UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2007/2008 Academic Session
Peperiksaan Semester Kedua
Sidang Akademik 2007/2008

April 2008
April 2008

ESA 372/3 – Aircraft Aerodynamics
Aerodinamik Pesawat

Duration : 3 hours
[Masa : 3 jam]

INSTRUCTION TO CANDIDATES
ARAHAN KEPADA CALON :

Please ensure that this paper contains **ELEVEN (11)** printed pages and **FIVE (5)** questions before you begin examination.
*Sila pastikan bahawa kertas peperiksaan ini mengandungi **SEBELAS (11)** mukasurat bercetak dan **LIMA (5)** soalan sebelum anda memulakan peperiksaan ini.*

Answer **FOUR (4)** questions.
*Jawab **EMPAT (4)** soalan.*

Student may answer the questions either in English or Bahasa Malaysia.
Pelajar boleh menjawab soalan dalam Bahasa Inggeris atau Bahasa Malaysia.

Each questions must begin from a new page.
Setiap soalan mestilah dimulakan pada mukasurat yang baru.

1. (a) Explain what does it mean with the following drag terms :

i. drag polar
ii. skin friction drag
iii. profile drag and
iv. wave drag.

Terangkan apa yang yang dimaksudkan dengan istilah daya seret berikut :

i. Seretan kutub
ii. Seretan geseran kulit
iii. Seretan susuk dan
iv. Seretan gelombang

(10 marks/*markah*)

(b) Explain each term that is used in the equation below :

Terangkan maksud setiap istilah yang digunakan di dalam persamaan-persamaan di bawah :

$$C_{D_{wing}} = C_{D_0} + C_{D_L}$$

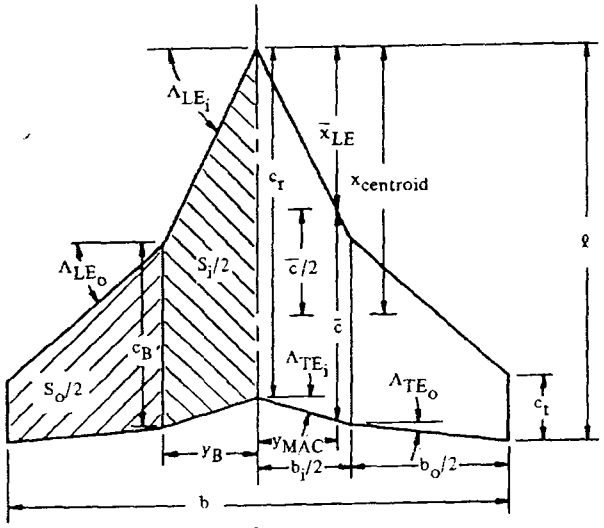
$$C_{D_0} = (R_{rf} R_{LS} c_{fw})(1 + L'(t/c) + 100\ (t/c)^4) S_{wet} / S$$

$$C_{D_L} = C_{L_w}{}^2 / \pi Ae + 2\pi C_{Lw} \varepsilon_t \upsilon + 4\pi^2 (\varepsilon_t)^2 \omega$$

(15 marks/*markah*)

2.

DOUBLE-DELTA AND CRANKED WING PLANFORM PARAMETERS



Rajah 2.1 Data geometri sayap

Figure 2.1 shows a cranked wing plan form with the given data as follows:
Rajah 2.1 memperlihatkan suatu sayap gerak dengan data sebagai berikut:

Wing span b = 10
Rentang sayap b = 10

Inner board wing span y_B = 3
Rentang sayap bahagian dalam y_B = 4

Leading edge swept angle inner wing part $\Lambda_{LE\_i} = 10^0$
Sudut pinggir depan sayap tersapu bahagian dalam $\Lambda_{LE\_i} = 10^0$

Trailing edge swept angle inner wing part $\Lambda_{TE\_i} = 10^0$
Sudut pinggir mengekor sayap tersapu bahagian dalam $\Lambda_{TE\_i} = 10^0$

Leading edge swept angle outer wing part $\Lambda_{LE\_O} = 15^0$
Sudut pinggir depan sayaptersapu bahagian luar $\Lambda_{LE\_O} = 15^0$

Trailling edge swept angle outer part $\Lambda_{TE-O} = 5^0$
Sudut mengekor sayp tersapu bahagian luar $\Lambda_{TE-O} = 5^0$

The root chord length of wing inner part $c_{r\_i} = 4$
Panjang perentas punca bahagian sayap dalam $c_{r\_i} = 4$

Determine the geometry parameter for the wing as depicted in the figure as mentioned above :
Tentukan parameter geometri sayap seperti rajah tersebut di atas :

(a) The length of root and the tip chord of outer wing part c_{r_0} and c_{t_i}

Panjang perentas punca dan perentas hujung sayap bahagian luar c_{r_0} *dan* c_{t_i}

(4 marks/*markah*)

(b) The mean aerodynamic chord c_{mac}

Min perentas aerodinamik c_{mac}

(4 marks/*markah*)

(c) Wing area reference S_{ref}

Luas sayap rujukan S_{ref}

(4 marks/*markah*)

(d) Aspect ratio A_R dan taper ratio λ

Nisbah bidang A_R *dan nisbah tirus* λ

(4 marks/*markah*)

(e) Location of the coordinate the mean aerodynamic chord ($x_{c\ mac}$, y_{c-mac})

Kedudukan koordinat purata perentas aerodinamik ($x_{c\ mac}$, y_{c-mac} *)*

(4 marks/*markah*)

(f) If the wing as mentioned above has the aerodynamic characteristics for its airfoil at the Mach number data $M_\infty = 0.4$ as follows :

Jika sayap tersebut diatas mempunyai data ciri-ciri aerodinamik airfoil pada Nombor Mach $M_\infty = 0.4$ *sebagai berikut :*

$$\left(\frac{dc_\ell}{d\alpha}\right)_{airfoil} = 0.106 \text{ /deg} \quad , \quad \alpha_{L=0} = -1.2$$

Determine the lift coefficient for the wing at angle of attack $\alpha = 3^0$

Tentukan pemalar daya angkat sayap tersebut pada sudut serang $\alpha = 3^0$

(5 marks/*markah*)

3. (a) Given a data for The Plain trailing edge flap as follows :

Diberikan data dari pinggir mengekor kemudi rata sebagai berikut :

Airfoil NACA 0012 ; $\frac{c_f}{c} = 0.2$; $\delta_f = \mathbf{20^0}$; $R_L = 2.76 \times 10^6$

$\mathbf{Tan \frac{1}{2} \Phi_{TE} = 0.010}$.

By using figures as available in the "Buku Formula",
Dengan bantuan gambar seperti yang terdapat dalam "Buku Formula"

Determine :
Tentukan :

(i) The increment of the lift coefficient due to flap Δc_ℓ

Kenaikan pemalar daya angkat disebabkan oleh sayap Δc_ℓ

(3 marks/*markah*)

(ii) The slope curve of the lift coefficient due to flap $\left(\frac{\partial c_\ell}{\partial \alpha}\right)_f$

Kecerunan lengkung pemalar daya angkat disebabkan oleh sayap $\left(\frac{\partial c_\ell}{\partial \alpha}\right)_f$

(3 marks/*markah*)

(b) Given data for the single slotted edge flap as follows :

Diberikan data dari kepak berlubang alur satu sebagai berikut :

Airfoil NACA 64_2-215 ; $\frac{c_f}{c} = 0.25$; $\delta_f = \mathbf{25^0}$; $R_L = 6.0 \times 10^6$

$\mathbf{Tan \frac{1}{2} \Phi_{TE} = 0.074}$. $\mathbf{\frac{c'}{c} = 1.10}$,

Mach number M = 0.3
Nombor Mach M = 0.3

By using the figure as available in the "Buku Formula",
Dengan bantuan gambar seperti yang terdapat dalam "Buku Formula"

Determine :
Tentukan :

(i) The increment of the lift coefficient due to flap Δc_ℓ

Kenaikan pemalar daya angkat disebabkan oleh Δc_ℓ

(3 marks/*markah*)

(ii) The slope curve of the lift coefficient due to flap $\left(\frac{\partial c_\ell}{\partial \alpha}\right)_f$

Kecerunan lengkung pemalar daya angkat disebabkan oleh $\left(\frac{\partial c_\ell}{\partial \alpha}\right)_f$

(3 marks/*markah*)

(iii) The increment of maximum lift coefficient $\Delta c_{\ell-max}$

Kenaikan maksimum pemalar daya angkat $\Delta c_{\ell-max}$

(4 marks/*markah*)

(c) The same as problem 2 (b) , but with the shape of flap is "**Fowler Flap**"

*Sama seperti soalan 2 (b), tetapi dengan bentuk kepak ialah "**Fowler Flap**"*

Airfoil NACA 64_2-215 ; $\frac{c_f}{c} = 0.25$; $\delta_f = \mathbf{25^0}$; $R_L = 6.0 \times 10^6$

$$\mathbf{Tan}\,\frac{1}{2}\Phi_{TE} = \mathbf{0.074}\,.\,\frac{c'}{c} = \mathbf{1.20}\ ,$$

By use the Figures as available in the "Buku Formula",
Dengan bantuan gambar seperti yang terdapat dalam "Buku Formula"

Determine :
Tentukan :

(i) The increment of the lift coefficient due to flap Δc_ℓ

Kenaikan pemalar daya angkat disebabkan oleh Δc_ℓ

(3 marks/*markah*)

(ii) The slope curve of the lift coefficient due to flap $\left(\frac{\partial c_\ell}{\partial \alpha}\right)_f$

Kecerungan lengkung pemalar daya angkat disebabkan oleh $\left(\frac{\partial c_\ell}{\partial \alpha}\right)_f$

(3 marks/*markah*)

(iii) The increment of maximum lift coefficient $\Delta c_{\ell-max}$

Kenaikan maksimum pemalar daya angkat $\Delta c_{\ell-max}$

(3 marks/*markah*)

4. Given a rectangular wing planform with the data geometry as shown in the Figure 4.1 belows :

Diberikan sayap empat persegi panjang dengan data geometri seperti pada Rajah 4.1 dibawah :

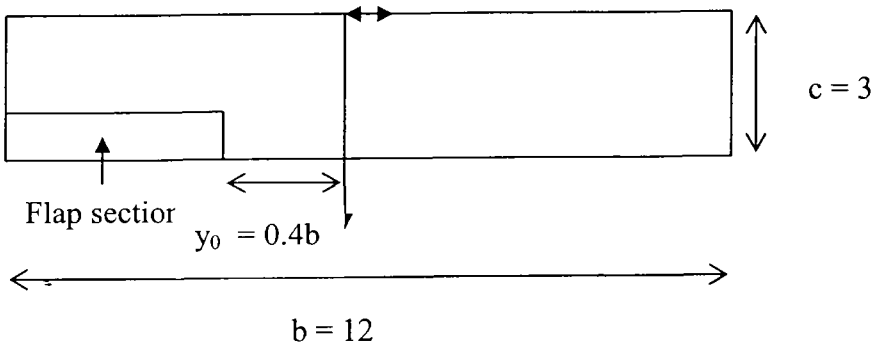


Figure 4.1
Rajah 4.1

Wing span b = 12 meter
Rentang sayap b = 12 meter

Wing chord c = 2 meter
Perentas sayap c = 2 meter

The flap start from the position $y_0 = 0.3$ b
Flap dimulai dari posisi

The flap as mentioned above represent a single slotted flap with the data as given in the problem number 3 (b).
Flap tersebut diatas berupa "single slotted flap" dengan data seperti yang di berikan dalam soalan nombor 3 (b).

Using the wing geometry data as given above and also flap data as given in the problem number 3 (b). For the Mach number M = 0.3 determine :
Dengan data geometri sayap seperti di atas dan data kepak soalan nombor 3 (b). Untuk nombor Mach M = 0.3 tentukan :

(a) Determine the geometrical parameter of wing and flap which would be required for the aerodynamic characteristic calculations related to the lift coefficients (as example : wing area, aspect ratio, taper ratio etc.)

Tentukan besaran besaran parameter geometry sayap + kepak yang diperlukan dalam perkiraan aerodinamik sayap dan kepak dalam hal berkenaan dengan pemalar daya angkat (misalnya : luasan sayap, aspek ratio, taper ratio, dan lain-lainnya).

(5 marks/*markah*)

(b) The slope of lift coefficient curve $\left(\frac{dC_\ell}{d\alpha}\right)_{Wing}$

Kecerungan lengkung pekali daya angkat sayap $\left(\frac{dC_\ell}{d\alpha}\right)_{Wing}$

(5 marks/*markah*)

(c) The slope of lift coefficient curve $\left(\frac{dC_\ell}{d\alpha}\right)_{Wing+flap}$ due to flap deflection

Kecerungan lengkung pekali daya angkat sayap akibat flap defleksi $\left(\frac{dC_\ell}{d\alpha}\right)_{Wing+flap}$

(5 marks/*markah*)

(d) Calculate the zero lift drag coefficient for this wing $(C_{d0})_{wing}$. Assume that the wing's Reynolds number is 10^7.

Kirakan berapa besarnya pemalar daya seret pada pada pemalar daya angkat sifar untuk sayap tersebut diatas. $(C_{d0})_{wing}$. *Anggap nombor Reynolds sayap=*10^7

(5 marks/*markah*)

(e) If the the flap which originally was a single slotted flap then replaced by a fowler flap with the aerodynamics characteristics as given in the problem 3 (c). Assume that the zero lift angle of attack for this configuration is $\alpha_{L=0} = -2.3^0$. Calculate the lift coefficient of the wing and flap for the angle of attack $\alpha = 5^0$.

Jika kepak dari yang semula adalah kepak jenis single slotted digantikan dengan kepak jenis "Fowler flap" dengan data aerodinamik "fowler flap" seperti soalan nombor 3 (c). Anggap sudut serang pada pemalar daya angkat sifar adalah $\alpha_{L=0} = -2.3^0$ *hitung pemalar daya angkat sayap + kepak apad sudut serang* $\alpha = 5^0$.

(5 marks/*markah*)

5. An aircraft with the data for the wing, airfoil and flower flap as described in the problems number 3 and number 4. In addition to this, the additional data aircraft are given as follow :

Suatu Pesawat terbang dengan data sayap, airfoil dan single slotted flap seperti yang diberikan pada soalan nombor 3 dan nombor 4 tersebut di atas. Disamping itu pesawat tersebut mempunyai data tambahan sebagai berikut.

Horizontal tail area $\mathbf{S_h = 0.15\ S_w}$
Luas ekor mendatar $\mathbf{S_h = 0.15\ S_w}$

Tail incidence angle $\mathbf{i_h = 2^0}$
Sudut ekor terpasang $\mathbf{i_h = 2^0}$

Horizontal tail dynamics pressure $\mathbf{n_h = 0.80}$
Tekanan dinamik ekor mendatar $\mathbf{n_h = 0.80}$

The slope of tail lift coefficient $\left(\frac{dC_\ell}{d\alpha}\right)_{th}$ = 5.84 /rad

Kecerunan lengkung pekali angkat ekor $\left(\frac{dC_\ell}{d\alpha}\right)_{th}$ = 5.84 /rad

Horizontal distance among the mean aerodynamic control points of wing and horizontal tail $\ell_h = 3.5\ c_{mac}$
Jarak mendatar purata antara titik kawalan aerodinamik sayap dan ekor mendatar $\ell_h = 3.5\ c_{mac}$

Vertical distance wing and horizontal tail $h_h = 0.85\ c_{mac}$
Jarak vertikal sayap dan ekor mendatar $h_h = 0.85\ c_{mac}$

Fuselage diameter $d_f = 2.5\ c_{mac}$
Diameter badan pesawat $d_f = 2.5\ c_{mac}$

The wing incidence $i_w = 3^0$
Sudut sayap terpasang $i_w = 3^0$

Calculate
Kirakan :

(a) *The wing body lift curve slope* $(C_{L\alpha})_{WF}$

Kecerunan lengkung pekali daya angkat sayap–badan pesawat $(C_{L\alpha})_{WF}$

(5 marks/*markah*)

(b) *The airplane lift curve slope coefficients* $(C_{L\alpha})_A$

Kecerunan lengkung pekali daya angkat pesawat $(C_{L\alpha})_A$

(5 marks/*markah*)

(c) *The airplane zero angle of attack lift coefficient* $(C_{L\ \alpha=0})_A$

Pekali daya angkat pesawat pada sudut serang sifar $(C_{L\ \alpha=0})_A$

(5 marks/*markah*)

(d) *The airplane zero lift angle of attack* $(\alpha_{L=0})_A$

Sudut serang pada pekali daya angkat sifar $(\alpha_{L=0})_A$

(5 marks/*markah*)

(e) *The airplane maximum lift coefficients* $(C_{Lmax})_A$

Pekali daya angkat maximum pesawat $(C_{Lmax})_A$

(5 marks/*markah*)

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