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]

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*

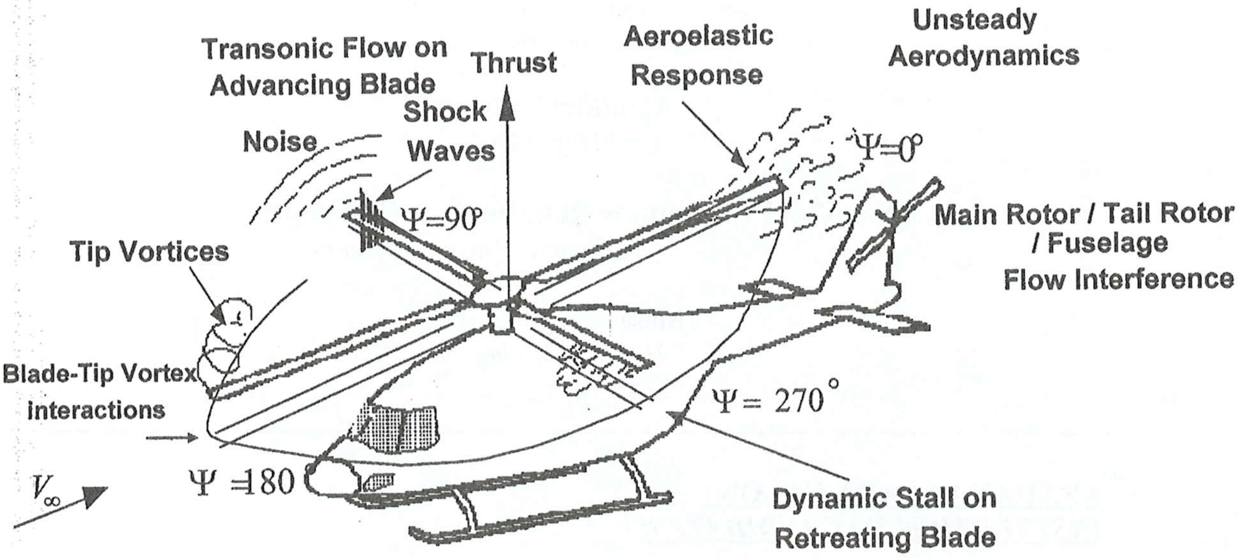
Soalan boleh dijawab dalam Bahasa Inggeris kecuali satu soalan mestilah dijawab dalam Bahasa Malaysia.
The question can be answered in English but one question must be ansawered in Bahasa Malaysia.

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

...2/-

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

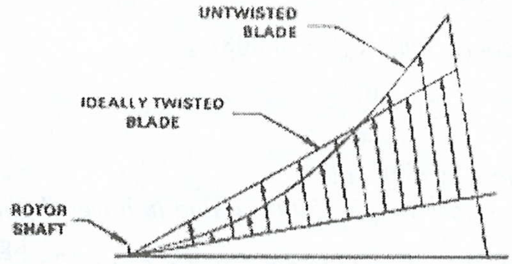
(iv) Aerodinamik tak mantap debaran terjadi pada aliran melalui bilah helikopter

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 piuhan dan tanpa piuhan. Terangkan kegunaan sudut piuhan 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* $g = 10 \frac{\text{m}}{\text{sec}^2}$*)*

(b) (i) Terangkan mengapa terjadi daya angkat tak simentri 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 $R_B = 6\,\mathrm{m}$
Bilangan Bilah $N_B = 3$
Purata pekali geseran $c_{do} = 0.008$
Kelajuan tip $\Omega R_B = 200 \dfrac{\mathrm{m}}{\mathrm{sec}}$
Min perentas bilah $\bar{c} = 0.6\,\mathrm{m}$

Berat helikopter : 18000 Newton
Helikopter terbang di atas paras laut (ketumpatan udara $\rho = 1.225 \dfrac{\mathrm{kg}}{\mathrm{m}^3}$
dan pecutan gravitasi $g = 10 \dfrac{\mathrm{m}}{\mathrm{sec}^2}$).

Rotor blade radius $R_B = 6\,\mathrm{m}$
The blade number $N_B = 3$
The average drag coefficients $c_{do} = 0.008$
The tip speed $\Omega R_B = 200 \dfrac{\mathrm{m}}{\mathrm{sec}}$
The mean blade chord $\bar{c} = 0.6\,\mathrm{m}$

Helicopter weight : 18000 Newton
The helicopter fly at sea level (air density $\rho = 1.225 \dfrac{\mathrm{kg}}{\mathrm{m}^3}$ *and gravitational acceleration* $g = 10 \dfrac{\mathrm{m}}{\mathrm{sec}^2}$ *).*

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 $\Omega R_B = 200 \dfrac{\text{m}}{\text{sec}}$
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 $\rho = 1.225 \dfrac{\text{kg}}{\text{m}^3}$ dan pecutan gravitasi $g = 10 \dfrac{\text{m}}{\text{sec}^2}$). Bila helikopter ini sedang melakukan terbang ke arah depan dengan haluju 30 m/sec dan sudut serang Tip Path Plane $\alpha_{TPP} = 5^0$.
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 $\Omega R_B = 200 \dfrac{\text{m}}{\text{sec}}$
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 $\rho = 1.225 \dfrac{\text{kg}}{\text{m}^3}$ *and gravitational acceleration* $g = 10 \dfrac{\text{m}}{\text{sec}^2}$ *). When the helicopter flies forward at velocity 30 m/sec and the Tip Path plane angle of attack,* $\alpha_{TPP} = 5^0$.
Kirakan :

(i) Dengan menggunakan kaedah lelaran Newton (3 iterasi). Tentukan nisbah aliran masuk λ_i

Using Iteration Newton's Iteration method (up to 3th iterations). Determine the inflow ratio λ_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

Parsite drag power coefficients Cp_p

(2 markah/*marks*)

(iv) Pekali kuasa seretan susuk Cp_{d0}

Profile drag power coefficients Cp_{d0}

(2 markah/*marks*)

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

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 : $\theta(\frac{r}{R_B}) = 8^0 - 2^0 \left(\frac{r}{R_B}\right)$
Pic terhimpun $\theta_{1c} = 5^0$

Pic kitar $\theta_{1s} = 3^0$
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 haluju 30 m/sec dan sudut serang Tip Path Plane $\alpha_{TPP} = 5^0$.
Dengan anggapan kecepatan imbas seragam dapat diformulasikan variasi sudut berkon sebagai :

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

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

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

Dan sudut serang efektif diberikan sebagai :

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

Kirakan :

The helicopter's data is given as bellows:

Rotor blade radius $R_B = 6\,\mathrm{m}$
The blade number $N_B = 4$
The average drag coefficients $c_{do} = 0.008$
The tip speed $\Omega R_B = 200\,\frac{\mathrm{m}}{\mathrm{sec}}$
The mean blade chord $\bar{c} = 0.6\,\mathrm{m}$
Pitch distribution: $\theta(\frac{r}{R_B}) = 8^0 - 2^0\left(\frac{r}{R_B}\right)$
Collective pitch $\theta_{1c} = 5^0$
Cyclic pitch $\theta_{1s} = 3^0$
Helicopter weight : 20000 Newton
Equivalent flat plate area 30 % Rotor blade area
The helicopter fly at sea level (air density $\rho = 1.225\frac{\mathrm{kg}}{\mathrm{m}^3}$ *and gravitational acceleration* $g = 10\frac{\mathrm{m}}{\mathrm{sec}^2}$*). When the helicopter flies forward at velocity 30 m/sec and the Tip Path Plane angle of attacl* $\alpha_{TPP} = 5^0$.
With assumption that the induced velocity is uniform the coning angle can be formulated as :

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

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

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

and the effective angle of attack as given:

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

Calculate:

(i) Dengan menggunakan kaedah lelaran Newton (3 iterasi). Tentukan nisbah aliran masuk λ_i

Using Iteration Newton's Iteration method (up to 3th iterations). Determine the inflow ratio λ_i

(5 markah/*marks*)

(ii) Anggarkan pekali t sudut berkon: sudut β_0 , β_{1s} dan θ_{1c}

Estimate the coning angle coefficients: angle β_0 , β_{1s} *and* θ_{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 $\psi = 0^0$, 90^0 dan 180^0.

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* $\psi = 0^0$, 90^0 *and* 180^0.

(5 markah/*marks*)

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

$c_\ell(\alpha) = 0.108\ (\alpha + 1.2\ )$ and

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

α in degree

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

$c_\ell(\alpha) = 0.108\ (\alpha + 1.2\ )$ and

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

α in degree