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Design Project of Multirole Fighter Aircraft (Dassault Rafale)

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ABSTRACT –

The aim of the design project to the design a multirole fighter aircraft to carry out the structural design part of the airplane .To carry out comparative studies of different types of airplanes and their specifications and performance details with reference to the design work under taken .To carry out preliminary weight estimation, selection of design parameters, power plant selection, aero foil selection, fixing the geometry of wing, tail, control surfaces, landing gear selection and also structural design of preliminary design of an aircraft wing like shrink's curve, structural load distribution, shear force, bending moment and torque diagrams .Also detailed design of a aircraft wing and preliminary detailed design of fuselage and design of aircraft wing .To carry out drag estimation, performance calculations, stability analysis and V-n diagram .And preliminary detailed design of fuselage .And design of control surface wing –root attachment and landing gear. Also, finally preparation of a detailed design report with CAD drawing.

Keyword: Mulitrole fighter, Preliminary, Shrink's curve, Stability.

I. INTRODUCTION TO AIRCRAFT

An aircraft is a vehicle capable of flight, encompassing various types like airplanes, helicopters, and gliders, each designed for specific purposes and utilizing different principles of flight.

Definition:

Aircraft are generally defined as any device that can fly, whether heavier-than-air (like airplanes) or lighter-than-air (like hot air balloons).

Types:

Fixed-wing aircraft: These rely on wings to generate lift, including airplanes, seaplanes, and gliders.

Rotorcraft: These use rotating wings (rotors) for lift and propulsion, such as helicopters and autogiros.

Other types: This category includes lighter-than-air aircraft like hot air balloons and dirigibles.

Flight Principles:

Aircraft utilize principles of aerodynamics, where the shape of the wings and other surfaces interact with air to create lift, thrust, and control.

Aircraft use various propulsion methods, including propellers, jet engines, and rockets, depending on the type and intended use of the aircraft.

Applications:

Aircraft are used for a wide range of purposes, including passenger and cargo transport, military operations, research, and recreation.

History:

The development of aircraft has been a fascinating journey, with key milestones including the Wright brothers' first successful flight in 1903.

II. COMPONENTS OF AIRCRAFT

An aircraft is composed of several key components: the fuselage (main body), wings (for lift), empennage (tail assembly), landing gear, engines, and various systems like avionics, hydraulics, and power systems.

Structural Components:

Fuselage: The main body of the aircraft, designed to house passengers, cargo, and sometimes engines.

Wings: Generate lift through their airfoil shape, allowing the aircraft to fly.

Empennage (Tail Assembly): Provides stability and control, including the horizontal and vertical stabilizers, rudder, and elevator.

Landing Gear: Supports the aircraft on the ground and facilitates takeoff and landing.

Propulsion and Power:

Engines: Provide the power to propel the aircraft, typically located on the wings or in the fuselage.

Propellers: (For propeller-driven aircraft) convert engine power into thrust.

Power Systems: Supply electrical and hydraulic power to various aircraft systems. Avionics: Electronic systems for navigation, communication, and flight control.

Control Surfaces:

Ailerons: Control the roll (side-to-side) movement of the aircraft. Elevators: Control the pitch (up-and-down) movement of the aircraft. Rudder: Controls the yaw (left-to-right) movement of the aircraft. Winglets: Vertical extensions on the wingtips that help reduce drag.

III.CAMPARATIVE DETAILS

When comparing aircraft, key parameters include dimensions (length, wingspan, height), weight (empty, maximum takeoff, payload), performance (speed, range, climb rate), and capacity (passengers, cargo).

1. **Performance:**

Speed: The maximum speed the aircraft can achieve, often measured in Mach number (speed of sound) or miles per hour.

Range: The maximum distance the aircraft can fly on a given amount of fuel. Climb Rate: How quickly the aircraft can gain altitude.

Maneuverability: The ability of the aircraft to change direction and perform turns. Stability: The aircraft's tendency to maintain a straight and level flight path.

Fuel Economy: How efficiently the aircraft uses fuel.

2. **Capacity:**

Passenger Capacity: The number of passengers the aircraft can accommodate.

Cargo Capacity: The amount of cargo the aircraft can carry, measured in weight or volume.

PARAMETER	**LOCKHEED YF-12**	**SUKHOI 30 MKI**	**DASSAULT RAFALE**	**HAL TEJAS**	**MIKOYAN MIG-31**
CREW	2	2	1-2	1	2
LENGTH(m)	30.97	21.9	15.27	13.2	21.62
WINGSPAN(m)	16.94	14.7	10.9	8.2	13.46
HEIGHT(m)	5.64	6.4	5.34	4.4	6.15
WING AREA(m2)	167.22	62	45.7	38.4	61.6
EMPTY WEIGHT (kg)	27,218	18,400	10,300	6,560	21,820
LOADED WEIGHT (kg)	45,100	24,900	15,000	9,800	41,00
MAX. TAKEOFF WEIGHT (kg)	56, 245	38,800	24,500	13,500	46,200
RATE OF CLIMB (m/s)	85.3	300	305	250	208

DRYTHRUST (kN)	2*60.0	2*76.7	2*50.04	1*53.9	2*93.1
MAX SPEED (km/h)	3.35	2.0	1.8	1.6	2.83
COMPAT RADIUS (km)	2,000	1,500	1,850	500	1,500
RANGE (km)	4,828	3,000	3,700	1,850	3,000
SERVICE CEILING(m)	24,400	17,300	15,240	16,500	20,600
WING LOADING (kg/m2)	270	401	328	255	665
THRUST/WEIGHT	0.75	1.07	1.1	1.07	0.85
POWER PLANT	2*pratt&whitney j58-p-1 turbojets	2*AL-31FP turbofans	2*Snecma M88 turbofans	1*F404- GE-IN2 turbofan	2*SoloviewD- 30F6 turbofans
ASPECT RATIO	1.72	3.5	6.8	1.75	2.94

IV WING SELECTION

What is Aero foil?

Aero foil refers to a cross-sectional shape having a design with a curved surface that provides the most favorable ratio between lift and drag in flight. Lift is the component that helps the force turns out to be perpendicular to the motion's direction while drag is the component that is parallel to the motion's direction.

Aero foil Terminology

An aero foil consists of various cross-sectional shapes. Different types of aero foils are used for the construction of aircraft wings. To differentiate between different aerofoil shapes, an aerofoil's properties are defined and specific terminologies are used Aerofoil Terminology. An Aerofoil is being designed with a shape that has the capability of producing lift with relatively high efficiency as it passes through the air. An aero foil can have many cross-sectional shapes. The terms which are related to aero foils are as follows.

Chord: Chord can be defined as the distance between the leading edge, at the front of the aero foil that is the point, and has maximum curvature and the trailing edge, at the rear of the aero foil, that is the point with a maximum curvature along the chord line. It is a distance between the leading and trailing edges measured along the chord line.

- **Chord Line:** Chord line is the straight line connecting the leading and trailing edges.
- **Leading-Edge:** It is an edged part of an aerofoil that hits the air particles first.
- **Lower Surface:** The lower surface is a higher static pressure surface which is also known as a pressure surface. It is the surface of an aerofoil between the leading and trailing edges, on the lower side.
- **Mean Camber Line:** It is a line joining the leading and trailing edges of an aerofoil, at an equal distance from the upper and lower surfaces.
- **Maximum Camber:** It is the maximum distance of the mean camber line from the chord line.
- **Maximum Thickness:** It is the maximum distance of the lower surface from the upper surface.
- **Trailing Edge:** It is an edged part from an aerofoil that hits the air particles last.
- **Upper Surface:** The upper surface is associated with high velocity and low static pressure, which is also known as suction surface. It is the surface of an aerofoil between the leading and trailing edges, on the upper side.

1. **Aerodynamic Centre:** The centre where the pitching moment is independent of lift coefficient and angle of attack.
2. **Centre Of Pressure:** The centre where the pitching moment is zero.
3. **The Angle of Attack (AOA):** The angle of attack is formed between a reference line on a body and the oncoming flow.
4. **Pitching Moment:** The moment or torque produced on the aerofoil by the aerodynamic force is known as the Pitching moment.

An aircraft wing is a crucial aerodynamic surface designed to generate lift, enabling heavier-than-air craft to fly. It's an airfoil with a specific shape and angle of attack, crucial for controlling lift and drag during flight.

WING STRUCTURE:

MONOCOQUE STRUCTURE:

A monocoque structure, meaning "single shell" in French, is a structural design where the outer skin or shell supports the majority of the applied stresses, similar to an eggshell, rather than relying on a separate frame.

Key Concept:

In a monocoque structure, the external skin, or shell, acts as the primary load-bearing component, distributing stresses across the entire structure.

SEMI-MONOCOQUE STRUCTURE:

A semi-monocoque structure, often used in aircraft fuselages, combines a strong outer skin that carries loads with an internal framework of stringers, frames, and bulkheads for added support and rigidity, allowing for efficient stress distribution and structural integrity.

Key Characteristics:

Stressed Skin:

The outer skin (or shell) is a primary load-bearing component, meaning it carries a significant portion of the stresses and loads imposed on the structure.

Internal Reinforcement:

A network of internal structural elements, including:

Stringers: Longitudinal members that run along the length of the fuselage, helping to resist tension and compression loads.

Frames: Circumferential members that maintain the shape of the fuselage and distribute loads into the skin.

Bulkheads: Strong, transverse members that carry concentrated loads and provide additional support.

Key Parameters in Wing Design:

Aspect Ratio:

The ratio of wingspan to average chord length. High aspect ratio (long, narrow wings) is good for lift and endurance, while low aspect ratio (short, wide wings) is better for maneuverability.

Sweep Angle:

The angle at which the wing extends relative to the direction of flight. Swept wings (swept back) is common for high-speed aircraft, as they delay compressibility effects.

Taper Ratio:

The ratio of the wing tip chord to the root chord. Tapered wings (where the chord length decreases towards the tip) provide better lift distribution and reduced induced drag.

Dihedral Angle:

The angle at which the wing extends from the fuselage. Dihedral angle affects the lateral stability of the aircraft.

Airfoil Shape: The cross-sectional shapes of the wings, affects lift and drag characteristics.

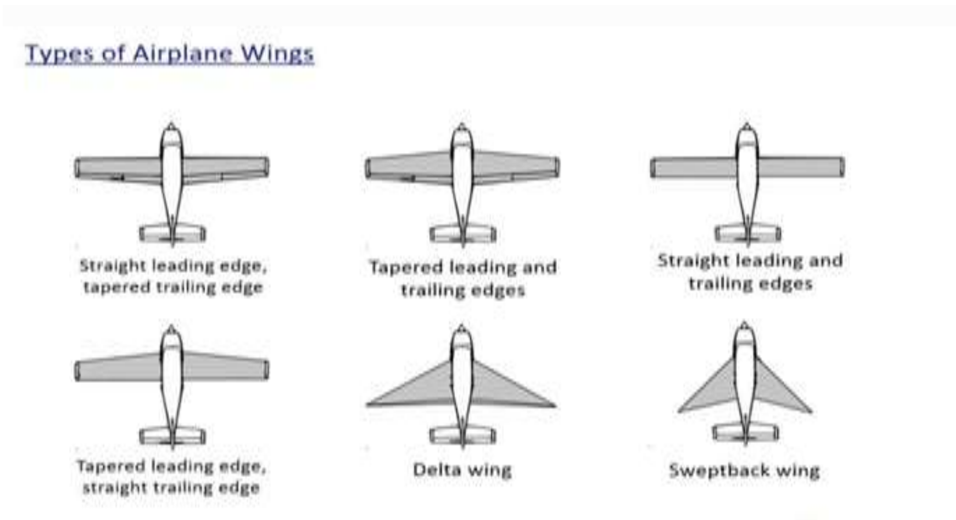


Fig 1: Airfoil Shape

V FUSELAGE SELECTION

The fuselage is the main body or "shell" of an aircraft, essentially the part that houses the crew, passengers, and cargo. It's a long, hollow structure that attaches to the wings, tail, and other components. The fuselage's design and construction are critical for both aerodynamics and structural integrity.

Key Functions:

Structural Support: The fuselage provides the primary support for the entire aircraft, holding all other components together.

Load Carriage: It carries the weight of the crew, passengers, cargo, fuel, and sometimes the engines.

Aerodynamic Efficiency: The fuselage's shape is designed to minimize drag, allowing for efficient flight.

Passenger and Cargo Accommodation: It provides space for passengers, crew, and cargo, with specific areas designated for each, according to Grupo One Air.

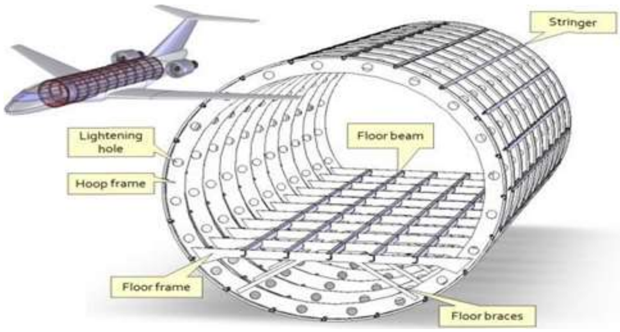


Fig 2: Fuselage Structure

VI.LANDING GEAR SELECTION

For multi-role fighter aircraft, landing gear selection involves balancing factors like ground handling, operational needs, and structural integrity, with tricycle and tandem configurations being common choices.

Common Landing Gear Configurations:

Tricycle Landing Gear:

This is the most prevalent type, featuring two main wheels positioned towards the aircraft's center and a nose wheel for steering.

Tail wheel (Conventional) Landing Gear:

This configuration uses a tail wheel instead of a nose wheel, with the main wheels located further forward.

Tandem Landing Gear:

This setup uses multiple wheels (usually two) under the main landing gear, increasing the number of wheels to reduce load on each individual wheel.

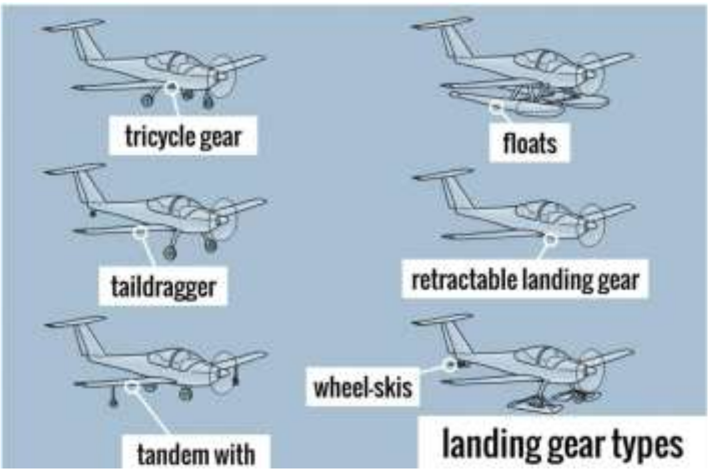


Fig 3: Landing Gear Types

VII.ENGINE (POWER PLANT) SELECTION

Definition:

An aircraft power plant is the engine, or propulsion system, that creates the force (thrust) necessary for an aircraft to move through the air.

Aircraft power plants, or engines, come in various forms, broadly categorized as piston engines, gas turbine engines (including turbojets, turbofans, turboprops, and turbo shafts), and electric motors.

Types of power plant:

1. **Piston Engines:**

These are similar to car engines, using reciprocating motion of pistons to generate power.

Commonly used in smaller, slower aircraft like general aviation planes. Can be either air-cooled or water-cooled.

Include radial, inline, and V-type engine configurations.

2. **Gas Turbine Engines:**

These engines use a turbine to extract energy from the combustion of fuel and air. Turbojet: The simplest type, producing thrust by accelerating exhaust gases directly.

Turbofan: Similar to a turbojet, but with a large fan at the front to improve efficiency, especially at lower speeds.

Turboprop: Connects the turbine to a propeller, similar to a piston engine, but with higher speed and efficiency.

Turbo shaft: Used primarily in helicopters, providing power to the rotor system.

3. **Other Types:**

Rockets: Used for high-speed, long-duration flight, or as a supplemental engine for takeoff or climb.

Electric Motors: Increasingly used in smaller aircraft and drones, offering potential for reduced emissions and noise.

Ramjets and Scramjets: Used for very high-speed flight, but are not as common as other types.

Winkle engine: A type of rotary engine.

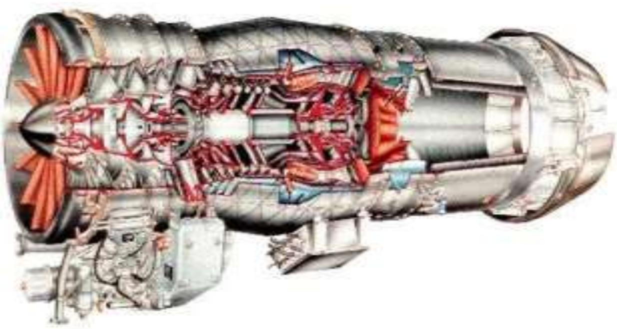


Fig 4: Snecma M88 And Its Cross Section

V-N DIAGRAM

A V-n diagram (Velocity-Load Factor diagram) is a graphical representation of an aircraft's flight envelope, showing the relationship between airspeed (V) and load factor (n). It helps pilots and engineers understand the aircraft's structural and aerodynamic limits.

Key Components:

1. **Positive Limit Load factor:** The maximum G-force an aircraft can sustain without structural damage.
2. **Negative Limit Load Factor:** The maximum negative G-force (inverted flight) the aircraft can endure.
3. **Stall Region:** The lower curved boundary where the aircraft stalls due to insufficient lift.
4. **Structural Limit (Red Line):** The maximum speed beyond which structural failure occurs.
5. **Manoeuvrings Speed (Va):** The speed at which the aircraft can sustain its maximum load factor without damage.
6. **Cruise & Dive Speeds:** The normal operating range and maximum permissible speeds.

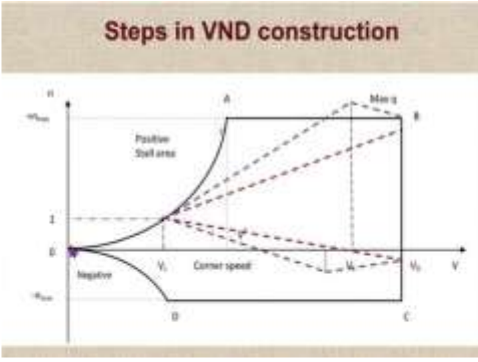
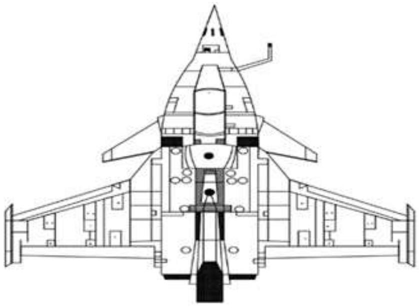


Fig 5: VN Diagram Construction

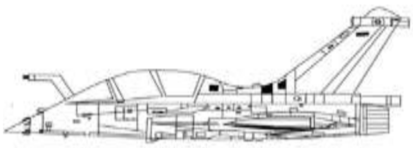
VIII.THREE VIEW DIAGRAM FOR AIRCRAFT

TOP VIEW



FORNT VIEW

SIDE VIEW



IX. CONCLUSION

Multirole fighter aircraft represent a significant step forward in military aviation, offering a combination of versatility, cost-effectiveness, and adaptability. They remain a crucial part of modern air power and continue to evolve with advancements in technology and design.

Versatility: Multi-role fighters are designed to perform multiple roles, including air- to-air combat (fighting other aircraft), air-to-ground combat (attacking ground targets), and other tasks like reconnaissance, electronic warfare, and forward air control.

Cost-effectiveness: Utilizing a single airframe for various missions reduces overall costs compared to having separate aircraft for each role.

Advanced Capabilities: These aircraft are equipped with advanced sensors and avionics, allowing them to collect information, engage targets, and participate in electronic warfare.

Examples: Some well-known multi-role fighters include the F/A-18 Hornet, the Eurofighter Typhoon, and the Dassault Rafale.

Evolution: The concept of multi-role fighters has evolved over time, with newer generations offering even greater capabilities and versatility

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