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UNIVERSITI SAINS MALAYSIA

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

April/Mei 2006  
*April/May 2006*

**ESA 474/3 – Elemen Rekabentuk Helikopter**  
*Helicopter Design Element*

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

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

Sila pastikan bahawa kertas soalan ini mengandungi **ENAM BELAS (16)** mukasurat dan **LIMA (5)** soalan sebelum anda memulakan peperiksaan.

*Please ensure that this paper contains **SIXTEEN (16)** printed pages and **FIVE (5)** questions before you begin examination.*

Jawab **EMPAT (4)** soalan.

*Answer **FOUR (4)** the questions*

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

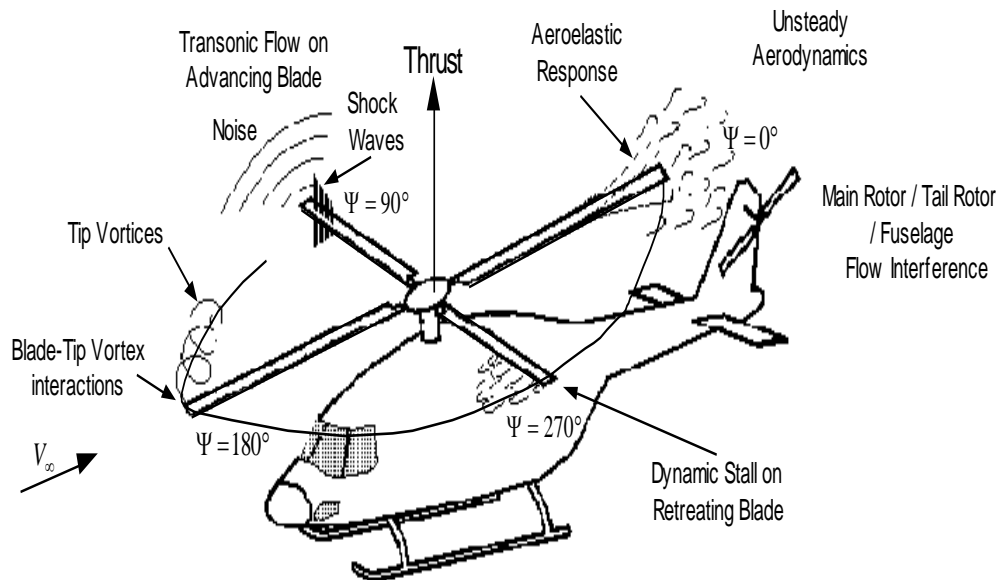
*The question can be answered in English but one question must be answered in Bahasa Malaysia.*

Setiap soalan mestilah dimulakan pada mukasurat yang baru.

*Each questions must begin from a new page.*

1. (a) **Rajah 1.1** memperlihatkan soalan soalan aerodinamik yang terjadi aliran disekitar bilah pemutar helikopter

*Figure 1.1 shows a typical aerodynamics problems appears around the flow past through rotor blade helicopter*



**Rajah 1.1:** Soalan aerodinamik disekitar bilah pemutar helikopter

*Figure 1.1: Aerodynamics problems around the rotor blade helicopter*

Terangkan mengapa:

*Explain why:*

- (i) persoalan aliran transonik  
*the transonic flow problem*
- (ii) interaksi bilah vorteks  
*blade vortex interaction*

- (iii) Tegun dinamik

*dynamics stall*

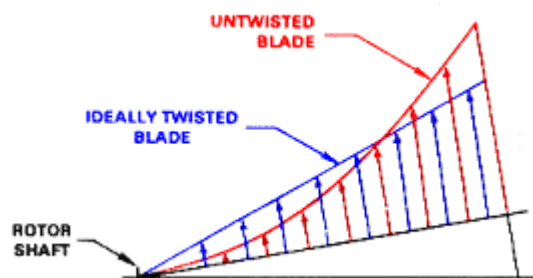
- (iv) Aerodinamik tak mantap debaran terjadi pada aliran melalui bilah helikopter

*flutter unsteady aerodynamics appears in the flow past through rotor blade helicopter.*

**(15 markah/marks)**

- (b) **Rajah 1.3** memperlihatkan pengagihan beban antara pemutar dengan bilah memiliki puihan dan tanpa puihan. Terangkan kegunaan sudut puihan pada bilah pemutar helikopter tersebut.

*Figure 1.3 shows load distribution between twist and untwisted blade. Explain the function of the twisted angle on the blade.*



- Rajah 1.3 :** Agihan daya angkat di atas bilah pemutar terpiuh dan tidak terpiuh

*Figure 1.3 : Distribution of lift on twisted and untwisted rotor blade*

**(5 markah/marks)**

- (c) Terangkan pengertian teknik dari sistem pemutar bersendi dan sistem pemutar tidak bersendi.

*Explain the technical terms of the articulated rotor and non articulated*

**(5 markah/marks)**

- 2 (a) Helikopter dengan data-data berikut:

*A helicopter's data is given bellows:*

Jejari bilah pemutar  $R_B = 6 \text{ m}$

Bilangan Bilah  $N_B = 3$

Purata pekali geseran  $c_{do} = 0.008$

Kelajuan tip  $\Omega R_B = 200 \frac{\text{m}}{\text{sec}}$

Min perentas bilah  $\bar{c} = 0.6 \text{ m}$

Jika berat helikopter ialah 5000 kg dan dalam keadaan penerbangan

Pegun pada paras laut ( anggap ketumpakaan udara  $\rho = 1.225 \frac{\text{kg}}{\text{m}^3}$  )

dan pecutan graviti  $g = 10 \frac{\text{m}}{\text{sec}^2}$

*Rotor blade radius  $R_B = 6 \text{ m}$*

*The blade number  $N_B = 3$*

*The average drag coefficients  $c_{do} = 0.008$*

*The tip speed  $\Omega R_B = 200 \frac{\text{m}}{\text{sec}}$*

*The mean blade chord  $\bar{c} = 0.6 \text{ m}$*

*If the helicopter has mass weight 5000 kg and in hover flight*

*conditions at sea level ( assume the air density  $\rho = 1.225 \frac{\text{kg}}{\text{m}^3}$  and the*

*gravitational accelerations  $g = 10 \frac{\text{m}}{\text{sec}^2}$  )*

Dengan menggunakan teori momentum, kirakan:

*Use a momentum theory, calculate:*

- (i) Pembebanan cakera

*The disk loading*

**(3 markah/marks)**

- (ii) Nisbah aliran masuk teraruh

*Induced inflow ratio*

**(3 markah/marks)**

- (iii) Pekali kuasa teraruh unggul

*Ideal induced power coefficients*

**(4 markah/marks)**

- (iv) Angka merit

*Figure of merit*

**(4 markah/marks)**

- (v) Kesan nisbah bilah

*Effective blade ratio*

**(4 markah/marks)**

- (b) (i) Terangkan mengapa terjadi daya angkat tak simetri di bilah pemutar helikopter semasa helikopter terbang ke depan.

*Explain why dissymmetry lift occurred on the rotor blade helicopter at the moment helicopter fly forward.*

**(4 markah/marks)**

- (ii) Terangkan mengapa di dalam analisis prestasi bilah rotor helikopter dengan kaedah momentum memberikan hasil analisis lebih rendah dibandingkan dengan prestasi yang sebenarnya.

*Explain why on the performance analysis by using the momentum theory tend to give a lower result compared to the actual performance.*

**(3 markah/marks)**

3. Diberikan data helikopter berikut:

*The helicopter's data is given as bellows:*

Jejari bilah pemutar  $R_B = 6 \text{ m}$

Bilangan Bilah  $N_B = 3$

Purata pekali geseran  $c_{do} = 0.008$

Kelajuan tip  $\Omega R_B = 200 \frac{\text{m}}{\text{sec}}$

Min perentas bilah  $\bar{c} = 0.6 \text{ m}$

Berat helikopter : 18000 Newton

Helikopter terbang di atas paras laut ( ketumpatan udara  $\rho = 1.225 \frac{\text{kg}}{\text{m}^3}$

dan pecutan gravitasi  $g = 10 \frac{\text{m}}{\text{sec}^2}$  ).

*Rotor blade radius*  $R_B = 6 \text{ m}$

*The blade number*  $N_B = 3$

*The average drag coefficients*  $c_{do} = 0.008$

*The tip speed*  $\Omega R_B = 200 \frac{\text{m}}{\text{sec}}$

*The mean blade chord*  $\bar{c} = 0.6 \text{ m}$

*Helicopter weight* : 18000 Newton

*The helicopter fly at sea level* ( air density  $\rho = 1.225 \frac{\text{kg}}{\text{m}^3}$  and

*gravitational acceleration*  $g = 10 \frac{\text{m}}{\text{sec}^2}$  ).

Dengan menggunakan teori momentum, kira:

*Using momentum theory, calculate:*

- (i) Pekali tujahan

*The thrust coefficient*

**(2 markah/marks)**

- (ii) Nisbah aliran masuk teraruh semasa terapung

*The induced velocity at hover*

**(2 markah/marks)**

- (iii) Nisbah aliran masuk teraruh pada pendakian dengan halaju 20 m/saat.

*The induced velocity at climb with speed 20 m/sec*

**(2 markah/marks)**

- (iv) Halaju penurunan semasa terjadinya keadaan gelang vorteks

*Descent velocity at vortex ring state*

**(2 markah/marks)**

- (v) Halaju penurunan semasa terjadinya keadaan permulaan gelora

*Descent velocity at turbulent wake state*

**(2 markah/marks)**

- (vi) Halaju penurunan semasa terjadinya keadaan pecah kitar angin

*Descent velocity at the wind mill brake state*

**(2 markah/marks)**

- (vii) Angka merit semasa terapung

*Figure of merit at hover*

**(2 markah/marks)**

- (viii) Angka merit semasa pendakian dengan halaju 25 m/saat

*Figure of merit at climb speed 25 m/sec*

**(2 markah/marks)**

- (ix) Jika helikopter tersebut menurun pada kelajuan sama dengan halaju teraruh, kirakan pekali kuasa teraruh unggul yang diperlukan.

*If the helicopter descent with speed of descent equal to the induced velocity, calculate the ideal induced power coefficient*

**(3 markah/marks)**

- (x) Jika laju tip menjadi 180 m/saat pada semasa helikopter terbang menanjak (climb) 20 m/saat, kirakan penurunan peratus penurunan pekali kuasa teraruh unggul bila dibandingkan laju tip 200 m/saat

*If the tip speed becomes 180 m/sec at the time helicopter fly climb at speed of 20 m/se, Calculate the percentage of the decrease of the ideal power coefficient compared to the helicopter at tip speed 200 m/sec.*

**(3 markah/marks)**

- (xi) Terangkan anggapan yang digunakan dalam analisis aerodinamik bilah pemutar helikopter dengan kaedah teori Momentum

*Explain the assumptions had been used in the aerodynamic analysis of rotor blade helicopter with the Momentum Theory Method.*

**(3 markah/marks)**

4. Diberikan data helikopter berikut:

*The helicopter's data is given as bellows:*

Jejari bilah pemutar  $R_B = 6 \text{ m}$

Bilangan Bilah  $N_B = 4$

Purata pekali geseran  $c_{do} = 0.008$

Kelajuan tip  $\Omega R_B = 200 \frac{\text{m}}{\text{sec}}$

Min perentas bilah  $\bar{c} = 0.6 \text{ m}$

Berat helikopter: 18000 Newton

Luasan plat datar setara 30 % luasan bilah pemutar

Helikopter terbang di atas paras laut (ketumpatan udara  $\rho = 1.225 \frac{\text{kg}}{\text{m}^3}$

dan pecutan gravitasi  $g = 10 \frac{\text{m}}{\text{sec}^2}$ ). Bila helikopter ini sedang melakukan terbang ke arah depan dengan halaju 30 m/sec dan sudut serang Tip Path Plane  $\alpha_{\text{TPP}} = 5^\circ$ .

Kirakan :

*Rotor blade radius  $R_B = 6 \text{ m}$*

*The blade number  $N_B = 4$*

*The average drag coefficients  $c_{do} = 0.008$*

*The tip speed  $\Omega R_B = 200 \frac{\text{m}}{\text{sec}}$*

*The mean blade chord  $\bar{c} = 0.6 \text{ m}$*

*Helicopter weight : 18000 Newton*

*Equivalent flat plate area 30 % Rotor blade area*

*A helicopter flies at sea level ( air density  $\rho = 1.225 \frac{\text{kg}}{\text{m}^3}$  and*

*gravitational acceleration  $g = 10 \frac{\text{m}}{\text{sec}^2}$  ). When the helicopter flies forward at velocity 30 m/sec and the Tip Path plane angle of attack,  $\alpha_{\text{TPP}} = 5^\circ$ .*

*Kirakan :*

- (i) Dengan menggunakan kaedah lelaran Newton (3 iterasi ). Tentukan nisbah aliran masuk  $\lambda_i$

*Using Iteration Newton's Iteration method (up to 3th iterations). Determine the inflow ratio  $\lambda_i$*

**(6 markah/marks)**

- (ii) Pekali kuasa teraruh unggul  $C_{p_i}$

*Ideal induced power coefficients  $C_{p_i}$*

**(2 markah/marks)**

- (iii) Pekali kuasa seretan parasit

*Parasite drag power coefficients  $C_{p_p}$*

**(2 markah/marks)**

- (iv) Pekali kuasa seretan susuk  $C_{p_{d0}}$

*Profile drag power coefficients  $C_{p_{d0}}$*

**(2 markah/marks)**

- (v) Bila sudut serang Tip Path Plane  $\alpha_{\text{TPP}} = 10^\circ$ , dengan kaedah lelaran Newton (3 iterasi ). Tentukan nisbah aliran masuk  $\lambda_i$

*If the angle of attack Tip Path Plane  $\alpha_{\text{TPP}} = 10^\circ$  Using Iteration Newton's Iteration method ( up to 3th iterations). Determine the inflow ratio  $\lambda_i$*

**(6 markah/marks)**

- (vi) Pekali kuasa jumlah untuk nombor soalan 4 (iv)

*Total power coefficient for the problem Number 4(iv)*

**(4 markah/marks)**

- (vii) Terangkan mengapa halaju kendalian helikopter memiliki kecepatan terbang kedepan tidak dapat melebihi nilai nisbah lanjutan  $\mu > 0.4$

*Explain why the operational speed of the helicopter can not exceed for the advance ratio  $\mu > 0.4$*

**(3 markah/marks)**

5. Diberikan data helikopter berikut:

Jejari bilah pemutar  $R_B = 6 \text{ m}$

Bilangan Bilah  $N_B = 4$

Purata pekali geseran  $c_{do} = 0.008$

Kelajuan tip  $\Omega R_B = 200 \frac{\text{m}}{\text{sec}}$

Min perentas bilah  $\bar{c} = 0.6 \text{ m}$

Agihan pic :  $\theta\left(\frac{r}{R_B}\right) = 8^\circ - 2^\circ \left(\frac{r}{R_B}\right)$

Pic terhimpun  $\theta_{lc} = 5^\circ$

Pic kitar  $\theta_{ls} = 3^\circ$

Berat helikopter: 20000 Newton

Luasan plat datar setara 30 % luasan bilah pemutar

Helikopter terbang di atas paras laut ( ketumpatan udara  $\rho = 1.225 \frac{\text{kg}}{\text{m}^3}$

dan pecutan graviti  $g = 10 \frac{\text{m}}{\text{sec}^2}$  ). Bila helikoter ini sedang melakukan terbang ke arah depan (forward) dengan halaju 30 m/sec dan sudut serang Tip Path Plane  $\alpha_{\text{TPP}} = 5^\circ$ .

Dengan anggapan kecepatan imbas seragam dapat diformulasikan variasi sudut berkon sebagai :

$$\beta_0 = \gamma \left[ \frac{\theta_{80\%R}}{8} (1 + \mu^2) - \frac{\mu^2}{60} \theta_{\text{tw}} - \frac{\lambda_{\text{TPP}}}{6} + \mu \frac{\beta_{lc} + \theta_{ls}}{6} \right]$$

$$\beta_{lc} + \theta_{ls} = \frac{-\frac{8}{3}\mu \left[ \theta_{75\%R} - \frac{3}{4}\lambda_{\text{TPP}} \right]}{1 + \frac{3}{2}\mu^2}$$

$$\beta_{ls} - \theta_{lc} = \frac{-\frac{4}{3}\mu\beta_0}{1 + \frac{1}{2}\mu^2}$$

Dan sudut serang efektif diberikan sebagai :

$$\alpha_{\text{effective}} = \frac{U_T \theta - U_P}{U_T} = \frac{1}{U_T} \left[ \begin{array}{l} \Omega r \{ \theta_0 + (\theta_{lc} - \beta_{ls}) \cos \psi + (\theta_{ls} + \beta_{lc}) \sin \psi \} \\ U_\infty \theta_0 \sin \psi + U_\infty (\theta_{lc} - \beta_{ls}) \cos \psi \sin \psi \\ + U_\infty (\theta_{ls} + \beta_{lc}) \sin^2 \psi - U_\infty \beta_0 \cos \psi \\ - V \alpha_{\text{TPP}} - v \end{array} \right]$$

Kirakan :

The helicopter's data is given as bellows:

Rotor blade radius  $R_B = 6 \text{ m}$

The blade number  $N_B = 4$

The average drag coefficients  $c_{do} = 0.008$

The tip speed  $\Omega R_B = 200 \frac{\text{m}}{\text{sec}}$

The mean blade chord  $\bar{c} = 0.6 \text{ m}$

Pitch distribution:  $\theta\left(\frac{r}{R_B}\right) = 8^\circ - 2^\circ \left(\frac{r}{R_B}\right)$

Collective pitch  $\theta_{1c} = 5^\circ$

Cyclic pitch  $\theta_{1s} = 3^\circ$

Helicopter weight : 20000 Newton

Equivalent flat plate area 30 % Rotor blade area

The helicopter fly at sea level (air density  $\rho = 1.225 \frac{\text{kg}}{\text{m}^3}$  and gravitational acceleration  $g = 10 \frac{\text{m}}{\text{sec}^2}$ ). When the helicopter flies forward at velocity 30

m/sec and the Tip Path Plane angle of attack  $\alpha_{\text{TPP}} = 5^\circ$ .

With assumption that the induced velocity is uniform the coning angle can be formulated as :

$$\beta_0 = \gamma \left[ \frac{\theta_{80\%R}}{8} (1 + \mu^2) - \frac{\mu^2}{60} \theta_{\text{tw}} - \frac{\lambda_{\text{TPP}}}{6} + \mu \frac{\beta_{1c} + \theta_{1s}}{6} \right]$$

$$\beta_{1c} + \theta_{1s} = \frac{-\frac{8}{3} \mu \left[ \theta_{75\%R} - \frac{3}{4} \lambda_{\text{TPP}} \right]}{1 + \frac{3}{2} \mu^2}$$

$$\beta_{1s} - \theta_{1c} = \frac{-\frac{4}{3} \mu \beta_0}{1 + \frac{1}{2} \mu^2}$$

and the effective angle of attack as given:

$$\alpha_{\text{effective}} = \frac{U_T \theta - U_P}{U_T} = \frac{1}{U_T} \left[ \begin{array}{l} \Omega r \{ \theta_0 + (\theta_{1c} - \beta_{1s}) \cos \psi + (\theta_{1s} + \beta_{1c}) \sin \psi \} \\ U_\infty \theta_0 \sin \psi + U_\infty (\theta_{1c} - \beta_{1s}) \cos \psi \sin \psi \\ + U_\infty (\theta_{1s} + \beta_{1c}) \sin^2 \psi - U_\infty \beta_0 \cos \psi \\ - V \alpha_{\text{TPP}} - v \end{array} \right]$$

Calculate:

- (i) Dengan menggunakan kaedah lelaran Newton (3 iterasi). Tentukan nisbah aliran masuk  $\lambda_i$

*Using Iteration Newton's Iteration method (up to 3th iterations). Determine the inflow ratio  $\lambda_i$*

**(5 markah/marks)**

- (ii) Anggarkan pekali t sudut berkon: sudut  $\beta_0$ ,  $\beta_{1s}$  dan  $\theta_{1c}$

*Estimate the coning angle coefficients: angle  $\beta_0$ ,  $\beta_{1s}$  and  $\theta_{1c}$*

**(5 markah/marks)**

- (iii) Perkirakan sudut serang efektif pada titik kawalan yang berjarak  $r = 0.5 R_B$  terhadap paksi putar bila bilah terletak pada sudut azimuth  $\psi = 0^\circ$ ,  $90^\circ$  dan  $180^\circ$ .

*Estimate the effective angle of attack at a control point on the blade which located at  $r = 0.5 R_B$  with respect to the rotational axis for the blade azimuth position at  $\psi = 0^\circ$ ,  $90^\circ$  and  $180^\circ$ .*

**(5 markah/marks)**

- (iv) Jika ciri-ciri aerodinamik keratan keranjang udara bilah pemutar diberikan sebagai:

$$c_l(\alpha) = 0.108(\alpha + 1.2) \quad \text{and}$$

$$c_d(\alpha) = 0.008 + 0.01\alpha + 0.005\alpha^2$$

$\alpha$  in degree

*If the aerodynamic characteristics for the airfoil section of the rotor blade are given as :*

$$c_l(\alpha) = 0.108(\alpha + 1.2) \quad \text{and}$$

$$c_d(\alpha) = 0.008 + 0.01\alpha + 0.005\alpha^2$$

$\alpha$  in degree

Tentukan pekali daya angkat dan daya seret untuk soalan 5.4 di atas.

*Determine the coefficient lift and drag for the problem as given in 5.4.*

**(5 markah/marks)**

- (v) Tentukan pekali daya lateral  $C_Y$  dan Daya horizontal  $C_H$  untuk helikopter yang sedang terbang ke hadapan ini.

*Determine the coefficient lateral forces and horizontal forces for the helicopter in this forward flight.*

**(5 markah/marks)**

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