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UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua  
Sidang Akademik 2004/2005  
*Second Semester Examination  
2004/2005 Academic Session*

Mac 2005  
*March 2005*

**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 **EMPAT BELAS (14)** mukasurat dan **LIMA (5)** soalan sebelum anda memulakan peperiksaan.

*Please ensure that this paper contains **FOURTEEN (14)** printed pages and **FIVE (5)** questions before you begin examination.*

Jawab **EMPAT (4)** soalan sahaja.

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

Jawab semua soalan dalam Bahasa Malaysia.

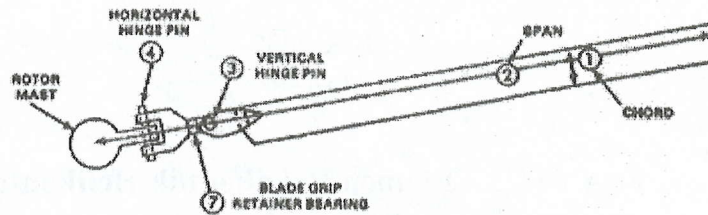
*Answer all questions in Bahasa Malaysia.*

Setiap soalan mestilah dimulakan pada mukasurat yang baru.

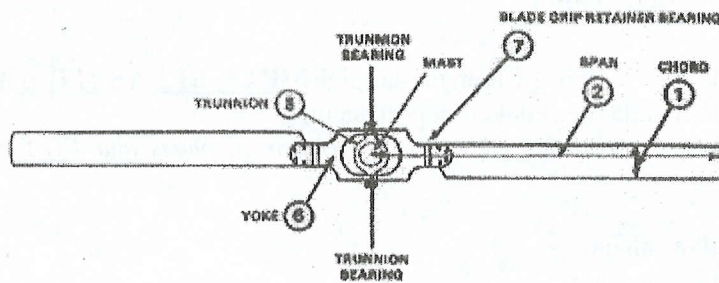
*Each questions must begin from a new page.*

1. (a) Rajah 1.1 dan 1.2 menunjukkan satu sistem rotor helikopter yang disendikan sepenuhnya dan sistem pemutar separa tegar. Terangkan istilah-istilah teknik yang terdapat dalam gambar.

*Figure 1.1 and 1.2 shows a typical rotor system of the helicopter (fully articulated and semi rigid rotor system), explain the technical terms are shown in that figure :*



**Rajah 1.1 : Fully Articulated rotor system**  
*Figure 1.1 : Fully Articulated rotor system*



**Rajah 1.2 : Semi rigid rotor system**  
*Figure 1.2 : Semi rigid rotor system*

Terangkan istilah teknik berikut:

*Explain the following technical terms:*

(i) perentas bilah

*chord*

**(2 markah/marks)**

(ii) rentang bilah

*the span*

**(2 markah/marks)**

(iii) "vertical hinge pin" (drag hinge)

*"vertical hinge pin" (drag hinge)*

**(2 markah/marks)**

(iv) "horizontal hinge pin"

*"horizontal hinge pin"*

**(2 markah/marks)**

(v) trunnion

*the trunnion*

**(2 markah/marks)**

(vi) yoke

*the yoke*

**(2 markah/marks)**

(vii) "blade twist"

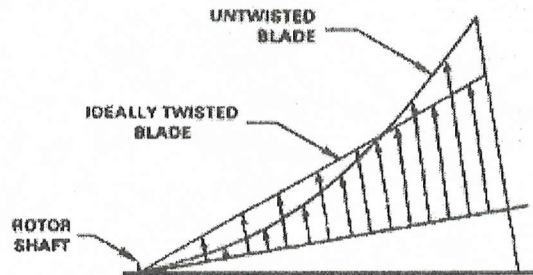
*"the blade twist"*

**(2 markah/marks)**

...4/-

- (b) Rajah 1.3 menunjukkan pengagihan beban antara rotor dengan bilah memiliki twist dan tanpa twist. Terangkan kegunaan sudut twist pada rotor bilah 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 : Distribution of lift on twisted and untwisted rotor blade**  
*Figure 1.3 : Distribution of lift on twisted and untwisted rotor blade*

(5 markah/marks)

- (c) Terangkan pengertian teknik dari
- (i) sistem articulated rotor
  - (ii) sistem non articulated rotor

*Explain the technical terms of*

- (i) *the articulated rotor*
- (ii) *non articulated*

(6 markah/marks)

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2. (a) Helikopter dengan data data 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  $\bar{c} = 0.6 \text{ m}$

Jika berat helikopter ialah 4000 kg dan dalam keadaan penerbangan hover pada paras laut ( anggap ketumpatan udara  $\rho = 1.225 \frac{\text{kg}}{\text{m}^3}$  ) dan

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

*A helicopter's data is given 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  $\bar{c} = 0.6 \text{ m}$*

*If the helicopter has mass weight 4000 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  $g = 10 \frac{\text{m}}{\text{sec}^2}$  )*

...6/-



- (b) (i) Terangkan mengapa terjadi disimetri daya angkat di rotor bilah helikopter semasa helikopter terbang ke depan.

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

**(2 markah/marks)**

- (ii) Terangkan mengapa keadaan pegun terjadi pada bahagian belakang (retreating side) semasa helikopter melakukan terbang ke depan.

*Explain why stall is occurred in retreating side when the helicopter in forward flight.*

**(2 markah/marks)**

- (iii) Terangkan mengapa terjadi gelombang kejutan pada bahagian "advancing side" semasa helikopter terbang ke depan.

*Explain why shock wave appeared in advancing side when the helicopter in forward flight.*

**(2 markah/marks)**

- (iv) Terangkan apa yang dimaksudkan dengan persoalan "tip vortices interaction" di rotor bilah helikopter.

*Explain what it is mean by tip vortices interaction on the rotor blade helicopter*

**(2 markah/marks)**

3. 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  $\bar{c} = 0.6 \text{ m}$

Berat helikopter : 20000 Newton

*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*  $\bar{c} = 0.6 \text{ m}$

*Helicopter weight* : 20000 Newton

Helikopter terbang di atas paras laut ( ketumpatan udara  $\rho = 1.225 \frac{\text{kg}}{\text{m}^3}$  dan pecutan graviti  $g = 10 \frac{\text{m}}{\text{sec}^2}$  ). Dengan menggunakan teori momentum , kira:

*Helicopter flies at sea level (air density  $\rho = 1.225 \frac{\text{kg}}{\text{m}^3}$  and gravity  $g = 10 \frac{\text{m}}{\text{sec}^2}$ ).*

*Using momentum theory, calculate:*

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- (i) Pekali tujuh  
*The thrust coefficient*  
**(2 markah/marks)**
- (ii) Nisbah aliran masuk teraruh semasa hover  
*The induced velocity at hover*  
**(2 markah/marks)**
- (iii) Halaju teraruh dengan halaju semasa mendaki 20 m/saat.  
*The induced velocity at climb with speed 20 m/sec.*  
**(2 markah/marks)**
- (iv) Halaju penurunan semasa terjadinya “vortex ring state”  
*Descent velocity at vortex ring state*  
**(2 markah/marks)**
- (v) Halaju penurunan semasa terjadinya “turbulent wake state”  
*Descent velocity at turbulent wake state*  
**(2 markah/marks)**
- (vi) Halaju penurunan semasa terjadinya “wind mill brake state”  
*Descent velocity at the wind mill brake state*
- (vii) Angka merit semasa hover  
*Figure of merit at hover*  
**(2 markah/marks)**

...10/-



- (viii) Angka merit semasa mendaki dengan halaju 20 m/saat

*Figure of merit at climb speed 20 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 semasa helikopter terbang mendaki 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/sec, 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 pemutar bilah helikopter dengan kaedah teori Momentum.

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

**(5 markah/marks)**

4. 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  $\bar{c} = 0.6 \text{ m}$

Berat helikopter : 20000 Newton

Luasan plat datar setara 30% (luasan rotor bilah)

*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  $\bar{c} = 0.6 \text{ m}$*

*Helicopter weight : 20000 Newton*

*Equivalent flat plate area 30% (Rotor blade area)*

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 helikopter ini sedang melakukan terbang ke arah depan (forward) dengan halaju 30 m/sec dan sudut serang Tip Path Plane  $\alpha_{\text{TPP}} = 5^\circ$ .

Kirakan:

*Helicopter flies at sea level (air density  $\rho = 1.225 \frac{\text{kg}}{\text{m}^3}$  and gravity  $g = 10 \frac{\text{m}}{\text{sec}^2}$ ).*

*When the helicopter move forward with velocity 30 m/sec and Tip Path Plane angle of attack  $\alpha_{\text{TPP}} = 5^\circ$ , calculate:*

- (i) Dengan menggunakan kaedah iterasi 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  $C_{p_p}$

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

**(2 markah/marks)**

- (iv) pekali kuasa seretan profil  $C_{p_{d0}}$

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

**(2 markah/marks)**

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

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

**(6 markah/marks)**

- (vi) Jumlah pekali kuasa untuk no soalan 4 (iv)

*Total power coefficient for the problem No 4(iv)*

**(4 markah/marks)**

5. (a) Terangkan konsep Kaedah Elemen bilah dalam analisis aerodinamik pemutar bilah helikopter.

*Explain the concept of Blade Element Method in the aerodynamic analysis of the rotor blade helicopters*

**(6 markah/marks)**

- (b) Terangkan konsep "Prescribed Wake Method" dalam analisis aerodinamik pemutar bilah helikopter.

*Explain the concept of Free Wake Method in the aerodynamic analysis of the rotor blade helicopters.*

**(6 markah/marks)**

- (c) Terangkan konsep "Free Wake Method" dalam analisis aerodinamik pemutar bilah helikopter.

*Explain the concept of Free Wake Method in the aerodynamic analysis of the rotor blade helicopters.*

**(6 markah/marks)**

- (d) Terangkan mengapa di dalam analisis aerodinamik pemutar bilah helikopter dengan ketiga teori di atas memerlukan data pekali tujuh sebagai data masukan.

*Explain why on the use of three method as mentioned as above in their aerodynamics analysis of rotor blade helicopter need the thrust power coefficient as an input data.*

**(4 markah/marks)**

- (e) Terangkan mengapa model dinamik pegun perlu disertakan dalam analisis aerodinamik pemutar bilah helikopter.

*Explain why the dynamics stall model need to be implemented in the aerodynamics analysis of the rotor blade helicopter*

**(3 markah/marks)**

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