UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2005/2006
Second Semester Examination
2005/2006 Academic Session

April/Mei 2006
April/May 2006

ESA 372/3 – Aerodinamik Pesawat
Aircraft Aerodynamics

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

ARAHAN KEPADA CALON :
INSTRUCTION TO CANDIDATES:

Sila pastikan bahawa kertas soalan ini mengandungi **LIMA BELAS (15)** mukasurat bercetak dan **SEMBILAN (9)** soalan sebelum anda memulakan peperiksaan.
*Please ensure that this paper contains **FIFTEEN (15)** printed pages and **NINE (9)** questions before you begin examination.*

Bahagian A: Jawab **DUA (2)** soalan. **Bahagian B**: Jawab **TIGA (3)** soalan.
***Part A**: Answer **TWO (2)** questions. **Part B**: Answer **THREE (3)** questions.*

Soalan boleh dijawab dalam Bahasa Inggeris kecuali satu soalan mestilah dijawab dalam Bahasa Malaysia.
The question 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.

BAHAGIAN A/*PART A*

1. Apakah kategori-kategori pesawat berdasarkan nombor Mach? Berikan julat nombor Mach untuk kategori-kategori yang berbeza.

   What are the categories of aircraft based on flight Mach number? Give the range of Mach number for different categories.

(100 markah/*marks*)

2. Secara ringkas terangkan maksud:

   Briefly explain the meanings of:

   (a) 'Luas Bersih Sayap'

   'Net Wing Area'

   (b) 'Seretan Trim'

   'Trim Drag'

   (c) 'Perentas Aerodinamik Min'

   'Mean Aerodynamic Chord'

   (d) 'Seretan Parasit'

   'Parasite Drag'

   (e) 'Faktor Kecekapan Oswald'

   'Oswald Efficiency Factor'.

(100 markah/*marks*)

3. Secara matematik buktikan Perentas Aerodinamik Min (MAC) bagi sebuah rujukan sayap tersapu boleh dihuraikan oleh

$$\overline{C} = \frac{2}{3} C_r \frac{1+\lambda+\lambda^2}{1+\lambda}$$

Mathematically prove that Mean Aerodynamic Chord (MAC) of a reference swept wing can be expressed as

$$\overline{C} = \frac{2}{3} C_r \frac{1+\lambda+\lambda^2}{1+\lambda}$$

di mana C_r adalah perentas sayap pada punca dan λ adalah nisbah tirus sayap

where C_r is the wing chord at root and λ is the wing taper ratio.

(100 markah/*marks*)

4. Jawab hanya satu daripada soalan berikut (a atau b):

Answer just one of the following questions (a or b):

(a) Secara ringkas terangkan bagaimana seretan gelombang bagi pesawat pejuang boleh dikurangkan pada laju supersonik. Apakah kesan kebolehmampatan pada isipadu dan keratan rentas komponen pesawat apabila seretan gelombang dikurangkan?

Briefly explain how the wave drag of fighter aircraft can be reduced at supersonic speeds. What are the compressibility effects of volume and cross section of aircraft components on the wave drag reduction?

(100 markah/*marks*)

ATAU/*OR*

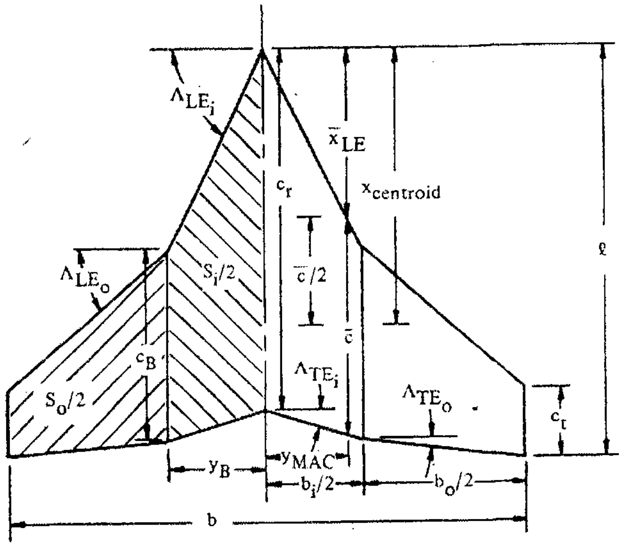
(b) Apakah konsep 'Nombor Mach Genting' (M_{crit}) dan kesannya pada peningkatan seretan pada pesawat subsonik yang tinggi? Apakah kaitan di antara Nombor Mach Genting dan Nombor Mach pada jajap/aras (M_C)?

What is the concept of 'Critical Mach Number' (M_{crit}) and its effect on the drag rise of a high-subsonic aircraft? What is the relation between Critical Mach Number and Mach number at cruise (M_C)?

(100 markah/*marks*)

BAHAGIAN B/*PART B*

5.



Gambarajah 1.1 memperlihatkan suatu sayap gerak dengan data sebagai berikut :

***Figure 1.1** shows a a cranked wing plan form with the given data as follows :*

Rentang sayap b = 10
Rentang sayap bahagian dalam y_B = 3
Sudut pinggir depan tersapu sayap bahagian dalam $\Lambda_{LE\_1} = 20^0$
Sudut pinggir depan tersapu sayap bahagian $\Lambda_{LE\_2} = 5^0$
Sudut pinggir belakang tersapu sayap bahagian luar $\Lambda_{TE\_1} = 10^0$
Sudut pinggir depan tersapu $\Lambda_{TE\_2} = 5^0$

Tentukan parameter geometri sayap seperti rajah tersebut di atas

Wing span $b = 10$
Inner board wing span $y_B = 3$
Leading edge swept angle
Inner wing part $\Lambda_{LE\_1} = 20^0$
Leading edge swept angle
Outer wing part $\Lambda_{LE\_2} = 5^0$
Trailing edge swept angle
Outer wing part $\Lambda_{TE\_1} = 10^0$
Leading edge swept angle $\Lambda_{TE\_2} = 5^0$

Tentukan parameter sayap tersebut di atas

Determine the geometry parameter for the wing as depicted in above figure

(i) Pengagihan perentas c(y)

The chord distribution c(y)

(4 markah/*marks*)

(ii) Min perentas aerodinamik c_{mac}

The mean aerodynamic chord c_{mac}

(4 markah/*marks*)

(iii) Luas sayap acuhan S_{ref}

Wing area reference S_{ref}

(4 markah/*marks*)

(iv) Nisbah bidang A_R dan nisbah tirus λ

Aspect ratio A_R *and taper ratio* λ

(4 markah/*marks*)

(v) Kedudukan 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*)

(vi) Jika sayap tersebut diatas mempunyai data ciri ciri aerodinamik airfoil pada Nombor Mach M_∞ = 0.4 yang berikut:

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

If the wing as mentioned above has the aerodynamics characteristics for its airfoil data as follows:

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

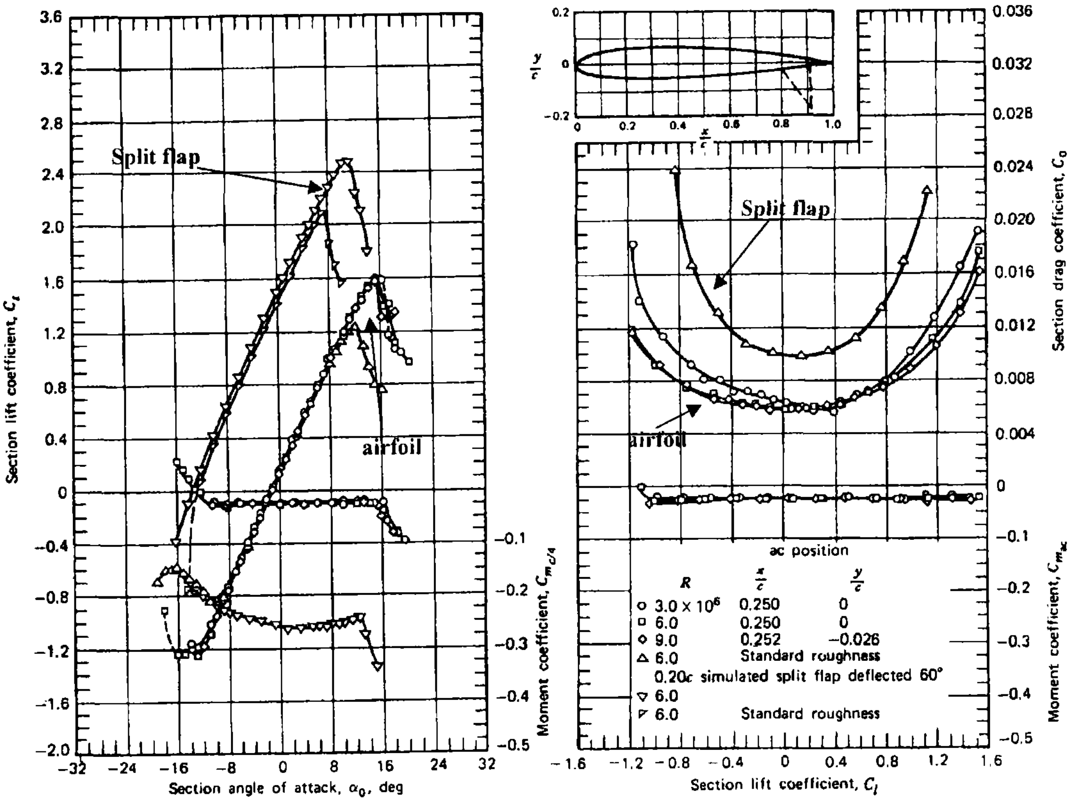
Tentukan pemalar daya angkat sayap tersebut pada sudut serang $\alpha = 5^0$

Determined the lift coefficient for the wing at angle of attack $\alpha = 5^0$

(4 markah/*marks*)

6. Diberikan airfoil NACA serie 1412 dengan data ciri aerodinamik seperti **Gambarajah 2.1** di bawah. Rajah tersebut dihasilkan dari suatu eksperimen aerodinamik di terowong angin pada Nombor Mach M_∞ = 0.3

*A given an airfoil NACA serie 1412 with the aerodynamics characteristics as shown in the **Figure 2.1** belows. This data was resulted from the experiment of wind tunnel which conducted at the Mach Number Mach M_∞ = 0.3*



Gambarajah 2.1: Ciri ciri aerodinamik Naca 1412 Airfoil

Figure 2.1: Aerodynamics Characteristics of Naca 1412 Airfoil

Dengan dengan data tersebut di atas (seperti ditunjukan oleh arah panah airfoil) tentukan ciri ciri aerodinamik airfoil untuk besaran-besaran berikut:

With using above data, (as shown by arrow for the airfoil) determine the aerodynamics characteristics for the airfoil in term of following quantities:

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

Zero lift angle of attack $\alpha_{L=0}$ = ?

(ii) Kurva kemiringan pemalar daya angkat $\left(\frac{dc_\ell}{d\alpha}\right)_{airfoil}$

slope curve of lift coefficient $\left(\frac{dc_\ell}{d\alpha}\right)_{airfoil}$

(iii) Pemalaran daya angkat maksimum dan sudut tegun $c_{\ell max} = ?$ dan $\alpha_{stall} = ?$

The maximum lift coefficient and the stall angle $c_{\ell max} = ?$ *and* $\alpha_{stall} = ?$

(iv) Pemalar daya seret minimum $c_{d\,min}$

the minimum drag coefficient $c_{d\,min}$

(v) Pemalar moment angguk $c_{mc/4} = ?$

the pitching moment coefficient $c_{mc/4} = ?$

(vi) Tentukan sudut serang reka bentuk untuk airfoil tersebut $\alpha_{des} = ?$

Determine the angle of attack design for this airfoil $\alpha_{des} = ?$

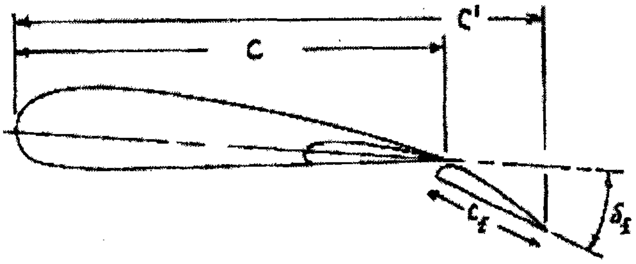
(vii) Terangkan maksud digit dari airfoil Naca 1412 ini

Explain the mean of digit for this airfoil Naca 1412.

(12 markah/*marks*)

7. Keronjong udara di atas dilengkapi dengan kepak jenis flower yang dipesongkan pada sudut pesongan 15^0 dengan konfigurasi seperti **Gambarajah 2.2** dengan $c' = 1.235$ c

Above airfoil was equipped with fowler type of flap with the defection flap angle $\delta_f = 15^0$ *as it was shown in the* ***Figure 2.2*** *with* $c' = 1.235\ c$



Gambarajah 2.2: Geometri kepak fowler

Figure 2.2: *Geometry fowler flap*

Tentukan:

Determine:

(i) Kenaikan pekali daya angkat Δc_ℓ pada sudut serang $\alpha = 0$

The increment of lift coefficient increment Δc_ℓ *at zero angle of attack* $\alpha = 0$

(ii) Kemiringan kurva pekali daya angkat keronjong udara akibat pesongan kepak $\left(\frac{dc_\ell}{d\alpha}\right)_{airfoil+flap}$

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

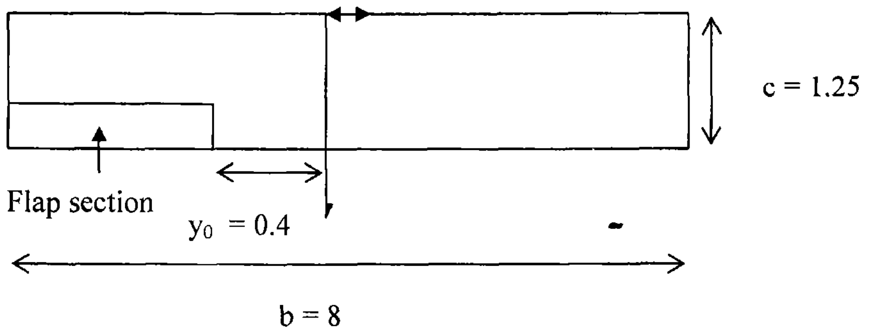
(iii) Kenaikan pekali daya angkat maksimum $(\Delta c_{\ell\max})_{airfoil+flap}$

The increment of maximum lift coefficient $(\Delta c_{\ell\max})_{airfoil+flap}$

(13 markah/*marks*)

8. Diberikan sayap empat persegi panjang dengan data geometri seperti pada **Gambarajah 3.1** dibawah:

*Given a rectangular wing planform with the geometry data as shown in the **figure 3.1** belows:*



Gambarajah 3.1/*Figure 3.1*

rentang sayap b = 8 meter
perentas sayap = 1.25 meter
flap dimulai dari posisi $y_0 = 0.4$ b
Data flap seperti pada soalan nombor 7

wing span b = 8 meter
wing chord = 1.25 meter
the flap start from the position $y_0 = 0.4$ b
Data flap as question number 7

Menggunakan data geometri sayap seperti di atas dan data soalan no7. untuk nombor Mach, tentukan:

Using the geometry data of wing as given above and also airfoil data as given in question number 7, determine:

(i) Tentukan besaran besaran parameter geometry sayap + flap 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 parameter geometry 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*)

(ii) Kemiringan kurva 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*)

(iii) Kemiringan kurva pekali daya angkat sayap akibat kepak pesongan $\left(\frac{dC_\ell}{d\alpha}\right)_{Wing+flap}$

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

(5 markah/*marks*)

(iv) Terangkan mengapa sudut serang sayap pada pekali daya angkat sifar sama dengan keronjong udara $\left(C_{\ell\ \alpha=0}\right)_{wing} = \left(c_{\ell\ \alpha=0}\right)_{airfoil}$

Explain why the angle of attack for zero lift coefficient for the wing is equal to its airfoil. $\left(C_{\ell\ \alpha=0}\right)_{wing} = \left(c_{\ell\ \alpha=0}\right)_{airfoil}$

(5 markah/*marks*)

(v) Jika kepak dari yang semula adalah kepak jenis fowler digantikan dengan kepak jenis split dengan data aerodinamik kepak split seperti Rajah 2.1 hitung pemalar daya angkat sayap dan kepak pada sudut serang $\alpha = 5^{0}$.

If the the flap which originally fowler flap then replaced by the split flap which the aerodynamics characteristics for this type of split flap as shown in figure 2.1 , calculate the lift coefficient wing and flap for the angle of attack $\alpha = 5^0$.

(5 markah/*marks*)

9. Suatu Pesawat terbang dengan data sayap, airfoil dan flap flower seperti yang diberikan pada soalan no 7 dan no 8 tersebut di atas. Disamping itu pesawat mempunyai data tambahan sebagai berikut.

An aircraft with the data for the wing, airfoil and flower flap as described in the problems no 7 and no 8, In addition to this the additional data aircraft are given as follow :

Luas ekor mendatar $S_h = 0.20 \ S_w$

Sudut ekor terpasang $i_h = 4^0$

Tekanan dinamik ekor mendatar $n_h = 0.85$

Kemiring kurva pekali angkat ekor $\left(\dfrac{dC_\ell}{d\alpha}\right)_{th} = 5.84$ /rad

Jarak mendatar antara min aerodinamik titik kontrol sayap dan ekor mendatar $\ell_h = 3.5 \ c_{mac}$

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

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

Sudut sayap terpasang $i_w = 3^0$

Horizontal tail area $S_h = 0.20 \ S_w$

Tail incidence angle $i_h = 4^0$

Horizontal tail dynamics pressure $n_h = 0.85$

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

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

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

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

The wing incidence $i_w = 3^0$

Kirakan:

Calculate:

(i) Kemiringan kurva pekali daya angkat sayap –badan pesawat $(C_{L\alpha})_{WF}$

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

(5 markah/*marks*)

(ii) Kemiringan kurva pekali daya angkat pesawat $(C_{L\alpha})_A$

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

(5 markah/*marks*)

(iii) 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*)

(iv) 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*)

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

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

(5 markah/*marks*)

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