UNIVERSITI SAINS MALAYSIA

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

April 2007
April 2007

ESA 486/3 – Senibina Pelancar

Launcher Architecture

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

ARAHAN KEPADA CALON :
INSTRUCTION TO CANDIDATES:

Sila pastikan bahawa kertas soalan ini mengandungi **SEBELAS (11)** mukasurat termasuk lampiran dan **TIGA (3)** soalan sebelum anda memulakan peperiksaan.
*Please ensure that this paper contains **ELEVEN (11)** printed pages included attachment and **THREE (3)** questions before you begin examination.*

Jawab **TIGA (3)** soalan sahaja.
*Answer **THREE (3)** 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. Di bawah ialah data yang digunakan untuk tentukan nisbah jisim tangki bahan bakar kepada jisim bahan bakar (PT2P) bagi Micron.

Diameter tangki, $D = 0.7$ m
Nisbah percampuran, $K_G = 2.3$
Pemalar keselamatan, $f = 1.875$
Bahan dorong 1 = Oksigen + Kerosen
Bahan dorong 2 = N_2O_4 + UDMH
Bahan untuk tangki = Aloi aluminium (Magnesium 7 %)
Ketumpatan O_2, $\rho = 1130$ kg/m^3
Ketumpatan N_2O_4, $\rho = 1450$ kg/m^3
Ketumpatan Kerosene, $\rho = 800$ kg/m^3
Ketumpatan UDMH, $\rho = 789$ kg/m^3
Ketumpatan Aloi aluminium (Magnesium 7%), $\rho = 2640$ kg/m^3
Tegasan (tegangan), $\sigma_T = 400$ MPa
Tegasan (mampatan), $\sigma_C = 240$ MPa
Ketebalan minimum yang diperlukan, $\delta = 1.5$ mm
Tekanan dalaman (TPS) = 0.45 MPa
Tekanan dalaman (PFS) = 2.0 MPa

The following data is used to determine the ratio of the propellant tank mass to the propellant mass (PT2P) for Micron.

Tank diameter, $D = 0.7$ m
Mixture ratio. $K_G = 2.3$
Safety coefficient, $f = 1.875$
Propellant 1 = Oxygen + kerosene
Propellant 2 = N_2O_4 + UDMH
Tank material = Aluminum alloy (Magnesium 7%)
Density O_2, $\rho = 1130$ kg/m^3
Density N_2O_4, $\rho = 1450$ kg/m^3
Density Kerosene, $\rho = 800$ kg/m^3
Density UDMH, $\rho = 789$ kg/m^3
Density Aluminum Alloy (Magnesium 7%), $\rho = 2640$ kg/m^3
Stress (tension), $\sigma_T = 400$ MPa
Stress (Compression), $\sigma_C = 240$ MPa
Minimum thickness required. $\delta = 1.5$ mm
Internal pressure (TPS) = 0.45 MPa
Internal pressure (PFS) = 2.0 MPa

(a) Tentukan ketebalan yang diperlukan untuk tangki bahan bakar sekiranya campuran bahan dorong yang digunakan adalah O_2 + K, manakala sistem suapan yang digunakan adalah sistem tekanan.

Determine the required thickness for the propellant tank if the propellant used is O_2 + K, while the feeding system is pressurized feeding system.

(15 markah/*marks*)

(b) Sekiranya jisim campuran bahan dorong yang digunakan adalah 7000 kg, tentukan nisbah jisim tangki bahan bakar kepada jisim bahan bakar (PT2P). (sistem suapan yang digunakan adalah sistem tekanan)

If the mass of the propellant is 7000 kg, determine the ratio of the propellant tank mass to the propellant mass (PT2P). (the fuel feeding system used is the pressurized feeding system)

(35 markah/*marks*)

(c) Sekiranya jenis campuran bahan bakar digantikan dengan N_2O_4 dan UDMH, dan jisim campuran bahan bakar masih 7000 kg, berapakah nilai PT2P? (sistem suapan yang digunakan adalah sistem tekanan)

If the propellant is replaced with N_2O_4 and UDMH and the mass of the propellant is still the same as 7000 kg, what is the value of PT2P? (the fuel feeding system used is the pressurized feeding system)

(35 markah/*marks*)

(d) Dengan menggunakan jawapan anda di b, c dan d, sebagai seorang jurutera aeroangkasa, bagaimanakah PT2P memberi kesan terhadap parameter beban bayar, μ_{PL}?

Using the answer obtained in b, c and d, as an aerospace engineer, how can PT2P influence the payload parameter, μ_{PL}?

(15 markah/*marks*)

2. (a) Data yang berikutnya menunjukkan sistem tujahan tahap A-4, termasuk dua enjin.

Ketumpatan bahan oksida (N_2O_4), $\rho = 1450$ kg/m^3
Kadar aliran jisim bahan oksida, $\dot{m}_{OX} = 6$ kg/s (per enjin)
Ketumpatan bahan api (N_2H_4), $\rho = 1016$ kg/m^3
Kadar aliran jisim bahan api, $\dot{m}_F = 5$ kg/s (per enjin)
Masa namaan untuk tujahan enjin pada tujahan penuh = 410 s
Isipadu bahan oksida yang terperangkap, $T_{OX} = 0.9$ m^3
Isipadu bahan api yang terperangkap, $T_F = 1.8$ m^3
Isipadu tangki kosong, U = 2.5 % daripada isipadu bahan dorong

Tentukan isipadu bahan dorong.

The following data described the A-4 stage propulsion system, including two engines

Oxidizer (N_2O_4) density, $\rho = 1450$ kg/m^3
Oxidizer mass flow rate, $\dot{m}_{OX} = 6$ kg/s (per engine)
Fuel (N_2H_4) density, $\rho = 1016$ kg/m^3
Fuel mass flow rate, $\dot{m}_F = 5$ kg/s (per engine)
Nominal engine-firing duration at full thrust = 410 s
Trapped oxidizer volume, $T_{OX} = 0.9$ m^3
Trapped fuel volume, $T_F = 1.8$ m^3
Tank Ullage Volume, U = 2.5 % of propellant volume

Determine the volume of the propellant tanks.

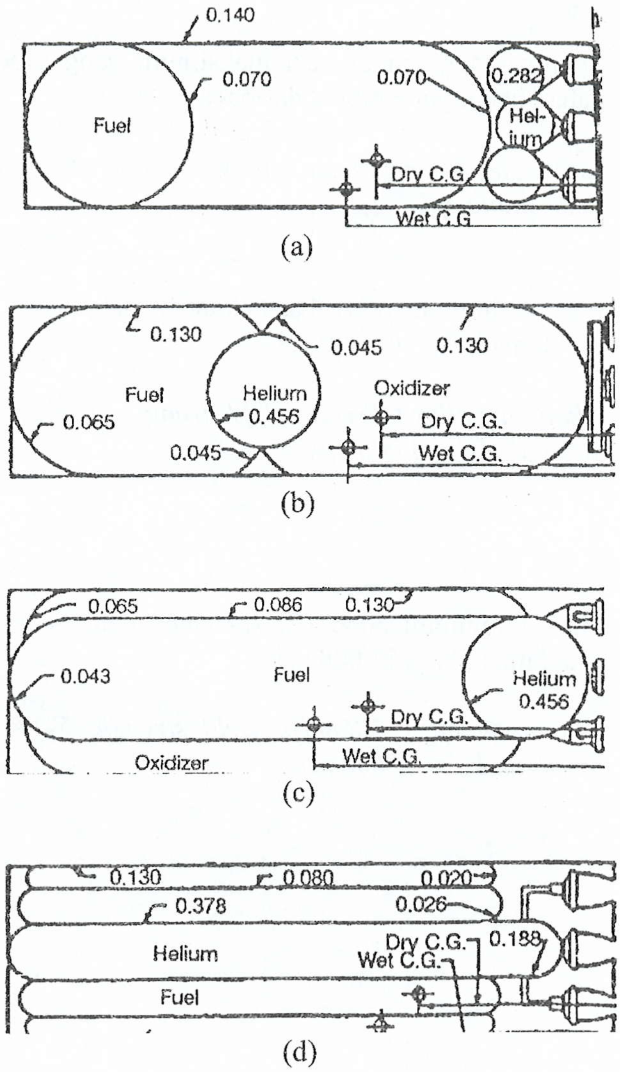
(30 markah/*marks*)

(b) **Gambarajah 1** adalah empat susunan asas tangki bahan bakar.

***Figure 1** are four fundamental arrangements of propellant-tank.*

Namakan jenis susunan mengikut gambarajah 1 dan tujuan susunan tersebut.

Name the type of the arrangement according to the Figure 1 and state the objectives of the arrangement.



Gambarajah 1/*Figure 1*

(40 markah/*marks*)

(c) Satu permulaan fana untuk sistem tujahan prabungkusan cecair tersimpan digunakan untuk peluru berpandu yang dilancarkan dari pesawat terbang, diprogramkan untuk tidak mencapai tahap utama sehingga peluru berpandu tersebut tiba pada jarak tertentu daripada pesawat terbang.

The start transient of a prepackaged storable liquid propulsion system for an aircraft-launched missile is programmed not to attain main-stage level until the missile reaches a specified distance from the aircraft.

Tentukan tegasan operasi maksimum yang dibenarkan untuk tangki bahan bakar yang dibuat daripada

Calculate the maximum allowable operating stresses of propellant tanks made of

(d) Aloi aluminium 6061-T6, kekuatan alah, F_y = 35,000 psi, kekuatan muktamad, F_u = 45,000 psi

Aluminum alloy 6061-T6, yield strength, F_y = 35,000 psi, ultimate strength, F_u = 45,000 psi

(15 markah/*marks*)

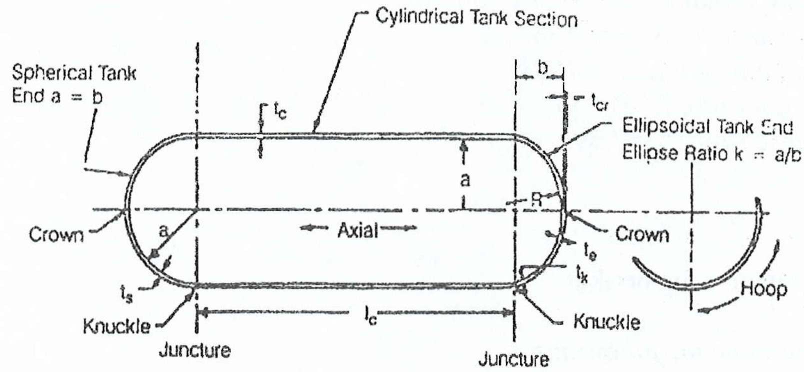
(e) Aloi aluminium 6066-T6, kekuatan alah, F_y = 50,000 psi, kekuatan muktaman, F_u = 57,000 psi.

Aluminum alloy 6066-T6, yield strengh, F_y = 50,000 psi, ultimate strength, F_u = 57,000 psi.

(15 markah/*marks*)

3. Data di bawah adalah data untuk rekabentuk sistem tujahan tahap A-4, yang terdiri daripada bahagian sebuah tangki bahan bakar yang berbentuk silinder dan hujungnya berbentuk elips seperti yang ditunjukkan pada **Gambarajah 2**.

*The following design data characterize the A-4 stage propulsion system, which employs a cylindrical propellant tank section with ellipsoidal ends as shown in **Figure 2**.*



Gambarajah 2/*Figure 2*

Isipadu tangki bahan oksida yang diperlukan, V_{TO} = 120 ft^3
Tekanan maksimum yang beroperasi dalam tangki bahan oksida, p_{TO} = 180 psia
Isipadu tangki bahan api yang diperlukan, V_{TF} = 143.5 ft^3
Tekanan maksimum yang beroperasi dalam tangki bahan api, p_{TF} = 170 psia
Radius dalaman bagi bahagian silinder, a = 41 in.
Bahan binaan tangki, aloi aluminium 6066-T6
Kekuatan alah, Fy : 50,000 psia
Kekuatan muktamad, Fu : 57,000 psia
Ketumpatan, ρ : 0.101 lb/in^3
Modulus Young, E : 10.4×10^6 psia
Nisbah Poisson, v = 0.36
Pekali kimpalan, e_w = 100%
Nisbah rekabentuk, E' = 4.56
Nisbah elips, k = 1.395

Required design volume of the oxidizer tank, $V_{TO} = 120 ft^3$
Maximum oxidizer tank pressure, $p_{TO} = 180$ psia
Required design volume of the fuel tank, $V_{TF} = 143.5 ft^3$
Maximum fuel tank pressure, $p_{TF} = 170$ psia
Internal radius of the cylindrical section, $a = 41$ in
Tank construction material, aluminum alloy 6066-T6
Yield Strength, Fy : 50,000 psia
Ultimate Strength, Fu : 57,000 psia
Density, ρ : 0.101 lb/in^3
Young Modulus, E : 10.4 x 106 psia
Poisson's ratio, $v = 0.36$
Weld efficiency, $e_w = 100\%$
Design ratio, $E' = 4.56$
Ellipse ratio, $k = 1.395$

Tentukan yang berikut:

Determine the followings:

(a) Dimensi dalaman tangki yang diperlukan.

Required internal dimensions of tank.

(20 markah/*marks*)

(b) Ketebalan dinding tangki yang diperlukan pada setiap bahagian Pertimbangkan beban tekanan dalaman, ketakselanjaran dan tegasan lentur lokal.

Required thickness of the tank walls at various sections, considering internal pressure loads, discontinuity, and local bending stresses.

(40 markah/*marks*)

(c) Anggaran jisim tangki.

Approximate mass of the tank.

(20 markah/*marks*)

(d) Tekanan kritikal beban luaran, sekiranya pemalar lengkokan $C_b = 0.10$ pada hujung tangki.

Lampiran/*Formula*

Senibina Pelancar
Launcher Architecture

1. Thickness, $\delta = \dfrac{P \times f \times R}{\sigma_T}$

2. mass (oxidizer), $M_{ox} = \dfrac{M_P \times K_G}{1 + K_G}$

3. mass (fuel), $M_f = \dfrac{M_P}{1 + K_G}$

4. volume (oxidizer/fuel), $V_x = \dfrac{m_x}{\rho_x}$

5. Height (oxidizer/fuel),

$$H = \frac{\left(1.065V - \frac{4}{3}\pi R^3\right)}{\pi R^2}$$

6. Area (oxidizer/fuel),
$A = (2 \times \pi \times R \times H) + (4 \times \pi \times R^2)$

7. mass of the tank (oxidizer/fuel),
$m_b = S \times \delta \times \rho$

8. $m_k = m_{box} + m_{bf}$

9. $PT2P = \dfrac{m_k}{m_P}$

10. $\mu_{PL} = 1 - (1 - \mu_k)(1 + PT2P) - (n_0 \times \gamma_{EN}) - \mu_{OE}$

11. $V = \dfrac{\dot{m} \times 2 \times Isp}{\rho}$ for oxidizer and fuel

12. $U = (V + T) \times \%$

13. $V_t = V + T + U$

14. System involves personnel safety during start transient,

$$S_w = \frac{F_y}{1.25}$$

Or

$$S_w = \frac{F_u}{1.5}$$

15. During mainstage operation

$$S_w = \frac{F_y}{1.15}$$

Or

$$S_w = \frac{F_u}{1.35}$$

16. Volume of an oxidizer tank consists of two ellipsoidal ends without a cylindrical section

$$v_{to} = \frac{2 \times 2\pi a^2 b}{3}$$

17. tank ellipse ratio, $k = \dfrac{a}{b}$

18. The volume of the fuel tank

$$V_{tf} = \pi a^2 l_C$$

19. The required wall thickness at the knuckle of the oxidizer tank end

$$t_{ko} = \frac{Kp_t a}{S_w}$$

20. The required wall thickness at the crown of the oxidizer-tank end

$$t_{cro} = \frac{p_t R}{2S_w}$$

21. The equivalent wall thickness of the oxidizer-tank end

$$t_{co} = \frac{(t_{ko} + t_{cro})}{2}$$

22. The required wall thickness at the knuckle of the fuel tank end

$$t_{kf} = \frac{t_{ko} p_{tf}}{p_{to}}$$

23. The required wall thickness at the crown of the fuel-tank end

$$t_{crf} = \frac{p_{tf} t_{cro}}{p_{to}}$$

24. The required wall thickness of the cylindrical tank section

$$t_c = \frac{a \cdot p_{tf}}{S_w}$$

25. The weight of the oxidizer tank end

$$W_{eo} = \frac{\pi a^2 t_{eo} E' \rho}{2k}$$

26. The weight of the fuel-tank end

$$W_{ef} = \frac{W_{eo} t_{ef}}{t_{eo}}$$

27. The weight of the cylindrical tank section

$$W_c = 2\pi a l_c t_c \rho$$

28. The critical external loading pressure for the oxidizer for the oxidizer ends

$$P_{creo} = \frac{C_b 2E t_{eo}^2}{R^2}$$

29. The critical external loading pressure for the fuel tank end

$$P_{cref} = \frac{C_b 2E t_{ef}^2}{R^2}$$

30. short tanks $l_c < 4.9a\sqrt{a/t_c}$ (short tanks)

$$P_{crc} = 0.807 \frac{E t_c^2}{l_c a} \sqrt[4]{\left(\frac{1}{1-\nu^2}\right)^3 \frac{t_c^2}{a^2}}$$

31. long tanks, $l_c \geq 4.9a\sqrt{a/t_c}$

$$P_{crc} = \frac{E t_c^3}{4(1-\nu^2)a^3}$$

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