UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Pertama
Sidang Akademik 2003/2004

September/Oktober 2003

EBB 222/3- Metalurgi Fizikal

Masa: 3 jam

Sila pastikan bahawa kertas peperiksaan ini mengandungi DUA PULUH TUJUH muka surat bercetak sebelum anda memulakan peperiksaan.

Kertas soalan ini mengandungi TUJUH soalan.

Jawab **LIMA** soalan. Jika calon menjawab lebih daripada lima soalan hanya lima soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah.

Mulakan jawapan anda untuk setiap soalan pada muka surat yang baru.

Jawab semua soalan dalam bahasa Inggeris. Jika calon memilih untuk menjawab dalam bahasa Malaysia, hanya satu soalan dibenarkan.

...2/-

1. [a] Sudut di antara dua arah dalam hablur kubus ditakrifkan melalui perhubungan berikut:

$$\cos \phi = \frac{h_1 \bullet h_2 + k_1 \bullet k_2 + 1_1 \bullet 1_2}{\sqrt{h_1^2 + k_1^2 + 1_1^2} \bullet \sqrt{h_2^2 + k_2^2 + 1_2^2}}$$

dimana h_1, k_1 dan l_1 adalah indeks arah dari salah satu arah.

(i) Dengan menggunakan persamaan di atas, kirakan sudut antara [321] dan $[11\bar{1}]$.

(ii) Dengan cara yang sama, kirakan sudut antara [321] dan [101].

(35 markah)

The angle between two directions in a cubic crystal is defined by the relationship:

$$\cos \phi = \frac{h_1 \bullet h_2 + k_1 \bullet k_2 + 1_1 \bullet 1_2}{\sqrt{h_1^2 + k_1^2 + 1_1^2} \bullet \sqrt{h_2^2 + k_2^2 + 1_2^2}}$$

where h_1, k_1 and l_1 are the direction indices of one of the directions, and h_2, k_2 and l_2 are the direction indices of the other direction.

(i) With the aid of this equation, compute the angle between [321] and $[11\bar{1}]$.

(ii) In the same manner, compute the angle between [321] and [101].

(35 marks)

...3/-

[b] Untuk hablur tunggal dari bahan tertentu, sifat fiziknya adalah tak isotoopi, ini bermakna sifat fiziknya bersandar pada arah kristalografi. Salah satu contoh sifat itu adalah modulus kekenyalan. Untuk hablur tunggal kubus, modulus kekenyalan bagi arah am [uvw], E_{uvw}, diperihalkan melalui kehubungan berikut

$$\frac{1}{E_{uuw}} = \frac{1}{E_{\langle 100\rangle}} - 3\left(\frac{1}{E_{\langle 100\rangle}} - \frac{1}{E_{\langle 111\rangle}}\right)(\alpha^2\beta^2 + \beta^2\gamma^2 + \gamma^2\alpha^2.)$$

dimana $E_{<100>}$ dan $E_{<111>}$ adalah berturutan modulus kekenyalan bagi arah [100] dan [111]; α, β, dan γ adalah kosinus sudut antara [uvw] dan arah-arah [100], [010], dan [001] berturutan. Tunjukkan bahawa nilai $E_{<110>}$ bagi aluminium, tembaga dan besi pada jadual-1 adalah benar.

(35 markah)

For single crystals of some substances, the physical properties are anisotropic; that is, they are dependent on crystallographic direction. One such property is the modulus of elasticity. For cubic single crystals, the modulus of elascity in a general [uvw] direction, E_{uvw}, is described by the relationship.

$$\frac{1}{E_{uuw}} = \frac{1}{E_{\langle 100\rangle}} - 3\left(\frac{1}{E_{\langle 100\rangle}} - \frac{1}{E_{\langle 111\rangle}}\right)(\alpha^2\beta^2 + \beta^2\gamma^2 + \gamma^2\alpha^2.)$$

Where $E_{<100>}$ and $E_{<111>}$ are the moduli of elasticity in [100] and [111] directions, respectively; α, β, and γ are the cosines of the angles between [uυw] and the respective [100], [010], and [001] directions. Verify that the $E_{<110>}$ values for aluminum, copper, and iron in Table1. are correct.

(35 marks)

...4/-

Jadual 1 Nilai-nilai Modulus Elastisiti Kristalografik bagi beberapa logam Pada berbagai orientasi.

Table1 *Modulus of Elasticity Values for Several Metals at Various Crystallographic Orientations*

Metal	Modulus of Elasticity (Gpa) [100]	[110]	[111]
Aluminum	63.7	72.6	76.1
Copper	66.7	130.3	191.1
Iron	125.0	210.5	272.7
Tungsten	384.6	384.6	384.6

c) Huraikan dengan jelas makna dari

(i) Tegasan sebenar

(ii) Ubahbentuk plastik

(iii) Kekuatan alah

(iv) Kemuluran

(v) Perleheran

(30 markah)

Describe the meaning of

(i) True stress

(ii) Plastic deformation

(iii) Yield strength

(iv) Duetility

(v) Necking

(30 marks)

...5/-

2. [a] Andaikan sebuah kehelan pinggir memiliki vektor Burgers dengan arah] $[0\bar{1}0]$ dan meluncur pada satah (100).

(i) Akankah kehelan ini berpunding atau berjog apabila kehelan pinggir lain dengan arah vektor Burgers [010] dan meluncur pada satah (001) memotong kehelan pertama.

(ii) Akankah kehelan pertama berpunding atau berjog apabila sebuah kehelan skru dengan arah vektor Burgers [100] dan meluncur pada satah (001) memotong kehelan pertama.

(35 markah)

Suppose an edge dislocation has a Burgers vector in the $[0\bar{1}0]$ *direction and glides in the (100) plane.*

(i) Will this dislocation be kinked or jogged if another edge dislocation having a b vector direction of [010] moving in the (001) plane passes through it?

(ii) Will it be kinked or jogged if a screw dislocation having a b vector in the [100] direction gliding in the (001) plane passes through it?

(35 marks)

[b] Tindakbalas kehelan kubus berpusat muka berikut akan berlaku

$$\frac{a}{2}[1\bar{1}0] \rightarrow \frac{a}{6}[21\bar{1}] + \frac{a}{6}[121]$$

(i) Buktikan bahawa tindakbalas ini akan berlaku.

(ii) Apa jenis kehelan (a / 6< 121 >) itu?

(iii) Apa jenis ketaksempurnaan hablur yang terjadi akibat tindakbalas kehelan itu?

(iv) Apa yang menentukan jarak pemisah antara kehelan (a/6) $[21\bar{1}]$ dengan kehelan (a/6[121])?

(35 markah)

...6/-

The following face-centered cubic dislocation reaction will occur:

$$\frac{a}{2}[110] \rightarrow \frac{a}{6}[21\bar{1}] + \frac{a}{6}[121]$$

(i) *Prove that the reaction will occur.*

(ii) *What kind of dislocations are the (a/6)<121>?*

(iii) *What kind of crystal imperfection result from this dislocation reaction?*

(iv) *What determines the distance of separation of the (a/6)[21$\bar{1}$] and the (a/6)[121] dislocations?*

(35 marks)

[c] Huraikan dengan jelas makna berikut:

(i) Satah gelincir

(ii) Punding

(iii) Jog

(iv) Kehelan separa

(v) Gagal tindakan

(30 markah)

Describe the following meaning of

(i) *Slip plane*

(ii) *Kink*

(iii) *Jog*

(iv) *Partual dislocation*

(v) *Stacking fault*

(30 marks)

...7/-

3. [a] Apabila paksi hablur kubus berpusat muka terletak di sepanjang [321] dan hablur tunggal ini dibebankan dengan tegangan hingga mencapai tegasan setinggi 100 gm/mm^2, kirakan tegasan ricih terlerai pada satah gelincir $(11\bar{1})$ dan selari dengan arah gelincir [101].(Catatan: Gunakan data dari soalan 1-a).

(35 markah)

If the axis of a face-centered cubic crystal lies along [321] and it is loaded in tension to a stress of 100 gm/mm^2, what will be the resolved shear stress on the $(11\bar{1})$ slip plane and parallel to the [101] slip direction? Note: Use the data from problem 1-a).

(35 marks)

[b] Ujikaji telah menunjukkan bahawa hablur tunggal sejumlah logam memiliki tegasan ricih terlerai genting yang bersandar kepada ketumpatan kehelan ρ_D mengikuti kehubungan berikut:

$$\tau_{crss} = \tau_0 + A\sqrt{p_D}$$

di mana τ_0 dan A adalah pemalar bagi tembaga, tegasan ricih terlerai genting adalah 0.69 MPa untuk ketumpatan kehelan $10^4 mm^{-2}$. Apabila diketahui bahawa nilai τ_0 untuk tembaga adalah 0.069 MPa, kirakan τ_{crss} bagi ketumpatan kehelan $10^6\ mm^{-2}$.

(35 markah)

...8/-

Experimentally it has been observed for single crystals of a number of metal that the critical resolved shear stress τ_{crss} is a function of the dislocation density ρ_D as

$$\tau_{crss} = \tau_0 + A\sqrt{p_D}$$

Where τ_0 and A are constants. For copper, the critical resolved shear stress is 0.69 MPa (100 psi) at a dislocation density of 10^4 mm^{-2}. If it is known that the value of τ_0 for copper is 0.069 MPa (10 psi), compute the τ_{crss} at a dislocation density of 10^6 mm^{-2}.

(35 marks)

[c] Huraikan dengan jelas makna berikut:

(i) Sistem gelincir

(ii) Tegasan ricih terlerai genting

(iii) Faktor schmid

(iv) Kembaran

(v) Gelangsaran sempadan ira

(30 markah)

Describe the following meaning of:

(i) Slip system

(ii) Critical resolved shear stress

(iii) Schmid factor

(iv) Twinning

(v) Grain-boundary sliding

(30 marks)

...9/-

4. [a] Dengan bantuan gambarajah, jelaskan proses-proses berikut:

(i) Penggelekan sejuk

(15 markah)

(ii) Penyepuhlindapan dan penyepuhlindapan

(20 markah)

(iii) Kerja paras

(15 markah)

Describes with aid of diagram the following processes:

(i) Cold rolling

(15 marks)

(ii) Annealing and self annealing

(20 marks)

(iii) Hot working

(15 marks)

...10/-

[b] Cu-30%Zn akan dihasilkan daripada tebal asal 30mm yang menpunyai kekuatan alah melebihi 345 MPa dan pemanjangan sekurang-kurangnya 10%. Apakah julat ketebalan akhir yang mesti diperolehi? Sifat kerja sejuk 70:30 loyang diberikan dalam Rajah 1.

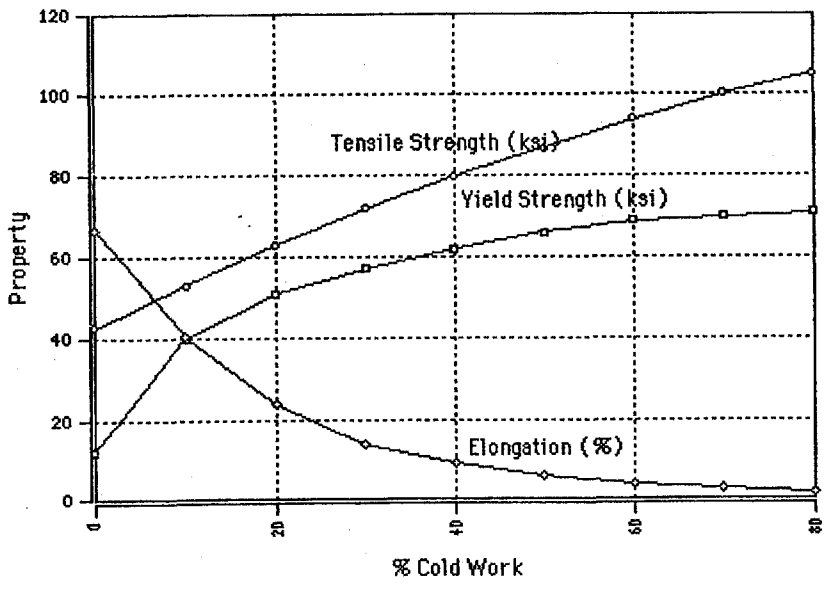
Nota: Untuk menukar skala daripada ksi kepada MPa andaikan ksi = 6.896 MPa.

(50 markah)

A Cu-30%Zn to be fabricated from original 30mm thick to have yield strength greater than 345 MPa and the elongation of at least 10%. What range of final thicknesses must be obtained? The properties of the cold worked 70:30 brass is given by Figure 1.

Note: To convert the scale from ksi to MPa assume that ksi= 6.896 MPa.

(50 marks)



Rajah 1

Figure 1

...11/-

5. [a] Jelaskan tiga peringkat penuaan atau pengerasan mendakan dengan bantuan gambarajah.

(30 markah)

Describe the three stages of age or precipitation hardening with aid of diagram.

(30 marks)

[b] Jelaskan tindakbalas Eutektoid dan pembentukan martensit.

(20 markah)

Describe the Eutectoid reaction and Martensite transformation.

(20 marks)

[c] Bagi aloi Fe-0.4%C, tentukan dengan menggunakan Rajah 2:

(i) Suhu dimana austenit mula membentuk semasa penyejukan.

(ii) Mikrojuzuk utama terbentuk.

(iii) Komposisi dan amaun setiap fasa yang hadir di atas suhu eutektoid.

(iv) Komposisi dan amaun setiap fasa yang hadir di bawah suhu eutektoid.

(v) Komposisi dan amaun setiap mikrojuzuk yang hadir suhu eutektoid.

(50 markah)

...12/-

For a Fe-0.4%C alloy Determine using Figure 2:

(i) *The temperature at which austenite first begin to transform on cooling.*

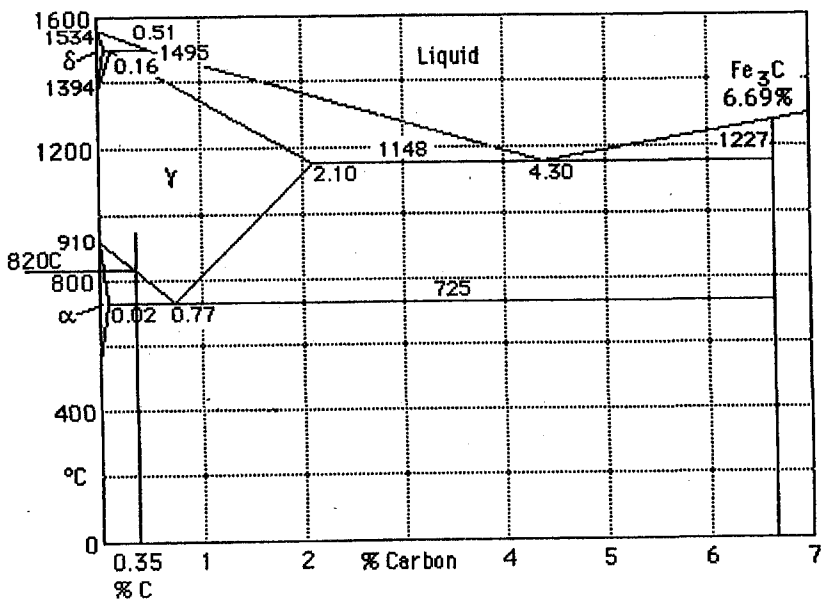
(ii) *The primary micro-constituent that forms.*

(iii) *The composition and amount of each phase present just above the eutectoid temperature.*

(iv) *The composition and amount of each phase present just below the eutectoid temperature.*

(v) *The composition and amount of each micro-constituents present just below the eutectoid temperature.*

(50 marks)



Rajah 2

Figure 2

...13/-

6. [a] Jelaskan dalam rawatan haba keluli, pembinaan gambarajah T-T-T dan dengan bantuan gambarajah, nyatakan bagaimana anda memperolehi fasa berikut:

(i) Pearlit halus

(ii) Bainit

(iii) Pearlit / Martensit

(iv) Martensit

(30 markah)

Describe, in heat treatment of steel, the construction of T-T-T diagram and explain with aid diagrams how you can obtain the following:

(i) Fine Perlite

(ii) Bainite

(iii) Pearlite / Martensite

(iv) Martensite

(30 marks)

[b] Apakah kekerasan dan kebolehkerasan? Jelaskan ujian Jominy dan bagaimana menentukan kadar penyejukan?

(30 markah)

What are the hardness and the hardenability? Describe Jominy test and how to define the cooling rate?

(30 marks)

...14/-

[c] Bina profil jejarian untuk yang berikut:

(i) Spesimen aloi keluli 8640 berdiameter 50 mm yang telah dilindapkejut dalam minyak teraduk sederhana.

(ii) Spesimen aloi keluli 5140 berdiameter 75 mm yang telah dilindapkejut dalam minyak teraduk sederhana.

(iii) Spesimen aloi keluli 8630 berdiameter 90 mm yang telah dilindapkejut dalam air teraduk sederhana.

(iv) Spesimen aloi keluli 8660 berdiameter 100 mm yang telah dilindapkejut dalam air teraduk sederhana.

Gunakan Rajah (3), (4) dan (5).

(40 markah)

Construct radial profiles for the following:

(i) A 50 mm diameter cylindrical specimen of an 8640 steel alloy that has been quenched in moderately agitated oil.

(ii) A 75 mm diameter cylindrical specimen of an 5140 steel alloy that has been quenched in moderately agitated oil.

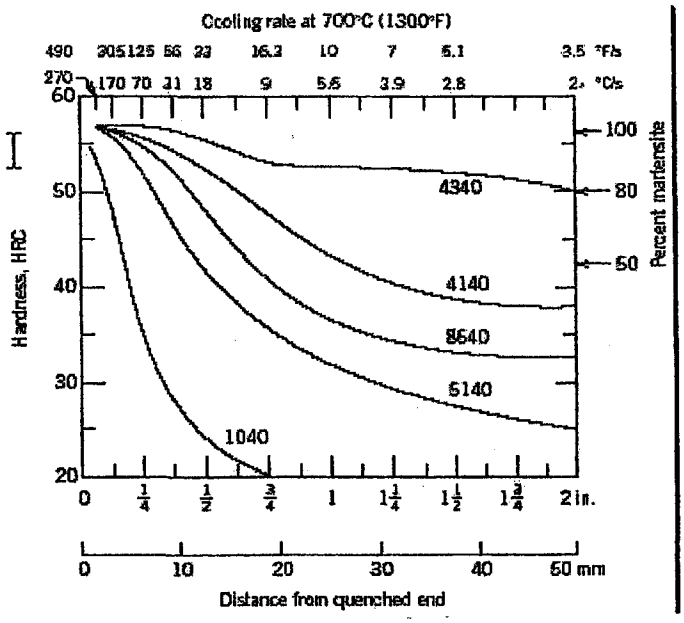
(iii) A 90 mm diameter cylindrical specimen of an 8630 steel alloy that has been quenched in moderately agitated water.

(v) A 100 mm diameter cylindrical specimen of an 8660 steel alloy that has been quenched in moderately agitated water

Use Figures (3), (4) and (5).

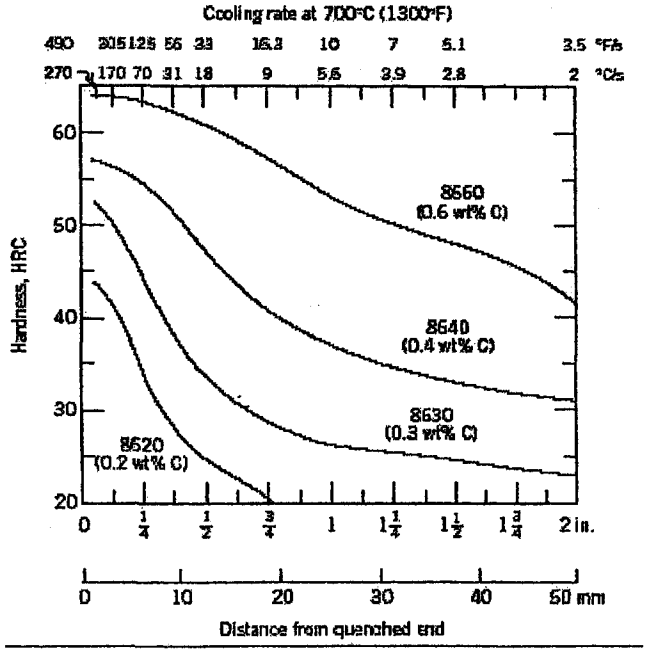
(40 marks)

...15/-



Rajah 3: Lengkungan kebolehkerasan bagi lima aloi keluli yang berbeza.

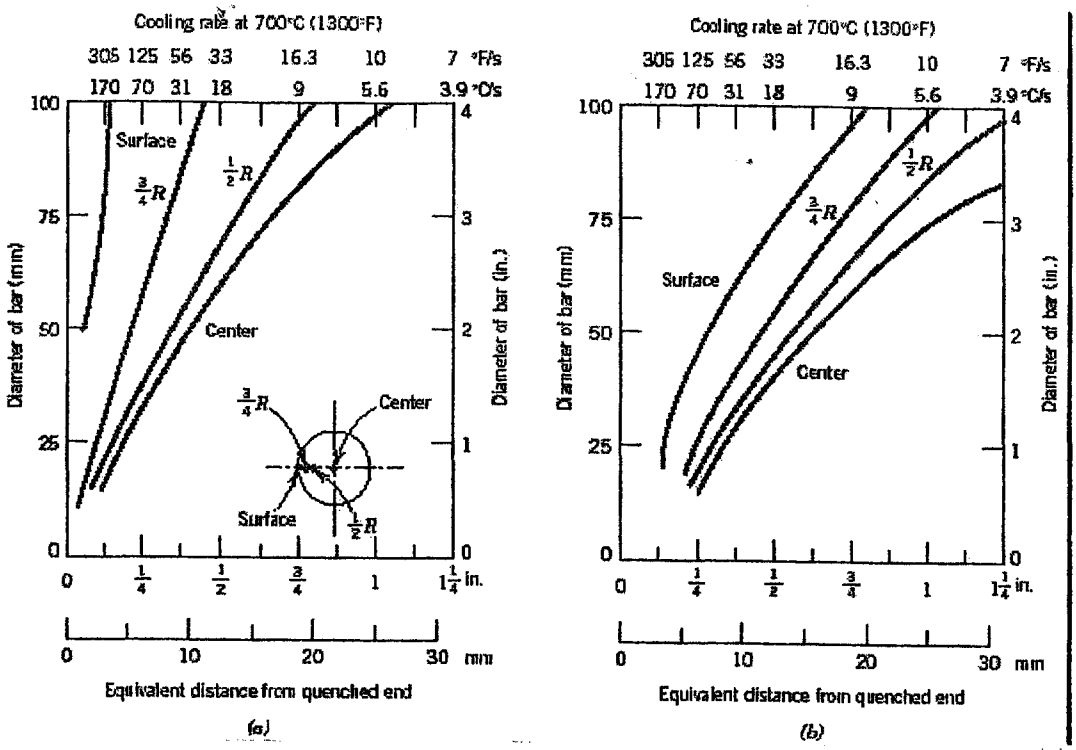
Figure 3: Hardenability curves for five different steel alloys



Rajah 4: Lengkungan kebolehkerasan bagi empat aloi keluli siri 8600.

Figure 4: Hardenability curves for four 8600 series steel alloys

...16/-



Rajah 5: Kadar penyejukan sebagai fungsi diameter pada permukaan $\frac{3}{4}$R, $\frac{1}{2}$R dan posisi pusat bagi bar silinder yang dilindapkejut dalam:

(a) air teraduk sederahana

(b) minyak teraduk sederhana

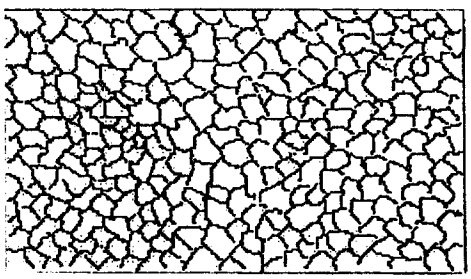
Figure 5: Cooling rate as a function of diameter at surface, $\frac{3}{4}$R, $\frac{1}{2}$R and center positions for cylindrical bars quenched in midly agitated:

(a) water

(b) oil

...17/-

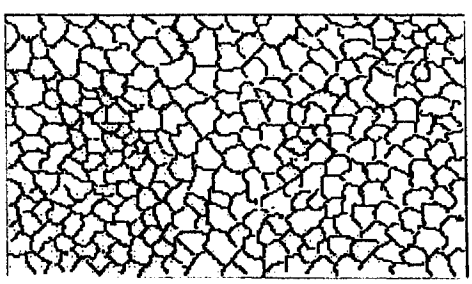
7. [a] Bagi gambarajah berikut (i - ix), pilih jawapan anda dalam satu daripada bulatan yang bertentangan dengan setiap gambarajah.



i) Halus, butiran yang sama dengan Sedikit beberapa kehelan, kekuatan Rendah dan kemuluran baik dan Kekonduksian elektrik yang tinggi.

- kerja sejuk
- pemulihan
- penghabluran semula
- pertumbuhan butir

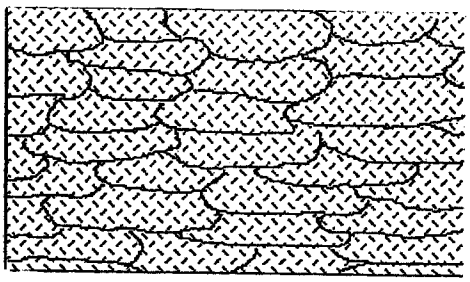
For the following diagrams (i - ix), select your answer in one of the circles against each diagrams.



Fine, equiaxed grains with few dislocations, low strength and good ductility and high electrical conductivity.

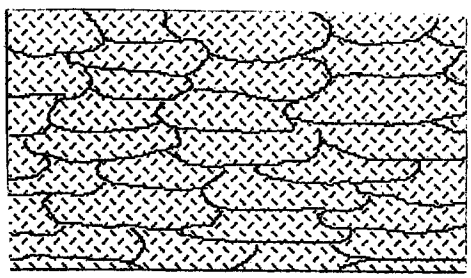
- *Cold Worked*
- *Recovery*
- *Recrystallization*
- *Grain Growth*

...18/-



ii) Pemanjangan butir dengan ketumpatan kehelan yang seragam dan tinggi, kekuatan tinggi dan kemuluran rendah dan kekonduksian elektrik rendah.

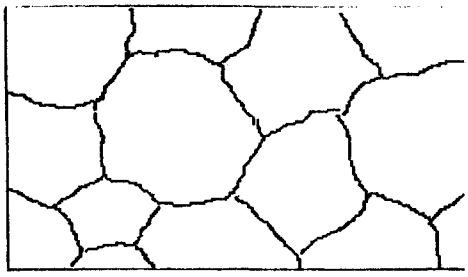
- kerja sejuk
- pemulihan
- penghabluran semula
- pertumbuhan butir



Elongated grains with a high and uniform dislocation density, high strength and low ductility and low electrical conductivity.

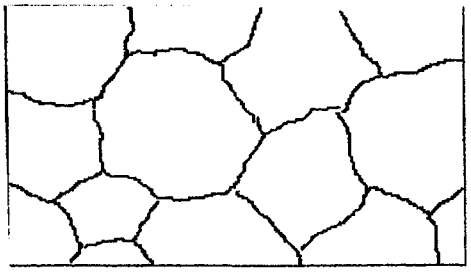
- *Cold Worked*
- *Recovery*
- *Recrystallization*
- *Grain Growth*

...19/-



iii.) Butiran yang sama besar bersama beberapa kehelan, kekuatan rendah dan kemuluran baik dan kekonduksian elektrik tinggi.

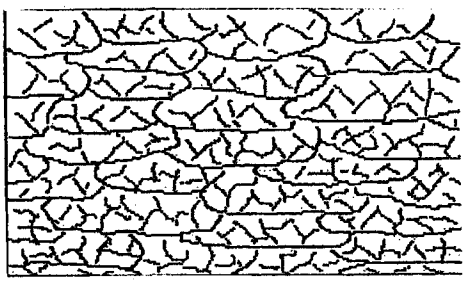
- kerja sejuk
- pemulihan
- penghabluran semula
- pertumbuhan butir



Large, equiaxed grains with few dislocations, low strength and good ductility and high electrical conductivity.

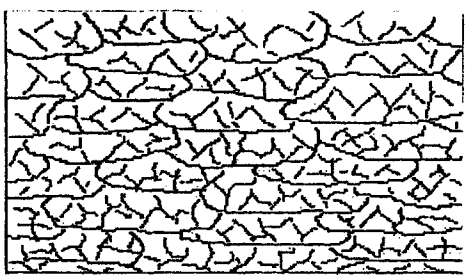
- *Cold Worked*
- *Recovery*
- *Recrystallization*
- *Grain Growth*

...20/-



iv) Pemanjangan butir bersama penyusunan kehelan dalam jaringan, kekuatan tinggi dan kemuluran baik dan kekonduksian elektrik tinggi

- kerja sejuk
- pemulihan
- penghabluran semula
- pertumbuhan butir

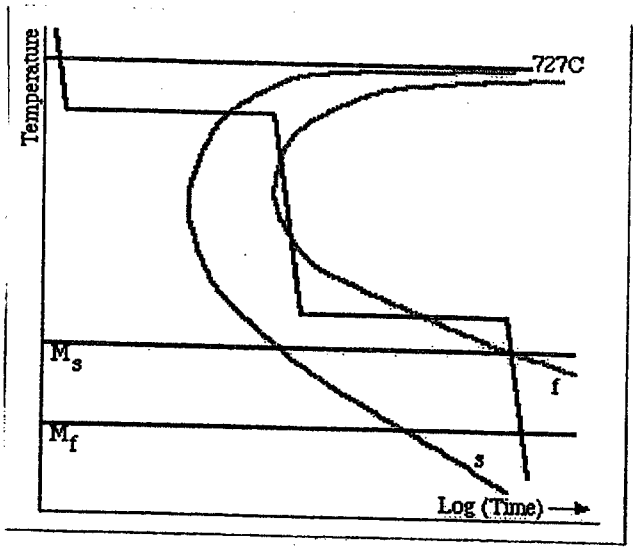


Elongated grains with dislocation arranged in networks, high strength, and good ductility and high electrical conductivity.

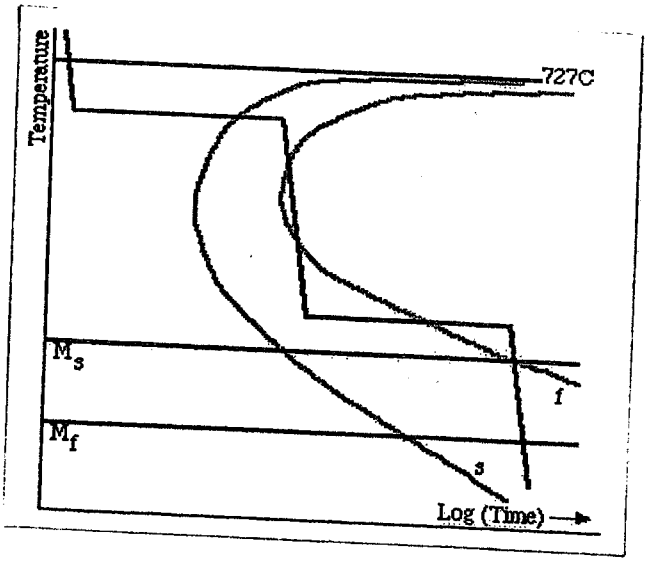
- *Cold Worked*
- *Recovery*
- *Recrystallization*
- *Grain Growth*

...21/-

v.



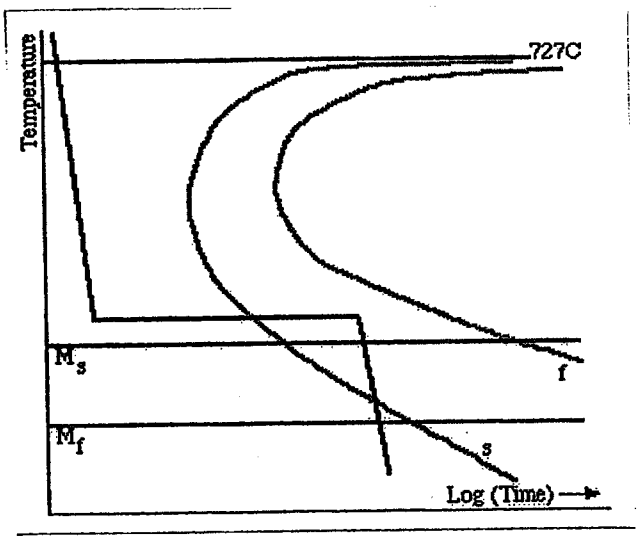
- Pearlit
- Bainit
- Martensit
- Pearlit & Martensit
- Pearlit & Bainit
- Bainit & Martensit



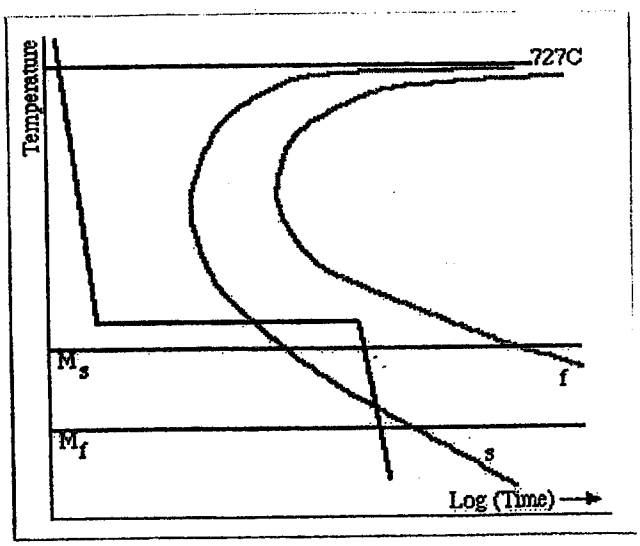
- *Pearlite*
- *Bainite*
- *Martensite*
- *Pearlite & Martensite*
- *Pearlite & Bainite*
- *Bainite & Martensite*

...22/-

vi.



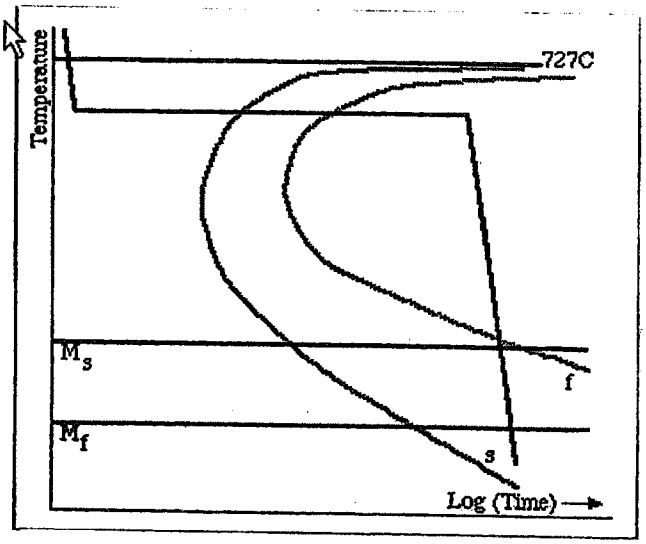
- Pearlit
- Bainit
- Martensit
- Pearlit & Martensit
- Pearlit & Bainit
- Bainit & Martensit



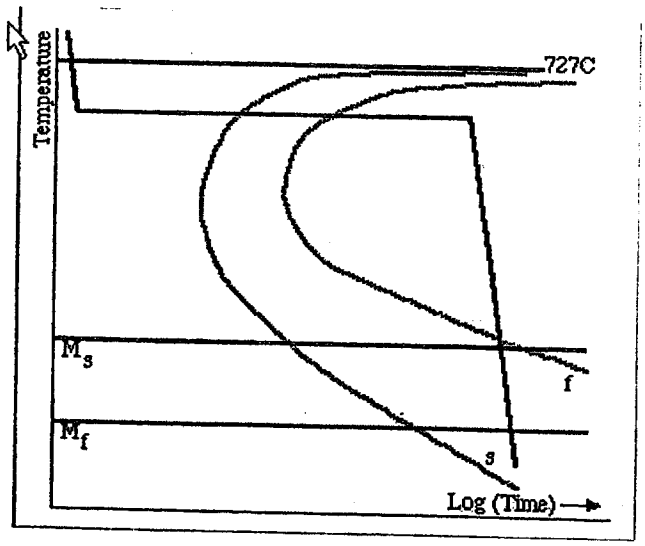
- *Pearlite*
- *Bainite*
- *Martensite*
- *Pearlite & Martensite*
- *Pearlite & Bainite*
- *Bainite & Martensite*

...23/-

vii.



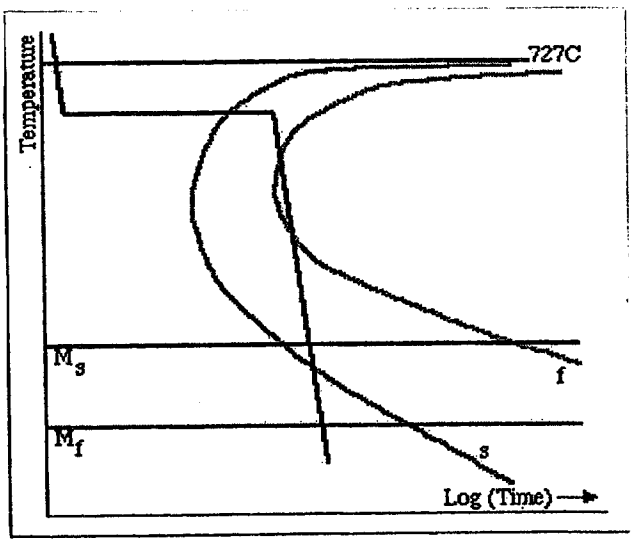
- Pearlit
- Bainit
- Martensit
- Pearlit & Martensit
- Pearlit & Bainit
- Bainit & Martensit



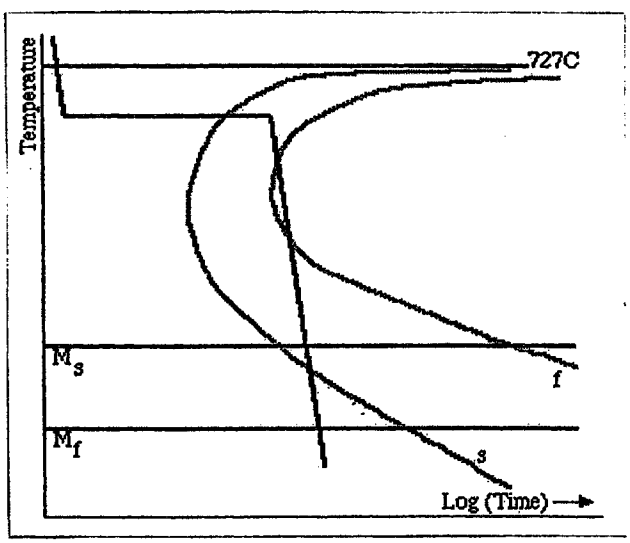
- *Pearlite*
- *Bainite*
- *Martensite*
- *Pearlite & Martensite*
- *Pearlite & Bainite*
- *Bainite & Martensite*

...24/-

viii.



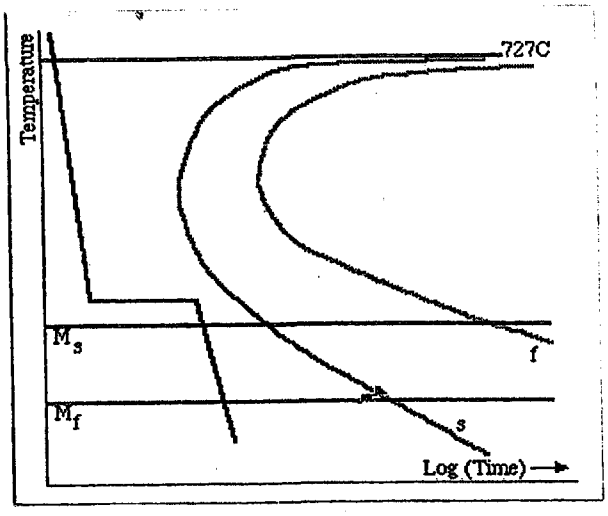
- Pearlit
- Bainit
- Martensit
- Pearlit & Martensit
- Pearlit & Bainit
- Bainit & Martensit



- *Pearlite*
- *Bainite*
- *Martensite*
- *Pearlite & Martensite*
- *Pearlite & Bainite*
- *Bainite & Martensite*

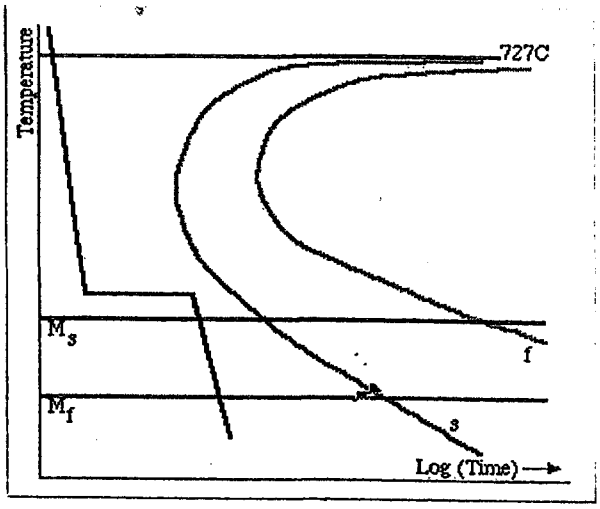
...25/-

ix.



- Pearlit
- Bainit
- Martensit
- Pearlit & Martensit
- Pearlit & Bainit
- Bainit & Martensit

(50 markah)



- *Pearlite*
- *Bainite*
- *Martensite*
- *Pearlite & Martensite*
- *Pearlite & Bainite*
- *Bainite & Martensite*

(50 marks)

...26/-

7. [b] Data berikut diperolehi apabila logam kerja sejuk disepuhlindap:

The following data were obtained when a cold-worked metal was annealed:

Bilangan data : **n: = 8** **I: = 0..n-1**

Number of data : **n: = 8** **I: = 0..n-1**

Annealing temperature	Residual stresses	Tensile strength	Grain size
$T_i :=$	$\sigma_{R_i} :=$	$\sigma_{t_i} :=$	$grain_i :=$
523·K	21000·psi	52000·psi	0.003·in
548·K	21000·psi	52000·psi	0.003·in
573·K	5000·psi	52000·psi	0.003·in
598·K	0·psi	52000·psi	0.003·in
623·K	0·psi	34000·psi	0.001·in
648·K	0·psi	30000·psi	0.001·in
673·K	0·psi	27000·psi	0.0035·in
698·K	0·psi	25000·psi	0.0072·in

...27/-

(i) Anggarkan suhu pemulihan, penghabluran semula dan pertumbuhan butir.

(ii) Cadangkan suhu yang sesuai untuk memperolehi dawai kekuatan tinggi kekonduksian elektrik yang tinggi.

(iii) Cadangkan suhu yang sesuai bagi proses kerja panas.

(iv) Anggarkan suhu lebur bagi aloi tersebut.

Nota: Buat lukisan dalam Mpa bagi tegasan dan mm bagi saiz butir.
Psi = 6896 Pa dan
1 in = 25 mm.

(50 markah)

(i) Estimate the recovery, recrystallization and grain growth temperatures.

(ii) Recommend a suitable temperature for obtaining a high-strength, high-electrical conductivity wire.

(iii) Recommend a suitable temperature for a hot-working process.

(iv) Estimate the melting temperature of the alloy.

Note: Make your drawing in Mpa for stresses and mm for grain size.
Psi = 6896 Pa and
1 in = 25 mm

(50 marks)

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