SIMULATION OF WEIGHT AND PERFORMANCE OTIMISATION OF A SINGLE SEATER HOME BASED AIRCRAFT

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Abstract - To simulate the gross weight of aircraft and optimise its performance by using various historical data for the specified mission profile using "C"

Keywords - Aircraft – Gross Weight - Simulation - Mission Profile – C - Software

INTRODUCTION

Three major types of airplane designs are

A. Conceptual design
B. Preliminary design
C. Detailed design

A. Conceptual design:

It depends on what are the major factors for designing the aircraft.

Power plant Location:

The Power plant location is either padded (or) Buried type engines are more preferred. Rear location is preferred for low drag, reduced shock & to the whole thrust.

Selection of Engine:

The engine should be selected according to the power required.

Wing selection: The selection of wing depends upon the selection of

(1) Low wing

(2) Mid wing

(3) High wing

B. Preliminary design:

Preliminary is based on Loitering. 'U' is the mathematical method of skinning the aircraft, the aircraft look like a masked body.
Preliminary design is done with help of 'C' SOFTWARE.

C. Detailed design:

In the detailed design considers each & every rivets, bolts, paints etc. In this design the connection & allocations are made.

GROSS WEIGHT:

The gross weight of aircraft will be given by equation,

$$W_o = W_{crew} + W_{payload} + W_{fuel} + W_{empty}$$

Empty weight includes structure, landing gear, lift equipment avionic instruments.

To simplify fuel weight and empty weight calculation take fraction of them based on total weight.

$$W_o = W_{crew} + W_{payload} + \left(\frac{W_f}{W_o} + \frac{W_E}{W_o}\right) W_o$$

$$W_{crew} + W_{payload} = W_o - \left(\frac{W_f}{W_o}\right) W_o - \left(\frac{W_E}{W_o}\right) W_o$$

$$W_o = \frac{W_{crew} + W_{payload}}{1 - \frac{W_f}{W_o} - \frac{W_E}{W_o}} \rightarrow A$$

This is the equation for the gross weight of an aircraft.

STEP 1:

In the first step we consider the pay load and crew weight. It is given as

$$W_{payload} + W_{crew} = 80 + 30 = 110Kg$$

STEP 2:

In the second step we can guess the total weight of the aircraft from the various historical data as 800Kg.

$$W_{total} = 800Kg$$

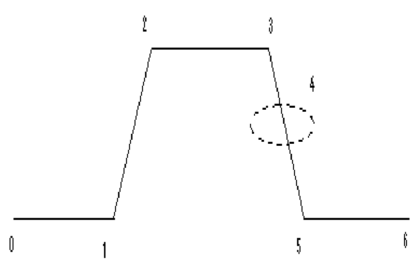
STEP 3:

The fuel weight includes mission fuel and fuel reserved for emergency purpose.

$$W_f = W_{fuelmission} + W_{fuelreserved}$$

Mission fuel weight can be calculated from the fuel fractions for various mission segments.

MISSION PROFILE:



0-1WARM UP& TAKE-OFF
1-2CLIMB
2-3CRUISE
3-4LOITER
4-5DESCEND
5-6LANDING

MISSION 0-1:

The mission 0-1 is the engine start, warm up and the take-off. From the historical data, it is found to be,

$$\frac{W_1}{W_0} = 0.995$$

MISSION 1-2:

The mission 1-2 is the climb. The fuel fraction from historical data was

$$\frac{W_2}{W_1} = 0.995$$

MISSION 2-3:

The mission 2-3 is cruise. The fuel fraction for this mission was found from the range equation (i.e.) Brequet equation,

$$R_{cr} = 375\left(\frac{\eta_{propeller}}{C_p}\right)_{cr}\left(\frac{L}{D}\right)_{cr}\ln\left(\frac{W_2}{W_3}\right)$$

From the historical data,

$$\eta_{propeller} = 0.7$$

$$C_p = 0.7lba/hp/hr$$

$$\frac{L}{D} = 9$$

The range from historical data is 900Km,

$$900 = 375\left(\frac{0.7}{0.7}\right) \times 9 \times \ln\left(\frac{W_2}{W_3}\right)$$

$$\frac{W_3}{W_2} = 0.7659$$

MISSION 3-4:

The mission 3-4 is the loiter. The fraction for the mission is found from the Endurance equation,

$$E_{loiter} = \left(\frac{1}{C_p}\right)_{loiter} \left(\frac{L}{D}\right)_{loiter} \ln\left(\frac{W_3}{W_4}\right)$$

From the historical data,

$$E_{loiter} = 20\min$$

$$C_p = 0.6$$

$$\frac{L}{D} = 11$$

$$0.33 = \left(\frac{1}{0.6}\right) \times 11 \times \ln\left(\frac{W_3}{W_4}\right)$$

$$\frac{W_4}{W_3} = 0.981$$

MISSION 4-5:

The mission 4-5 is the descent. The fraction of fuel for this fraction from historical data is found to be,

$$\frac{W_5}{W_4} = 0.995$$

MISSION 5-6:

The mission 5-6 is the landing. Taxing and shut-off. The fuel fraction of this mission was found to be,

$$\frac{W_6}{W_5} = 0.998$$

The fuel fraction is found from product of all the values,

$$m_{ff} = \frac{W_6}{W_5} \times \frac{W_5}{W_4} \times \frac{W_4}{W_3} \times \frac{W_3}{W_2} \times \frac{W_2}{W_1} \times \frac{W_1}{W_0}$$

$$m_{ff} = 0.995 \times 0.995 \times 0.7659 \times 0.981 \times 0.995 \times 0.998$$

$$m_{ff} = 0.7386$$

$$\frac{W_f}{W_o} = 1 - m_{ff}$$

$$\frac{W_f}{W_o} = 1 - 0.7386$$

$$W_f = 0.2613 \times 800$$

$$W_f = 209.077Kg$$

RESERVED FUEL:

The reserved fuel is the fuel which is used for the emergency purpose.

$$W_{reservedfuel} = 0177 \times 0.25 \times 800$$

$$W_{reservedfuel} = 34Kg$$

OPERATING EMPTY WEIGHT:

The operating empty of aircraft is calculated from equation,

$$W_{OE} = W_{total} - W_{fuel} - W_{crew}$$

$$W_{OE} = 800 - 209.07 - 110 = 480.93Kg$$

TRAPPED FUEL:

The trapped fuel is considered to be 0.5% of the total weight,

$$W_{trapped} = 0.005 \times 800$$

$$W_{trapped} = 4Kg$$

GROSS WEIGHT:

The gross weight of aircraft can be determined by formula,

$$W_o = \frac{W_{crew} + W_{payload}}{1 - \frac{W_f}{W_o} - \frac{W_E}{W_o}}$$

$$W_o = 771.72Kg$$

%ERROR:

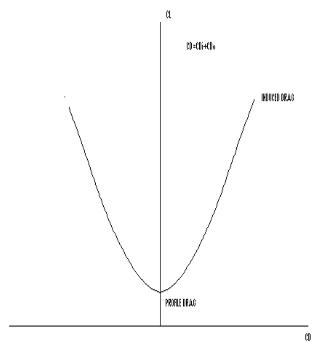
The percentage of error from the gross weight can be calculated from formula,

$$\%ERROR = \frac{W_{actual} - W_{assumed}}{W_{actual}} \times 100$$

$$\%ERROR = \frac{800 - 771.72}{771.72} \times 100$$

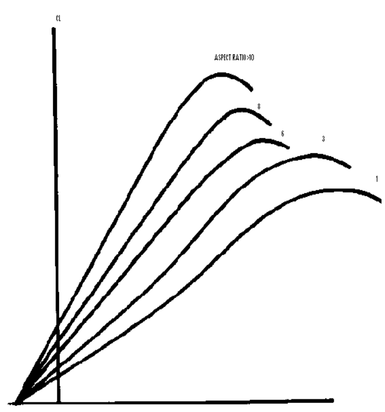
$$\%ERROR = 3.6\%$$

C_L Vs C_D:



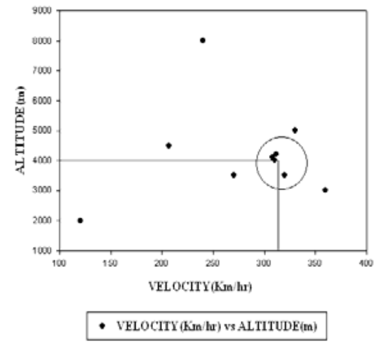
The C_L Vs C_D was drawn in general. It is also called as drag polar. It has the major impact on endurance of the aircraft, performance and aerodynamic properties.

C_L Vs α :



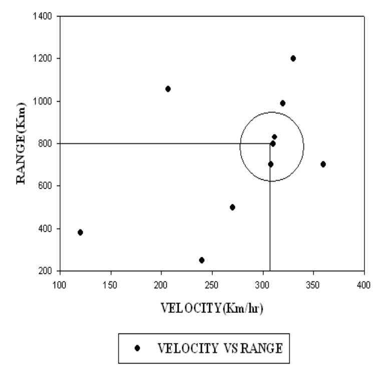
The general curve was drawn in C_L Vs α. It gives the information of variation of lift with angle of attack and the stalling region. Reduce the curve slope without any change of lift angle of incidence is seen in C_L Vs α characteristics. Increase of stalling angle without appreciable change in maximum lift coefficient is also seen in C_L Vs α graph.

VELOCITY Vs ALTITUDE:



The values from the comparative study done were used to draw graphs. The velocity Vs altitude graph was drawn and approximate or optimized values of maximum altitude at velocity 300Km/hr was found to be 4000m.

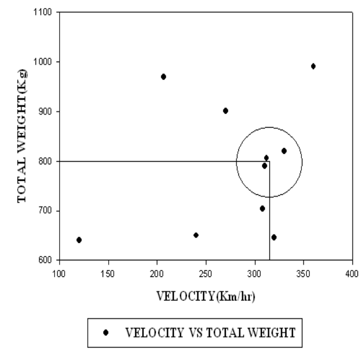
VELOCITY Vs RANGE:



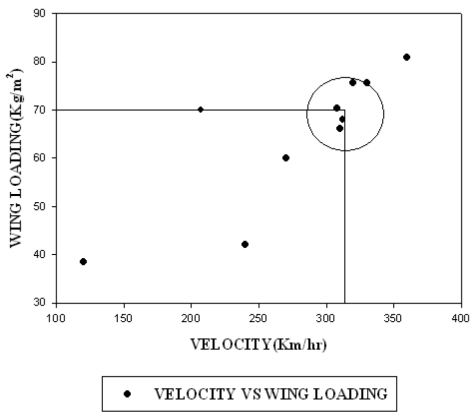
The values from the comparative study were used to plot the points in the graph, velocity Vs range. The approximate values of range of the aircraft at max speed 300Km/hr was 900Km.

VELOCITY Vs GROSS WEIGHT:

The values of velocity and gross weight (W_o) from the comparative study were used to draw from the graph, velocity Vs gross weight. From the graph, the optimum value of (W_o) was found to be 675Kg at max speed of 350Km/hr.



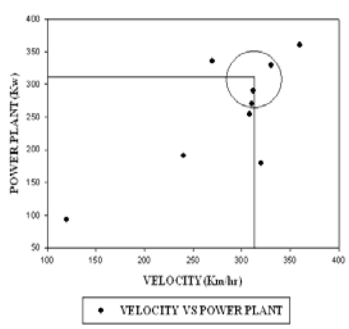
VELOCITY Vs WING LOADING:



The plot velocity Vs wing loading (W/S) was drawn from the values obtained from the comparative study of the aircraft. The main parameters (W/S) was optimized sing the graph by drawing a circle of constant radius. The value of wing loading is optimally 70Kg/m^2.

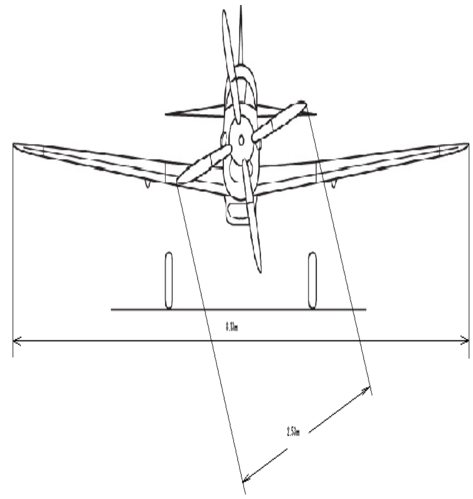
VELOCITY Vs POWER PLANT:

The below graph was drawn between velocity and power plant from the historical data. From the above graph for velocity 300Km/hr was optimized to 275Kw

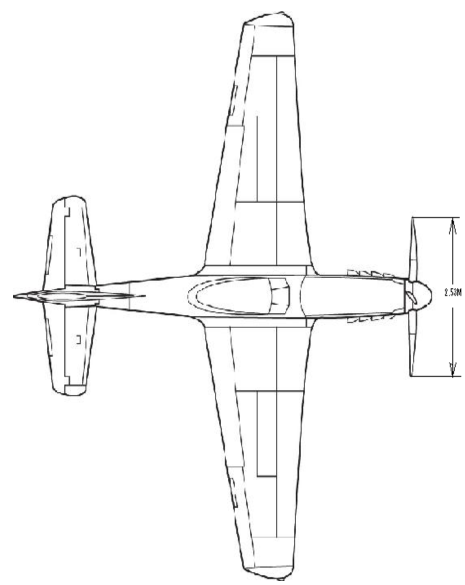


THREE VIEWS OF SINGLE SEATER HOME BUILT AIFCRAFT

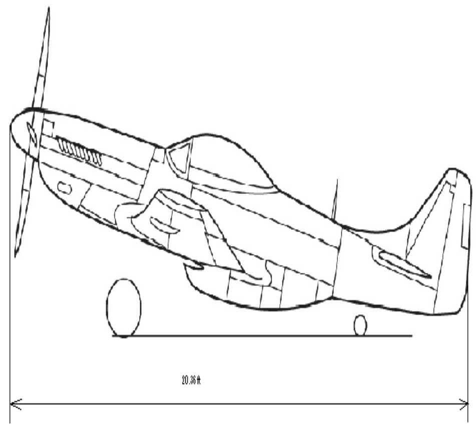
FRONT VIEW



TOP VIEW



SIDE VIEW



PERFORMANCE DETAILS OF VARIOUS AIRCRAFT:

SL. NO	AIRCRAFT NAME	MAX. SPEED (Km/Hr)	CRUISE SPEED (Km/Hr)	RATE OF CLIMB (m/s)	SERVICE SEALING (m)	WING LOADING (Kg/m^2)
1	Su-26	450	310	18	4000	66.058
2	Su-31	450	312	18	4200	68.058
3	ZIVKO EDGE 540	426	308	19.81	4100	70.3
4	YAK 50	480	270	20.12	3500	60.00
5	CAP 232	350	330	18	5000	75.57
6	YAK 54	460	360	15	3000	80.94
7	ALBATROS L79	165	120	3.2	2000	38.55
8	Z 242	250	207	5.5	4500	70
9	AEROCAM SLICK	400	320	15	3500	75.52
10	ZUIN Z-50	293	240	15	8000	42

CONCLUSION:

The weight of the aircraft was determined as 771.72Kg

$$W_{payload} = 110Kg$$

$$W_f = 209.07Kg$$

$$W_{OE} = 476.93Kg$$

and the main parameters for the design of aircraft was plotted graphically to achieve a conclusion on optimum values. So that aircrafts performance can be theoretically performed.

SYMBOLS USED

W-Weight of aircraft
W_o-Overall weight
W_f-weight of fuel
W_e-Empty weight
L_f – fuselage length
D_f – diameter of fuselage
S_w - wing area
T_w - wing thickness
b_w,b – wing span
S_{ht} – horizontal tail area
t_{ht} – horizontal tail thickness
b_{ht} - horizontal tail span
AR – aspect ratio
t_{vt} - vertical tail thickness
b_{vt} – vertical tail span
Cd_o – drag polar
Cd – coefficient of drag
C_L - coefficient of lift
F, T – thrust
T/W-Thrust loading
W/S-Wing loading
A.R-Aspect ratio
C_r,C_t-Chord length of root,tip
T_r,T_t-Thickness of root,tip
C_{Dp}-Coefficient of drag of wetted surface area
C.G-Center of gravity
β -Dihedral angle
R-Range
E-Endurance
μ -Ground friction
$V\infty$ -Free stream velocity
C-Chord
Lf-Length of fuselage
VT-Vertical tail
HT-Horizontal tail
ℓ -Density(kg/m^3)
g-Gravity
s-Distance
H-Height
h-altitude
ROC – rate of climb
V, u – velocity
D – Drag
L – Lift
H – Altitude
g – Acceleration of gravity
W_o – optimum weight
Λ - sweep angle

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