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DESIGN OF A FIFTH GENERATION AIR SUPERIORITY FIGHTER AIRCRAFT

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***Abstract**-Air Superiority Fighter is considered to be an effective dogfighter which is stealthy, highly maneuverable to surprise enemy along with improve survivability against the missile fire. This new generation fighter aircraft requires fantastic aerodynamics design, low wing loading (W/S), high thrust to weight ratio (T/W) with super cruise ability. Conceptual design is the first step to design an aircraft. In this paper conceptual design of an Air Superiority Fighter Aircraft is proposed to carry 1 crew member (pilot) that can fly at maximum Mach No of 2.3 covering a range of 1500 km with maximum ceiling of 61,000 ft. Payload capacity of this proposed aircraft is 6000 lb. that covers two advanced missiles & one advanced gun. The Air Superiority Fighter Aircraft was designed to undertake all the following missions like: combat air petrol, air to air combat, maritime attack, close air support, suppression, destruction of enemy air defense and reconnaissance.*

Keywords: Aircraft; Fighter; Combat; Air-Superiority; Missile

1. INTRODUCTION

Air Superiority Fighters are designed with a view to entering and seizing control of enemy airspace. Generally an air superiority fighter is blesses with long range and beyond visual range (BVR). These dogfighters generally require more time to make themselves prepared to go for mission. These class of aircraft claims high maintenance cost. Being expensive, the number of production of air superiority fighters is less. Few examples of air superiority fighters are: F-15, F-22, SU-30 MKI, Euro fighter etc. Air superiority fighters are capable of engaging enemy fighters than compared to others type of aircraft (i.e. Multirole Fighters).

Aerospace vehicle design is a prominent branch of engineering design. Engineering design refers to the procedure or technique of devising a system component or process to meet desired requirements. Conceptual design is the very first thing approach of designing an aircraft when it covers size, weight and configurations and performance parameters of different components. Maximum take-off weight. Thrust to weight ratio and Wing Loading are determined at preliminary stage.

2. MISSION PROFILE & DESIGN REQUIREMENT

The design parameters of the air superiority fighters are also listed below:

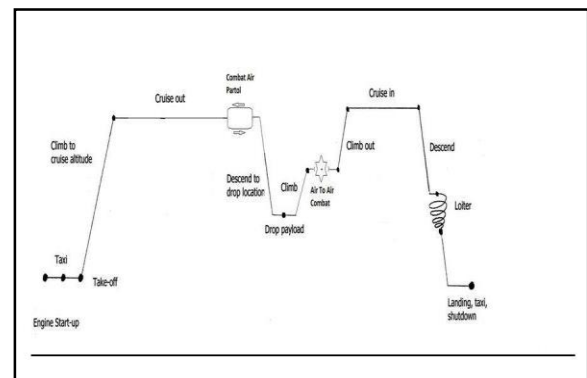| Parameters	Minimum Requirements
Range	1500 km (4921260 ft.) 810NM
Max. Mac	2.3
Ceiling	18.59 km (61000 ft.)
Payload	2721.55 kg (6000 lb.)
Load factor	+9 -3
Crew	1

Fig.1: Mission Profile

3. CONCEPTUAL DESIGN

Conceptual Design is an umbrella term given to all forms of non-aesthetic design management disciplines.

3.1 Selection of Wing

Monoplane, mid wing, swept back, plain flap, Fixed Wing with fixed shape was selected. The reason for selecting mid wing is that it is more attractive compared to low wing or high wing. For the reinforcement of the wing structure, a strut is not usually used. Having aerodynamically streamlined the mid wing configuration has less interference drag compared to low wing or high wing.

3.2 Selection of Tail

Aft conventional tail, Fixed and twin tail configuration was selected. The reason for selecting twin tail is that on the fuselage it can position the rudders away from the aircraft centerline, which may become blanketed by the wing or forward fuselage at high angle of attacks [1]. Twin tails can also reduce the height required with a single tail. Twin tails are more effective though it is heavier than usual area centerline-mounted single tail.
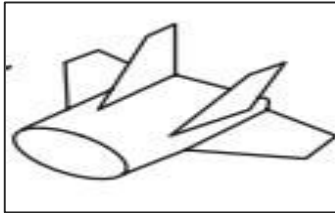

Fig.2: Twin tail

3.3 Selection of Landing Gear

Retractable, Tricycle landing gear is selected. Tricycle landing gear is selected for safety reason though it increase manufacturing, maintenance and operational costs. Tricycle landing gear reduces the frontal area of wheel so that aircraft performance is increased. Though retractable landing gear is expensive and harder to design and manufacture, it has some unique advantages. When a retractable landing gear is used drag will be less due to smooth airflow characteristics on flight, hence increasing the performance of the aircraft.
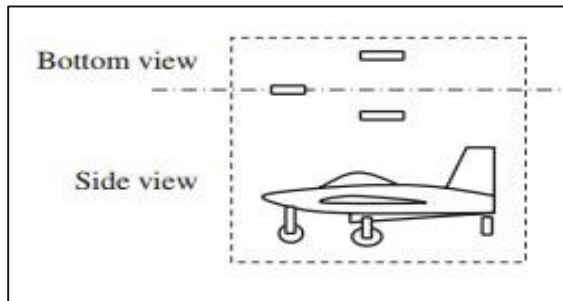

Fig.3: Tri-cycle landing gear

3.4 Selection of Propulsion System

Twin engine, turbofan buried inside the rear fuselage was selected. The reason for selecting turbofan engine is that it improves the propulsive efficiency and specific fuel consumption than a turbojet engine. A turbofan engine is able to operate efficiently at both subsonic and supersonic speed. An afterburner is used to provide a temporary increment of thrust, both for supersonic flight and flight take-off.

3.5 Selection of Fuselage

Cockpit attached door configuration was taken for designing the fuselage of the air superiority fighter. Being a combat aircraft the cockpit is unpressurized. One seat with seat ejection facilities was allocated for pilot in the cockpit.

4. PRELIMINARY DESIGN

The preliminary design phase tends to employ the outcomes of a calculation procedure. As the name implies, at the preliminary design phase, the parameters determined are not final and will be altered later. Three primary aircraft parameters of W_{TO}, S, and T (or P) form the output of the preliminary design phase. These three parameters will govern the aircraft size, the manufacturing cost, and the complexity of calculations. [2]

4.1 Maximum Takeoff Weight

To determine maximum take-off weight the following equation was used.

$$W_{TO} = \frac{W_{PL} + W_C}{1 - \left(\frac{W_f}{W_{TO}}\right) - \left(\frac{W_E}{W_{TO}}\right)}$$

For our designed air superiority fighter the weight of crew and payload is 220 lb. and 6000 lb. respectively. The calculated fuel-weight fraction of the aircraft is 0.5476. From empirical equation we know for a fighter aircraft empty weight fraction,

$$\frac{W_E}{W_{TO}} = -1.10 \times 10^{-5} W_{TO} + 9.70$$

We calculate maximum take-off weight (W_{TO}) = 56391.022 lb. (25578.9675 kg)

4.2 Thrust to Weight Ratio

From the relation of thrust to weight ratio with wing loading in case of stall speed, maximum speed, take-off run, rate of climb and service ceiling, we plot all the derived equation considering thrust to weight ratio in vertical axis and wing loading in horizontal axis. This provide us an acceptable region along with a design point where design point shows thrust to weight ratio is 1.273

4.3 Determination of Wing Surface Area and Engine Thrust:

Wing Area, $S = \frac{W_{TO}}{\left(\frac{W}{S}\right)_d} = \frac{56391.022 \, lb}{125.6 \frac{lb}{ft^2}} = 448.97$ ft^2 =41.71 m^2

Engine Thrust, $T = W_{TO} \times \left(\frac{T}{W}\right)_d = 56391.022 \times 1.273$ lb. $= 71785.77$ lb.
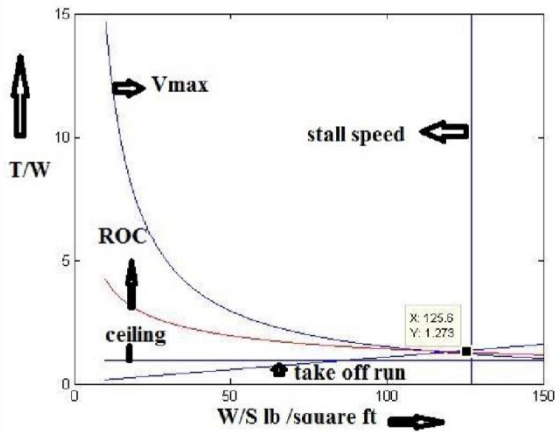
Fig.4: Matching plot for designed air superiority fighter

5. DETAIL DESIGN

Details design means the elaborate design of the aircraft component like: wing, fuselage, propulsion systems, landing gear, Tail.

5.1 Wing Design

The wing is used to generate aerodynamic force mainly known as lift to keep the aircraft airborne. We calculate the sweep angle as 67 degree and taper ratio as 0.3. Calculated value of wing span is 10.22 m, flap span 6.645 m, flap area 9.1983 m^2 and flap chord 1.3837 m. Wing chord was found as 4.089 m. With a view to finding out a suitable airfoil for the wing the calculated lift co-efficient of airfoil was 1.79. This criteria was fulfilled by NASA SC (2)-0414 AIRFOIL (sc20414-il). The selected airfoil has maximum thickness of 14% that is located at 36% of chord where maximum camber of 1.5% was found at 83% of chord.

We check whether the lift distribution over wing is elliptic or not. Matlab graph depicts that lift distribution over wing is elliptical. Determination of cruise and take-off lift co-efficient of aircraft was accomplished by using both computational (Matlab) and analytical approach. Their value was found as 0.1403 and 1.831 respectively. Change in the zero lift angle of attack for inboard (flap) section was -3.289 degree. Calculated wing drag was found as 8876.51 lb_f.
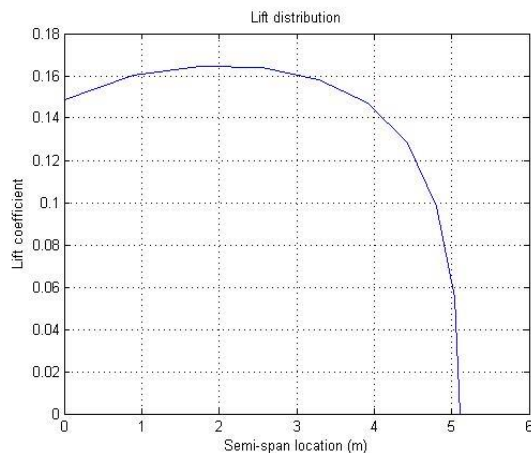

Figure 5: Lift distribution over the wing

5.2 Tail Design

By analyzing both historical data and different jet aircraft some parameters were selected for horizontal tail as:
V_H =0.24, S_h/ S = 0.183, AR_h = 2.30, λ_h= 0.3 Λ_h= 48, Γ_h = 0.

For vertical tail we select:
V_V = 0.06, S_v/S = 0.346, AR_v=1.3
$(t/c)_{max}$ = 7%, λ_v = 0.22, Λv=35

The planform area of horizontal tail is determined as 6.82 m^2. Wing/fuselage aerodynamic pitching moment co-efficient is calculated as -0.028. The horizontal tail lift co-efficient at cruise is -0.1461. So, NACA 0009airfoil was selected. Calculated mean aerodynamic chord of horizontal tail is 1.72 m, downwash angle at zero angle of attack is 2.044 degree, downwash slope is 1.599 deg. /deg. and downwash is 2.044 degree. Calculated horizontal tail span is 3.96 m and horizontal tail tip chord is .846 m and root chord is 2.35 m. Finally static longitudinal stability derivative of our designed aircraft appears to be negative. So, the aircraft is statically longitudinally stable. Calculated vertical tail reference area is 3.41 m^2. Vertical tail mean aerodynamic chord is 1.6153 m and span is 2.10 m, tip chord is 0.5127 m and root chord is 2.330 m.

5.3 Prolusion System

Calculated thrust requirement is 71842.162 lb. We selected the engine from manufacturing catalogs. We select 2 × NPO Saturn izdeliye 117 (AL-41F1) for initial production, izdeliye 30 for later production thrust vectoring turbofan. Its dry thrust is 93.1 kN / 107 kN (21,000 lbf / 24,300 lbf) each. Thrust with afterburner is 147 kN / 167 kN (33,067 lb_f / 37,500 lb_f) each.

Fig.6: izdeliye 117 (AL-41F1)

5.4 Fuselage Design

A major driving force in the design of the pilot cockpit and passenger cabin is human factor. For this air superiority fighter aircraft we will not focus to the design of the passenger cabin. The major purpose of the fuselage is to accommodate wing and others payload and provides cabin and cargo compartment. Fuselage design is accomplished according to Federal Aviation Rules, FAR-25. Length and diameter of the fuselage was taken

19.8 m (64.96 ft.) & 2.08 m (6.84ft.). Total volume of the fuel tank designed as 17.50 m^3(618 ft^3). Number of fuel tank are 4. Apart from overall length the only fuselage length of the aircraft is 14.94 m (49.02 ft).

5.5 Landing Gear

Calculated landing gear height is 2.1938 m. The distance between main gear and aircraft forward cg is 0.8869 m when the main gear and aft cg is 0.4767m. Tip-back angle is found as 19.69degree. Wheel base and wheel track is calculated as 5.91 m and 2.86 m respectively.

6. HIGH LIFT DEVICE SELECTION

High lift devices were used for the desired better performance for the aircrafts. These devices are essentially used to achieve the extra amount of lift needed in flight when the main wing airfoil section is unable to deliver that. Leading edge flap was used as the high lift device in the leading edge of the wing. Plain flap was selected as the high lift device for the trailing edge because of its simplicity. Even though it was simple one but many modern aircrafts such as F-15E Eagle and MIG-29 employ plain flaps.
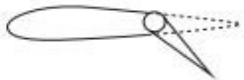

Fig.6(a): Leading Edge Flap
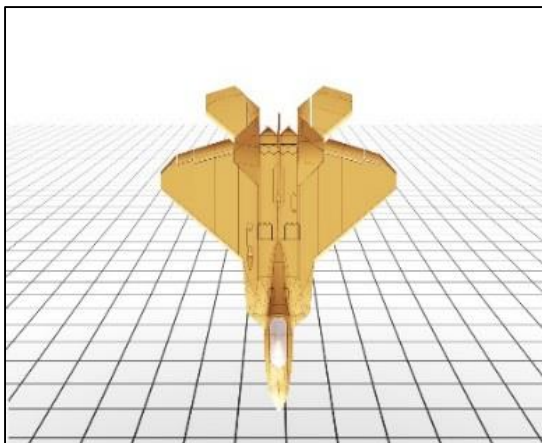

Fig.6(b): Plain Flap

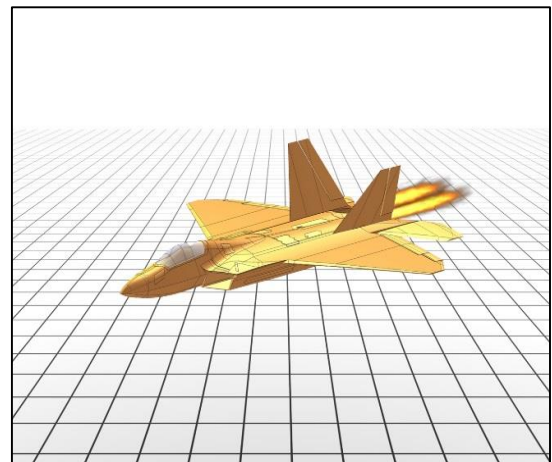## 7. FINAL MODEL

Fig.7(a): Isometric view
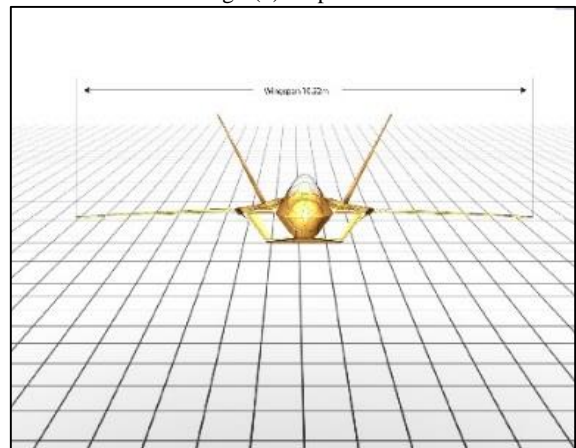

Fig.7(b): Top view
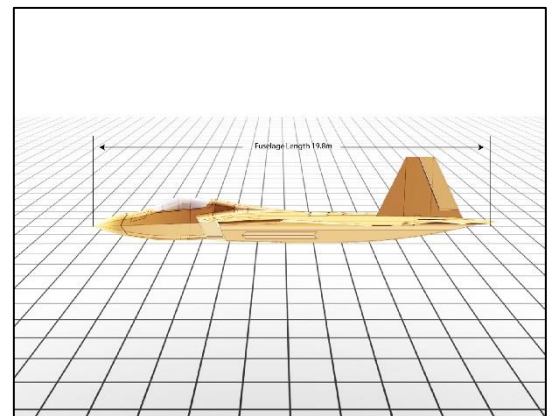

Fig.7(c): Front view

Fig.7(d): Side view

8. NOVEL IDEAS

During the design process of the air superiority fighter few novel ideas were developed that are described below:

1. The thrust to weight ratio is slightly higher for the designed aircraft that could be a demerit but as our calculated maximum takeoff weight is less so the ultimate value of total thrust requirement is less.

2. The wing area and span of the air superiority fighter aircraft is less compared to any others similar category aircraft of this time. Being low wing area and aspect ratio, the aircraft will require low space in the hanger as a result the ground accommodation problem will not too much acute.

3. Calculated takeoff distance for our aircraft was about 1000ft which has made it a unique one to takeoff from aircraft carrier as most of the famous aircraft carriers provide take off distance greater than 1000 ft. For example, USS George Washington (CVN-73), the length of this carrier is 1,092 feet (332.8 m). As a result, our designed air superiority fighter cans easily takeoff from that kind of carriers.

9. COMPARISON WITH SIMILAR AIRCRAFT

The comparison between the designed aircraft and similar established aircraft if shown below:

Parameters	F-22 Raptor	Designed Aircraft
No. of crew	1	1
Length	18.92 m	19.80 m
Wing span	13.56 m	10.22 m
Take-off weight	83,500 lb.	56391.022 lb.
Engine	Pratt & Whitney F119	2 × NPO Saturn izdeliye 117 (AL-41F1)
Maximum Range	2960 km	1500 km 810 NM
Maximum Speed	1.82 Mach	2.3 Mach
Thrust to Weight Ratio (T/W)	1.08	1.273
Wing Loading (W/S)	377 kg / m^2	619.86 kg/m^2
Ceiling	20 km	18.59 km
Wing Area (S)	78.04 m^2	41.81 m^2
Rate of Climb (ROC$_{max}$)	350 m / sec.	272 m/sec.
Stall Speed (V$_{stall}$)	56.54 m/sec. (184.42 ft. /sec.)	61.74 m/sec. (202.56 ft./sec)

10. CONCLUSION

Air Superiority Fighter is a very advanced next generation fighter aircraft which is highly controllable and considered as a queen of air to air combat and dogfight. As the aircraft is used for military purposes so it was very difficult & sometimes impossible for us as designers to find out the proper aeronautical information for an aircraft like this. As s a result lot of assumptions were taken which hampers the design accuracy little bit. As budding aircraft designers we wish if proper data and information are available the design could be more accurate.

11. REFERENCES

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12. NOMENCLATURE

Symbol	Meaning	Unit
V_H	Horizontal Tail Volume co-efficient	-
V_V	Vertical Tail Volume co-efficient	-
S_h/S	Ratio of Horizontal Tail to wing reference area	-
S_v/S	Ratio of Horizontal Tail to wing reference area	-
AR_h	Aspect Ratio of Horizontal Tail	-
AR_v	Aspect Ratio of Vertical Tail	-
λ_h	Taper Ratio of horizontal Tail	-
λ_v	Taper Ratio of vertical Tail	-
Λ_h	Sweep Angle for horizontal Tail	Degree
Λv	Sweep Angle for vertical Tail	Degree
Γ_h	Dihedral angle for horizontal Tail	Degree
$(t/c)_{max}$	Maximum thickness to chord ratio	-
L_f/D_f	Fuselage length to diameter ratio	-