International Journal of Scientific Research and Engineering Development-– Volume 7 Issue 2, Mar- Apr 2024
Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Numerical Study on Transforming the Fighter Aircraft to Enhance Maneuverability and Performance

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Abstract:

The purpose of this research is to thoroughly examine fighter jet aircraft, including their design, capabilities, and role in current military operations. Fighter jets are the pinnacle of aviation technology, designed for speed, agility, and lethality. This study dives at numerous components of fighter jet aircraft, such as aerodynamic design, propulsion systems, avionics, weapons, and operational missions, using a multidimensional approach. This research examines the evolution of fighter aircraft from their conception to the current day, highlighting the technological developments and innovations that impacted their growth. Furthermore, the strategic significance of fighter planes in attaining air supremacy, waging aerial combat, and supporting ground operations is investigated, giving light on their crucial role in modern warfare. This research uses a detailed examination of fighter jet aircraft.

Keywords: ***Fighter Aircraft, Design Concepts, Aerodynamic Performance, Structural Integrity***

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I. INTRODUCTION

Designing a modern fighter aircraft is a multifaceted process that incorporates several disciplines and factors. Here's a full breakdown of the essential actions and components involved:

Mission Analysis: The design process begins with a comprehensive review of the anticipated mission profiles. Fighter aircraft are built to excel in specialized missions such as air superiority, ground attack, and multi-role operations. Understanding the mission criteria helps to define the aircraft's performance characteristics.

Conceptual Design: Engineers start by developing concepts based on mission objectives, aerodynamic principles, and technical capabilities. This step includes determining the aircraft's dimensions, weight, propulsion system, and basic layout.

Aerodynamic Analysis: Aerodynamicists utilize computational fluid dynamics (CFD) and wind tunnel tests to maximize the aircraft's Designed for performance and stability. This involves reducing drag, increasing mobility, and maintaining stability at varying speeds and altitudes.

Structural construct: Structural engineers construct the airframe to resist the tremendous loads and stresses that occur during flying maneuvers. Advanced materials such as carbon fiber composites are employed to strike a compromise between strength, weight, and durability.

Propulsion System Integration: Fighter aircraft rely on strong jet engines to fly. To improve performance and decrease radar cross-section, the engine's intake design, thrust-to-weight ratio, and engine location must all be considered when integrating it with the aircraft.

Avionics and Systems Integration: Avionics engineers use modern electronics and sensors for navigation, targeting, communication, and defense systems. Integration of these systems necessitates careful consideration of power consumption, weight distribution, and Electromagnetic compatibility.

Weapon Integration: Fighter aircraft are armed with a wide range of weaponry, including guns, missiles, bombs, and electronic warfare pods. Designers must verify that weapon storage, deployment methods, and targeting systems are compatible.

Human Factors: The cockpit design is crucial for pilot comfort, visibility, and operating efficiency. Human factors specialists focus on cockpit layout, control ergonomics, and pilot interface to improve situational awareness and reduce pilot workload.

Testing and Prototyping: Once the design is complete, prototypes are created for comprehensive testing. This involves ground testing for structural integrity, system integration, and flight testing to confirm performance in real-world scenarios.

Iterative Refinement: The design process frequently includes several iterations based on test results and feedback. Engineers adjust the design to increase performance, and address issues and fulfill changing needs.

Certification and Production: Following successful testing and validation, the aircraft is certified by regulatory agencies. Following approval, production begins, which includes manufacturing, assembly, and quality control operations.

To summarize, developing a modern fighter aircraft is a multidisciplinary endeavor requiring skills in aerodynamics, propulsion, materials science, avionics, and human aspects. The objective is to develop a highly competent and dependable platform that can satisfy the demanding requirements of modern aerial combat.\

II. DESCRIPTION

Airframe: The aircraft's structure, which includes the fuselage, wings, tail assembly, landing gear, and other components, adds considerably to its weight. Modern fighter aircraft frequently make use of lightweight materials such as sophisticated composites, titanium, and aluminium alloys to decrease weight while preserving strength.

Propulsion System: The aircraft's engines and accompanying components such as fuel tanks and engine accessories add significant weight. Fighter jets generally use turbofan or turbojet engines, which vary in weight based on parameters such as thrust power and fuel economy.

Avionics: Advanced avionics systems, such as flight control computers, radar, navigation devices, communication systems, and electronic warfare suites, are required for modern fighters. Because of the intricacy of their components as well as the necessity for redundancy and reliability, these systems can be rather large.

Weapon Systems: Armaments such as missiles, bombs, guns, and accompanying targeting systems add to the aircraft's overall weight. Weapon weight varies according to the size, type, and amount carried by the fighter.

Fuel: The amount of fuel carried by the aircraft directly influences its weight, especially during take-off and combats missions. Fighter aircraft frequently include both internal fuel tanks and facilities for external fuel tanks or in-flight refuelling devices.

Payload and Mission Equipment: Reconnaissance pods, electronic countermeasure devices, and specific mission payloads can all add weight to the aircraft.

III. METHODOLOGY:

A Set of 10 fighter aircraft considered for comparative study in various parameters such as maximum Thrust, Length, Height, Wing Span, Cruise Speed, Range, Payload, Power plant, No of Engines, Service Ceiling, Aspect Ratio ,Gross Weight, and Wing Loading etc..,

The following aircraft are taken for the comparative studies,

- F-22 Raptor (United States)
- F-35 Lightning II (United States)
- Eurofighter Typhoon (Europe)
- Su-35 (Russia):5J-20 (China)
- Rafale (France)
- Mig-29 (Russia)
- Gripen E/F (Sweden)
- HAL Tejas (India)
- JAS 39 Gripen (Sweden)

We evaluated the parameters required for the aircraft design after analyzing the data from the comparative study. computation of the aircraft's overall weight This is the total of the aircraft's empty weight, fuel weight, and payload weight.

Weight Estimation:

When estimating an aircraft's weight, a number of elements must be taken into account, including the design, materials, cargo, fuel, and other components. Empty weight, payload, fuel, operational items, and total weight are among the various forms of weight. Extensive computations based on particular aircraft specs, load distributions, and flight plans are required for precise weight estimation.

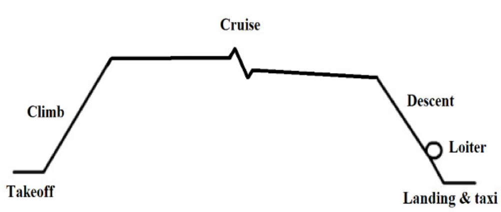


Figure-1:

Formula for the fighter aircraft's total weight:
Total weight =Empty weight +Payload +Fuel Weight.

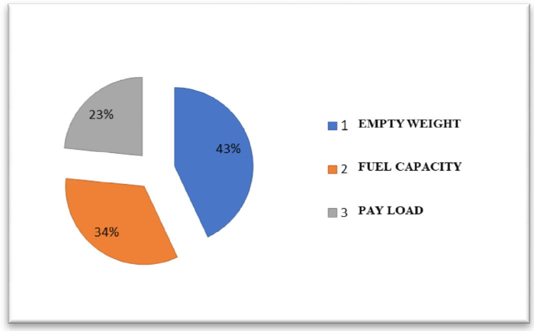


Figure-2:

$$W = W_{payload} + W_{fuel} + w_e$$

Weapon load of a fighter aircraft formula:

Weapon Load = Maximum Payload Capacity-Weight of other Equipment

Consider the aerodynamic needs of a fighter jet when designing it, such as speed, manoeuvrability, and mission profile. After that, examine the lift coefficient. When designing the aircraft's lifting body, take aerodynamic principles into consideration to ensure efficient lift generation at various angles of attack, Reynolds numbers, and Mach numbers. Determine and modify the lift coefficient (CL) in accordance with fluid velocity, density, and reference area in order to achieve the necessary performance criteria. Make sure the power plant you choose for your fighter jet can provide enough thrust to meet performance criteria.

Depending on power output, fuel efficiency, weight, and reliability, take into consideration a variety of engine options. Verify that the selected engine has adequate thrust for combat missions and fast manoeuvres. A fighter jet's fuselage is designed with its intended usage in mind. Maximize aerodynamic efficiency, structural integrity, and internal cargo capacity by optimizing the fuselage form. Incorporate weapons systems, fuel tanks, and avionics into the fuselage design. Design of Landing Gears Select a design that satisfies the fighter jet's operational requirements.

Use a tricycle landing gear system (one nose gear and two major landing gears beneath the wings) for ground handling and stability. To save drag and consume less fuel during flight, the landing gear should be designed to retract inside the fuselage. However, it should still be able to extend for stability and support during take-off and landing.

IV. RESULT AND DISCUSSION

The airplane has a mean value based on the comparison study's parameters. We provide plots and tables to analyse the aircraft parameters listed below.

Aircraft Model	Wing Span	Length	Height	Wing Area	Max Seating Capacity
F-22 Raptor	13.56	18.92	5.08	78.04	1
F-35 Lightning II	13.1	15.7	4.48	62.06	1
Eurofighter Typhoon	11.09	15.96	5.29	51.2	2
Su-35	15.3	21.9	5.9	62	1
J-20	13.5	20.4	4.45	78	1
Rafale	10.9	15.27	5.34	45.7	2
Mig-29	11.36	17.37	4.73	38	1
Gripen E/F	8.6	15.2	4.5	25.54	1
HAL Tejas	8.2	13.2	4.4	38.4	1
JAS 39 Gripen	8.6	15.2	4.5	30	1

Table-1

Aircraft Model	Payload	Range	Power plant	Number of Engines	Empty Weight
F-22 Raptor	8,000	3,000	Two Pratt & Whitney F119-PW-100 turbofan engines.	2	19,700
F-35 Lightning II	6,800	2,200	Pratt & whitney (F135-PW-100)	1	15,686
Eurofighter Typhoon	7,500	1390	Twin Eurojet EJ200 turbofan engines.	2	11,000
Su-35	8,000	3,600	Two Saturn AL-41F1S turbofan engines.	2	19,000
J-20	8,000	6,000	Two Xian WS-15 turbofan engines (rumored).	2	19,391
Rafale	9,500	3,700	Twin Snecma M88-2 turbofan engines.	2	10,600
Mig-29	3,500	1,430	Twin Klimov RD-33 turbofan engines.	2	11,000
Gripen E/F	5,300	4,000	One General Electric F414G turbofan engine.	1	8,500
HAL Tejas	5,300	3,000	One General Electric F404-GE-IN20 turbofan engine.	1	6,560
JAS 39 Gripen	5,300	4,000	Volvo Aero RM12 turbofan engine.	1	8,500

Table-2

Aircraft Model	Max Takeoff Weight	Fuel Capacity	Max Speed	Cruise Speed	Service Ceiling
F-22 Raptor	38,000	8,200	2,414	2,414	20,000
F-35 Lightning II	31,800	8,278	1,930	1,930	15,000
Eurofighter Typhoon	23,500	4,996	2,125	2,125	19,812
Su-35	34,500	11,500	2,390	1,170	18,000
J-20	37,013	11,340	2,500	1,120	20,000
Rafale	24,500	4,700	2,130	1,100	15,240
Mig-29	18,000	43,000	2,400	1,080	18,000
Gripen E/F	16,500	3,400	2,470	1,470	16,500
HAL Tejas	13,500	2,458	2,000	1,100	15,000
JAS 39 Gripen	16,500	3,400	2,470	1,470	16,500

Table-3

Aircraft Model	Aspect Ratio	Chord Length	Max Thrust	Wing Loading	Gross Weight
F-22 Raptor	2.36	5.5	1,56,000	377	29.41
F-35 Lightning II	2.66	4.64	1,91,000	526	22,471
Eurofighter Typhoon	2.205	3.7	90,000	312	16,000
Su-35	3.66	6.4	14,500	500.8	25,300
J-20	3.65	3.7	1,80,000	340	32,092
Rafale	2.8	3.85	75,000	440	15,000
Mig-29	3.3	3.45	81,000	470	18,000
Gripen E/F	2.6	3.6	97,900	380	16,500
HAL Tejas	2.5	3.7	80,100	332	13,500
JAS 39 Gripen	2.6	3.6	80,100	380	16,500

Table-4

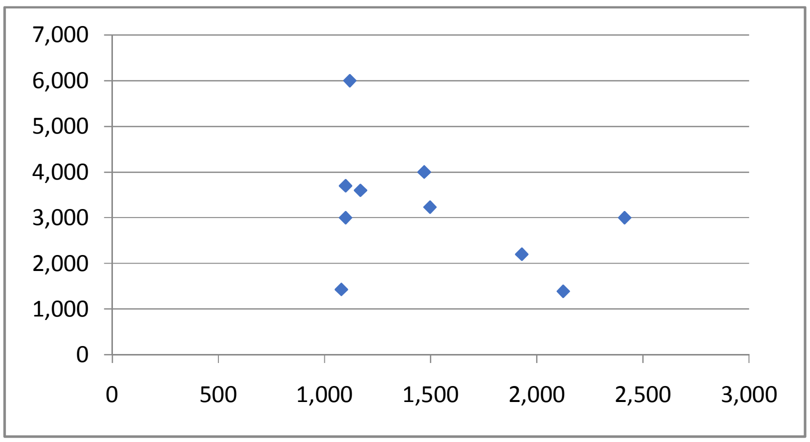
Powerplant	Length (m)	Diameter (m)	Thrust (kN)	Weight (kg)
Two Pratt & Whitney F119-PW-100 turbofan engines.	3.96	1.17	156	1724
Pratt & Whitney (F135-PW-100)	5.6	1.17	191	2268
Twin Eurojet EJ200 Turbofan Engines.	4.89	1.01	90	1,100
Twin Snecma M88-2 Turbofan Engines	4.96	0.91	75	1,140
Twin Klimov RD-33 Turbofan Engines	4.9	1	81.4	1,250
One General Electric F414G Turbofan Engine.	3.91	0.89	98	1109
One General Electric F404-GE-IN20 Turbofan Engine	3.91	3.89	78.7	1035
Volvo Aero RM12 Turbofan Engine	4.3	0.95	80.5	1070

Table-5: Powerplant Selection

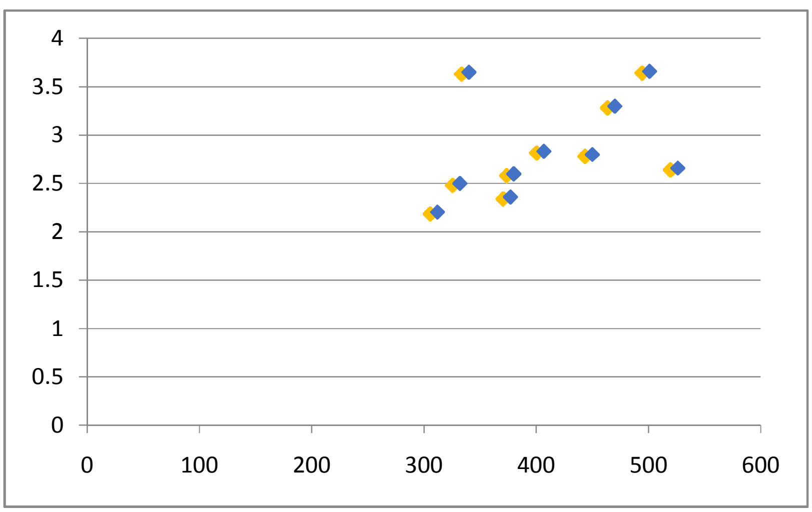
Powerplant	T/W	Bypass Ratio	Pressure Ratio	SFC (lb/(lbf.hr)
Two Pratt & Whitney F119-PW-100 turbofan engines.	9.2:1	0.32	-	0.77
Pratt & Whitney (F135-PW-100)	8.6:1	0.57	-	0.9
Twin Eurojet EJ200 Turbofan Engines.	6:1	0.4:1	26:1	0.8
Twin Snecma M88-2 Turbofan Engines	6.6	0.4	27:1	0.7
Twin Klimov RD-33 Turbofan Engines	6.6:1	0.6	21:01	0.8
One General Electric F414G Turbofan Engine.	9	0.34	40:1	0.8
One General Electric F404-GE-IN20 Turbofan Engine	7.75:1	0.34	26:1	0.8
Volvo Aero RM12 Turbofan Engine	7.5:1	0.3	26:1	0.8

Table-6: Powerplant Selection

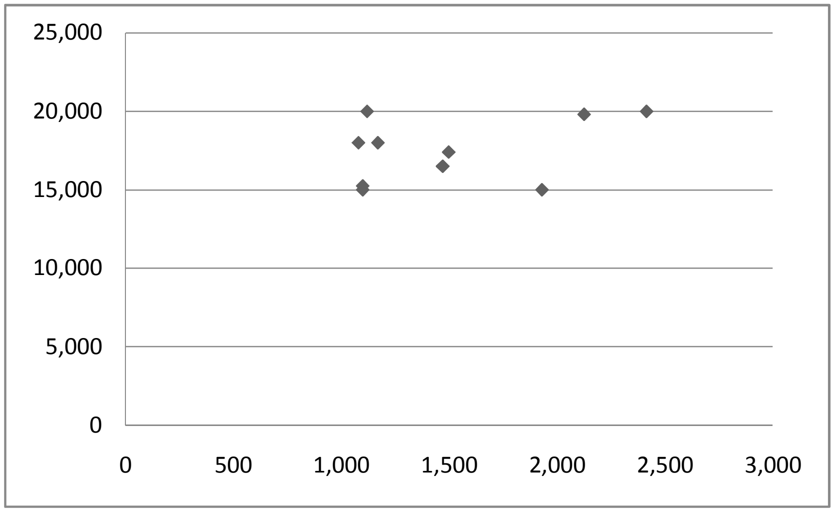
CURISE SPEED VS RANGE



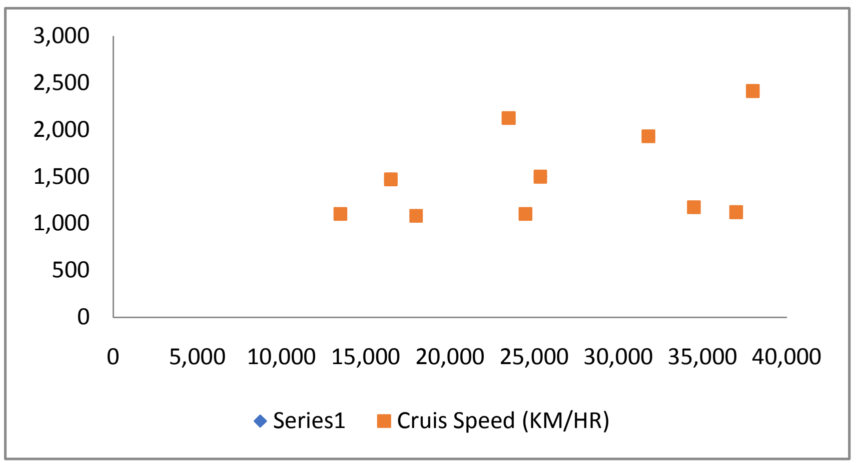
WING LOADING VS ASPECT RATIO



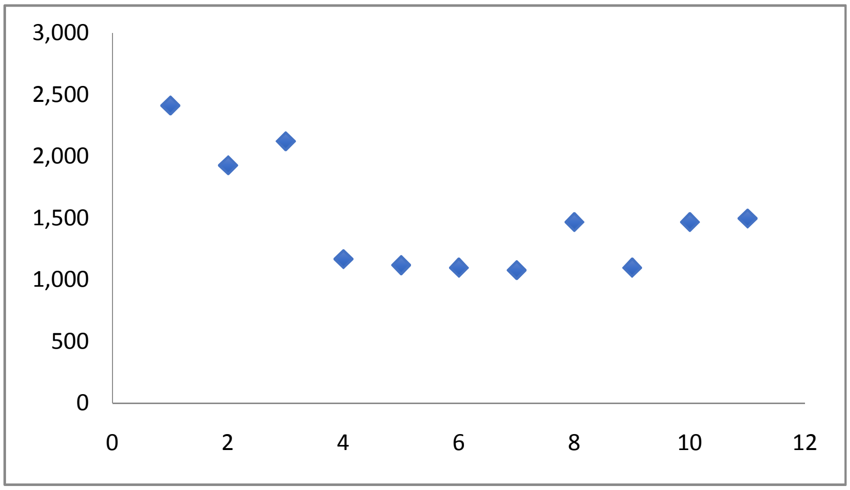
CRUISE SPEED VS SERVICE CELLING



MAX-TAKE OFF WEIGHT VS CRUISE SPEED



WING SPAN VS CRUISE SPEED



V. AVERAGE DESIGN PARAMETERS

Parameters	Average
Wing Span (M)	11.458
Length(M)	17.018
Height(M)	4.82
Wing Area(M^2)	50.894
Max Seating Capacity	2
Max Take –off Weight(KG)	25,381
Fuel Capacity(L)	10,127
Max Speed (KM/HR)	2,283
Cruise Speed (KM/HR0	1,498
Service Ceiling (M)	17,405
Pay Load (KG)	7,078
Range (KM)	3,232
Power Plant	
Number of Engine	2
Empty Weight (KG)	12,994
Aspect Ratio	2.8335
Chord Length (M)	4.214
Max Thrust(N)	104,560
Wing Loading (KG/M^2)	406.78
Gross Weight	17539.241
Altitute (M)	16,164

Table-7:

VI. CONCLUSION:

To summarize, the core design of our fighter jet aircraft model has been finalized by thorough computation and formulation of numerous design criteria and performance requirements. While we've made tremendous progress, it's important to recognize that the present design may require more modification to completely express our intended goals.

Our final concept satisfies the stringent specifications for a high-performance fighter jet, combining agility, speed, and modern weapons capability. It is critical to understand that perfection is a continual quest in design; consequently, our model will change through iterative improvements and modifications targeted at attaining maximum battle effectiveness.

Throughout this venture, we've gained essential insights and knowledge, highlighting

the significant effort put into its creation. Moving forward, we are dedicated to pushing the frontiers of innovation in aerial combat, keeping our fighter aircraft at the forefront of technical progress and operational excellence.

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