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UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua  
Sidang Akademik 2006/2007  
*Second Semester Examination*  
*2006/2007 Academic Session*

April 2007  
*April 2007*

**ESA 372/3 – Aerodinamik Pesawat**  
*Aircraft Aerodynamics*

Masa : [3 jam]  
*Hour : [3 hours]*

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**ARAHAN KEPADA CALON :**  
**INSTRUCTION TO CANDIDATES**

Sila pastikan bahawa kertas peperiksaan ini mengandungi **SEPULUH (10)** mukasurat bercetak dan **LIMA (5)** soalan sebelum anda memulakan peperiksaan ini.  
*Please ensure that this paper contains **TEN (10)** printed pages and **FIVE (5)** questions before you begin examination.*

Jawab **SEMUA** soalan.  
Semua soalan membawa jumlah markah yang sama.  
*Answer **ALL** questions.*  
*All questions carry the same marks.*

Soalan boleh dijawab dalam Bahasa Inggeris kecuali satu soalan mestilah dijawab dalam Bahasa Malaysia.  
*The questions can be answered in English but one question must be answered in Bahasa Malaysia.*

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

1. (a) Secara ringkas terangkan jenis-jenis kaedah pemecahan daya seretan untuk sesebuah kapal terbang. Mengapa kaedah pemecahan daya seretan yang kedua lebih diminati oleh jurutera?

*Briefly explain about types of drag breakdown method for an aircraft. Why Class II drag breakdown method is more preferable by engineers?*

**(6 markah/marks)**

- (b) Secara ringkas terangkan daya pergeseran kulit dan daya seretan tekanan.

*Briefly explain about skin friction and pressure drags.*

**(4 markah/marks)**

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

*Explain each term that is used in the equation below :*

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

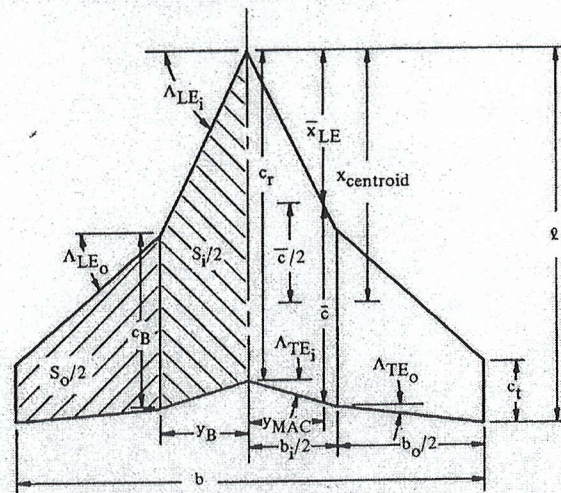
$$C_{D_0} = (R_{rf} R_{LS} c_{fw}) (1 + L'(t/c) + 100 (t/c)^4) S_{wet} / S$$

$$C_{D_L} = C_{L_w}^2 / \pi A e + 2 \pi C_{L_w} \varepsilon_t \nu + 4 \pi^2 (\varepsilon_t)^2 \omega$$

**(15 markah/marks)**

2.

## DOUBLE-DELTA AND CRANKED WING PLANFORM PARAMETERS



Rajah 2.1 Data geometri sayap

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

Rentang sayap  $b = 12$   
 Wing span  $b = 12$

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

Sudut "swept leading edge" sayap bahagian dalam  $\Lambda_{LE_i} = 15^\circ$   
 Leading edge swept angle inner wing part  $\Lambda_{LE_i} = 15^\circ$

Sudut "swept trailing edge" sayap bahagian dalam  $\Lambda_{TE_i} = 5^\circ$   
 Trailing edge swept angle inner wing part  $\Lambda_{TE_i} = 5^\circ$

Sudut "swept leading edge" sayap bahagian luar  $\Lambda_{LE_o} = 10^\circ$   
 Leading edge swept angle outer wing part  $\Lambda_{LE_o} = 10^\circ$

Sudut "trailing leading edge" bahagian luar  $\Lambda_{TE_o} = 5^\circ$   
 Trailing edge swept angle outer part  $\Lambda_{TE_o} = 5^\circ$

Panjang "Root chord" bahagian sayap dalam  $c_{r_i} = 2$   
 The root chord length of wing inner part  $c_{r_i} = 2$

Tentukan parameter geometri sayap seperti rajah tersebut di atas.

*Determine the geometry parameter for the wing as depicted in the figure as mentioned above.*

- (a) Panjang *root chord* dan *tip chord* sayap bahagian luar  $c_{r_0}$  dan  $c_{t_i}$   
*The length of root and the tip chord of outer wing part  $c_{r_0}$  and  $c_{t_i}$*   
**(4 markah/marks)**
- (b) Min perentas aerodinamik  $c_{mac}$   
*The mean aerodynamic chord  $c_{mac}$*   
**(4 markah/marks)**
- (c) Luas sayap acuan  $S_{ref}$   
*Wing area reference  $S_{ref}$*   
**(4 markah/marks)**
- (d) Nisbah bidang  $A_R$  dan nisbah tirus  $\lambda$   
*Aspect ratio  $A_R$  dan taper ratio  $\lambda$*   
**(4 markah/marks)**
- (e) Letak koordinat min perentas aerodinamik ( $x_{c_{mac}}$ ,  $y_{c_{mac}}$ )  
*Location of the coordinate the mean aerodynamic chord ( $x_{c_{mac}}$ ,  $y_{c_{mac}}$ )*  
**(4 markah/marks)**
- (f) Jika sayap tersebut diatas mempunyai data ciri ciri aerodinamik airfoil pada Nombor Mach  $M_\infty = 0.4$  sebagai berikut :  
*If the wing as mentioned above has the aerodynamics characteristics for its airfoil at the Mach number data  $M_\infty = 0.4$  as follows :*

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

Tentukan pemalar daya angkat sayap tersebut pada sudut serang  $\alpha = 5^\circ$

*Determine the lift coefficient for the wing at angle of attack  $\alpha = 5^\circ$*

**(5 markah/marks)**

3. (a) Diberikan data dari "Plain Trailing Edge Flap" sebagai berikut :  
Given a data for The Plain trailing edge flap as follows :

$$\text{Airfoil NACA 0009 ; } \frac{c_f}{c} = 0.2 ; \delta_f = 50^\circ ; R_L = 2.76 \times 10^6$$

$$\text{Tan } \frac{1}{2} \Phi_{TE} = 0.009 .$$

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

Tentukan :

Determine :

- (i) Kenaikan pemalar daya angkat kerana kepek  $\Delta c_\ell$   
The increment of the lift coefficient due to flap  $\Delta c_\ell$   
(3 markah/marks)
- (ii) Kecerunan lengkung pemalar daya angkat karena kepek  $\left( \frac{\partial c_\ell}{\partial \alpha} \right)_f$   
The slope curve of the lift coefficient due to flap  $\left( \frac{\partial c_\ell}{\partial \alpha} \right)_f$   
(3 markah/marks)

- (b) Diberikan data dari "Single Slotted flap" sebagai berikut :  
Given a data for the single slotted edge flap as follows :

$$\text{Airfoil NACA 65-210 ; } \frac{c_f}{c} = 0.25 ; \delta_f = 50^\circ ; R_L = 6.0 \times 10^6$$

$$\text{Tan } \frac{1}{2} \Phi_{TE} = 0.084 . \frac{c'}{c} = 1.08 ,$$

Nombor Mach  $M = 0.3$

Mach number  $M = 0.3$

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

Tentukan :  
Determine :

- (i) Kenaikan pemalar daya angkat kerana kepak  $\Delta c_\ell$   
The increment of the lift coefficient due to flap  $\Delta c_\ell$   
(3 markah/marks)
- (ii) Kecerunan lengkung pemalar daya angkat kerana kepak  $\left(\frac{\partial c_\ell}{\partial \alpha}\right)_f$   
The slope curve of the lift coefficient due to flap  $\left(\frac{\partial c_\ell}{\partial \alpha}\right)_f$   
(3 markah/marks)
- (iii) Kenaikan maksimum pemalar daya angkat  $\Delta c_{\ell-\max}$   
The increment of maximum lift coefficient  $\Delta c_{\ell-\max}$   
(3 markah/marks)
- (c) Sama seperti soalan 2 (b), tetapi dengan bentuk kepak ialah "Fowler Flap"  
The same as problem 2 (b) , but with the shape of flap is "Fowler Flap"

Airfoil NACA 65-210 ;  $\frac{c_f}{c} = 0.25$  ;  $\delta_f = 50^\circ$  ;  $R_L = 6.0 \times 10^6$

$$\tan \frac{1}{2} \Phi_{TE} = 0.084 \cdot \frac{c'}{c} = 1.20$$

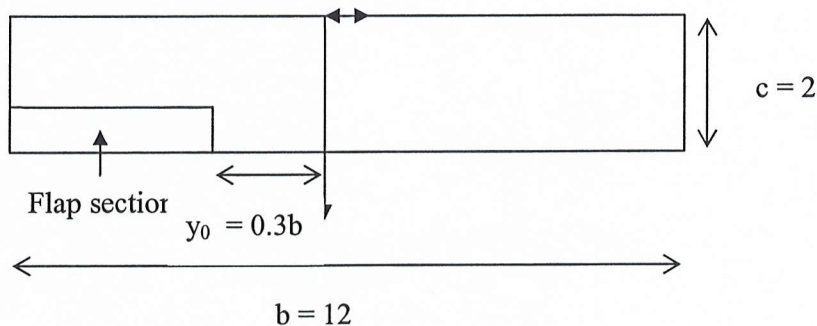
Dengan bantuan gambar seperti yang terdapat dalam "Buku Formula"  
By use the Figures as available in the "Buku Formula",

Tentukan :  
Determine :

- (i) Kenaikan pemalar daya angkat kerana kepak  $\Delta c_\ell$   
The increment of the lift coefficient due to flap  $\Delta c_\ell$   
(3 markah/marks)
- (ii) Kecerunan lengkung pemalar daya angkat kerana kepak  $\left(\frac{\partial c_\ell}{\partial \alpha}\right)_f$   
The slope curve of the lift coefficient due to flap  $\left(\frac{\partial c_\ell}{\partial \alpha}\right)_f$   
(3 markah/marks)
- (iii) Kenaikan maksimum pemalar daya angkat  $\Delta c_{\ell-\max}$   
The increment of maximum lift coefficient  $\Delta c_{\ell-\max}$   
(4 markah/marks)

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

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



Rajah 4.1  
Figure 4.1

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

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

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

Flap tersebut diatas berupa "single slotted flap" dengan data seperti yang di berikan dalam soalan nombor 3 (b).

*The flap as mentioned above represent a single slotted flap with the data as given in the problem number 3 (b).*

Dengan data geometri sayap seperti di atas dan data kepak soalan nombor 3 (b). Untuk nombor Mach  $M = 0.3$  tentukan :

*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 :*

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

*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.)*

**(5 markah/marks)**

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

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

**(5 markah/marks)**

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

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

**(5 markah/marks)**

- (d) Terangkan mengapa sudut serang sayap pada pekali daya angkat sifar sama dengan airfoilnya  $(C_{\ell \alpha=0})_{wing} = (c_{\ell \alpha=0})_{airfoil}$

*Explain why the angle of attack for zero lift coefficients for the wing is equal to that of the airfoil  $(C_{\ell \alpha=0})_{wing} = (c_{\ell \alpha=0})_{airfoil}$*

**(5 markah/marks)**

- (e) 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  $\alpha_{L=0} = -2.3^\circ$  hitung pemalar daya angkat sayap + kepak apad sudut serang  $\alpha = 5^\circ$ .

*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  $\alpha_{L=0} = -2.3^\circ$ . Calculate the lift coefficient of the wing and flap for the angle of attack  $\alpha = 5^\circ$ .*

**(5 markah/marks)**

5. 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.

*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 :*

Luas ekor mendatar  $S_h = 0.20 S_w$

*Horizontal tail area*  $S_h = 0.20 S_w$

Sudut ekor terpasang  $i_h = 4^\circ$

*Tail incidence angle*  $i_h = 4^\circ$

Tekanan dinamik ekor mendatar  $n_h = 0.85$

*Horizontal tail dynamics pressure*  $n_h = 0.85$

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

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

Jarak mendatar antara min aerodinamik titik kontrol sayap dan ekor mendatar

$\ell_h = 3.5 c_{mac}$

*Horizontal distance among the mean aerodynamic control points of wing and horizontal tail*  $\ell_h = 3.5 c_{mac}$

Jarak vertical sayap dan ekor mendatar  $h_h = 0.85 c_{mac}$

*Vertical distance wing and horizontal tail*  $h_h = 0.85 c_{mac}$

Diameter badan pesawat  $d_f = 2.5 c_{mac}$

*Fuselage diameter*  $d_f = 2.5 c_{mac}$

Sudut sayap terpasang  $i_w = 3^\circ$

*The wing incidence*  $i_w = 3^\circ$

Kirakan :

*Calculate*

- (a) Kecerunan lengkung pekali daya angkat sayap–badan pesawat  $(C_{L\alpha})_{WF}$   
*The wing body lift curve slope  $(C_{L\alpha})_{WF}$*  **(5 markah/marks)**
- (b) Kecerunan lengkung pekali daya angkat pesawat  $(C_{L\alpha})_A$   
*The airplane lift curve slope coefficients  $(C_{L\alpha})_A$*  **(5 markah/marks)**
- (c) Pekali daya angkat pesawat pada sudut serang sifar  $(C_{L\ \alpha=0})_A$   
*The airplane zero angle of attack lift coefficient  $(C_{L\ \alpha=0})_A$*  **(5 markah/marks)**
- (d) Sudut serang pada pekali daya angkat sifar  $(\alpha_{L=0})_A$   
*The airplane zero lift angle of attack  $(\alpha_{L=0})_A$*  **(5 markah/marks)**
- (e) Pekali daya angkat maximum pesawat  $(C_{Lmax})_A$   
*The airplane maximum lift coefficients  $(C_{Lmax})_A$*  **(5 markah/marks)**