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Design and Optimization of a Precision Attack Bomber Aircraft

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Abstract*—The design of a precision attack bomber aircraft is presented in this paper. Design requirements were selected from market analysis. The minimum requirements for aircraft design, extracted from market analysis were: - range: 1140 nm, maximum Mach number: 1.05, ceiling: 55000 ft., payload: 47000 lb., load factor: ranging from +6 to -2.5. The aircraft should be capable of carrying one crew members. The aircraft had to materialize a certain mission profile. This mission profile contains the flight segments like taxi, take-off, climb, cruise, cruise (payload dropping), descend and landing. The basic disciplines of aircraft design like aerodynamics, propulsion, engineering design, flight dynamics and management skill were carried out during design process. Initially in conceptual design phase, configuration of the basic components of aircraft such as wing, tail, propulsion system, fuselage, landing gear were selected through figure of merit analysis.

***Index Terms*—Aircraft design, Aerodynamics, Thrust, Figure of merit analysis, Mission Profile**

I. INTRODUCTION

A tactical military aircraft precision attack bomber has an initial role of carrying out air strikes with improved precision than bombers, and is designed to encounter great low-level air defenses while pressing the attack. The design purpose of the aircraft is to cover 2110 km with a payload of 47000 lb and maximum Mach of 1.05. The cruising height of the bomber is considered 55000 ft for better performance and fuel efficiency.

II. MISSION PROFILE

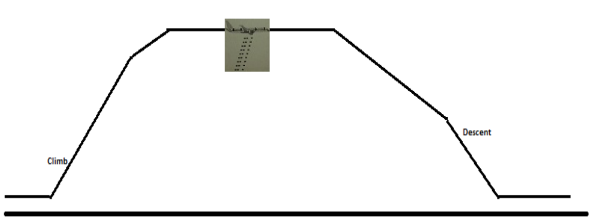

Fig. 1 —Mission Profile for the Precision Attack

III. NOMENCLATURE

$(L/D)_{max}$ = Lift to Drag Ratio; C = Engine Specific Fuel Consumption; T/W = Thrust to Weight Ratio; W_f = Fuel Weight; W_{TO} = Maximum Take-off Weight; C_{Lmax}= Maximum Lift Co-efficient; AR = Aspect Ratio; b = Wing Span; C_r = Root Chord; C_t = Tip Chord; MAC = Mean Aerodynamic Chord; S_h = Horizontal tail Area; b_h = Horizontal Tail Span; S_v = Vertical Tail Area; n = Load Factor; W_w = Wing Weight; b_v = Vertical Tail Span; χ_{LE} = Sweep Angle at Leading Edge; H_{LG} = Height of the Landing Gear

IV. PRELIMINARY DESIGN

As FAR-125.9, flight crew weight is assumed to be 200 lb and the required bomber that we have has a single crew member only.

SFC (Specific Fuel Consumption) of the turbofan engine is c=0.6 lb. / (lb. h) is considered.

$(L/D)_{max}=16$

$w_2/w_1=0.98$, $w_3/w_2=0.973$, $w_4/w_3=0.853$, $w_5/w_4=0.994$, $w_6/w_5=0.995$, $w_6/w_1=0.8044$

$w_{TO}= (w_{crew}+w_{payload})/ (1-w_{fuel}/w_{TO}-w_{empty}/w_{TO})$

Solving, Take-off weight W_{TO}=81586.79 lb.

Empty weight W_E=34378.696 lb

From Graph, Design Thrust to Weight Ratio (T/W) = 0.895

Design weight to area ratio, (W/S) = 75

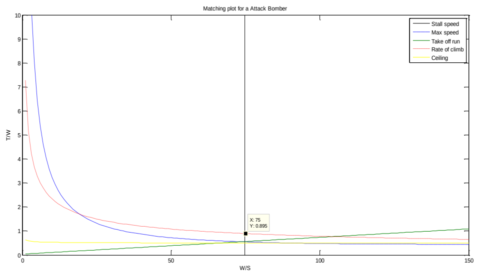

Fig. 2 —Engine Size and Wing Area Calculation in Matlab

V. DETAILED DESIGN

A. Wing Design

Suitable wing configuration chose for precision attack bomber is Mid Wing
Sweep Angle= 33°
Taper Ratio= 0.26
Aspect Ratio= 11
Wing Span= 92.77 ft.
Chord= 8.434 ft.
Twist Angle= -2°
Root Chord (C_R) =12.01 ft.
Tip Chord (C_T) = 3.12 ft.
Lift Co-efficient at take-off (C_{L_TO}) =0.42

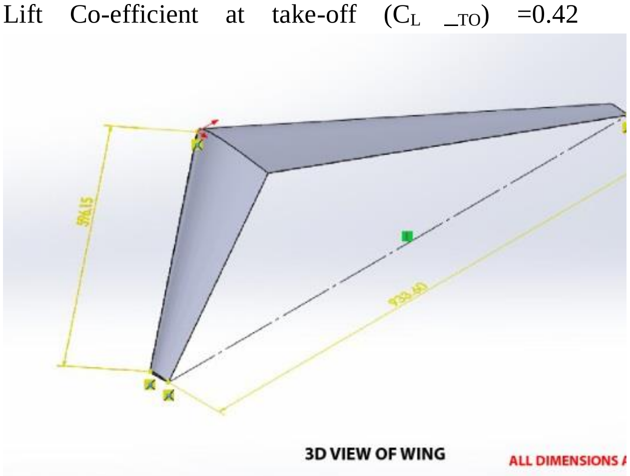

Fig.3 —3-D View of Wing in Solidworks

So the lift distribution over wing is elliptical. Flap up Zero Angle of attack= -13.7°, Flap down zero Angle of attack = -15.7°.

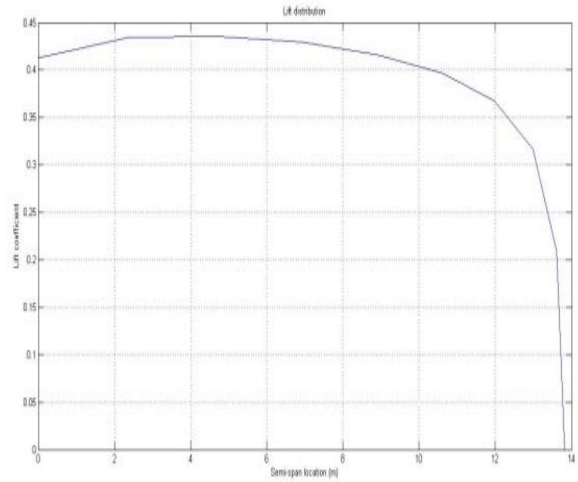

Fig.4 —Graph of Lift Distribution over Wing

From the historical trend it was found that for precision attack bomber, NACA 65_410 airfoil is used which will provide the desired lift and efficiency

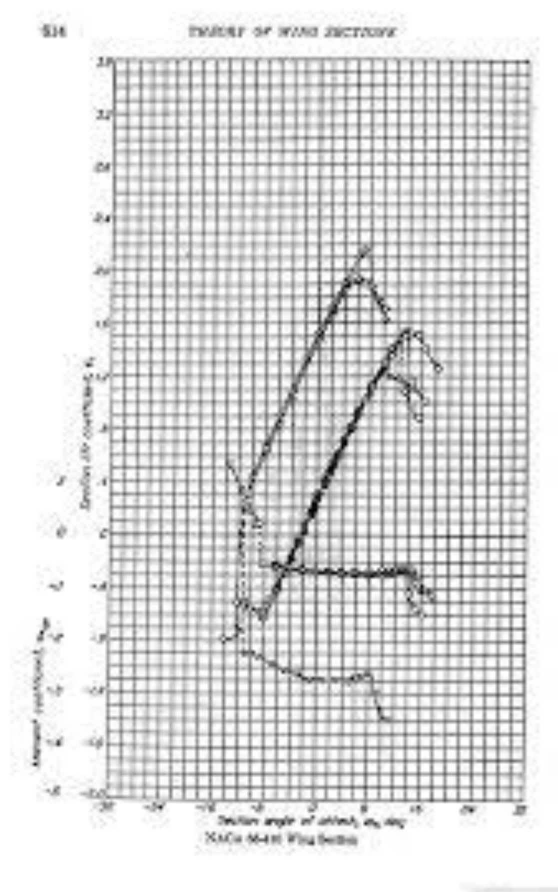

Fig.5 —NACA 65-410 Wing Section [6]

B. Tail Design

The optimum tail has been found for Precision Attack Bomber is Conventional tail.
Assuming Taper Ratio =0.3, AR_h = 10, l_{opt} = 36.48 ft., S_h= 72.35 ft., C_h = 2.69 ft.
Selected tail airfoil is NACA 63_006, horizontal sweep angle =33°, Dihedral angle = -2°, MAC_h = 2.69ft ,C_{th}=1.132ft, C_{rh}= 3.744ft
Assuming AR_{VT} = 1.3 [3]; Taper Ratio = 2, Sweep angle for vertical tail = 30°, MAC_{VT} = 11.06 ft., C_{tv}= 14.22ft
C_{rv}= 7.11ft

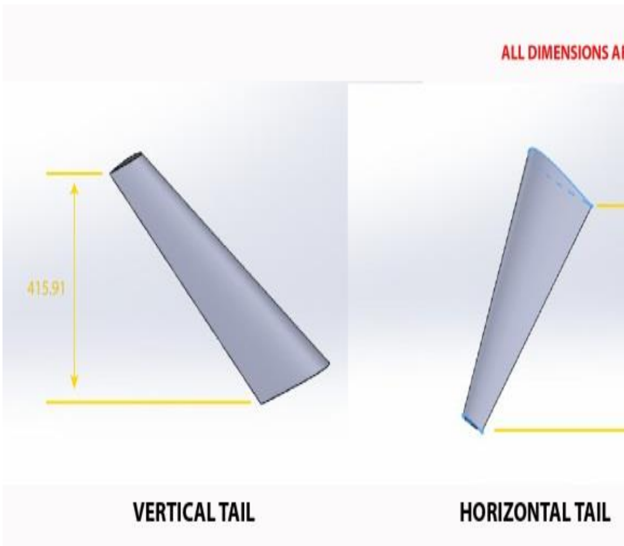

Fig. 6 —Vertical Tail and Horizontal Tail in Solidworks

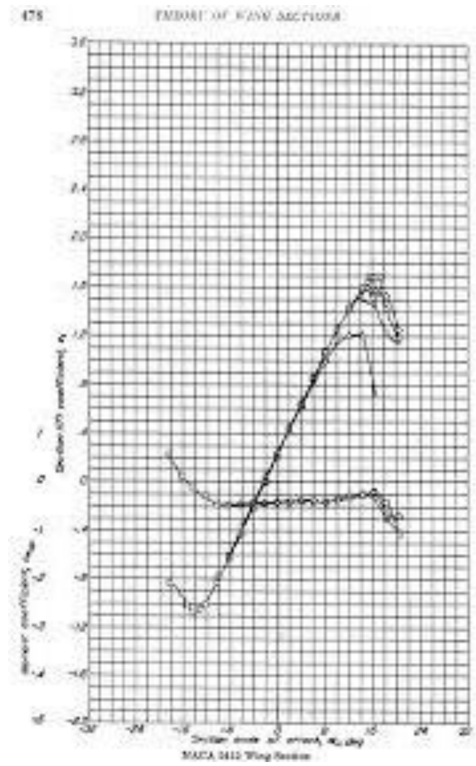

Fig. 7 —NACA 63006 Wing Section

C. Fuselage Design

Fuselage is designed with accommodating space for the cargo compartment, corresponding system, and fuel tanks.
The fuselage optimum length to diameter ratio $(l_f/D_f)_{opt}$ = 15 [4]
The length for keeping bomb or other fighting instruments = 65 ft
The diameter for keeping bomb or other fighting instruments = 4.33 ft
The required volume for other components = 241.155 ft^3
Two fuel tanks are required in the fuselage
The fuselage maximum diameter, D_f = 4.33 ft;.L_f/D_f = 15,;Unsweep angle = 5°; Cabin length, L_c = 5.01 ft

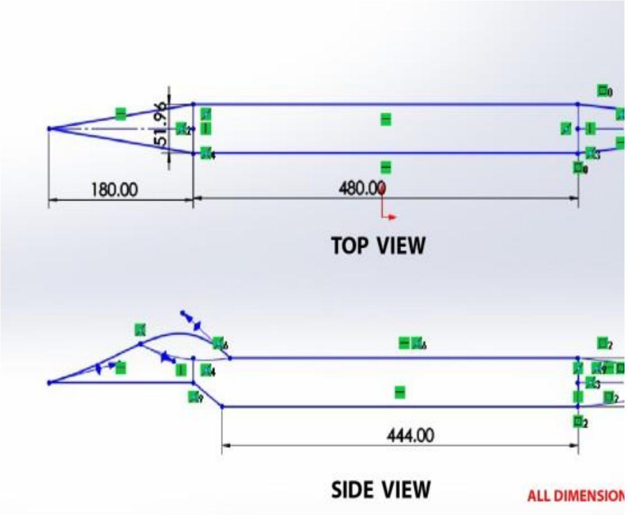

Fig.7 —Top View and Side View of Fuselage

D. Propulsion System Design

Total Thrust Required = 52517.7 N
From the graph of the Mach No Vs. Engine Type, the suitable engine for the precision attack bomber is "Low by pass ratio turbofan engine". Engine names for the corresponding thrusts will be considered here. [5] The suitable turbofan engine will be F 110-GE-129 (From Wikipedia containing the thrust for the specific engines)

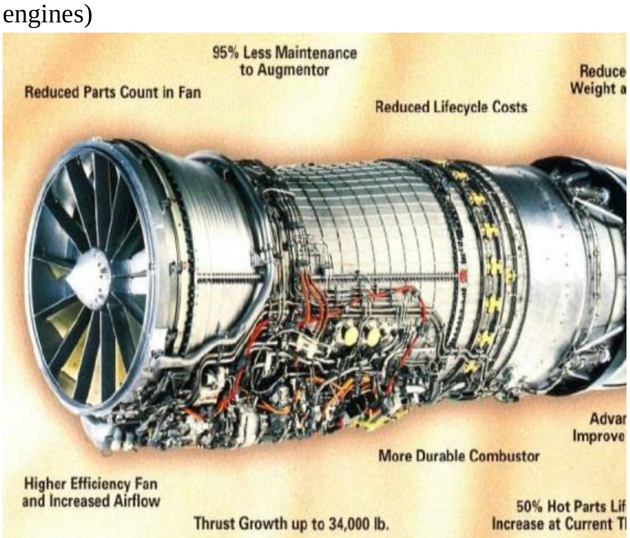

Fig.8 —F 110-GE-129 Engine

E. Landing Gear Design

Height of Center of gravity(cg) = 8.235 ft, Height of the landing gear = 6.07 ft, Drag during take-off = 3216.89 lb., lift (L_h) =-240.23 lb., M_{ACwf} = -17582.57lb-ft, L_{wf} = 42255.45 lb., F_f= 499.91 lb., Aircraft linear acceleration at the time of take-off rotation,α = 27.67 ft/s^2 , Tip back angle= 27.35°, The distance between the fuselage nose and the wing leading edge, L_f = 20.80 ft, Distance between fuselage unsweep point and the wing leading edge = 38.80 ft, Distance between the main gear and the fuselage unsweep point = 31.86 ft, The clearance angle = 10.78° The wheel base,B = 20.93 ft, Height of the landing gear,H_{LG} = 6.07 ft.

F. Weight of the Components

1)Wing weight= S_w MAC $(t/c)_{max}\rho_{mat}k_\rho$ $(AR.n_{ult} /\cos(\wedge_{0.25}))^{0.6}$ $\lambda^{0.04}$ g= 7828.79 N.
2) Horizontal tail weight= S_{HT} MAC_{HT} (t/c) max $\rho_{mat}k_{\rho HT}$ $(AR_{HT} /\cos(\wedge_{0.25}))^{0.6}\lambda_{HT}^{0.04}V_H^{0.3}(Ce/C_T)^{0.4}$g= 5535.49 N.
3) Vertical Tail Weight= S_{VT} MAC_{VT} (t/c) max $\rho_{mat}k_{\rho VT}$ $(AR_{VT} /\cos(\wedge_{0.25}))^{0.6}\lambda_{VT}^{0.04}V_V^{0.3}(C_R/C_V)^{0.4}$g= 3072.8 N.
4) Weight of Fuselage= $L_f D_{fmax}^2\rho_{mat}k^{\rho f}n_{ult}^{0.25}K_{inlet}$ g= 5109.74 N.
5) Weight of Landing Gear=$K_L K_{ret} K_{LG} W_L$ (H_{LG}/b) $n_{ultLG}^{0.2}$=1354.54 N.

VII. LIMITATIONS

Design got some short-comings as reports been prepared within a short time. Wind tunnel test and ground test of prototype are required for better performance analysis.

VIII. CONCLUSION

Mostly for close air support and naval air-to-surface mission, A Precision Attack Bomber is designed and for overlapping the tactical bomber mission. Iterative methods of numerical approaches are followed here for suitable result. Numerical results satisfied the requirements although there was not enough scope for doing test of every perspective of the bomber.

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[3] Sadraey, Mohammad H. *Aircraft design: A systems engineering approach*. John Wiley & Sons, 2012,.pp.321 Table 6.6

[4] M. H. Sadraey, ―A System Engineering Approach,‖*Aerospace Series,*1st ed. vol 1,pp. *375;Table 7.7*

[5] General Electric F110 Design and Development from (https://en.wikipedia.org/wiki/General_Electric_F110)