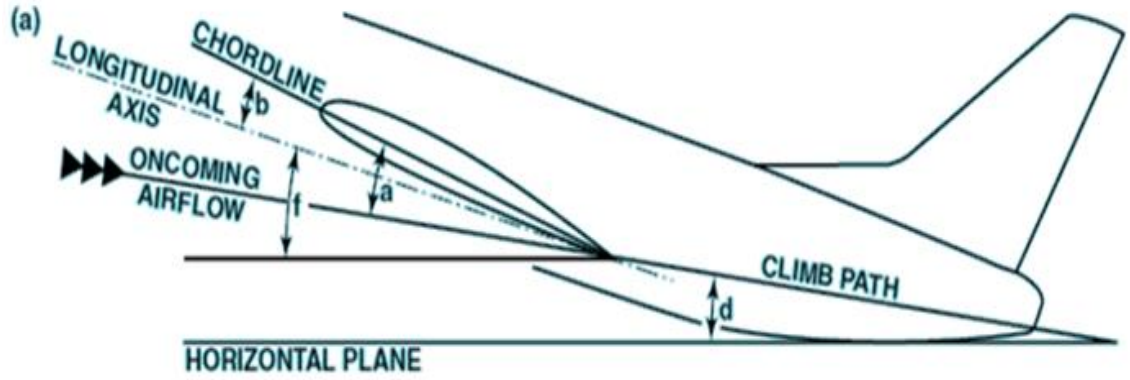


Figure 8.6: Angle of attack

NACA SERIES EXPLANATION

NACA 4 Digit

- 1st digit: maximum camber (as % of chord).
- 2nd digit (x10): location of maximum camber (as % of chord from leading edge (LE)).
- 3rd & 4th digits: maximum section thickness (as % of chord).

NACA 5 Digit

- 1st digit (x0.15): design lift coefficient.
- – 2nd & 3rd digits (x0.5): location of maximum camber (as % of chord from LE). – 4th & 5th digits: maximum section thickness (as % of chord).

NACA 6 Digit

- 1st digit: identifies the series type.
- 2nd digit (x10): location of minimum pressure (as % of chord from leading edge (LE)).
- 3rd digit: indicates an acceptable range of CL above/below design value for satisfactory low drag performance (as tenths of CL).
- 4th digit (x0.1): design CL.
- 5th & 6th digits: maximum section thickness (%c)

8.2 AEROFOIL CALCULATION AND SELECTION

The primary function of the wing is to generate lift force. This will be generated by a special wing cross section called aerofoil. Wing is a three-dimensional component, while the aerofoil is two-dimensional section. Because of the aerofoil section, two other outputs of the aerofoil, and consequently the wing, are drag and pitching moment. The wing may have a constant or a non-constant cross-section across the wing.

8.1 Aerofoil Selection

$L = W_{TO} = \frac{1}{2}\rho_{stall} V_{stall}^2 S C_{Lmax}$

C_{Lmax} = 1.4 (From Jan Raskom pg.91)

$S = \frac{(W_{TO})}{\left(\frac{W}{S}\right)} = \frac{14999.99}{420} = 35.7m^2$

$V_{stall} = \sqrt{\frac{2W_{TO}}{\rho_{stall} S C_L}} = \sqrt{\frac{2*14999.99}{0.121*35.71*1.4}}$ =70.422 m/s

8.1 Aerofoil Calculation

Assume Jet A-1 Fuel is being used, ρ_{fuel}= 804 kg/m^3

Volume of fuel = $\frac{Mass\ of\ fuel}{Density of fuel} = \frac{2837}{804}$=3.52 m^3

Assume 20% of fuel carrying in wings

$= \frac{t}{c} X \hat{c} X (0.5 X \hat{c}) X (0.5 X b X 0.75 X 2)$

3.52*20/100 = $\frac{t}{c}$*(2.56) *(0.5*2.56) *(0.5*8.5*0.75*2)

(t/c) = 0.0337

Thickness of the root = t_r = 0.0337* C_r = 0.119m

Thickness of the tip = t_p = 0.0337* C_t = 0.0595 m

Thickness of the tip = t_p = 0.0337* C_t = 0.0595 m



Figure 8.7: NACA 64-008A AIRFOIL - NACA 64-008A air foil

(n64008a-il) NACA 64-008A AIRFOIL

NACA 64-008A airfoil

C_L= 0.599

C_D= 0.067

Max thickness 8% at 40% chord.

Max camber 0% at 0% chord

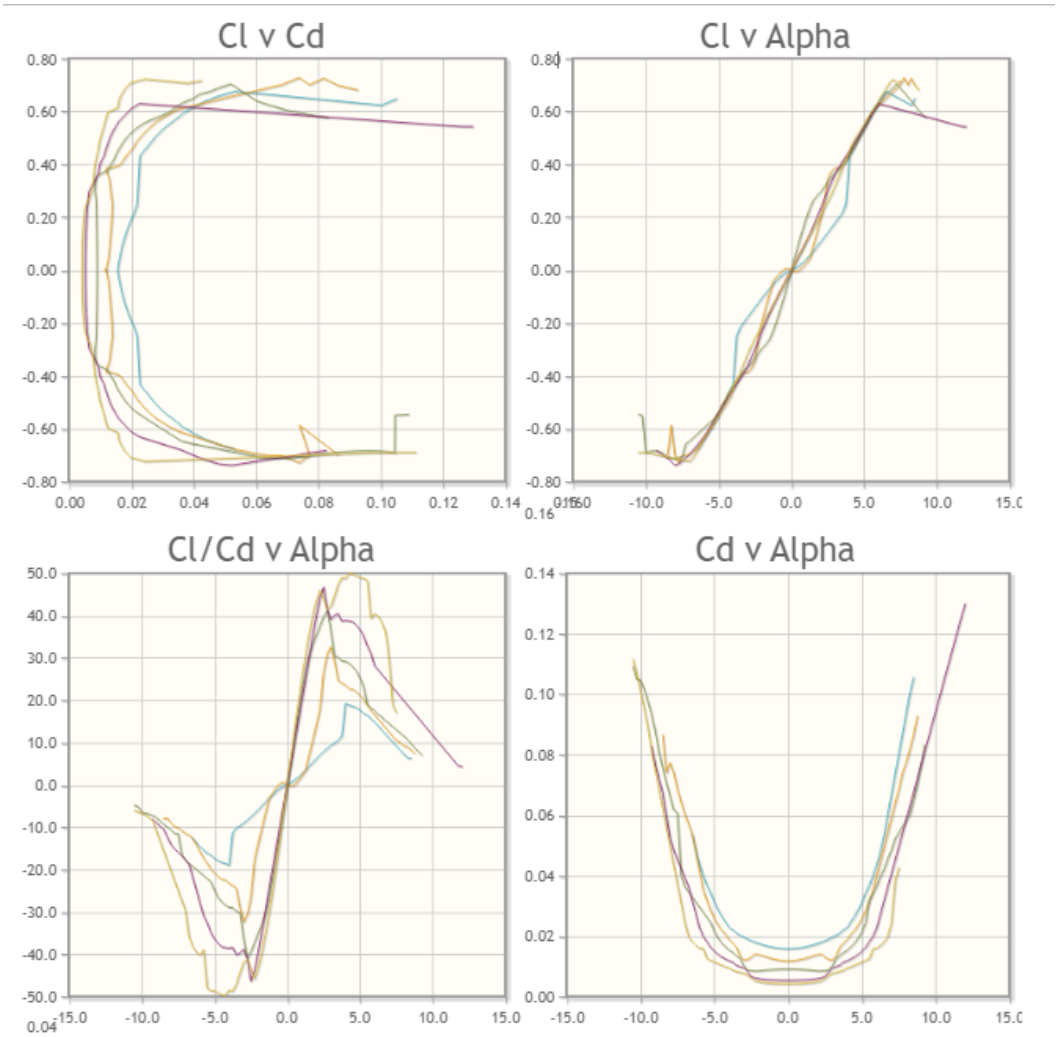


Figure 8.8 Lift coefficient versus Angle of Attack of NASA SC (2)-0710 airfoil

HIGH LIFTING DEVICES

In aircraft design and aerospace engineering, a high-lift device is a component or mechanism on an aircraft's wing that increases the amount of lift produced by the wing. The device may be a fixed component or a movable mechanism which is deployed when required. Common movable high-lift devices include wing flaps and slats. Fixed devices include leading-edge root extensions and boundary layer control systems, which are less commonly used.

Types of devices

• Flaps

• Slots & Slats

• Boundary layer control and blown flaps

• Leading edge root extension.

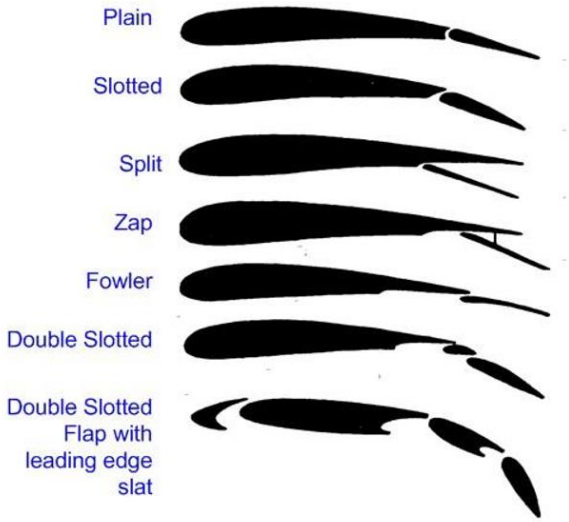


Figure 8.9 Types of flaps

8.3 TAIL SELECTION

Introduction

The tail of an aeroplane is called by various names, such as “empennage” and “stabilizer.” The preferred term is “stabilizer,” because it is at least partially descriptive of the component’s function. However, the stabilizer provides not

only stability but also some of the aeroplane's control. The tail of an aeroplane is designed to provide both stability and control of the aeroplane in pitch and yaw. There are many different forms an aircraft tail can take in meeting these dual requirements of stability and control. Most tail designs have a horizontal winglike structure and one or more vertical or near-vertical structures. Whenever practical, these structures are identified as the horizontal and vertical stabilizers, although some designs do not conveniently fit such a description. The many types of aeroplane tail design include, but are by no means limited to, the conventional, T-tail, cruciform-tail, dual-tail, triple-tail, V-tail, inverted Vtail, inverted Y-tail, twin-tail, boom-tail, high boom-tail, and multiple-plane tail designs.

8.3.1 Conventional Tail Design

The conventional tail design is the most common form. It has one vertical stabilizer placed at the tapered tail section of the fuselage and one horizontal stabilizer divided into two parts, one on each side of the vertical stabilizer. For many aeroplanes, the conventional arrangement provides adequate stability and control with the lowest structural weight. About three-quarters of the aeroplanes in operation today, including the Airbus A300, the Boeing 777 and 747, and the Beech Bonanza A-36, use this arrangement.

T-Tail Design

In the T-tail design, a common variation of the conventional tail, the horizontal stabilizer is positioned at the top of the vertical stabilizer. The horizontal stabilizer is then above the propeller flow, or prop wash, and the wing wake. Because the horizontal stabilizer is more efficient, it can, therefore, be made both smaller and lighter. The placement of the horizontal stabilizer on top of the vertical stabilizer can also make the vertical stabilizer more aerodynamically efficient. By making the vertical stabilizer more effective, its size may be reduced. However, the horizontal stabilizer in the T-tail layout imposes a bending and twisting load on the vertical stabilizer, requiring a stronger, and therefore, a heavier, structure. These loads are avoided in the conventional design. There is also the possibility that at the high pitch angle usually associated with landing the aeroplane, the horizontal stabilizer of the Ttail will be immersed in the slower and more turbulent flow of the wing wake.

Dual-Tail Design

The dual-Tail design, in which the two vertical stabilizers are placed at the ends of the horizontal stabilizers, was at one time fairly common on large flying boats and twin-engine propeller-driven bombers such as the North American-25. In some cases, this arrangement is attractive, because it places the vertical stabilizers in the prop wash of wing-mounted propellers. The result is the maintenance of good directional control during low-speed operations. The positioning of the two vertical stabilizers at the ends of the horizontal stabilizers allows for a smaller, lighter, and more aerodynamically efficient horizontal stabilizer. However, the overall weight of a plane with a dual-tail design is greater than that of a plane with the single conventional-tail design. The dual tail is part of the design of the Republic Fairchild A-10 ground-attack aeroplane, in which the plane's two jet engines are mounted to the rear of the fuselage. When this aeroplane is viewed from the rear and slightly to either side, the engine exhausts, blocked by the vertical stabilizer, are not easily visible.

Triple-Tail Design

The triple-tail design, with two vertical stabilizers placed at the ends of the horizontal stabilizers and one mounted on the fuselage, is attractive when the height of the vertical stabilizer must meet certain restrictions, such as hangar-door height. Certainly, this was the important consideration in the design of the Lockheed Constellation, one of the most significant passenger aeroplanes of the late 1940′s. Another well-known example of the triple-tail design is the Grumman E-2 Hawkeye.

V-Tail Design

The V-Tail, sometimes called the "butterfly" tail, has had limited application in aeroplane design, the most significant of which has been by the Beech Company in the Beech-craft Bonanza V-35. Clearly, the usual definition of horizontal and vertical stabilizers has no application to the V tail. The intended advantage of the V-tail design is that two surfaces might serve the same function as the three required in the conventional tail and its variants. Removal of one surface then would reduce the drag of the tail surfaces as well as the weight of the tail region. However, wind tunnel studies by the National

Advisory Committee on Aeronautics (NACA) have shown that for the V tail to achieve the same degree of stability as a conventional tail, the area of the V tail would have to be about the same size as that of the conventional tail.

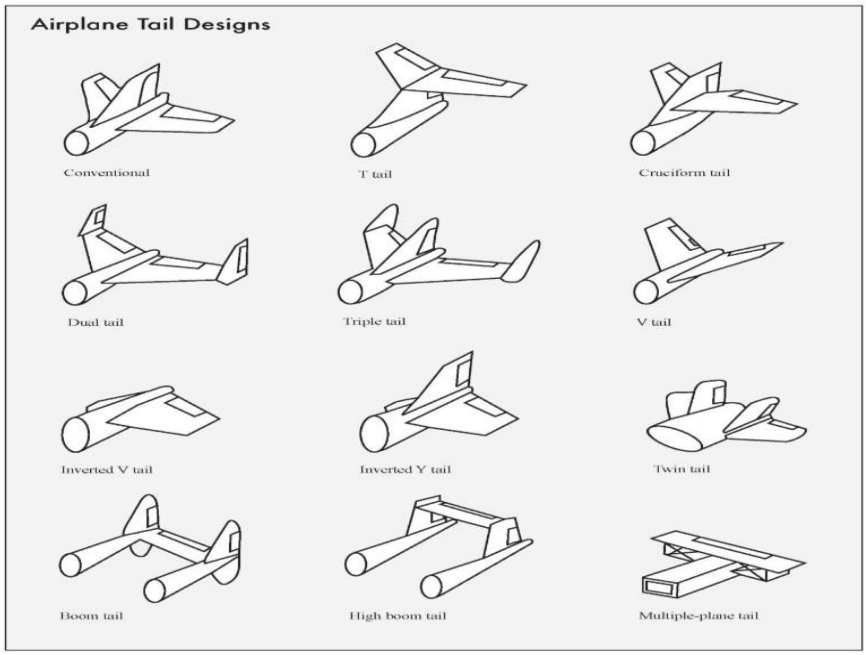


Figure 8.10 Types of tail

Inverted Y-Tail Design

The inverted Y tail is actually a conventional tail with a noticeable droop to the horizontal stabilizers. In other words, the outer ends of the horizontal stabilizers are lower than the ends attached to the fuselage. The F-4 Phantom, originally a mainstay of the McDonnell Company, used the inverted Y tail to keep the horizontal surfaces out of the wing wake at high angles of attack. It is interesting to note that the tips of the horizontal stabilizers on the first McDonnell Navy fighter, the F-2H Banshee, were bent decidedly upward.

Twin-Tail Design

The twin tail is a feature of various air superiority fighters used by both the U.S. Navy (the F-14 Tomcat) and the U.S Marine Corps (the F/A-18 Hornet). Although both the F-14 and F/A-18 designs have a superficial resemblance, they also have important differences. The tilt angle of the vertical stabilizer of the F14 is more pronounced than that of the F-18, so much so that it approaches that of the V tail on the Beech Model V-35 Bonanza. With two vertical

stabilizers, the twin tail is more effective than the conventional single tail of the same height.

Boom-Tail Design

Boom tails are used when an aircraft's fuselage does not extend entirely back to the horizontal stabilizer. In both the Lockheed P-38 Lightning fighter of World War II and the Fairchild C-119 cargo plane, engines were mounted on the booms. In the case of the C-119, the twin boom allowed easy access to the rear of the fuselage for loading and removing cargo. The twin boom has also been used for an aeroplane with engines mounted in the fuselage, with one engine, known as the tractor, in the nose of the aeroplane and one engine, known as the pusher, in the rear of the aeroplane. Because the thrust of both engines is along the centreline of the aeroplane, it is much easier in this arrangement to compensate for the loss of one engine than it is in the wing-mounted engine installation. Both the Cessna Sky master and the new Adam 309 have fuselage-mounted engines. In the case of the Adam 309, the horizontal stabilizer is raised to avoid propeller wake from the pusher, or rear-mounted, engine.

8.3 TAIL SECTION

The horizontal and vertical tails are designed to provide stability. The movable surfaces on tails namely elevator and rudder provide control. The complete design of tail surfaces requires information like c.g. location, shift in c.g location during flight and desirable level of stability. However to obtain the c.g. location, we need the weights of horizontal and vertical tails which depend on size type and location. Hence preliminary sizing is carried out in the following steps.

1) Choose tail arrangement from the various types shown in figure.
    i) Nearly 70% of the airplanes have conventional tail.
    ii) T-tail has the following advantages.
    a) The horizontal tail acts as an end plate on the vertical tail. This reduces the adverse effect of finite aspect ratio and increases the slope of the lift curve of the vertical tail. It leads to a smaller vertical tail.
    b) Horizontal tail is away from wing wake. The effect of propeller slips stream or down wash due to jet engine exhaust is minimal.

The disadvantage is that the vertical tail structure is heavier. Generally, airplanes with engines mounted on rear fuselage have T-tails.

iii) Cruciform tail: The horizontal tail is located in the middle of vertical tail. This arrangement is a compromise between conventional and T-tail.

iv) H-tail and triple tail: In these configurations the vertical tail is in two or three parts.

v) This helps in reducing the height of the vertical tail
It also provides some end plate effect on the horizontal tail.

vi) V-Tail: In this configuration the horizontal and vertical tail surfaces are combined. However there is not much reduction in total tail area. On the other hand, this configuration results in

vii) Undesirable coupling of longitudinal & lateral motions.

CONCLUSION

The aerofoil which I have selected for root, mean, tip chords are all with 9% thickness to chord ratio. The Double slotted flaps taken for high lifting device, will provide manoeuvrability for the fighter. In my Design Project fighters are equipped with Twin Tail Design. As mentioned above the twin tail design will give better stability performance to the aircraft.

RESULT

Root thickness = 0.119m

Tip thickness = 0.0595m

t/c = 0.0337

Aerofoil of Root: NASA SC (2)-0714 airfoil (NASA TP-2969)
Aerofoil of Tip: NASA SC (2)-0710 airfoil (NASA TP-2969)
Tail Configuration: Conventional Tail due its simplicity in build-up and higher operational functions at high speed

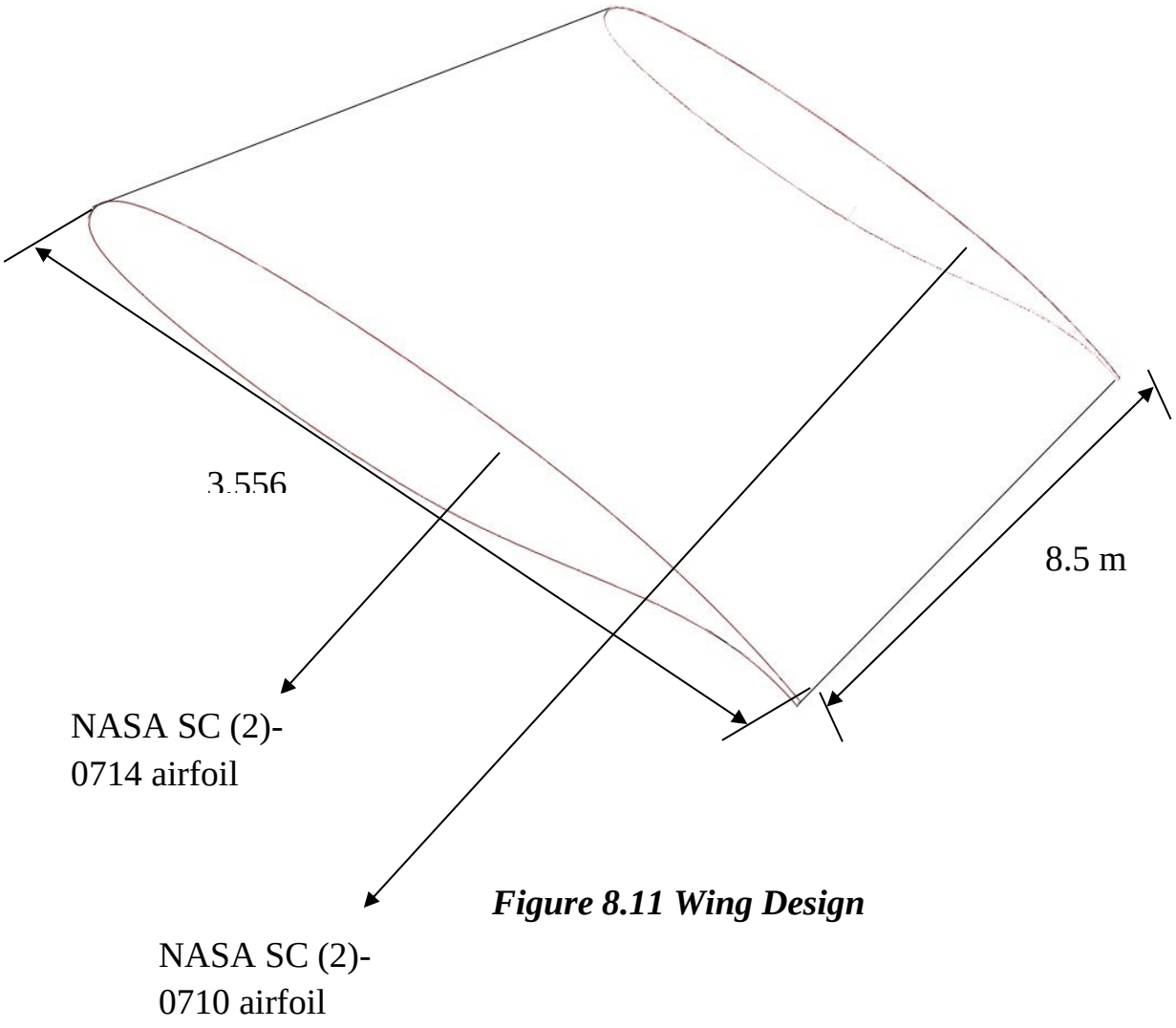


Figure 8.11 Wing Design

CHAPTER 9

FUSELAGE AND LANDING GEAR SELECTION

9.1 FUSELAGE SELECTION

In this chapter we discuss the ways of obtaining the internal and external dimensions of the fuselage. Subsequently we discuss ways to obtain a first estimate of the sizes of the tail surfaces. These two aspects and the dimensions of wing obtained in the previous chapter, would later enable us to prepare the layout of the airplane and then carryout the estimation of the location of the centre of gravity (cg) of the airplane.

Fuselage sizing

Total length of fuselage can be divided as that of

(i) nose,

(ii) cockpit,

(iii) payload compartment or engine compartment if the engine is in the Fuselage and tail fuselage

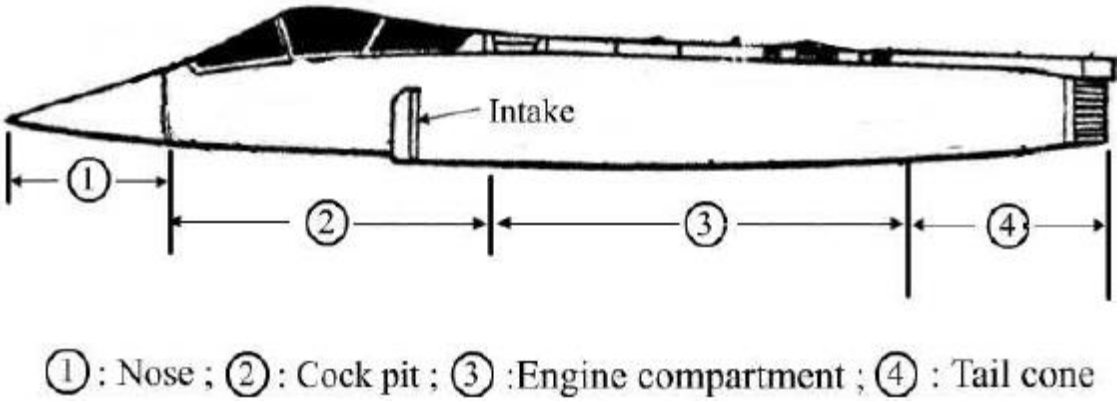


Figure 9.1 Fuselage of a Military

9.2 Length of Nose

The portion of fuselage ahead of cockpit is referred to as nose. It houses radar/ landing gear (in case of airplane with nose wheel landing gear), engine intake (in case of airplanes with engine in fuselage) etc. The length and layout

of nose can be chosen from the layouts of similar airplanes. For this purpose tabulate the ratios of length of nose to length of fuselage for similar airplanes. Cockpit houses pilot (s) and other flight crew. It has the flight deck with instruments and controls. The considerations for design of the cockpit are as follows.

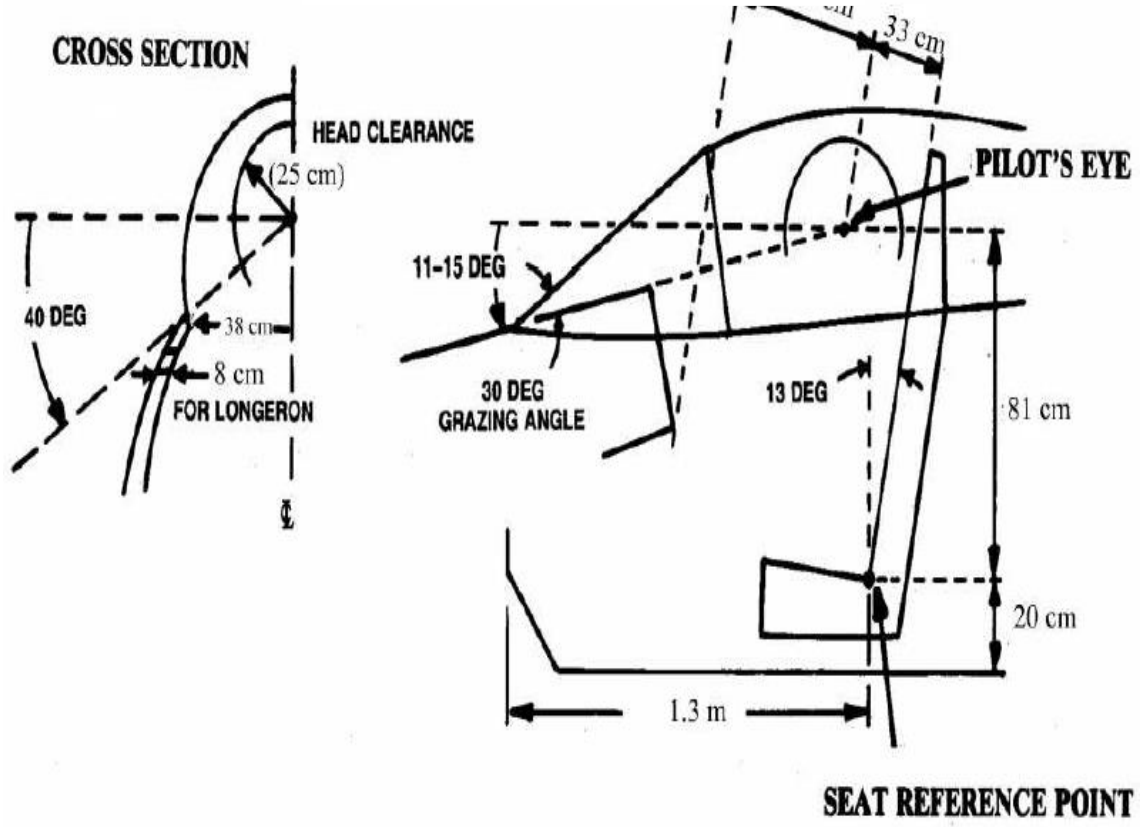
a) Pilots & crew members should be able to reach all controls comfortably. They must be able to see all instruments and communicate by voice or touch between them without undue efforts.

b) Visibility from cockpit should adhere to the standards during take-off, landing, and other phases of the flight. The shape of the wind shield should be in accordance with the fuselage aerodynamics.

c) For military airplanes the provision of ejection seat must also be considered.

The cockpits of military airplanes are designed to cater to 5to 95 percentile of male pilots {65.2 inches (165.6 cm) to 73.1 inches (185.7 cm) height}. Typical fighter cockpit layout is shown.

Fig 9.2. Cockpit Layout



9.3 Weapons Carriage

Weapons constitute the payload for military airplanes. The traditional weapons include guns, bombs and missiles. In future Lasers and other technologies may be used for guidance. The general design considerations are as follows.

I) Weapons constitute substantial portion of weight. Hence they should be located near c.g .to avoid large shift in c.g. when weapons are deployed.

II) The missiles are powered and mostly guided. Whereas bombs are generally not guided and are dropped or ejected using bombsight mechanism or computer. "Smart bombs" have guidance. Missiles are launched from the airplane. The smaller ones are rail-launched whereas the larger ones are ejector launched.

Options for weapons carriage:

There are four possibilities namely a) external,

b) semi-submerged, c) internal, d) conformal

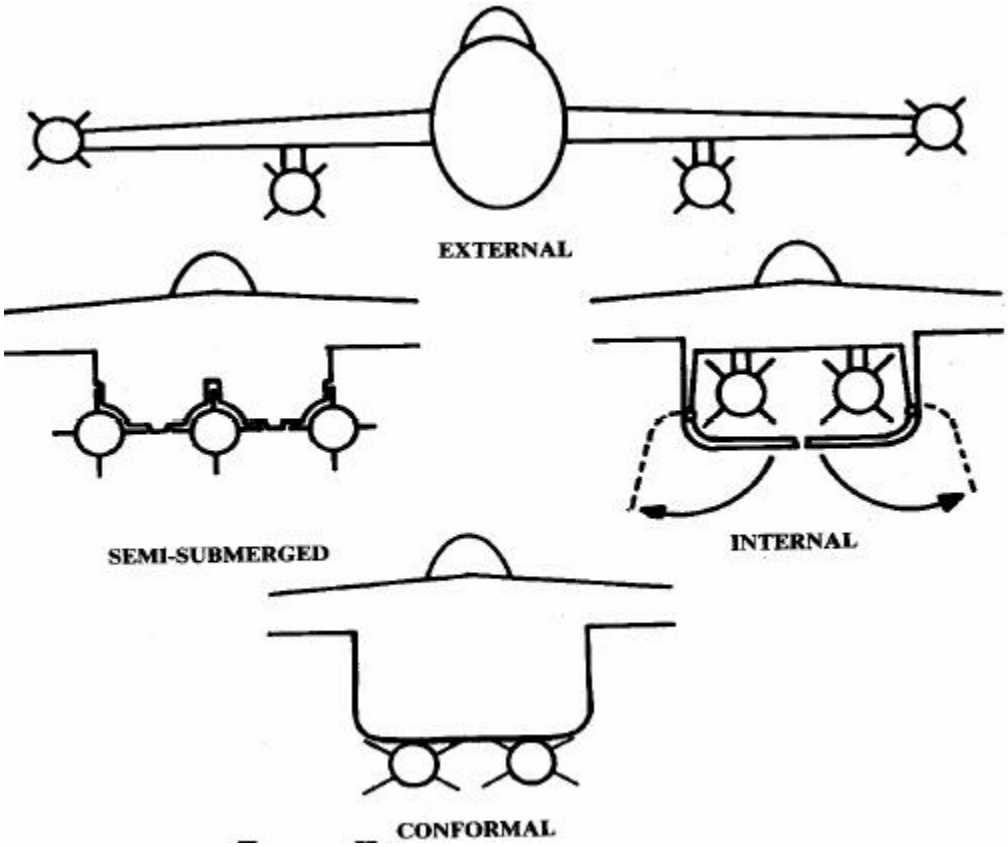


Figure 9.3 Weapon carriage configuration

9.4 Landing gear

The following three types of landing gears are mainly used in airplanes.
(i) Tricycle with single wheel or wheel bogey.
(ii) Bicycle with outrigger wheels on wings.
(iii) Tail wheel type.

The tricycle type is also called nose-wheel landing gear. It is the most commonly used landing gear. The main wheels and the nose wheels are located such that they take roughly 90% & 10% of the weight respectively.

In the bicycle type landing gear, the front and the rear landing gear are located on the fuselage reference line (see Fig.6.12). When this landing gear is used, outrigger wheels are provided on wing tips to prevent airplane from toppling sideways. In the tail wheel type or the tail dragger type landing gear, two mail wheels are provided ahead of the c.g and an auxiliary wheel near the tail.

This landing gear is used mainly in low speed airplanes and is generally non-retractable.

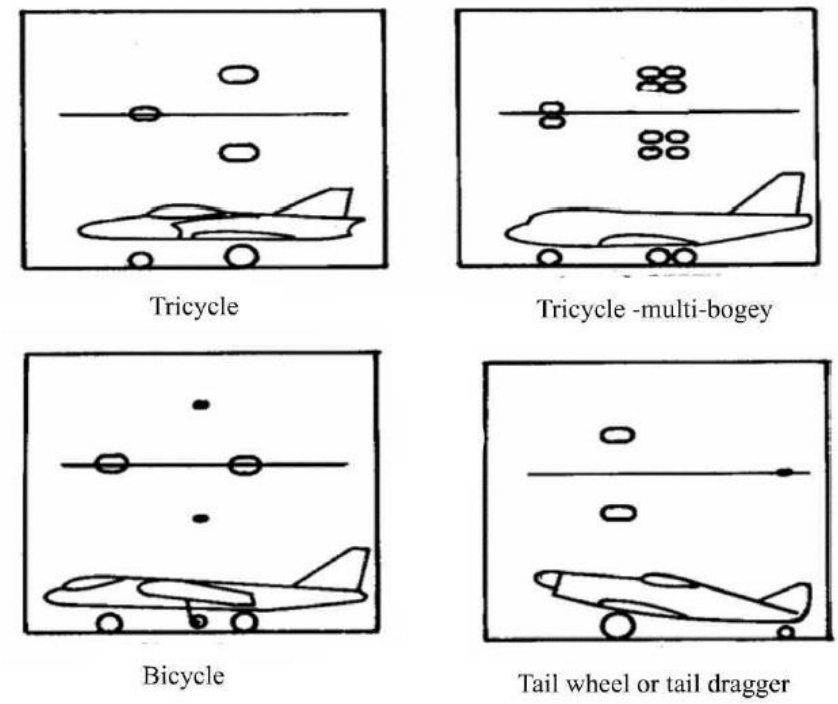


Figure 9.4 Landing Gear

Brief outline of landing gear design

Landing gear is one of the moving parts of the airplane. It constitutes 3 to 6% of the airplane weight and accounts for about 2% of the cost of the airplane. The requirements of a landing gear are as follows.

(a) Must be light and as small as possible

(b) Should provide smooth ride during taxing to the take-off position and to come to the parking slot after landing

(c) To allow airplane to accelerate during take-off run and allow rotation to achieve angle of attack corresponding to take-off.

(d) Retraction to reduce drag during flight.

(e) Safe energy absorption at touch down.

(f) Retarding the motion of airplane after all the wheels are in contact with ground.

The overturning angle is a measure of the airplane's tendency to overturn when turning around a sharp corner. This is measured as the angle from the c.g. to the main wheel, seen from rear at a location where the main wheel is aligned with the nose wheel. This angle should not be more than 630 for general airplanes and not more than 540 for carrier-based airplanes. This would help in deciding the wheel track i.e., lateral distance between main units.

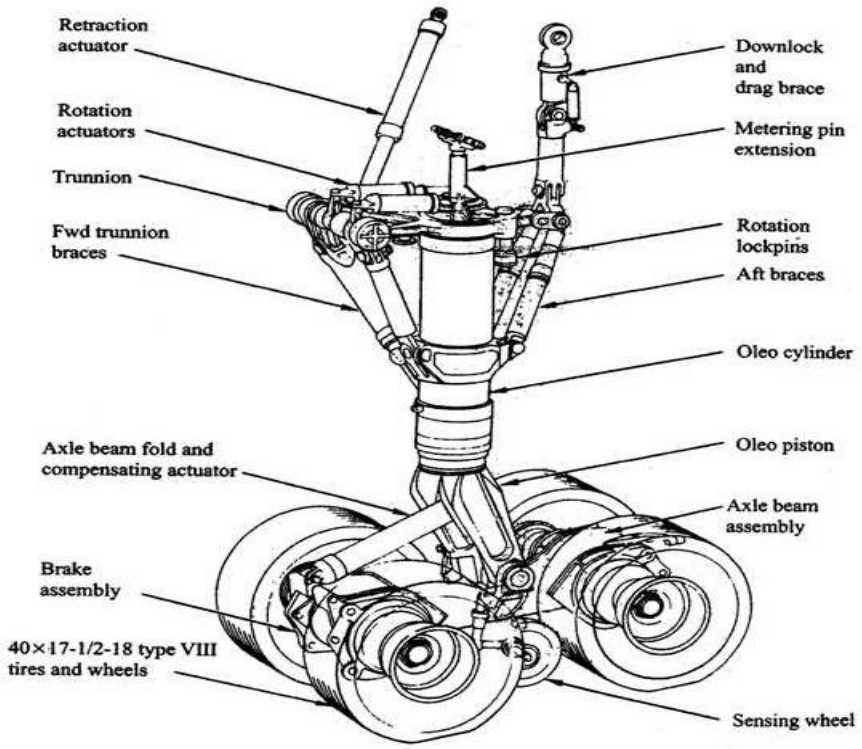


Figure 9.5 Nose Landing Gear

CHAPTER 10

LIFT AND DRAG CALCULATION

10.1 LIFT ESTIMATION

Lift is the force that directly opposes the weight of an airplane and holds the airplane in the air. Lift is generated by every part of the airplane, but most of the lift on a normal airliner is generated by the wings. Lift is a mechanical aerodynamic force produced by the motion of the airplane through the air. Because lift is a force, it is a vector quantity, having both a magnitude and a direction associated with it. Lift acts through the centre of pressure of the object and is directed perpendicular to the flow direction.

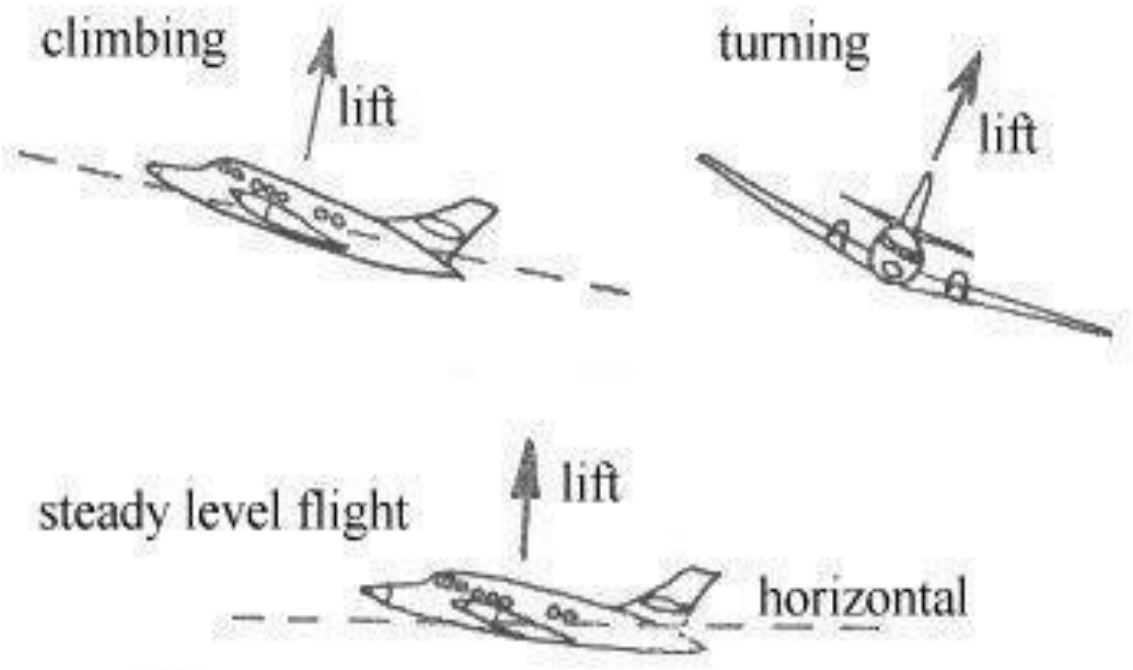


Figure 10.1: Lift Representation

1. **Lift at Take-off**

$$\boldsymbol{L = \frac{1}{2}\rho V^2 S C_L}$$

ρ = 1.225 kg/m^3 V= 0.6 * V_{TO} = 0.6*1.2*V_{Stall}

V_{Stall}= 77.084 m/s S= 59.25 m^2 C_L= 0.599

Therefore, V = 0.6*1.2*77.084 = 55.501 m/s

$L = \frac{1}{2} * 1.225 * 55.501^2 * 59.252 * 1.6$ = 178867.199 N

= 178kN

2. **Lift at Cruise**

ρ = 0.122 kg/m^3, Service Ceiling = 18000 m, V= 399.16 m/s

$L = \frac{1}{2} * 0.122 * 399.16^2 * 59.252 * 0.6$ = 961708.264 N

= 962 kN

3. **Lift at Landing**

ρ = 1.225 kg/m^3 V= 0.6 * V_{TO} = 0.6*1.2*V_{Stall}

V_{Stall}= 68.946 m/s S= 59.252 m^2 C_L= 0.6

Therefore, V = 0.6*1.2*68.946 = 49.641 m/s

$L = \frac{1}{2} * 1.225 * 68.946^2 * 59.252 * 2$ = 178867.907 N = 178 kN

4.Drag at Take-Off

$$\boldsymbol{D = \frac{1}{2}\rho V^2 S \left[C_{DO} + \frac{\emptyset {C_L}^2}{\pi e (AR)}\right]}$$

ρ = 1.225 kg/m^3 V= 0.6 * V_{TO} = 0.6*1.2*V_{Stall}

V_{Stall}= 74.084 m/s S= 59.252 m^2 C_L= 1.6

Therefore, V = 0.6*1.2*70.422 = 59.154 m/s

Aspect Ratio = 3.548; Service Ceiling = 18000 m; Wingspan = 14.5m

$\emptyset = \frac{\left(\frac{16h}{b}\right)^2}{1+\left(\frac{16h}{b}\right)^2}$ = 0.99 ; $C_{DO} = 2.68 * 10^{-4}$

Span efficiency factor, e = 0.971 (For tapered wing)

$$D = \frac{1}{2} * 1.225 * 55.501^2 * 59.252 * [2.68 * 10^{-4} + 0.1122 * (1.8)^2]$$

= 40669.492N = 40.66kN

5. Drag at Cruise

ρ = 0.122 kg/m^3 Service Ceiling = 18,000 m

V = 399.16 m/s

$$D = \frac{1}{2} * 0.122 * 399.16^2 * 59.252 * [2.68 * 10^{-4} + 0.1122 * (1.6)^2]$$

= 165563.6 N = 165.56 kN

6. Drag Landing

ρ = 1.225 kg/m^3 V= 0.6 * V_{TO} = 0.6*1.2*V_{Stall}

V_{Stall}= 68.946 m/s S= 35 m^2 C_L= 0.7868

Therefore, V = 0.6*1.2*68.946 = 49.642 m/s

$D = \frac{1}{2} * 1.225 * 64.08^2 * 35 * [2.68 * 10^{-4} + 0.1122 * (2)^2]$

=40154.709N

= 40.1 kN

Optimized values

Table 10.1: Lift and Drag optimised values

PARAMETERS	VALUES
Lift at Take-Off(L_{TO})	178kN
Lift at Cruise(L_C)	962kN
Lift at Landing (L_L)	178kN
Drag at Take-Off(D_{TO})	40.66kN
Drag at Cruise (D_C)	165.56kN
Drag at Landing (D_L)	40.1kN

CHAPTER 11

PERFORMANCE CALCULATIONS

INTRODUCTION

Our study of static performance (no acceleration) answered a number of questions about the capabilities of a given airplane-how fast it can fly, how far it can go, etc. However, there are more questions to be asked: How fast can it turn? How high can it "zoom"? What ground distances are covered during take-off and landing? The answers to these questions, involve accelerated flight, the subject of this chapter.

11.1 THRUST AND POWER

THRUST

By definition, the thrust available, denoted by T_A, is the thrust the power plant of the airplane. The various propulsion devices are described at length. The single purpose of these propulsion devices is to reliably provide thrust in order to propel the aircraft. Unlike the thrust $T_{R,}$ which has almost everything to do with the airframe of the airplane and virtually nothing to do with the power plant, the thrust available T_A has almost everything to do with the power plant and virtually nothing to do with the airframe.

CALCULATION:

$$S_{TO} = \frac{1.21 * W_{TO}}{g * \rho_{\infty} * S * \left(\frac{T}{W}\right) C_{Lmax}}$$

Where, W= W_{TO}= Max take-off weight = 345038.4N

g= Acceleration due to gravity= 9.81

S= Wing area = 59.252 m^2

C_{Lmax}= Max C_L of wing = 1.6

$$S_{TO} = 481.204m$$

11.2 Climb Performance:

C_{DO}=0.003; S = 35 $m^{2;}$ C_{LTO}=1.6; C_{LL}=1.8; AR= 2.38; M=2.16; e = 0.97.

V_{cruise}= 399.16 m/s

V= 0.25*V_{cruise}= 99.79 m/s

$$D = T_r = \frac{1}{2}\rho V^2 S\left[C_{DO} + \frac{{C_L}^2}{\pi e(AR)}\right]$$

Power Available, $P_a = T_r * V = 7.013*10^8$ kW

Thrust required, $T_A/T_R = \left[\frac{\rho}{\rho_0}\right]$* (1 + 0.7M)

T_A/T_R = 0.183

$\theta = \text{Sin}^{-1}\left(\frac{T-D}{W}\right)$

$\theta = 40.39^0$

$P_a = P_r$ W V sin16.31 = $7.013*10^8$ W

11.3 Rate of Climb:

(R/C) = $\frac{P_a - P_r}{W}$ = $= 112.16\ m/s$

i) $V_{(R/C)max} = \sqrt{\left[\frac{2}{\rho}\frac{W}{S}\sqrt{\frac{1}{3*\pi*e*AR*C_{DO}}}\right]}$ = 335.102 m/s

ii) $V_{\theta_{max}} = \sqrt{\left[\frac{2}{\rho}\frac{W}{S}\sqrt{\frac{1}{\pi*e*AR*C_{DO}}}\right]} * cos\theta_{max}$ = 423.25 m/s

$\theta_{max} = 40.39^0$

11.4 Gliding Performance

Rate of Sink(R/S) = $-\sqrt{\frac{2W}{\rho * S}}(\frac{C_D}{C_L})^{3/2}$

(R/S) = $7951.844\ m/s$

i) $V_{(\frac{R}{S})min} = \sqrt{\left[\frac{2*(W/S)}{\rho * C_{L_{(R/S)min}}}\right]}$

$$C_{L_{\theta min}} = \sqrt{(\pi * e * AR * C_{DO})} = 0.0488$$

$$C_{L_{(R/S)min}} = \sqrt{3} * C_{L_{\theta min}} = 0.08466$$

$V_{(\frac{R}{S})min}$ = 335.112 m/s

$$\gamma_{min} = \left(\frac{C_D}{C_L}\right) = \frac{0.449}{1.8} * \frac{180}{\pi} = 14.3^0$$

11.3 LANDING PERFORMANCE

APPROACH & LANDING

Consists of three phases:

• Airborne approach at constant glide angle (around 30) and constant speed.

• Flare - transitional manoeuvre with airspeed reduced from about 1.3 VStall down to touch-down speed.

• Ground roll - from touch-down to rest. Ground roll landing distance (s3 or s1) estimated from: Where Vav may be taken as 0.7 x touch-down speed (Vt or V2) and Vt is assumed as 1.3 x Vstall

SLO = 1.69 $W2\ g\ X\ \rho\ X\ S\ X\ CLmax\ X\ \{[D + \mu r(W - L)]\}av$

μr is higher than for take-off since brakes are applied - use μr = 0.4 for the paved surface. If thrust reversers (Tr) are applied, use:

SLO = 1.69$W2\ g\ X\ \rho\ X\ S\ X\ CLmax\ X\ \{T + [D + \mu r(W - L)]\}av$

CALCULATION:

$$S_L = \frac{1.69 * W^2}{g * \rho_\infty * S * C_{L\,max} * [D + \mu_r(W - L)]}$$

W=W_{TO}-W_F-W_{PL} = 35208 – 12076.344 - 7000 = 16131.656 Kg = 158251.54 N

$C_{L\,max}$=2

μ_r=0.4

D= 38922.170 N

L = 345523.927N

$$S_L = \frac{1.69 * 345038.4^2}{9.81 * 1.225 * 59.252 * 2 * [40154.709 + 0.4(166171.4)]}$$

S_L= 1325.04 m = 1.325 km

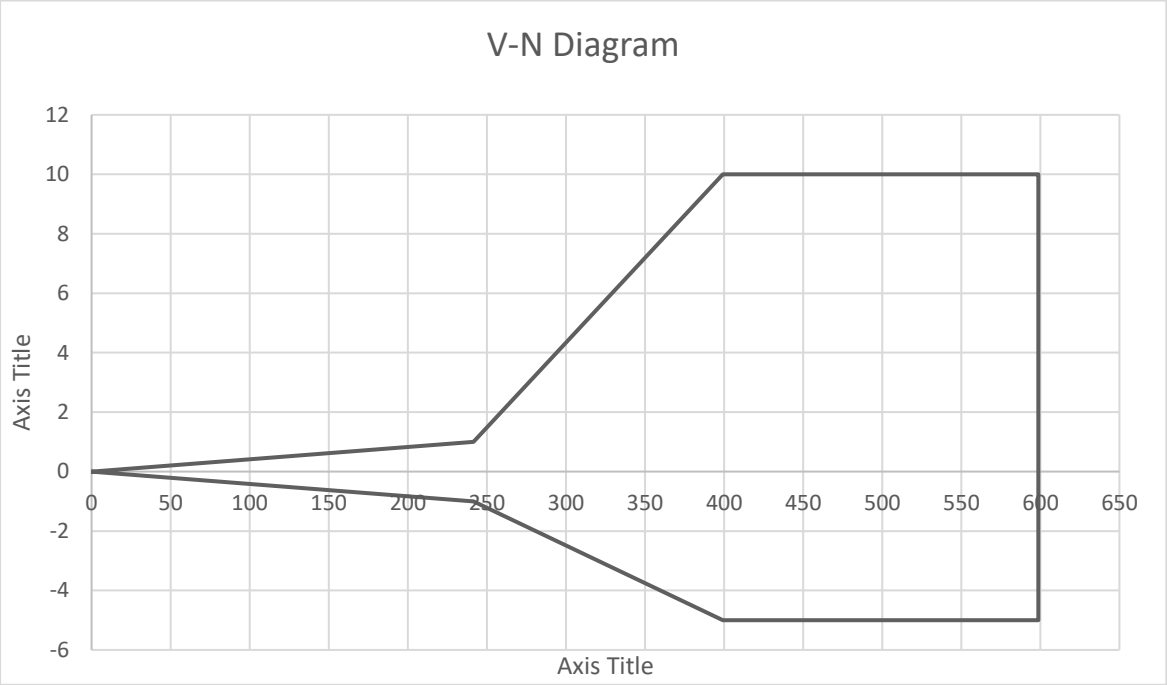
Optimized values

Table 11.1: Performance optimised values

PARAMETER	**VALUE**
Thrust required	194.64kN
Thrust available	1241.3kN
Power required	6.626*10^8 kW
Power available	7.518*10^8 kW

Rate of climb	260.26 m/s
Rate of sink	28.376 m/s
Take – off distance	481.45 m
Landing distance	1051.27 m

V-n Diagram:



0	0
241.434	1
399.16	10
598.74	10
598.74	-5
399.16	-5
241.436	-1
0	0

CHAPTER 12

THREE VIEWS OF FIGHTER AIRCRAFT

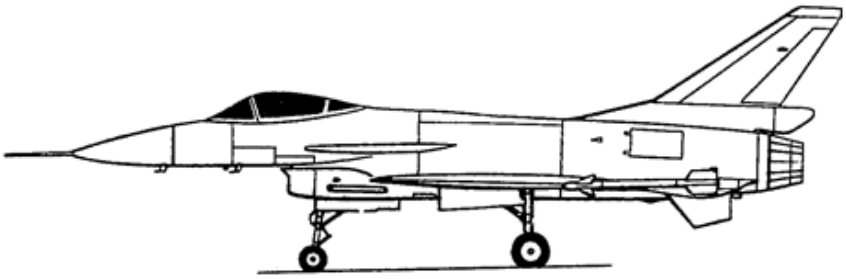


Figure 12.1 Side view of Fighter Aircraft

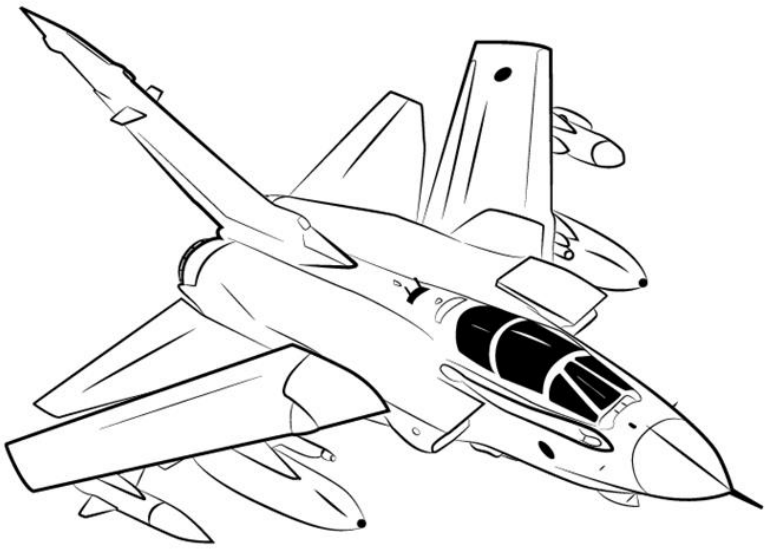


Figure 12.4 Isometric view of Fighter Aircraft

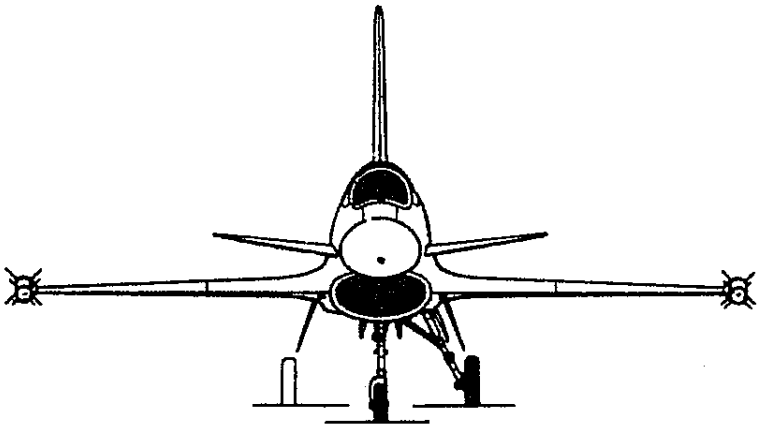


Figure 12.3 Front view of Fighter Aircraft

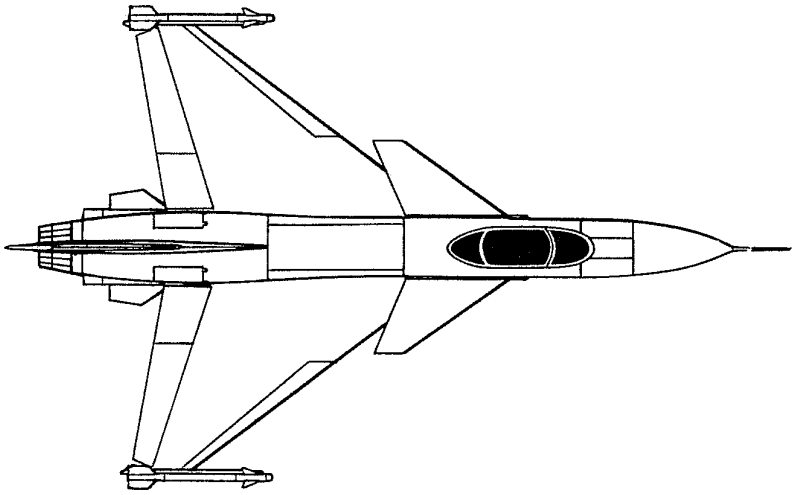


Figure 12.2 Top view of Fighter Aircraft

CHAPTER 13

RESULT AND DISCUSSION

Table 13.1: Finalised Design Parameters

Sl. No.	Parameter	Value with Units
1	Lift	178.8kN
	Lift at Take-Off L_{TO}	344.5kN
	Lift at Cruise L_C	
	Lift at Landing L_L	178.8kN
2	Drag	40.66kN
	Drag at Take-Off D_{TO}	38.92kN
	Drag at Cruise D_C	
	Drag at Landing D_L	40.15kN
3	Weight at Take-off: W_{TO}	35208 kg
	Empty Weight: W_E	18372 kg
	Payload Weight: W_{PL}	7000 kg
	Fuel Weight: W_F	12076.344 kg

4	C_L C_D Aerofoil Series: Root: Tip:	0.599
		0.073
		NACA 64-008A AIRFOIL
		NACA 64-008A AIRFOIL
5	Tail Configuration:	Conventional aft – tail configuration
6	Landing Gear Configuration:	Conventional retractable configuration
7	Take off Distance Landing Distance	481.204 m
		1325.049 m
8	Aspect Ratio	3.548
9	Wing Span	14.5 m
10	Chord Length	4.086 m
11	Wing Loading	420 kg/ m^2
12	Maximum cruise speed	1437 Kmph
13	Climb Angle	40.39^0

14	Glide Angle	14.3^0

DISCUSSION

The preliminary design of a Supersonic Fighter jet is done and the various design considerations and performance parameters required are calculated and found out. The obtained design values are not necessarily a define reflection of the airplane's true and conceptualized design, but the basic outlay development has been obtained.

The final design stays true to the desired considerations of the Supersonic Fighter Jet that can provide high performance and considerable reduction in run-way distance. Also, it has a considerable value of TSFC as well. This is no ideal design and is highly subjected to improvisations and innovations to make the design as ideal as possible.

CHAPTER 14

CONCLUSION AND FUTURE WORK

CONCLUSION

The preliminary design of a Multirole Fighter aircraft is done and the various design considerations and performance parameters required are calculated and found out. The obtained design values are not necessarily a definite reflection of the aeroplane's true and conceptualized design, but the basic outlay of development has been obtained.

The final design stays true to the desired considerations of a long-range aircraft that can provide high fuel efficiency as well. There is no ideal design as such and continuous changes, improvements and innovations serve to make the design as ideal as possible, while always looking to achieve optimum performance.

The design is a fine blend of science, creativity, the presence of mind and the application of each one of them at the appropriate time. Design of anything needs experience and an optimistic progress towards the ideal system. The scientific society always looks for the best product design. This involves the strong fundamentals of science and mathematics and their skilful applications, which is a tough job endowed upon the designer.

We have enough hard work for this design project. A design never gets completed in a fluttering sense but it is one step further towards the ideal system. But during the design of this aircraft, we learnt a lot about aeronautics and its implications when applied to an aircraft design.

The challenges we faced at various phases of the project made clear the fact that experience plays a vital role in the successful design of any aircraft or aircraft component. A lot of effort has been put into this project and as much as we have worked, we have learnt in turn.

FUTURE WORK

The above work will enhance the knowledge in continuation of the design given in Aircraft Design project-I

In Design Project – II will be studied for the design with Gust and manoeuvrability envelopes. Performance of Critical loading and the final calculation of V-n graph. A theoretical approach to Study of structural design will be undertaken. To estimate loads of wings, to estimate loads of fuselage. Balancing and manoeuvring loads on the tail plane, Aileron and Rudder load are started. Designing the structural layout of the aeroplane. Even some of the components like wings, the fuselage is designed. Finally, detailed design report will be prepared with sketches or drawings.

REFERENCES

1. Anderson, John D. Jr., (2001) “Introduction to Flight”, McGraw-Hill, New York.
2. Anderson, John D. Jr., (1999) “Fundementals of Aerodynamics”, McGraw-Hill, New York.
3. Anderson, John D. Jr., (1999) “Aircraft Performance and Design”, McGraw-Hill, New York.
4. Ball, R.E (2003)” The fundamentals of aircraft combat survivability analysis and design”, second edition AIAA Educational series.
5. Barton M.V. (1948) “Fundamentals of aircraft structures” Prentice-Hall, New York,.
6. George P. Sutton (2001) “Rocket Propulsion Elements”, John Wiley &Sons, 7th Edition, ISBN- 9780471326427.
7. Gerard Frawley & Jim Thorn (1996) “International Directory of Military Aircraft” Australian Aviation, ISBN – 187567120X, 9781875671205
8. Green W. (compiler) (1981) “The observer’s book of aircraft” Fredrick Warne .
9. Ira H. Abbott & Albert E. von Danhof, (1959) “Theory of Wing Section – Including summary of Airfoil data” Dover publications, ISBN - 0486605868 9780486605869
10. Jane's Publishing, 95th Sub Edition, ISBN - 9780710626141, 0710626142
11. John D. Anderson Jr. (2011) “Introduction to Flight” McGraw-Hill Education, ISBN 0073380245, 9780073380247
12. John D. Anderson Jr. (2016) “Fundamentals of Aerodynamics” McGraw-Hill Education, 6th Edition ISBN - 1259129918, 9781259129919
13. John D. Anderson Jr. (1999) “Aircraft Performance and Design” WCB/McGraw-Hill, ISBN - 9780070019713, 0-07-001971-1

14. Paul Jackson (Editor-in-Chief), (2004) “Jane’s All the World’s Aircraft”
15. Roskam, J. (1985) “Airplane Design”, Roskam Aviation and Engineering Corp. Ottawa, Kansas.
16. Raymer, Daniel P. (1992) “Aircraft Design : A Conceptual Approach”, AIAA Education Series, Washington, DC
17. Taylor, J. (2004) “Jane’s All the World’s Aircraft”, Jane’s, London, UK.
18. William Green (1961) “The Observer’s World Aircraft Directory” Frederick Warne & Co. Ltd, ISBN - 978-1125857120
19. http://www.airliners.net/aircraft-data
20. https://www.faa.gov/airports/engineering/aircraft_char_database/
21. http://airfoiltools.com/
22. http://www.combataircraft.com/
23. https://www.faa.gov/regulations_policies/handbooks_manuals/aircraft/amt_airframe_handbook/media/ama_Ch13.pdf
24. https://www.military.com/equipment/fighter-aircraft
25. http://www.airfoildb.com/
26. https://www.dassault-aviation.com/en/
27. https://www.militaryfactory.com/
28. https://www.lockheedmartin.com/
29. https://www.geaviation.com/commercial/engines
30. https://www.rolls-royce.com/products-and-services/civil-aerospace.aspx
31. www.wikipedia.com
32. www.airfoiltools.com
33. www.airliners.com
34. www.combataircraft.com