Aircraft Sizing Algorithm Documentation

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Contents

1 Rationale

We need to determine 2 very important things:

1. The thrust to weight ratio affects:
   - acceleration:
   - climb rate:
   - maximum speed:
   - turn rate:
   - Aircraft Endurance:
2. The stall speed is directly determined by the wing loading and the maximum lift coefficient. Wing Loading will affect:
   - stall speed
   - induced drag
   - take-off distance

2 Sizing Methodology

1. First Method:
   (a) Firstly use the stall speed to determine wing loading Stall speed should be independent of engine size
   (b) After figuring out wing loading, determine the thrust to weight ratio based on takeoff distance Rate of climb
2. Second Alternative Method:
   (a) Determine the Thrust to Weight Ratio
   (b) Determine the wing loading by direct computation

3 Common Definitions

q is the dynamic pressure of an aircraft flying. It is defined as

$$q = \frac{1}{2}\rho v^2$$

wherein ρ represents the density of the air, v represents the velocity the aircraft is flying at. The Matlab script below defines the global variables that is needed for this entire simulation,

```
%Global variable list
global L_wi; %This is a wing loading (N/m^2)
global T_W; %This is the thrust to weight ratio (dimensionless)
global rho; %This is the air density (kg/m^3)
global v_stall; %This is the stall speed of our aircraft (m/s)
global c_Lmax; %This is an estimation of how good is our biggest possible lift coefff
global q; %This is the dynamic pressure
global c_D0; %This is the drag coefficient near stall speed
global A_r; %Aspect ratio of the main wing
global e; %efficiency of the wing due to deviating from elliptic lift distribution
global G; %Gradient of ascent = rise of flight/run of flight
```

The script below handles the global variable initializations,

```
%Give Definition of Global variable
Global_Variables;

%Variables which are known/guessed (independent)
rho = 1.225; %This is the density of the air
v_stall = 8; %This is the estimation for stall speed
c_Lmax = 1.2; %the maximum lift coefficient we can get
climb_angle = 25; %This is from the RFP
c_D0 = 0.03; %This is the drag coefficient near stall speed
A_r = 9; %Aspect ratio of the main wing, typical values
e = 0.8; %efficiency of the wing due to deviating from elliptic lift distribution

%Variables that are dependent on other variables (dependent)
q = 1/2*rho*v_stall^2; %This is the dynamic pressure
G = tan(deg2rad(climb_angle)); %Gradient of ascent = rise of flight/run of flight
```

4 Stall Speed Constraint

Wing loading is basically the weight of the aircraft divided by the total wing area.

$$L_{wi} = \frac{W}{S} = \frac{1}{2}\rho v_{stall}^2 c_{L,max}$$

Our typical would be around $c_{L,max} \approx 1.2 \rightarrow 1.5$, Sweep only reduces your maximum coefficient of lift. The `Matlab` implementation is shown below,

```
%Give Definition of Global variable
Global_Variables;

%This Matlab script is used to compute the wing loading using the stall speed of the aircraft.
%We are getting the stall speed from the Requirements for the aircraft.
L_wi = 1/2*rho*(v_stall^2)*c_Lmax;
```

5 Climb Rate Constraint

The cimb rate G is defined as the ratio between vertical and horizontal distance travelled when the aircraft is climbing D is going to represent drag.

$$\frac{D}{W} = \frac{T}{W} - G \tag{1}$$

There is also another relation for drag to weight ratio,

$$\frac{D}{W} = \frac{qc_{D,0}}{L_{wi}} + L_{wi}\frac{1}{q\pi A_r e} \tag{2}$$

wherein A_r is the aspect ratio of the wings, and e represents the efficiency factor due to deviating from the elliptic lift distribution. Substituting equation 1 into equation 2 and solving for $\frac{T}{W}$,

$$\frac{D}{W} = \frac{T}{W} - G = \frac{qc_{D,0}}{L_{wi}} + L_{wi}\frac{1}{q\pi A_r e}$$

$$\frac{T}{W} = \frac{qc_{D,0}}{L_{wi}} + L_{wi}\frac{1}{q\pi A_r e} + G$$

wherein $c_{D,0}$ represents the zero-lift drag coefficient of an aircraft. For a clean propeller aircraft, $c_{D,0} = 0.02$. For a dirty propeller aircraft, then $c_{D,0} = 0.03$. The expression for thrust to weight ratio computations are implemented below,

```
%Give Definition of Global variable
Global_Variables;

%This computes the thrust to weight ratio based on the climb rate
T_W  = (q*c_D0)/(L_wi) + L_wi/(q*pi*A_r*e) + G;
```

6 Estimation of Motor Power Rating

The equation below was found in page 118,

$$\frac{T}{W} = \left(\frac{\eta_p}{V}\right)\left(\frac{P}{W}\right)$$

wherein η_p represents the propeller efficiency, P represents power of the engines, W represents the weight of the aircraft, V represents the true air speed of the aircraft.

7 Textual References

1. Page 117 has table for thrust to weight of typical aircrafts.
2. Page 119 has a table for power to weight ratio of typical aircrafts.
3. Page 124 has a tabel for typical wing loadings.
4. Page 126 has description on typical $c_{L,max}$ values.
5. Page 135 has descriptions of what $c_{D,0}$ should be.