AERO97064

Aircraft Performance and Flight Mechanics

Coursework 1

Name: Zijun Fang

CID: 01811420

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Part A (50%)

1) **How has the thickness to chord ratio of fighter wings changed from the first and second world wars? What reasons can you think of for this change?**

   Comparing the aircrafts between first and second world war, which the thickness to chord ratio has become smaller to the pervious aircraft, also for the industry techniques innovation, the thickness of the fighters has been decrease, for fitting more complex aerofoil structure. Different ratio between the aircrafts periods, when at the second world wars, the fighters have been enhanced air combat capabilities and supplements cruise time; also, the back seat of a fighter during second world war was mainly a machine gun seat, so that a smaller ratio can larger the sight view from the back seat.

2) **Now examine high speed fighter aircraft such as the McDonnell Douglas Phantom or Eurofighter, what has happened to the thickness to chord ratio of the wings as jet fighters start to be designed for flight at supersonic speeds?**

   According to the higher flight velocity (larger than 2.0 Mach), smaller ratio structure could accept the high velocity flight condition. Due to the smaller thickness to chord ratio, the high Mach number fighter will reduce the drag force under the high velocity condition, for the more, which under the high velocity flow, the aerofoil will face large space of vortex and turbulent flow, to decrease the ratio, it can protect the wing without unstable flow affects. Even the Eurofighter has constructed the wings as a triangular shape, making the cross-section structure of the wing more subtle and extreme, extensive in-depth research on disengaged vortex.

3) **The Panavia Tornado has a variable geometry wing, what is the reason for such a design and what stability and control challenges are there in developing such an aircraft?**

   The first reason for this aircraft design is that to create a long-duration combat air patrols, working conjunction with Boeing E-3D, when the second stage of wing structure open, it can save the fuel usage at a stable cruising speed; the other one is gaining a higher acceleration behaviour, as a result, F.3 Tornado has 80% commonality with the bomber, with greater supersonic acceleration and a stretched fuselage with more internal fuel capacity. The challenges are keeping the aircraft wing backward at high speed and generating more lift by placing forward wing. To adjust the wing structure at different controlling speeds.

4) **The Heinkel HE162 has a single engine mounted above the fuselage. What handling challenges might have been present when large changes in thrust setting were made?**

   The HE162 has been changed the traditional propeller plane, smaller turbine engine replaced the thrust generation method. For the single power setting of the aircraft, the duration of flight was one of challenges of this fighter, large weight of engine mounted above the fuselage to affect the strength on the aircraft.

5) **The Supermarine Spitfire has excellent aerodynamic characteristics often attributed to the shape of its wing. What is special about the shape of the aircraft's wing and how could it be expected to influence the aircraft's drag?**

   For the Supermarine aerofoil structure, which has a perfect aerodynamic characteristic; the curving edge structure is suitable for the streamline flow, also reducing the boundary-layer drag. The Supermarine aerofoil could reduce the induced drag coefficient at the minimum value compare to the other types (Ackroyd, 2016).

6) **The Westland Lysander has a stall speed of around 65mph. What is it about its design which gives it such low speed capabilities?**

   The Lysander was aerodynamically advanced, being equipped with fully automatic wing slots and slotted flaps and a variable incidence tail plane. The structure of foil become more complex to increase the laminar flow range by slots and slotted flaps, which increasing the lift force at the low speed condition (En.wikipedia.org, 2019).

Part B (50%)

An aircraft with the characteristics given below takes-off from a concrete runway at an altitude of 1500m above sea level in ISA conditions. The aircraft is a high-performance military trainer aircraft.

Stall speed (clean configuration – no deployment of high lift devices)	V_s	62m/s
Drag polar (clean)	Cd	C_D=0.0253+0.0610C_L^2
High lift device maximum lift increment (for both take-off and landing)	dCl	ΔC_L = 1.1
High lift device zero lift drag increment (for both take-off and landing)	dCd0	ΔC_{D0} = 0.012
Aircraft mass	M	5030 kg
Wing planform area	A	19.30 m^2
Maximum sea level thrust	T	19700 N

B-1 Take-off Condition

Calculate the distance travelled in each phase of the take-off run up to the standard 35ft (10.7m) height above the runway. Some assumptions will have to be made in undertaking these calculations, please provide justifications for the values chosen.

*** Calculating Functions:**

According to the first adjustment: which roll velocity is 20% greater than stall velocity

$$V_r = (1 + 20\%)V_s$$

The lift-off velocity of the aircraft: n=1; for ***W=L***

$$V_{lof} = \sqrt{\frac{2 * n * W}{\rho * C_L * A}}$$

To identify the coefficient of friction at concrete runway is **0.02.**

According to the ISA standard density table, which the density of the air at 1500m above the sea level is **1.058 kg/m³.**

The differential equation of distance travelling at ground roll:

$$ds = \frac{W}{2g\{T - [D + \mu(W - L)]\}} d(V^2)$$

The functions about lift and drag:

$$L = \frac{1}{2} * (C_L + \Delta C_L) * (V_r^2) * (\rho) * (A)$$
$$D = \frac{1}{2} * (C_{D0} + kC_L^2) * (V_r^2) * (\rho) * (A)$$

The lift coefficient at stall speed:

$$C_{Lstall} = \frac{2 * W}{\rho * V_s^2 * A}$$

The vertical distance ***h:***

$$h = \frac{S_{3a}^2}{2R}$$

The total distance of travel for three phases: weight ratio $\Delta n = 1.25$

$$S_1 = \int_0^{V_r} \frac{W}{2g\{T - [D + \mu(W - L)]\}} d(V^2)$$
$$S_2 = \int_{V_r}^{V_{lof}} \frac{W}{2g\{T - [D + \mu(W - L)]\}} d(V^2)$$
$$S_{3a} = \frac{V_{lof}^2}{\Delta n * g} \sin\left(\frac{T - D}{W}\right)$$
$$S_{3b} = \frac{10.7 - h}{\tan(\theta)}$$

*** the total calculation result is 749.5580 m.**

*** Programming Code:**

```
% matlab profile for aircraft takeoff
% for flight acceleration takeoff

%% input relevant values
A = 19.3;                   % unit: m^2
g = 9.81;                   % unit: m*s^-2
M = 5080;                   % unit: kg
T = 19700;                  % unit: N
Vs = 62;                    % unit: m*s^-1
R = 1.085;                  % unit: kg*m^-3 ISA
miu = 0.02;                 % non unit


%% Phase I distance integration
Vr = (1+0.2)*Vs;            % rotation speed
W = M*g;                    % weight of gravity
dCl = 1.1;                  % high-lift device lift coefficient
dCd0 = 0.012;               % high-lift device drag coeff-zero lift


Cls = ((2*W)/(R*(Vs^2)*A));         % stall speed lift coefficient
Clmin = Cls-dCl;                    % minimum lift coefficient
Cl = ((2*W)/(R*(Vr^2)*A));          % lift coefficient with high lift
Cd = 0.0253+0.0610*(Cl)^2;          % drag coefficent with lift


V = 0:0.1:Vr;                       % uniform section of velocity
Vq = V.^2;                          % square of each element
L = (0.5)*(R)*(Vq)*(Cl)*(A);        % lift-force to take off
D = (0.5)*(R)*(Vq)*(Cd)*(A);        % drag-force to take off
```

```
k = ((9.81*(T-(D+miu*(W-L)))));   % unit distance travel per V^2

i = 1;
sum1 = 0;
for i = 1:745
   sum1 = sum1+(W/k(i));
end

%% Phase II distance integration
n = 1.25;                          % ratio of weight to lift off
Vlof = ((2*n*W)/(R*Cl*A))^0.5;       % lift off velocity

v2 = Vr:0.1:Vlof;                  % uniform section of velocity
Vq2 = v2.^2;
L2 = (0.5)*(R)*(Vq2)*(Cl)*(A);       % lift-force to take off
D2 = (0.5)*(R)*(Vq2)*(Cd)*(A);       % drag-force to take off

k2 = ((0.2*9.81*(T-(D2+miu*(W-L2))))); % unit distance travel per V^2


j = 1;
sum2 = 0;
for i = 1:88
   sum2 = sum2+(W/k2(j));
end

%% Phase III distance calculation
dn = 1.0;                          % increment above
R = ((Vlof^2)/((dn)*g));           % circular path radius
Dlof = 4973.26068;                 % drag-force to take off
thetas = ((T-Dlof)/W);             % climbing angle sin-value
theta = asin(thetas);              % climbing angle
sum3a = R*thetas;                  % phase iii first region distance
h = (R*(1-cos(theta)));            % vertical distance
sum3b = (10.7-h)/(tan(theta));       % phase iii second region distance


%% General take off distance is
sumtf = sum1+sum2+sum3a+sum3b       % total take off distance
```

B-2 Landing Condition

The aircraft lands with 900kg of fuel having been consumed, calculate the landing distance required for the aircraft, as with the takeoff calculations justify all assumptions made.

According to the landing approaching speed records of Aermacchi MB-339FD aircraft: (En.wikipedia.org, 2019)

$$V_A = 68\, m/s$$

Under the high-lift device management:
The maximum drag coefficient:

$$C_{D0} + \Delta C_{D0} + kC_L^2 = C_{Dmax}$$

* The descending angle:

$$\theta_D = \frac{D - T}{W}$$

* Airborne Distance calculation: including circular flight path

$$S_A = \frac{15.2}{\theta_D} + \frac{V_A^2 * \theta_D}{0.4 * g}$$

* Transition distance after fighter landing:

$$S_T = 2 * S_A$$

* Based on the fighter craft without reverse thrust structure: $T_R = 0$

* The landing ground roll integration distance:

$$S_L = \int_0^{V_A} \frac{W}{2g\{[D + \mu(W - L)]\}} d(V^2)$$

*** the total calculation result is 680.2057m.**

*** Programming Code:**

```
% matlab profile for aircraft landing
% for flight decceleration landing

%% input relevant values
A = 19.3;                    % unit: m^2
g = 9.81;                    % unit: m*s^-2
M = 4180;                      % unit: kg
T = 19700;                     % unit: N
Vs = 62;                     % unit: m*s^-1
R = 1.085;                     % unit: kg*m^-3 ISA
miu = 0.02;                    % non unit
```

```
H = 15.2;                    % landing height
VA = 68;                   % landing speed - F16 fighter sample

W = M*g;                          % weight
Cls = ((2*W)/(R*(Vs^2)*A));          % stall speed lift coefficient
ClA = ((2*W)/(R*(VA^2)*A));          % approaching speed lift coefficient
dCl = 1.1;                        % maximum lift coefficient increment
Clmin = ClA-dCl;                    % minimum lift coefficient
Cd = 0.0253+0.0610*(ClA)^2;          % drag coefficent with lift
dCd0 = 0.012;                      % maximum drag coefficient increment
D = (0.5)*(Cd)*(VA^2)*(A)*(R);        % drag force calculation

%% Airborne and Trans distance
thetas = abs(D-T)/W;                            % descending angle
theta  = asin(thetas);                          % descending angle in sin-value
sumA = (H/(theta))+(((VA^2)*(theta))/(0.4*g));          % Airborne distance i region
sumT = 2*VA;                                  % transition distance

%% Ground roll distance integration
V = 0:0.1:VA;                   % uniform section of velocity
Vq = V.^2;                     % square of each element
Cdmax = Cd+dCd0;                 % maximum drag coefficient
L = (0.5)*(R)*(Vq)*(Cls)*(A);      % lift-force to take off
Dmax = (0.5)*(R)*(Vq)*(Cdmax)*(A);     % drag-force to take off


k = ((9.81*(T-(D+miu*(W-L)))));    % unit distance travel per V^2


i = 1;
sumL = 0;
for i = 1:834
   sumL = sumL+(W/k(i));
end

sum = sumA+sumT+sumL
```

Reference

Ackroyd, J. (2016). *The Aerodynamics of the Spitfire*. 2nd ed. [ebook] London: Journal of Aeronautical History. Available at: https://www.aerosociety.com/media/4953/the-aerodynamics-of-the-spitfire.pdf [Accessed 5 Dec. 2019].

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