UNIVERSITI SAINS MALAYSIA

First Semester Examination
2014/2015 Academic Session

December 2014 / January 2015

EBP 400/3 – Product Design and Failure Analysis
[Rekabentuk Produk dan Analisis Kegagalan]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains SEVENTEEN printed pages and FOUR pages ATTACHMENT before you begin the examination.
[Sila pastikan bahawa kertas peperiksaan ini mengandungi TUJUH BELAS muka surat beserta EMPAT muka surat LAMPIRAN yang bercetak sebelum anda memulakan peperiksaan ini.]

This paper consists of SEVEN questions. ONE question in PART A, THREE questions in PART B and THREE questions in PART C.
[Kertas soalan ini mengandungi TUJUH soalan. SATU soalan di BAHAGIAN A, TIGA soalan di BAHAGIAN B dan TIGA soalan di BAHAGIAN C.]

Instruction: Answer **FIVE** questions. Answer **ALL** questions from PART A, **TWO** questions from PART B and **TWO** questions from PART C. If a candidate answers more than five questions only the first five questions answered in the answer script would be examined.
*[**Arahan**: Jawab **LIMA** soalan. Jawab **SEMUA** soalan dari BAHAGIAN A, **DUA** soalan dari BAHAGIAN B dan **DUA** soalan dari BAHAGIAN C. Jika calon menjawab lebih daripada lima soalan hanya lima soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah.]*

The answers to all questions must start on a new page.
[Mulakan jawapan anda untuk semua soalan pada muka surat yang baru.]

You may answer a question either in Bahasa Malaysia or in English.
[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]

In the event of any discrepancies in the examination questions, the English version shall be used.
[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

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PART A / *BAHAGIAN A*

1. [a] Uniform walls, and fillet and radii are the critical part in design molding considerations. Elaborate those considerations with suitable diagrams to support your answer.

Dinding yang seragam, dan kambi dan jejari adalah bahagian yang penting dalam pertimbangan reka bentuk pengacuanan. Huraikan pertimbangan-pertimbangan tersebut dengan gambarajah yang sesuai untuk menyokong jawapan anda.

(50 marks/*markah*)

[b] In analyzing a failure, sample identification and preparation are very crucial in order to avoid removing evidence and/or introducing unwanted contaminants which would definitely jeopardise the analysis.

Therefore, describe things that need to be considered in conducting the abovementioned activities during a failure analysis procedure.

Dalam menganalisa suatu kegagalan, pengenalpastian dan penyediaan sampel adalah penting bagi mengelakkan kejadian memusnahkan bukti dan/atau mencemarkan sampel yang boleh mengganggu keputusan analisa.

Oleh yang demikian, jelaskan perkara-perkara yang perlu dipertimbangkan dalam menjalankan aktiviti tersebut semasa prosedur analisa kegagalan.

(50 marks/*markah*)

PART B / *BAHAGIAN B*

2. [a] A plastic product which has a sharp corner has been subjected to a certain load as shown in Figure 1. Discuss and sketch the deformation of the part (before and after) and how to minimize the deformation, respectively. Design justification factor must be included.

Produk plastik yang mempunyai sudut tajam telah tertakluk kepada beban tertentu seperti yang ditunjukkan dalam Rajah 1. Bincangkan dan lakarkan ubah bentuk bahagian tersebut (sebelum dan selepas) dan bagaimana untuk mengurangkan ubah bentuk. Justifikasi faktor reka bentuk harus disertakan.

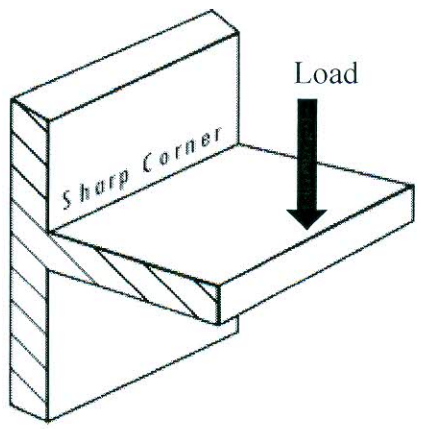


Figure 1 : Sharp corner with load

Rajah 1 : Sudut tajam dengan beban

(40 marks/*markah*)

[b] A cylinder container to withstand an internal pressure of 345 kPa has a diameter of 0.3 m. Material X has been selected; where it has 33% glass reinforced nylon 6. The wall thickness has been set at 6.35 mm maximum for molding convenience. Test and calculate for wall condition and maximum stress, respectively. Determine either the design is satisfied for a short or long term application. Given allowable tensile strength of the material is 124,106 kPa at 50% RH.

Satu bekas silinder untuk menahan tekanan dalaman 345 kPa mempunyai garis pusat berdiameter 0.3 m. Suatu bahan X telah dipilih; di mana ia mempunyai 33% kaca bertetulang nilon 6. Ketebalan maksimum dinding telah ditetapkan pada 6.35 mm untuk kemudahan acuan. Uji dan kirakan keadaan dinding dan tekanan maksimum, masing-masing. Tentukan juga sama ada reka bentuk ini sesuai untuk aplikasi jangka pendek atau panjang. Kekuatan tegangan bahan yang dibenarkan adalah 124,106 kPa pada 50% RH.

(60 marks/*markah*)

3. [a] For the design of assembly as in Figure 2, two different materials of plastic and metal are commonly mounted in automotive compartment. Explain **two** types of deformation experienced by the materials and discuss how to eliminate the buckling effects.

Bagi reka bentuk pemasangan seperti dalam Rajah 2, dua bahan yang berbeza daripada plastik dan logam biasanya dipasang di dalam petak automotif. Terangkan ***dua*** *jenis ubah bentuk yang dialami oleh bahan-bahan dan bincangkan bagaimana untuk menghilangkan kesan lengkokan.*

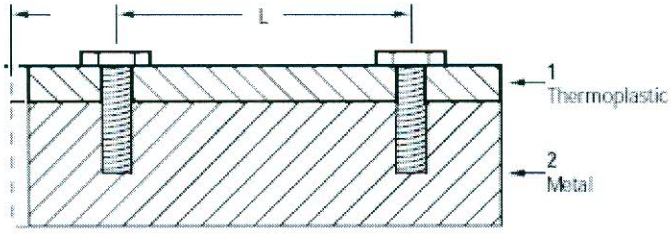


Figure 2: Automotive assembly involving plastic and metal screw

Rajah 2: Pemasangan automotif yang melibatkan skru logam dan plastik

(40 marks/*markah*)

[b] A ball-point pen made from polypropylene has the clip design shown in Figure 3a. When the pen is inserted into a pocket, the clip is subjected to a deflection of 2 mm at point A. If the limiting strain in the material is to be 0.5%, calculate

(i) a suitable thickness (d) for the clip

(ii) the initial stress in the clip when it is first inserted into the pocket and

(iii) the stress in the clip when it has been in the pocket for 1 week.

The creep curves in Figure 3b may be used and the short-term modulus of polypropylene is 1.6 GN/m^2.

Satu pen bola mata diperbuat daripada polipropilena mempunyai reka bentuk klip yang ditunjukkan dalam Rajah 3a. Apabila pen dimasukkan ke dalam poket, klip itu tertakluk kepada pesongan 2 mm pada titik A. Jika tekanan menghadkan dalam bahan ini adalah 0.5%, kirakan

(i) ketebalan yang sesuai (d) untuk klip

(ii) tegasan awal dalam klip apabila ia mula-mula dimasukkan ke dalam poket dan

(iii) tegasan dalam klip apabila ia telah berada dalam poket untuk 1 minggu.

Lengkung rayapan dalam Rajah 3b boleh digunakan dan modulus jangka pendek polipropilena adalah 1.6 GN/m^2.

(60 marks/*markah*)

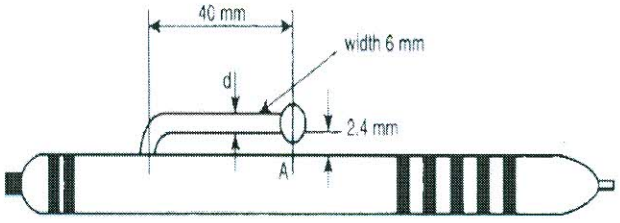


Figure 3a A ball pen

Rajah 3a Satu pen bola mata

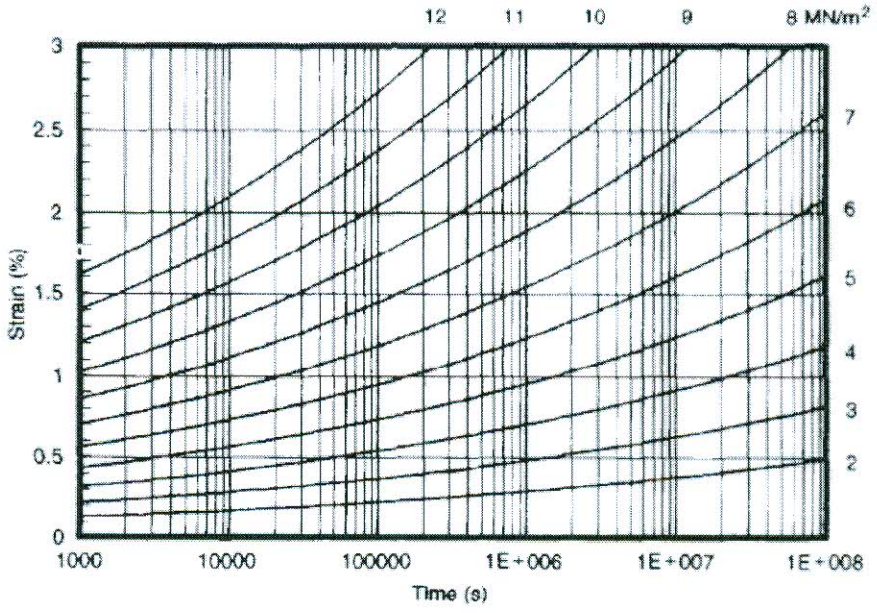


Figure 3b Creep curves for polypropylene at 20°C (density *909* kg/m^3)

Rajah 3b Lengkung rayapan untuk polipropilena pada 20°C

(ketumpatan 909 kg/m^3)

4. [a] Briefly explain three (3) types of finishing.

Terangkan secara ringkas tiga (3) jenis pengemasan.

(30 marks/*markah*)

[b] Outline the general guidelines of snap fit assembly and press fit assembly with suitable diagrams to support your answer.

Gariskan garis panduan umum pemasangan gegas sentap dan pemasangan gegas tekan dengan gambarajah yang sesuai untuk menyokong jawapan anda.

(40 marks/*markah*)

[c] Given a metal insert with outer diameter 12.7mm, is to be press-fit into a plastic boss with outer diameter 19.05mm (Figure 4). Determine the maximum interference of the assembly using a 2% allowable strain for that plastic boss. A Poisson's ratio for the boss is 0.35 (Please analyze by using the equation given in Appendix 4).

Diberi sisipan logam dengan luar diameter 12.7mm, adalah untuk menjadi gegas-tekan ke tombol plastik dengan diameter luar 19.05mm (Rajah 4). Tentukan interferen maksimum pemasangan menggunakan ketegangan dibenarkan 2% bagi tombol plastik. Nisbah Poisson untuk tombol adalah 0.35 (sila menganalisis dengan menggunakan persamaan yang diberikan dalam Lampiran 4).

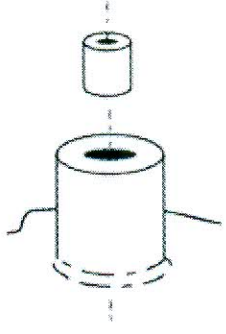


Figure 4 Press-fit a metal shaft into a plastic boss

Rajah 4 Gegas-tekan aci logam ke tombol plastik

(30 marks/*markah*)

PART C / *BAHAGIAN C*

5. [a] Repeated or cyclic loading can provide a condition known as auto-accelerating degradation phenomenon. Explain this phenomenon and its consequences towards failure of a plastics.

Pembebanan berulang atau secara berkitaran boleh menyebabkan keadaan yang dikenali sebagai fenomena auto-pecutan dalam degradasi. Terangkan fenomena ini dan akibatnya terhadap kegagalan suatu plastik.

(40 marks/*markah*)

[b] An injection moulding company producing components for automotive sensor casing made of PC/PBT blends, was facing a serious cracking problem that cause catastrophic failure. When these failed components were characterized through two analyses, i.e. fractography using polarized optical microscope and Differential Scanning Calorimetry (DSC), the following results were obtained (Figure 5 and 6).

Based on the results shown in Figure 5 and 6;

(i) Write a failure analysis report for the encountered defect.

(ii) Include in the report, your suggestion regarding the cause of the defect and;

(iii) Propose to the company, actions that need to be taken in order to avoid the problem from reoccurring

Satu syarikat pengacuanan suntikan menghasilkan komponen bagi perumah sensor automotif diperbuat daripada gaulan PC/PBT, telah menghadapi masalah keretakan yang serius yang menyebabkan kegagalan katastropik. Apabila komponen yang gagal tersebut dicirikan melalui 2 analisa, iaitu fraktografi menggunakan mikroskop optik terkutub dan Kalorimetri Imbasan Pembezaan (DSC), keputusan-keputusan berikut diperolehi (Rajah 5 dan 6).

Berdasarkan keputusan yang ditunjukkan dalam Rajah 5 dan 6;

(i) Tulis satu laporan analisa kegagalan bagi kecacatan yang dialami

(ii) Sertakan dalam laporan tersebut, cadangan anda tentang punca kecacatan dan;

(iii) Cadangkan kepada syarikat tersebut, tindakan yang perlu diambil bagi mengelakkan masalah itu berlaku lagi

(60 marks/*markah*)

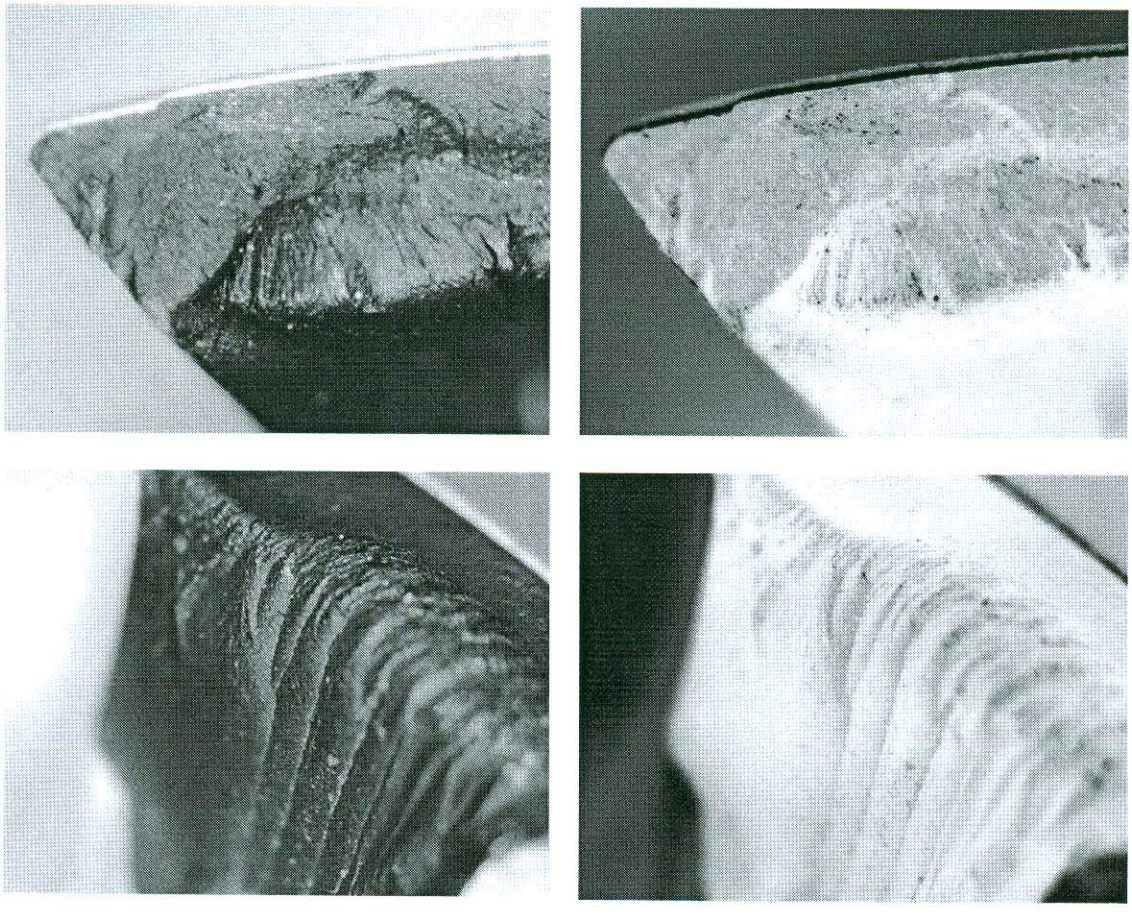
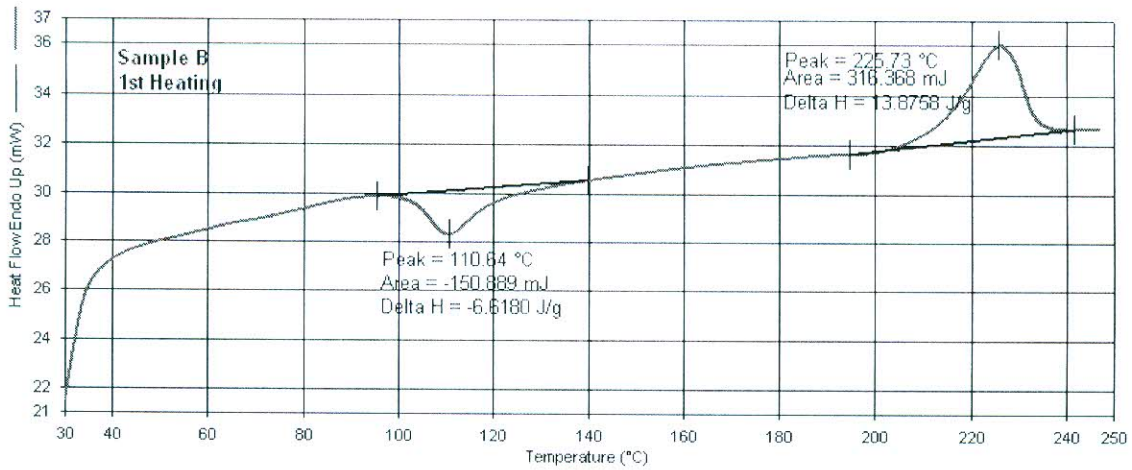
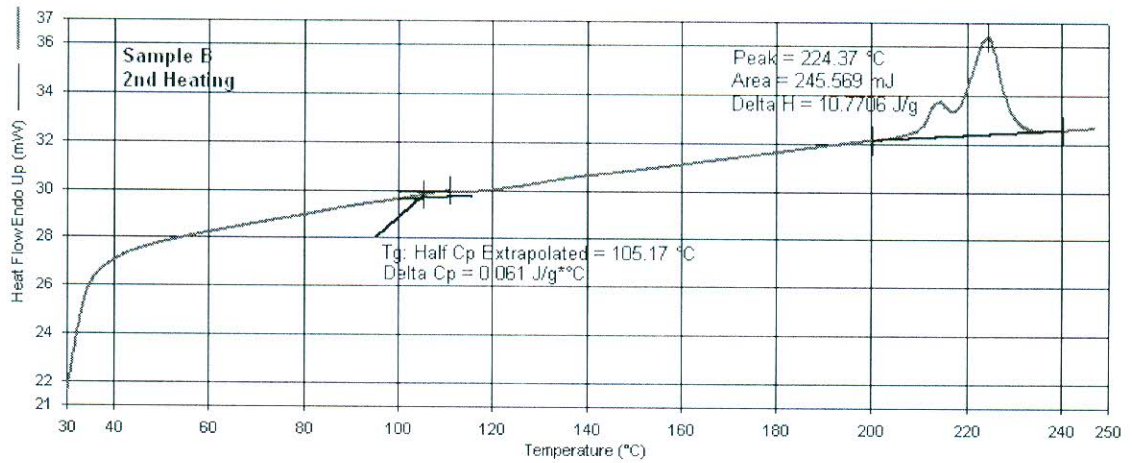


Figure 5: A few fractography images of the failed components

Rajah 5: Beberapa imej fraktografi bagi komponen-komponen yang gagal



(a)



(b)

Figure 6: DSC curves for one of the failed components, (a) 1st heating cycle and (b) 2nd heating cycle.

Rajah 6: Lengkungan DSC bagi salah satu komponen yang gagal, (a) kitaran pemanasan pertama dan (b)kitaran pemanasan kedua.

6. [a] Rotational moulded 'mancabs' for the shelter of workmen at the roadside experienced a significant cracking problem. It was discovered that the failure concentrated only on the upper part (i.e. roof) of the shelter (refer to Figure 7).

In order to investigate cause of the failure, the production company submitted the failed shelter to a consultant company where Fourier Transform Infra Red spectroscopy was implemented. FTIR spectra obtained from the analysis is shown in Figure 8.

Using the above given information, make a failure assessment of the product and suggest possible cause that could lead to the formation of crack in the defect sample.

Satu "mancabs" yang dihasilkan oleh pengacuanan putaran untuk pelindung bagi pekerja yang berkerja di jalanan mengalami masalah keretakan yang ketara. Didapati bahawa kegagalan tersebut tertumpu hanya di bahagian atas (iaitu bumbung) pelindung tersebut (lihat Rajah 7).

Bagi menyiasat punca kegagalan itu, syarikat yang menghasilkan pelindung tersebut telah menghantar pelindung yang gagal kepada satu syarikat perunding yang melaksanakan spektroskopi Infra Merah Terjelma Fourier. Spektrum-spektrum FTIR yang diperolehi dari analisa tersebut ditunjukkan dalam Rajah 8.

Menggunakan maklumat yang diberikan di atas, buat suatu penilaian kegagalan produk tersebut dan cadangkan punca yang berkemungkinan menyebabkan kehadiran retak dalam sampel yang berkenaan.

(60 marks/*markah*)

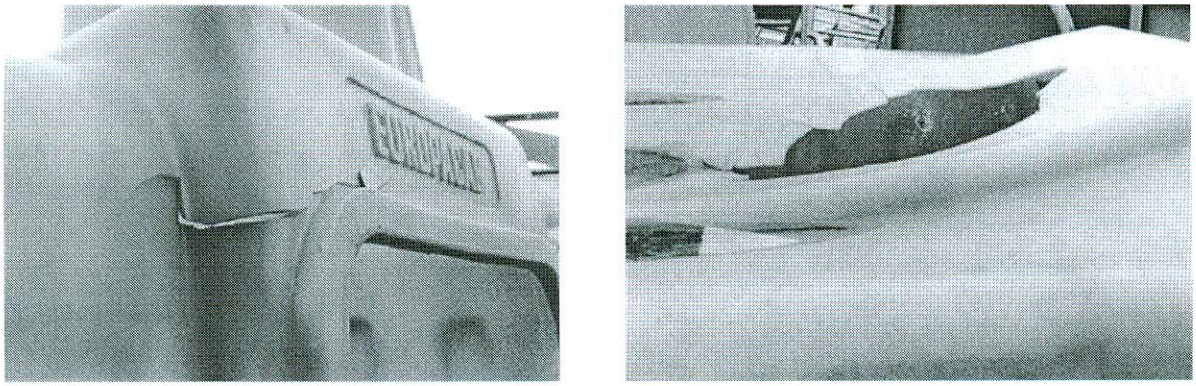


Figure 7: Visible cracking on upper parts of the "mancabs" shelter

Rajah 7: Keretakan yang jelas pada bahagian atas pelindung "mancabs"

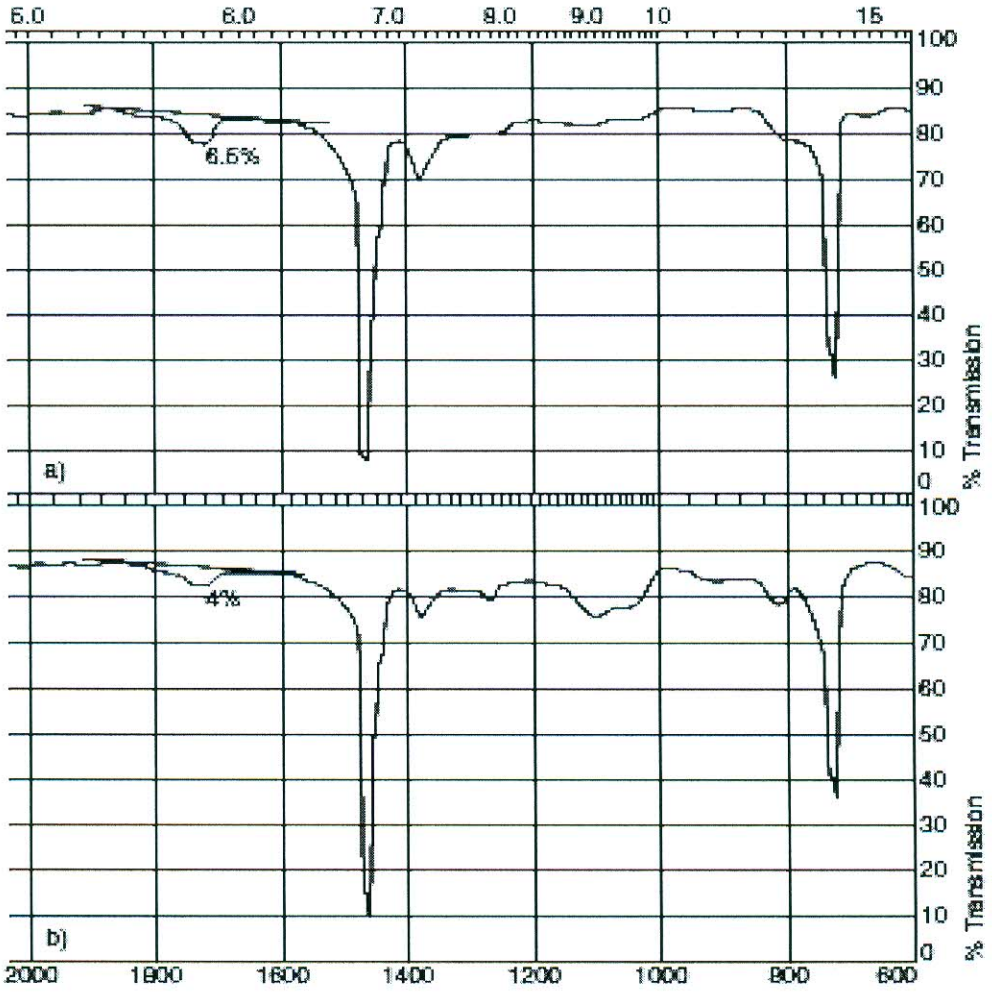


Figure 8: FTIR results of the failed shelter

Rajah 8: Keputusan FTIR bagi pelindung yang gagal

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[b] Describe how the application of additional feature of Energy Dispersive X-ray (EDX) which is coupled with Scanning Electron Microscope (SEM) could assist in identifying cause of failure in a plastic component. Use suitable examples to explain your answer.

Terangkan bagaimana penggunaan ciri tambahan Sinar-X Sebaran Tenaga (Energy Dispersive X-ray – EDX) yang digandingkan dengan Mikroskop Penskanan Elektron (SEM) dapat membantu dalam mengenalpasti punca suatu kegagalan komponen plastik. Gunakan contoh yang sesuai untuk menjelaskan jawapan anda.

(40 marks/*markah*)

7. [a] What is meant by accelerated testing and what is the purpose and importance of accelerated testing on failure analysis of a plastic component?

Apakah yang dimaksudkan dengan pengujianan yang dipercepatkan dan apakah tujuan serta kepentingannya terhadap analisis kegagalan suatu komponen plastik?

(50 marks/*markah*)

[b] Computer-aided failure modeling is a prefered technique in detecting plastic product failure before it occurs in practice. State the advantages and disadvantages of this technique.

Teknik pemodelan kegagalan berbantukan perisian merupakan teknik yang agak digemari bagi mengesan kegagalan suatu produk plastik sebelum kegagalan tersebut berlaku. Nyatakan kelebihan dan kelemahan teknik ini.

(50 marks/*markah*)

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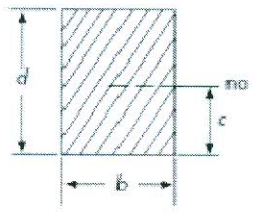
ATTACHMENTS
LAMPIRAN

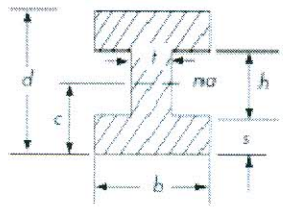
Appendix 1 : Section properties for some common cross-sections (na = neutral axis)

RECTANGULAR



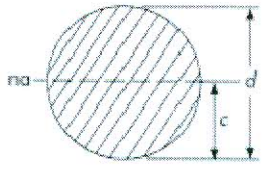
$$A = bd$$
$$c = \frac{d}{2}$$
$$I = \frac{bd^3}{12}$$
$$Z = \frac{bd^2}{6}$$

I-BEAM



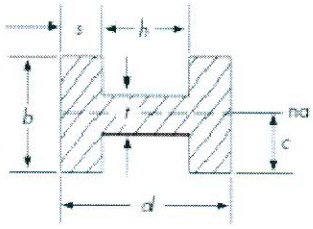
$$A = bd - h(b - t)$$
$$c = \frac{d}{2}$$
$$I = \frac{bd^3 - h^3(b - t)}{12}$$
$$Z = \frac{bd^3 - h^3(b - t)}{6d}$$

CIRCULAR



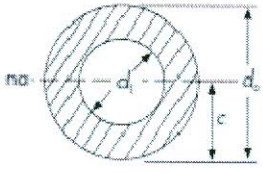
$$A = \frac{\pi d^2}{4}$$
$$c = \frac{d}{2}$$
$$I = \frac{\pi d^4}{64}$$
$$Z = \frac{\pi d^3}{32}$$

H-BEAM



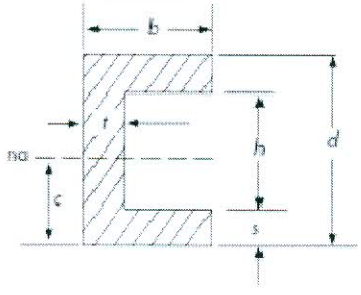
$$A = bd - h(b - t)$$
$$c = \frac{b}{2}$$
$$I = \frac{2sb^3 + ht^3}{12}$$
$$Z = \frac{2sb^3 + ht^3}{6b}$$

TUBE



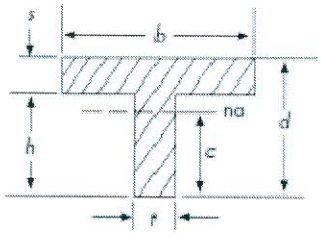
$$A = \frac{\pi(d_o^2 - d_i^2)}{4}$$
$$c = \frac{d_o}{2}$$
$$I = \frac{\pi(d_o^4 - d_i^4)}{64}$$
$$Z = \frac{\pi(d_o^4 - d_i^4)}{32d_o}$$

C-BEAM



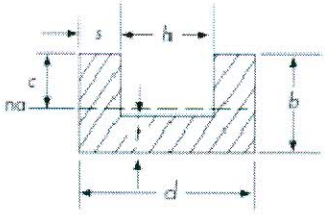
$$A = bd - h(b - t)$$
$$c = \frac{d}{2}$$
$$I = \frac{bd^3 - h^3(b - t)}{12}$$
$$Z = \frac{bd^3 - h^3(b - t)}{6d}$$

T-BEAM OR RIB



$$A = bs + ht$$
$$c = d - \frac{d^2t + s^2(b - t)}{2(bs + ht)}$$
$$Z = \frac{I}{c}$$
$$Z' = \frac{I}{(d - c)}$$
$$I = \frac{tc^3 + b(d - c)^3 - (b - t)(d - c - s)^3}{3}$$

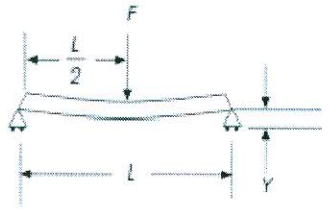
U-BEAM



$$A = bd - h(b - t)$$
$$c = b - \frac{2b^2s + ht^2}{2A}$$
$$I = \frac{2b^3s + ht^3}{3} - A(b - c)^2$$
$$Z = \frac{I}{c}$$
$$Z' = \frac{I}{(b - c)}$$

Appendix 2 : Maximum stress and deflection equations for selected beams

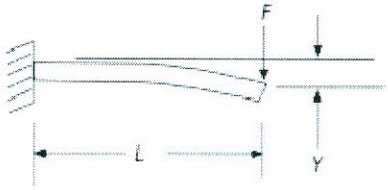
SIMPLY SUPPORTED BEAM
CONCENTRATED LOAD AT CENTER



(at load) $\sigma = \frac{FL}{4Z}$

(at load) $Y = \frac{FL^3}{48EI}$

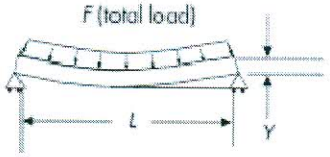
CANTILEVERED BEAM (ONE END FIXED)
CONCENTRATED LOAD AT FREE END



(at support) $\sigma = \frac{FL}{Z}$

(at load) $Y = \frac{FL^3}{3EI}$

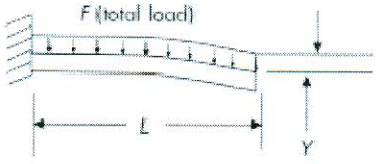
SIMPLY SUPPORTED BEAM
UNIFORMLY DISTRIBUTED LOAD



(at center) $\sigma = \frac{FL}{8Z}$

(at center) $Y = \frac{5FL^3}{384EI}$

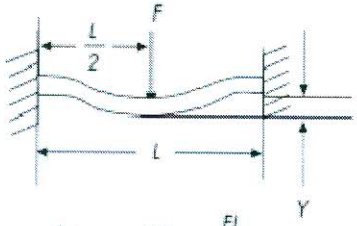
CANTILEVERED BEAM (ONE END FIXED)
UNIFORMLY DISTRIBUTED LOAD



(at support) $\sigma = \frac{FL}{2Z}$

(at free end) $Y = \frac{FL^3}{8EI}$

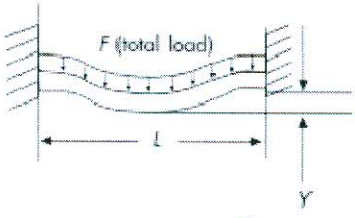
BOTH ENDS FIXED
CONCENTRATED LOAD AT CENTER



(at supports) $\sigma = \frac{FL}{8Z}$

(at load) $Y = \frac{FL^3}{192EI}$

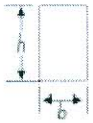
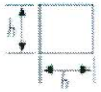
BOTH ENDS FIXED
UNIFORMLY DISTRIBUTED LOAD



(at supports) $\sigma = \frac{FL}{12Z}$

(at center) $Y = \frac{FL^3}{384EI}$

Appendix 3: Polar moments of inertia for common cross-sections

CROSS-SECTION	POLAR MOMENT OF INERTIA, J
	$\frac{\pi d^4}{32}$
	$\frac{\pi(d_o^4 - d_i^4)}{32}$
	$\frac{\pi b^2 h}{32}$
	$\frac{bh(b^2 + h^2)}{12}$
	$\frac{h^4}{6}$

Appendix 4: Radial deformation on the shaft

Condition A:

$$\delta = b \in \left(\frac{c^2 - b^2}{c^2 + b^2}\right)\left(\frac{c^2 + b^2}{c^2 - b^2} + \upsilon_{pl}\right) \tag{4.1}$$

Condition B:

$$\delta = \frac{2b^3 \in (c^2 - a^2)}{(c^2 + b^2)(b^2 - a^2)} \tag{4.2}$$