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.*

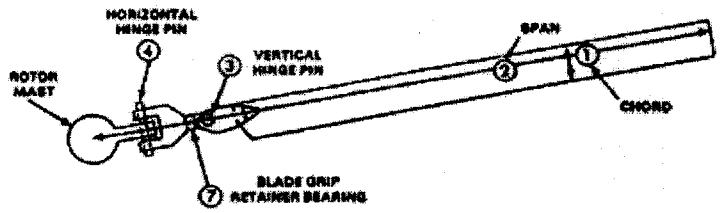
Jawab **EMPAT (4)** soalan sahaja.
*Answer **FOUR (4)** the questions only.*

Jawab semua soalan dalam Bahasa Malaysia.
*Answer all questions in Bahasa Malaysia.*

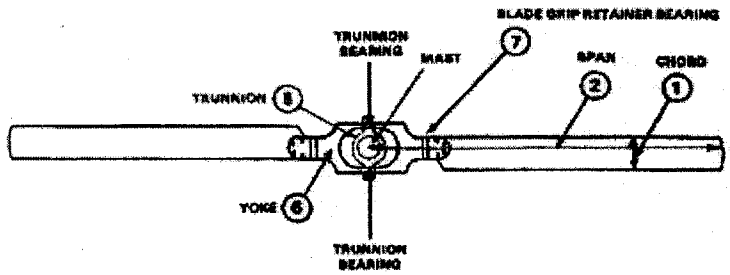
Setiap soalan mestilah dimulakan pada mukasurat yang baru.
*Each questions must begin from a new page.*

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*)**

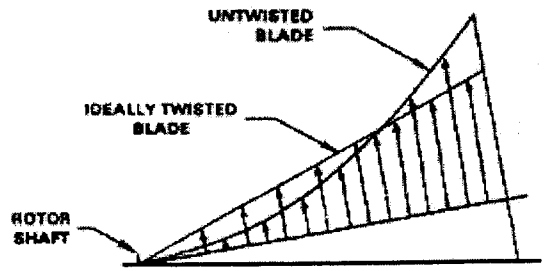
(vii) "blade twist"

*"the blade twist"*

**(2 markah/*marks*)**

(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*)**

2. (a) Helikopter dengan data data berikut:

Jejari bilah pemutar $R_B = 6\,m$
Bilangan Bilah $N_B = 4$
Purata pekali geseran $c_{do} = 0.008$
Kelajuan tip $\Omega R_B = 200 \frac{m}{sec}$
Min perentas bilah $\bar{c} = 0.6\,m$

Jika berat helikopter ialah 4000 kg dan dalam keadaan penerbangan hover pada paras laut ( anggap ketumpatan udara $\rho = 1.225 \frac{kg}{m^3}$ ) dan pecutan graviti $g = 10 \frac{m}{sec^2}$

*A helicopter's data is given bellows :*

*Rotor blade radius* $R_B = 6\,m$
*The blade number* $N_B = 4$
*The average drag coefficients* $c_{do} = 0.008$
*the tip speed* $\Omega R_B = 200 \frac{m}{sec}$
*the mean blade chord* $\bar{c} = 0.6\,m$

*If the helicopter has mass weight 4000 kg and in hover flight conditions at sea level ( assume the air density* $\rho = 1.225 \frac{kg}{m^3}$ *and the gravitational accelerations* $g = 10 \frac{m}{sec^2}$ *)*

Dengan menggunakan teori momentum, kirakan:

*Use a momentum theory to 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*

**(3 markah/*marks*)**

(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 $R_B = 6\,m$
Bilangan Bilah $N_B = 4$
Purata pekali geseran $c_{do} = 0.008$
Kelajuan tip $\Omega R_B = 200 \frac{m}{sec}$
Min perentas bilah $\bar{c} = 0.6\,m$
Berat helikopter : 20000 Newton

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

*Rotor blade radius* $R_B = 6\,m$
*The blade number* $N_B = 4$
*The average drag coefficients* $c_{do} = 0.008$
*The tip speed* $\Omega R_B = 200 \frac{m}{sec}$
*The mean blade chord* $\bar{c} = 0.6\,m$
*Helicopter weight : 20000 Newton*

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

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

(i) Pekali tujah

*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*)**

(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 $R_B = 6\,m$
Bilangan Bilah $N_B = 4$
Purata pekali geseran $c_{do} = 0.008$
Kelajuan tip $\Omega R_B = 200 \frac{m}{sec}$
Min perentas bilah $\bar{c} = 0.6\,m$
Berat helikopter : 20000 Newton
Luasan plat datar setara 30% (luasan rotor bilah)

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

*Rotor blade radius* $R_B = 6\,m$
*The blade number* $N_B = 4$
*The average drag coefficients* $c_{do} = 0.008$
*The tip speed* $\Omega R_B = 200 \frac{m}{sec}$
*The mean blade chord* $\bar{c} = 0.6\,m$
*Helicopter weight : 20000 Newton*
*Equivalent flat plate area 30 % (Rotor blade area)*

Helikopter terbang di atas paras laut ( ketumpatan udara $\rho = 1.225 \frac{kg}{m^3}$ dan pecutan graviti $g = 10 \frac{m}{sec^2}$ ). Bila helikopter ini sedang melakukan terbang ke arah depan (forward) dengan haluju 30 m/sec dan sudut serang Tip Path Plane $\alpha_{TPP} = 5^0$.
Kirakan:

*Helicopter flies at sea level (air density* $\rho = 1.225 \frac{kg}{m^3}$ *and gravity* $g = 10 \frac{m}{sec^2}$*).*
*When the helicopter move forward with velocity 30 m/sec and Tip Path Plane angle of attack* $\alpha_{TPP} = 5^0$*, 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 $Cp_i$

*Ideal induced power coefficients* $Cp_i$

**(2 markah/*marks*)**

(iii) pekali kuasa seretan parasit $Cp_p$

*parsite drag power coefficients* $Cp_p$

**(2 markah/*marks*)**

(iv) pekali kuasa seretan profil $Cp_{d0}$

*profile drag power coefficients* $Cp_{d0}$

**(2 markah/*marks*)**

(v) Bila sudut serang Tip Path Plane $\alpha_{TPP} = 10^0$, dengan kaedah iterasi Newton (3 iterasi). Tentukan nisbah aliran masuk $\lambda_i$

*If the angle of attack Tip Path Plane* $\alpha_{TPP} = 10^0$ *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*)**

(vii) Terangkan mengapa halaju operasi helikopter memiliki kecepatan terbang ke depan tidak dapat melebihi nilai nisbah lanjut $\mu > 0.4$

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

**(3 markah/*marks*)**

5. (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 tujah sebagai data masukan.

*Explain why on the use of three method as mentioned as above in their aerdynamics 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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