UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2006/2007
Second Semester Examination
2006/2007 Academic Session

April 2007
April 2007

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 peperiksaan ini mengandungi **SEBELAS (11)** mukasurat bercetak dan **LIMA (5)** soalan sebelum anda memulakan peperiksaan ini.
*Please ensure that this paper contains **ELEVEN (11)** printed pages and **FIVE (5)** questions before you begin examination.*

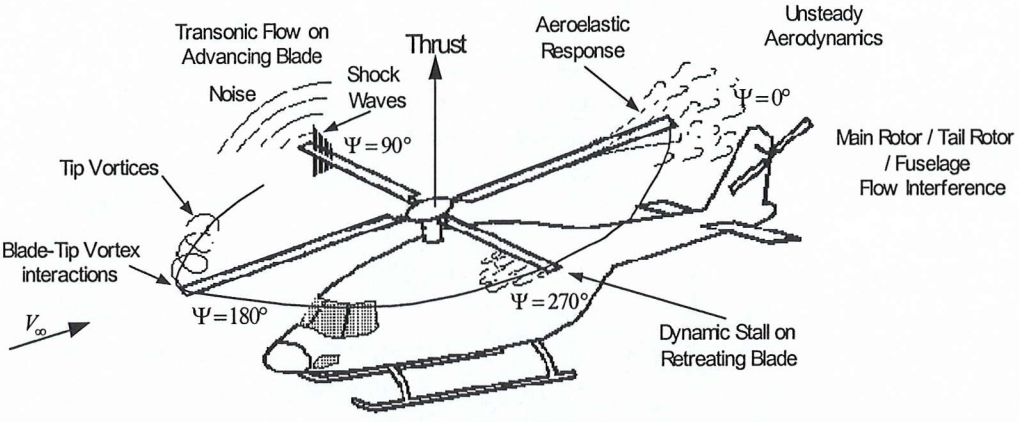
Jawab **SEMUA** soalan.
Semua soalan membawa jumlah markah yang sama.
*Answer **ALL** questions only.*
All questions carry the same marks.

Soalan boleh dijawab dalam Bahasa Inggeris kecuali satu soalan mestilah dijawab dalam Bahasa Malaysia.
The questions 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 di sekitar rotor blade helikopter.

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



Rajah 1.1 : Soalan aerodinamik di sekitar bilah rotor helikopter
Aerodynamics problems around the rotor blade helicopter

Terangkan mengapa ada bahagian dari bilah rotor yang mengalami fenomena aliran transonik, kibaran dan dinamik tegun.

Explain why part of the rotor blade experienced transonic flow phenomena, flutter and the dynamic stall.

(15 markah/*marks*)

(b) Terangkan mengapa bilah rotor helikopter perlu di *twist* dan juga perlu adanya sudut *conning.*

Explain why the rotor blade helicopter required to be twisted and the presence of conning angle.

(5 markah/*marks*)

(c) Terangkan pengertian teknik dari sistem *articulated rotor* dan *sistem non articulated rotor.*

Explain the technical terms of (1) the articulated rotor and (2) non articulated rotor.

(5 markah/*marks*)

2. (a) Helikopter dengan data data berikut :
A helicopter's data is given bellows :

- Jejari bilah pemutar $R_B = 6\,m$
Rotor blade radius $R_B = 6\,m$

- Bilangan Bilah $N_B = 4$
The blade number $N_B = 4$

- Purata pekali geseran $c_{do} = 0.010$
The average drag coefficients $c_{do} = 0.010$

- Kelajuan tip $\Omega R_B = 250\frac{m}{sec}$
The tip speed $\Omega R_B = 250\frac{m}{sec}$

- Min perentas bilah $\bar{c} = 0.15\,R_B$
The mean blade chord $\bar{c} = 0.15\,R_B$

Jika berat helikopter ialah 5000 kg dan dalam keadaan penerbangan hover pada paras laut (anggap ketumpatan udara $\rho = 1.225\frac{kg}{m^3}$) dan pecutan graviti $g = 10\frac{m}{sec^2}$.

If the helicopter has mass weight 6000 kg and in hover flight conditions at sea level (assume the air density $\rho = 1.225\frac{kg}{m^3}$ *and the gravitational accelerations* $g = 10\frac{m}{sec^2}$*)*

Nombor Lock $\gamma = 8$
Lock Number $\gamma = 8$

Sudut serang efektif $\alpha_{eff} = 3^0$
Effective angle of attack $\alpha_{eff} = 3^0$

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) Pengkali kuasa teraruh unggul
Ideal induced power coefficients

(3 markah/*marks*)

(iv) Angka merit
Figure of merit

(3 markah/*marks*)

(v) Kesan nisbah bilah
Effective blade ratio

(3 markah/*marks*)

(vi) Sudut conning β_0
Conning angle β_0

(3 markah/*marks*)

(b) 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.

(4 markah/*marks*)

(c) 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 $R_B = 8\,m$
Rotor blade radius $R_B = 8\,m$

Bilangan bilah $N_B = 3$
The blade number $N_B = 3$

Purata pekali geseran $c_{do} = 0.010$
The average drag coefficients $c_{do} = 0.010$

Kelajuan tip $\Omega R_B = 220 \frac{m}{sec}$
The tip speed $\Omega R_B = 220 \frac{m}{sec}$

Min perentas bilah $\bar{c} = 0.15 R_B$
The mean blade chord $\bar{c} = 0.15 R_B$

Berat helikopter : 16000 Newton
Helicopter weight : 16000 Newton

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

(i) Pengkali tujah
The thrust coefficient

(2 markah/*marks*)

(ii) Nisbah aliran masuk teraruh pada hover
The induced velocity at hover

(2 markah/*marks*)

(iii) Nisbah aliran masuk teraruh pada climb dengan halaju 15 m/saat.
The induced velocity at climb with speed 15 m/sec

(2 markah/*marks*)

(iv) Penurunan halaju *descent* semasa terjadinya keadaan gelang vortex.
Descent velocity at vortex ring state

(2 markah/*marks*)

(v) Penurunan halaju *descent* semasa terjadinya keadaan keracak gelora.
Descent velocity at turbulent wake state

(2 markah/*marks*)

(vi) Penurunan halaju *descent* semasa terjadinya keadaan brek kincir angin.
Descent velocity at the wind mill brake state

(2 markah/*marks*)

(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 kuaasa 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 150 m/saat pada semasa helikopter terbang menanjak (climb) 20 m/saat, kirakan penurunan peratus pekali kuasa teraruh unggul bila dibandingkan laju tip pada 200 m/saat
If the tip speed becomes 150 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 rotor 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.

(3 markah/*marks*)

4. Diberikan data helikopter berikut :
The helicopter's data is given as bellows :

Jejari bilah pemutar $R_B = 5\,m$
Rotor blade radius $R_B = 5\,m$

Bilangan bilah $N_B = 4$
The blade number $N_B = 4$

Purata pekali geseran $c_{do} = 0.012$
The average drag coefficients $c_{do} = 0.012$

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

Min perentas bilah $\bar{c} = 0.6\,m$
The mean blade chord $\bar{c} = 0.6\,m$

Berat helicopter : 18000 Newton
Helicopter weight : 18000 Newton

Luasan plat datar setara
Equivalent flat plate area 30 % luasan rotor bilah (Rotor blade area)

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

(i) Dengan menggunakan kaedah iteration 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*)

(ii) Pekali kuasa seret
Parsite drag power coefficients Cp_p

(2 markah/*marks*)

(iii) Pekali kuasa susuk seret Cp_{d0}

Profile drag power coefficients Cp_{d0}

(2 markah/*marks*)

(iv) Bila sudut serang Tip Path Plane $\alpha_{TPP} = 10^0$, dengan kaedah *iteration 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*)

(v) Jumlahkan pekali kuasa untuk no soalan 4 (iv)

Total power coefficient for the problem No 4(iv)

(4 markah/*marks*)

(vi) Terangkan mengapa opersional halaju helikopter memiliki kecepatan terbang ke depan tidak dapat melebihi 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. Diberikan data helikopter berikut :
The helicopter's data is given as bellows :

Jejari bilah pemutar $R_B = 7\,m$
Rotor blade radius $R_B = 7\,m$

Bilangan bilah $N_B = 4$
The blade number $N_B = 4$

Purata pekali geseran $c_{do} = 0.008$
The average drag coefficients $c_{do} = 0.008$

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

Min perentas bilah $\bar{c} = 0.6\,m$
The mean blade chord $\bar{c} = 0.6\,m$

Distribusi pitch : $\theta(\frac{r}{R_B}) = 8^0 - 2^0 \left(\frac{r}{R_B}\right)$
Pitch distribution : $\theta(\frac{r}{R_B}) = 8^0 - 2^0 \left(\frac{r}{R_B}\right)$

Collective pitch $\theta_{lc} = 5^0$
Cyclic pitch $\theta_{ls} = 3^0$

Berat helicopter : 20000 Newton
Helicopter weight : 20000 Newton

Luasan plat datar setara
Equivalent flat plate area 30 % luasan rotor bilah *(Rotor blade area)*

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

Dengan anggapan kecepatan imbas seragam dapat diformulasikan variasi sudut coning sebagai :
With assumption that the induced velocity is uniform the coning angle can be formulated as :

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

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

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

Dan sudut serang effective :
And the effective angle of attack diberikan sebagai :

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

Kirakan :

(i) Dengan menggunakan kaedah iteration 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 pemalar t coning angle β_0, β_{1s} dan θ_{1c}

Estimate the coning angle coefficients : angle β_0 , β_{1s} *dan* θ_{1c}

(5 markah/*marks*)

(iii) Anggarkan 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 keronjong udara bilah rotor diberikan sebagai :

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

$$c_\ell(\alpha) = 0.108\,(\alpha + 1.2) \quad \text{and}$$

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

α in degree

Tentukan besarnya pemalar daya angkat dan daya seret untuk soalan 5.4 diatas.

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

(5 markah/*marks*)

(v) Tentukan besarnya pemalar 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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