Second Semester Examination
2018/2019 Academic Session

June 2019

ESA369 – Flight Stability & Control
[Kestabilan & Kawalan Penerbangan]

Duration : 3 hours
(Masa : 3 jam)

Please check that this examination paper consists of **ELEVEN (11)** pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi ***SEBELAS (11)*** *muka surat yang bercetak sebelum anda memulakan peperiksaan ini].*

Instructions : Answer **FOUR (4)** questions. **All questions are COMPULSORY**.

*[**Arahan :** Jawab **EMPAT (4)** soalan. **Semua soalan WAJIB dijawab.]***

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai].

1. (a). State the definition of static stability of an aircraft. With the aid of a diagram, describe the conditions of longitudinal static stability by using 2 examples: i) a statically stable airplane, and ii) a statically unstable airplane.

(6 marks)

(b). Assume that you are a flight control engineer and are consulted by an airline company about the stability of a fixed-wing airplane. This company is going to modify the airplane by placing additional payloads to the front end of the airplane. Based on your calculation, its centre of gravity position will shift from $x_{cg} = 0.25\bar{c}$ to $x_{cg} = 0.1\bar{c}$. You need to examine whether the airplane can be trimmed during landing, $C_L = 1.0$. Assume that C_{M_0} and $C_{M_{\delta_e}}$ are not affected by the move of the centre of gravity and that $\delta_{e_{max}} = \pm 20°$.

The pitching moment characteristics of an airplane at the center of gravity position are given as follows:

$$x_{cg} = 0.25\bar{c}$$

$$C_{M_{cg}} = C_{M_0} + \frac{dC_{M_{cg}}}{dC_L} C_L + C_{M_{\delta_e}} \delta_e$$

where

$$C_{M_0} = 0.1$$

$$C_{M_{\delta_e}} = -0.01/°$$

$$\frac{dC_{M_{cg}}}{dC_L} = \left[\frac{X_{cg}}{\bar{c}}\right] - \left[\frac{X_{NP}}{\bar{c}}\right]$$

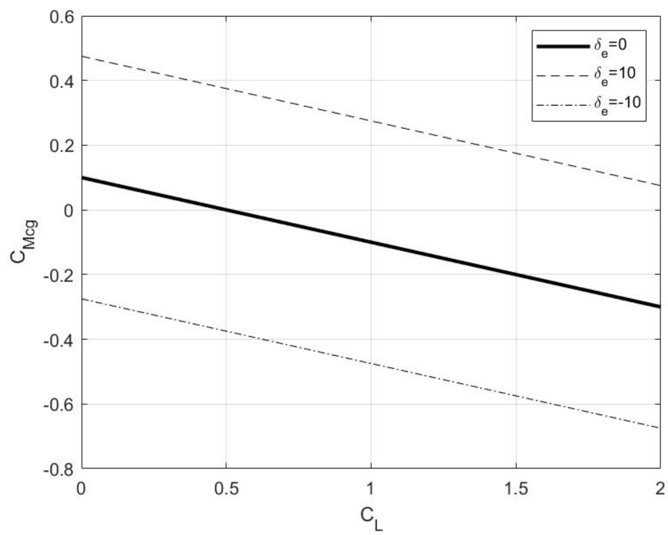


Figure 1

(14 marks)

(c). Describe the term ‘static margin’ and how can we use it in aircraft design.

(5 marks)

2. (a). Briefly explain about directional-lateral stability and state the conditions required for an aircraft to remain stable in this motion.

(5 marks)

(b). What is the major contributor to the rolling stability of an airplane? Explain how this contributor restores a statically stable airplane after the airplane is disturbed from a wings-level attitude.

(7 marks)

(c). A sketch of a half wing platform for a symmetrical airplane is given below:

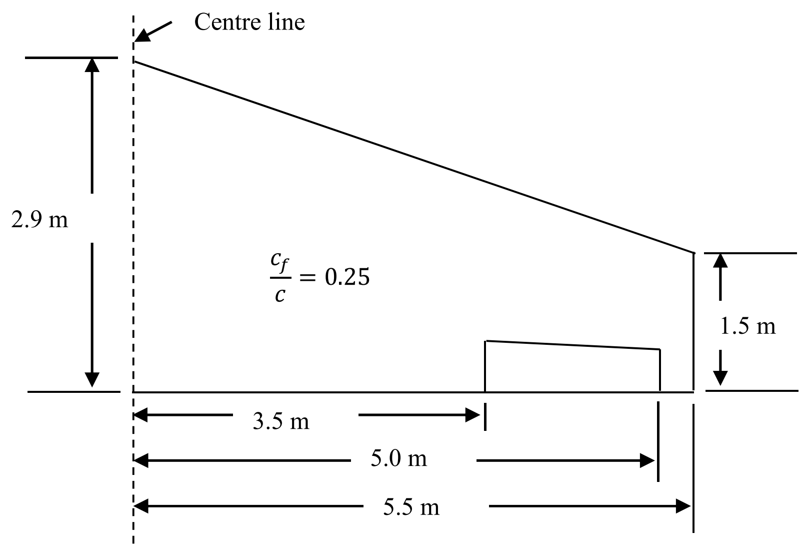


Figure 2

(i). Determine the roll control power using strip theory approximation:

$$C_{L_{\delta_a}} = \left[\frac{2C_{L_{\alpha_W}}\tau}{Sb}\right]\int_{y_1}^{y_2} cy\,dy$$

and assume that $C_{L_{\alpha_W}} = 4.5/rad$.

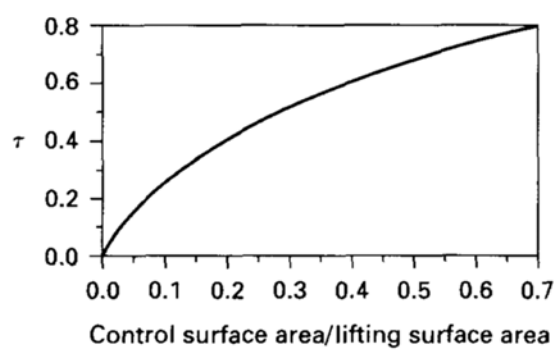


Figure 3

(11 marks)

(ii). What does this roll control power represent? How does it influence the roll control effectiveness?

(2 marks)

3. (a). Describe a system which is statically stable but dynamically unstable and give an example with the aid of a graphical representation.

(5 marks)

(b). Starting with the Z-force equation:

$$Z + mg\cos\theta\cos\Phi = m(\dot{w} + pv - qu)\ ,$$

and the expression of the Z-force in terms of the perturbations:

$$\Delta Z = \frac{\partial Z}{\partial u}\Delta u + \frac{\partial Z}{\partial w}\Delta w + \frac{\partial Z}{\partial \dot{w}}\Delta \dot{w} + \frac{\partial Z}{\partial q}\Delta q + \frac{\partial Z}{\partial \delta_e}\Delta \delta_e + \frac{\partial Z}{\partial \delta_T}\Delta \delta_T\ ,$$

use the small-disturbance theory to determine the linearized force equation:

$$-Z_u\Delta u + \left[(1 - Z_{\dot{w}})\frac{d}{dt} - Z_w\right]\Delta w - \left[(u_0 + Z_q)\frac{d}{dt} - g\sin\theta_0\right]\Delta\theta$$
$$= Z_{\delta_e}\Delta\delta_e + Z_{\delta_T}\Delta\delta_T\ .$$

Assume a steady-level flight for the reference flight conditions.

(15 marks)

(c). The longitudinal roots are given below:

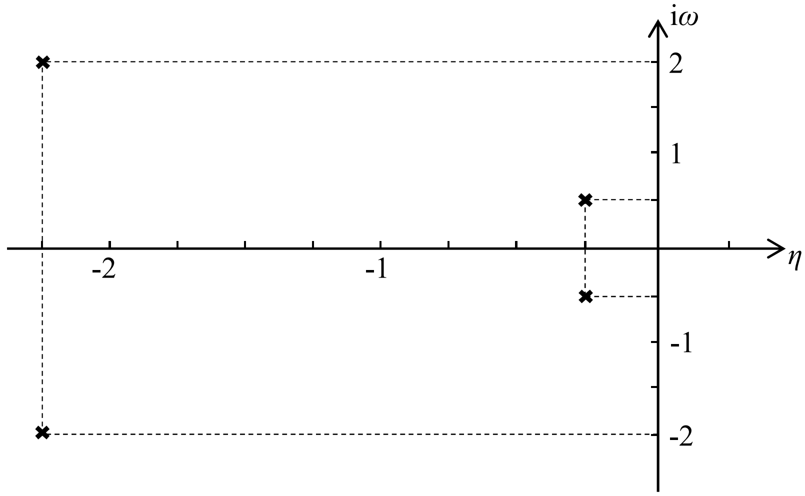


Figure 4

From these data, estimate the time to half-amplitude and the number of cycles for both the short-period and phugoid modes.

(5 marks)

4. (a). Explain why deflecting the ailerons produces a yawing moment.

(5 marks)

(b). The Dutch roll motion can be approximated using the following equations:

$$\begin{bmatrix} \Delta\dot{\beta} \\ \Delta\dot{r} \end{bmatrix} = \begin{bmatrix} \frac{Y_\beta}{u_0} & -(1-\frac{Y_r}{u_0}) \\ N_\beta & N_r \end{bmatrix} \begin{bmatrix} \Delta\beta \\ \Delta r \end{bmatrix} + \begin{bmatrix} \frac{Y_{\delta_r}}{u_0} \\ N_{\delta_r} \end{bmatrix} \Delta\delta_r \ .$$

Assume the coefficients in the plant matrix have the following numerical values:

$Y_\beta = -19.5\ ft/s^2$ $\quad N_r = -0.21/s$ $\quad Y_{\delta_r} = 4.7 ft/s^2$

$Y_r = 1.3\ ft/s$ $\quad u_0 = 400 ft/s$ $\quad N_{\delta_r} = -0.082\ /s^2$

$N_\beta = 1.5\ /s^2$

Determine the Dutch roll eigenvalues, the damping ratio, and the undamped natural frequency.

(10 marks)

(c). Using the Dutch roll approximation in 4.(b), determine the state feedback gains so that the damping ratio and the undamped natural frequency of the Dutch roll are 0.3 and 1.0 rad/s, respectively.

(10 marks)

1. (a). *Nyatakan definisi kestabilan statik pesawat. Dengan bantuan gambarajah, terangkan syarat-syarat kestabilan statik longitudinal dengan menggunakan 2 contoh: i) pesawat yang stabil secara statik dan ii) pesawat yang tidak stabil secara statik.*

(6 markah)

(b). *Anggapkan bahawa anda seorang jurutera kawalan penerbangan dan dirujuk oleh sebuah syarikat penerbangan tentang kestabilan pesawat sayap tetap. Syarikat ini akan mengubahsuai sebuah pesawat dengan meletakkan muatan tambahan ke hujung depan pesawat ini. Berdasarkan pengiraan anda, kedudukan pusat gravitinya akan beralih dari* $x_{cg} = 0.25\bar{c}$ *kepada* $x_{cg} = 0.1\bar{c}$. *Anda perlu memeriksa sama ada kapal terbang boleh ditrim semasa pendaratan di mana* $C_L = 1.0$. *Anggapkan bahawa* C_{M_0} *dan* $C_{M_{\delta_e}}$ *tidak akan dipengaruhi oleh pergerakkan kedudukan pusat graviti tersebut dan bahawa* $\delta_{e_{max}} = \pm 20°$.

Ciri-ciri momen anggul pesawat di kedudukan pusat gravitinya diberikan seperti berikut:

$$x_{cg} = 0.25\bar{c}$$

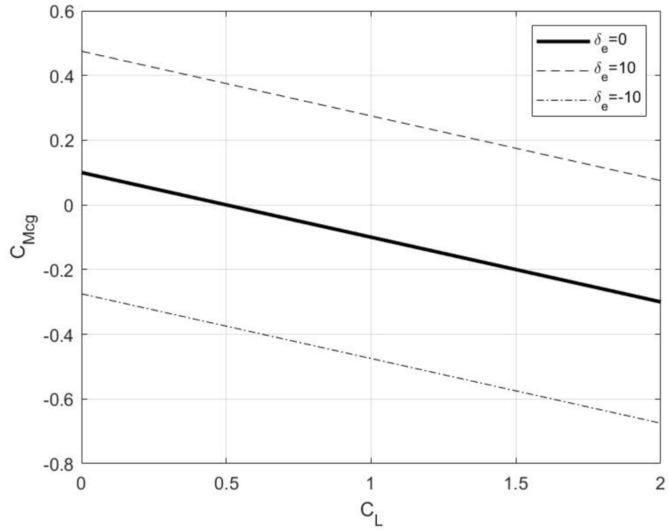
$$C_{M_{cg}} = C_{M_0} + \frac{dC_{M_{cg}}}{dC_L} C_L + C_{M_{\delta_e}} \delta_e$$

di mana

$$C_{M_0} = 0.1$$

$$C_{M_{\delta_e}} = -0.01/°$$

$$\frac{dC_{M_{cg}}}{dC_L} = \left[\frac{X_{cg}}{\bar{c}}\right] - \left[\frac{X_{NP}}{\bar{c}}\right]$$



Gambarajah 1

(14 markah)

(c). *Terangkan istilah 'margin statik' dan bagaimana kita boleh menggunakanya dalam reka bentuk pesawat.*

(5 markah)

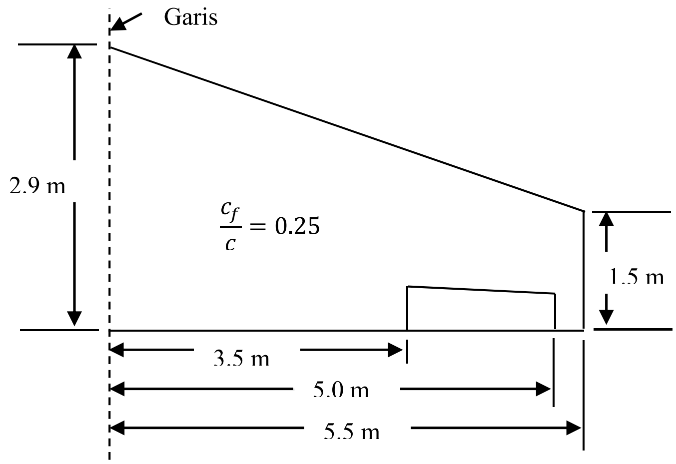
2. (a). *Terangkan secara ringkas tentang kestabilan berarah-sisian dan nyatakan syarat-syarat yang diperlukan untuk sebuah pesawat kekal stabil dalam pergerakan ini.*

(5 markah)

(b). *Apakah penyumbang utama kestabilan guling pesawat? Terangkan bagaimana penyumbang ini mengembalikan kestabilan statik pesawat selepas pesawat ini terganggu daripada sikap tahap sayap.*

(7 markah)

(c). *Lakaran bagi platform separuh sayap bagi pesawat simetri diberikan di bawah:*

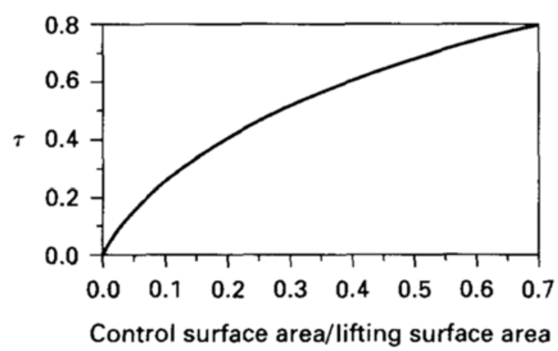


Gambarajah 2

(i). *Tentukan kuasa kawalan guling dengan menggunakan anggaran teori jalur:*

$$C_{L_{\delta_a}} = \left[\frac{2C_{L_{\alpha_W}}\tau}{Sb}\right]\int_{y_1}^{y_2} cy\,dy$$

dan anggapakan bahawa $C_{L_{\alpha_W}} = 4.5/rad.$



Gambarajah 3

(11 markah)

(ii). *Apakah yang dimaksudkan dengan kuasa kawalan guling ini? Bagaimanakah ia mempengaruhi keberkesanan kawalan guling?*

(2 markah)

3. (a). *Terangkan sebuah sistem yang stabil secara statik tetapi tidak stabil secara dinamik dan memberikan contoh dengan bantuan gambarajah.*

(5 markah)

(b). *Bermula dengan persamaan daya Z:*

$$Z + mg\cos\theta\cos\Phi = m(\dot{w} + pv - qu)\ ,$$

dan ungkapan daya Z dalam bentuk gangguan:

$$\Delta Z = \frac{\partial Z}{\partial u}\Delta u + \frac{\partial Z}{\partial w}\Delta w + \frac{\partial Z}{\partial \dot{w}}\Delta \dot{w} + \frac{\partial Z}{\partial q}\Delta q + \frac{\partial Z}{\partial \delta_e}\Delta \delta_e + \frac{\partial Z}{\partial \delta_T}\Delta \delta_T\ ,$$

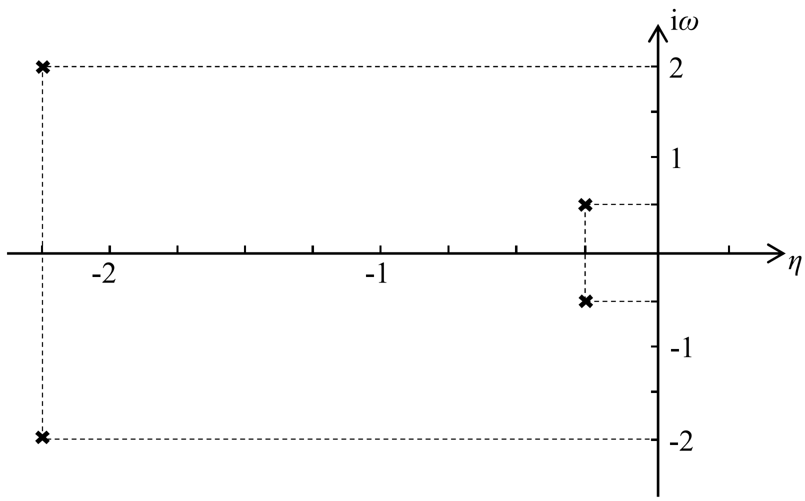
gunakan teori gangguan kecil untuk menentukan persamaan daya yang linear:

$$-Z_u\Delta u + \left[(1 - Z_{\dot{w}})\frac{d}{dt} - Z_w\right]\Delta w - \left[\left(u_0 + Z_q\right)\frac{d}{dt} - g\sin\theta_0\right]\Delta\theta$$
$$= Z_{\delta_e}\Delta\delta_e + Z_{\delta_T}\Delta\delta_T\ .$$

Anggapkan penerbangan tahap mantap bagi keadaan rujukan penerbangan.

(15 markah)

(c). *Punca-punca longitudinal diberikan di bawah:*



Gambarajah 4

Daripada data-data ini, anggarkan masa bagi separuh amplitud dan bilangan kitaran bagi mod jangka pendek dan phugoid.

(5 markah)

4. (a). *Terangkan mengapa momen rewang terhasil apabila aileron dipesongkan.*

(5 markah)

(b). *Pergerakan Dutch roll boleh dianggarkan dengan menggunakan persamaan berikut:*

$$\begin{bmatrix}\Delta\dot{\beta}\\ \Delta\dot{r}\end{bmatrix} = \begin{bmatrix}\frac{Y_\beta}{u_0} & -(1-\frac{Y_r}{u_0})\\ N_\beta & N_r\end{bmatrix}\begin{bmatrix}\Delta\beta\\ \Delta r\end{bmatrix} + \begin{bmatrix}\frac{Y_{\delta_r}}{u_0}\\ N_{\delta_r}\end{bmatrix}\Delta\delta_r .$$

Anggapkan koefisien dalam matriks ini mempunyai nilai berangka berikut:

$Y_\beta = -19.5\ ft/s^2$ $N_r = -0.21/s$ $Y_{\delta_r} = 4.7 ft/s^2$

$Y_r = 1.3\ ft/s$ $u_0 = 400 ft/s$ $N_{\delta_r} = -0.082\ /s^2$

$N_\beta = 1.5\ /s^2$

Tentukan nilai eigen Dutch roll, nisbah redaman dan kekerapan semula jadi yang tidak teredam.

(10 markah)

(c). *Dengan menggunakan anggaran Dutch roll dalam 4(b), tentukan gandaan suap balik supaya nisbah redaman dan kekerapan semula jadi yang tidak teredam Dutch roll ialah 0.3 dan 1.0 rad/s masing-masing.*

(10 markah)

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