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THE NATIONAL UNIVERSITY OF IRELAND, CORK

COLÁISTE NA hOLLSCOILE, CORCAIGH
UNIVERSITY COLLEGE, CORK

SUMMER EXAMINATIONS, 2006

B.E. DEGREE (ELECTRICAL)

PRODUCTION ENGINEERING
ME4002

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Time allowed**:** 3 hours

Answer any *five* questions

All questions carry equal marks

The use of a Casio fx570w or fx570ms calculator is permitted

The use of mathematics tables is permitted

1. The prototype component shown below in Figure 1 is to be manufactured in a high shrinkage polymer by injection moulding. The component consists of a 60x40x32mm box containing two 5mm thick partitions, four identical hollow cylindrical bosses, two 5x8mm through-holes in the vertical sides along section *C-C*, and two end-slots 5x2x24mm along section *B-B* as shown. Criticise the design and suggest improvements, using sketches where appropriate to illustrate your answers. All dimensions are in mm. (Diagrams are not to scale.)

[*20 marks*]

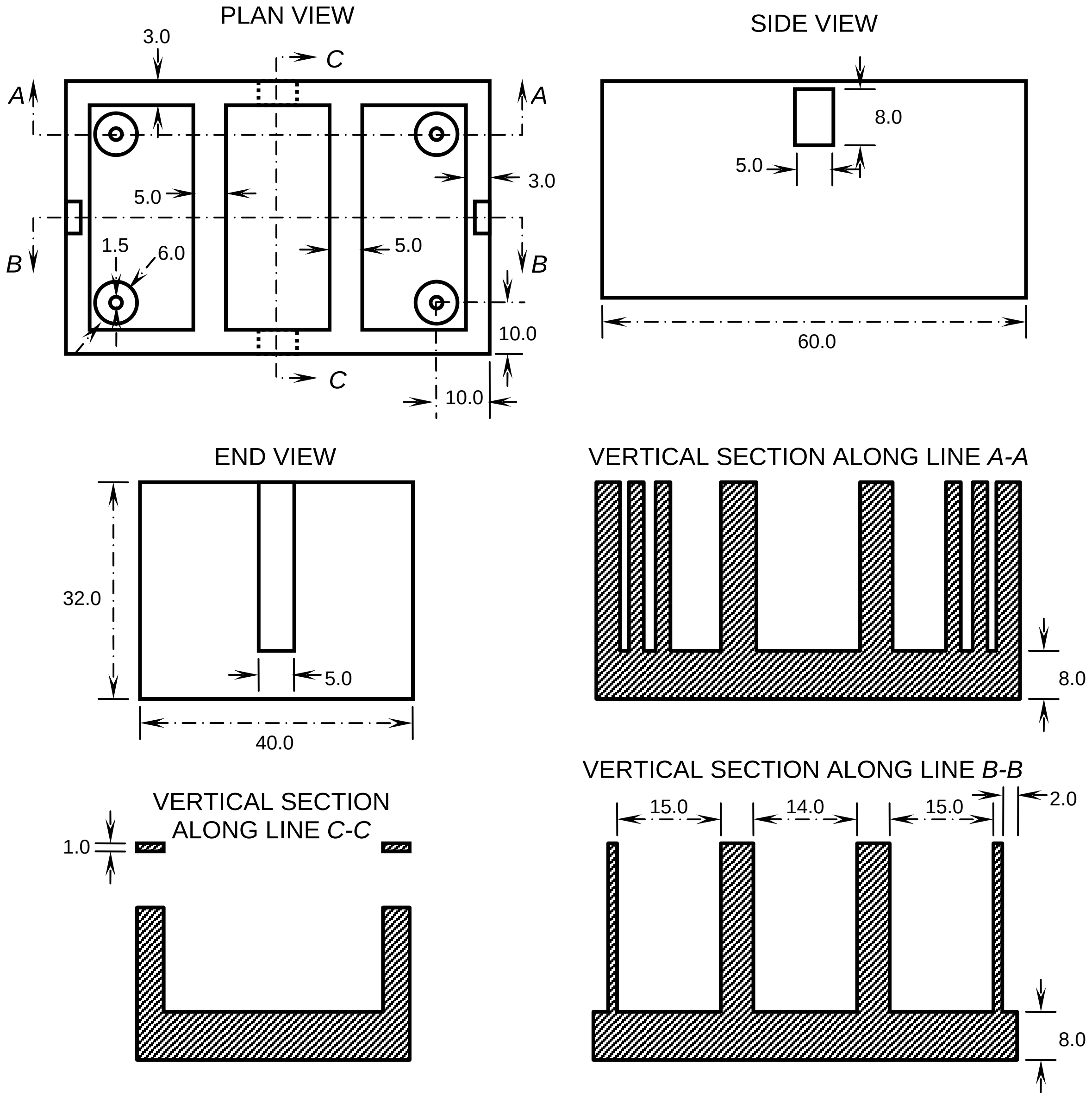

Figure 1: Component geometry for Question 1.

(*Questions continued on next page*)

2. A heat sink with ten identical fins has the cross-section shown below in Figure 2 and is to be manufactured by direct extrusion in an aluminium alloy from a cylindrical billet 100mm in diameter and 0.5m long. The ten fins of the heat sink are equally sized and spaced. The required ram pressure p is given by:

$$p = K_x \overline{Y}_f \left(\varepsilon_x + \frac{2L_0}{D_0} \right)$$

and the shape factor K_x by:

$$K_x = 0.98 + 0.02 \left(\frac{C_x}{C_c} \right)^{2.25}$$

where C_x and C_c are the perimeters of the component and equivalent area circle respectively. Calculate the reduction ratio, the true strain ε_x (assuming a = 0.27 and b = 1.8), the average flow stress $\overline{Y}_f$ (assuming K = 240MPa and n = 0.15), and hence the ram force F required. Assuming that no butt remains in the extruder, calculate the length of extruded heat sink that will be produced. (Figure 2 is not drawn to scale, all dimensions are in mm).

[*20 marks*]

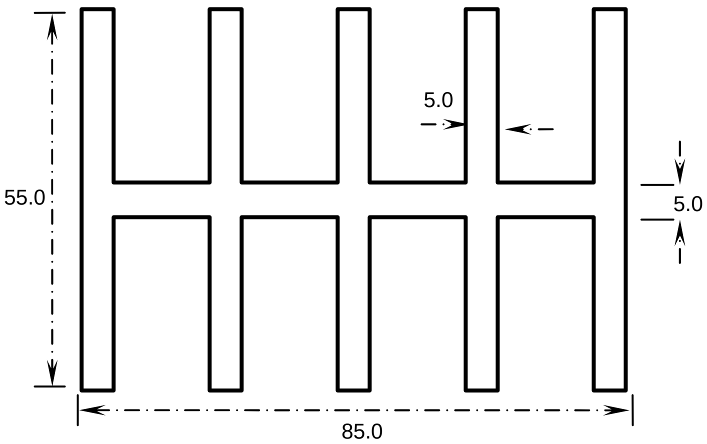

Figure 2: Component geometry for Question 2.

3. The ‘T’-piece shown overleaf in Figure 3 is to be constructed from 5 pieces of mild steel: two pieces of straight pipe, and three flat circular flange plates. The overall length of the component is 500mm; all other dimensions may be estimated. Assess the suitability of the component for manufacture by (a) manual arc welding, and (b) adhesive bonding, giving advantages and disadvantages of the proposed design for each process. For both manufacturing techniques, suggest design modifications to improve the accuracy and integrity of the finished component. (Diagram is not drawn to scale.)

[*20 marks*]

(*Questions continued on next page*)

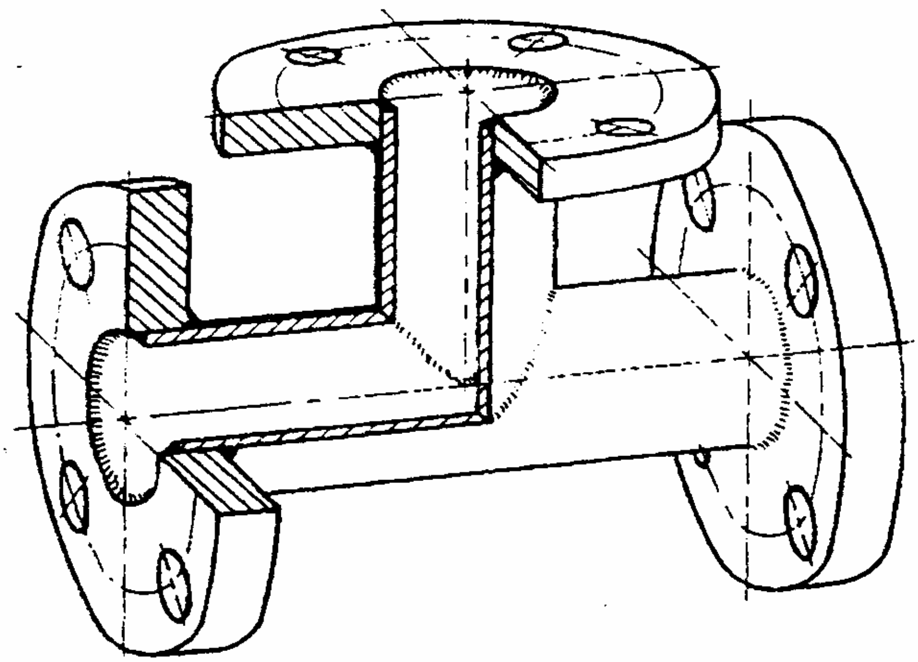

Figure 3: Component assembly for Question 3.

4. Every summer, an oil-fired power station must shut down one of its four boilers for two weeks so that the equipment may be inspected for defects. Of particular concern are the two tube bundles in the condenser. Both bundles consist of 4,000 individual stainless steel tubes that pass through holes in support plates at each end and at 2m intervals along their length. The tubes have an outer diameter of 30mm, a nominal wall thickness of 4mm, and are 10m long. Only access to the inside of each tube at either end is possible. The tubes are susceptible to internal and external corrosion that gradually thins the tube wall over the middle 6m of the tube, external radial cracks near the tube supports, and internal and external longitudinal cracks anywhere along the tube length.

All leaking tubes, and any tubes that are deemed likely to fail before the next annual shutdown, must be blanked off before the condenser is put back in service. Critical defects are cracks more than 30% deep, and wall thinning of more than 50%. If more than 40% of the tubes in a bundle are defective, the entire bundle must be replaced.

Describe how the tube bundles could be inspected using eddy current testing, using sketches where appropriate. Answers should include details of the principles of applicable eddy current techniques, the apparatus required, critical parameters, any precautions required to ensure detection of the defects outlined above, and any advantages and disadvantages of the proposed methods.

[*20 marks*]

(*Questions continued on next page*)

5. (a) Describe the four main scattering mechanisms which may occur as X-rays or γ-rays pass through a material. Explain how the scattered radiation may degrade the quality of a radiographic image, and hence define the term “build up factor”.

[*10 marks*]

(b) A butt weld joining two lengths of steel plate 10mm thick is to be inspected using X-rays. A radiographic film is placed 0.5 m from the far side of the joint, and an X-ray tube with a 5mm diameter aperture and 150kV potential is situated 150mm from the near side of the joint. For a 2mm wide defect located on the far side of the joint at the weld root, calculate:

(i) the minimum wavelength of the source;
(ii) the geometric unsharpness;
(iii) the magnification of the defect;
(iv) the size of the defect as it appears on the radiograph.
($h = 6.626 \times 10^{-34}$ Js, $c = 3 \times 10^{8}$ ms^{-1}, $e = 1.602 \times 10^{-19}$ C)

[*10 marks*]

6. For each NDT requirement given below, describe the most suitable method of achieving the stated objective. Give a brief outline of the underlying theory and state any precautions to be taken to ensure consistent, reproducible results. Support your answers with sketches as appropriate and use qualitative arguments where possible.

(a) Accurately determine the depth of surface-breaking cracks more than 2mm deep in an aluminium storage vessel with walls 20mm thick. The locations of the defects are known, having been determined previously by ultrasonic inspection.

[*7 marks*]

(b) Detecting delaminations in 0.5x0.5m square composite panels, consisting of five layers of 1 mm thick polymer sheet, bonded together with adhesive. The technique should be capable of determining which of the layers have delaminated.

[*7 marks*]

(c) Detecting surface-breaking cracks and small sub-surface defects larger than 1mm in steel shafts.

[*6 marks*]

(*End*)

(*Material property sheet overleaf*)

PROPERTIES OF TYPICAL ENGINEERING MATERIALS

Material	Alloy constituents	0.1% proof (yield) stress	Young's modulus	Density	Specific heat capacity	Coefficient of linear thermal expansion	Thermal conduct-ivity	Electrical resistivity (per cube)	Relative cost	
METALS AND ALLOYS	% by mass	σ_y (MPa)	E (GPa)	ρ x 10^3 (kg·m^{-3})	c (10^3 J·kg^{-1}·K^{-1})	α (10^{-6}·K^{-1})	λ (W·m^{-1}·K^{-1})	ρ_e (Ω·m)	(k€·m^{-3})	Notes
CAST IRON grey	3.5C	100-250	100-150	7.0-7.4	0.52	11	50	700x10^{-9}	0.8	
malleable	2.5C	250-500	170	7.3	0.52	11	40	340x10^{-9}	1.0	
STEEL mild	0.06-0.25C	250-500	210	7.9	0.45	11	50	120x10^{-9}	1.2	
medium carbon	0.25-0.6C	250-700	210	7.9	0.45	11	50	230x10^{-9}	1.5	
alloy	Ni Cr Mo	700-1000	215	7.9	0.45	11	30	300x10^{-9}	2	
stainless	0.2C 16Cr	500-1000	215	7.8	0.5	10	25	720x10^{-9}	4-7	Martensitic
	0.1C 18Cr 8Ni	200-800	215	7.8	0.5	16	16	740x10^{-9}	4-7	Austenitic
MAGNESIUM alloy	8Al 0.5Zn	150-250	40	1.8	1.0	25	100	600x10^{-9}	7	
ALUMINIUM pure		30-140	70	2.7	0.88	27	240	36x10^{-9}	2.2	
alloy	4Cu 1Mg	125-400	70	2.8	0.9	27	180	38x10^{-9}	3.4	"Duralumin"
TITANIUM alloy	4Al 4Mn	1000	110	4.5	0.5	9	17 (1)	500x10^{-9} (1)	80	(1) Pure metal
ZINC alloy	4Al 1Cu	250	108	7	0.4	30	100	700x10^{-9}	3.2	"Mazak"
NICKEL alloy	Cr Co	100-800	190	8.5	0.4	13	15	1200x10^{-9}	30	"Inconel"/"Nimonic"
COPPER pure		50-300	130	8.9	0.38	17	400	17x10^{-9}	8	
bronze	7.5 Sn	150-750	100	8.9	0.38	18	60	140x10^{-9}	20	
brass	30-40 Zn	150-500	100	8.5	0.37	18-23	130	65x10^{-9}	9	

THERMOPLASTIC POLYMERS	Ultimate tensile stress (MPa)								
Polyethylene PE	5-25	0.1-1.0	0.9-0.95	2.3	100-200	0.4	>10^{14}	0.6	
Polypropylene PP (g)	25-35	1-1.5	0.9		110-170	0.2	>10^{14}	0.7	
Polyvinyl chloride PVC	60	2.5	1.4	1-2	50	0.15	>10^{14}	1	
Polytetrafluoroethylene PTFE	15-40	4-6	2.2	1	100-200	0.25	>10^{17}	22	"Fluon"/"Teflon"
Polystyrene PS	50	1-3	1.1	1.3	60-80	0.15	>10^{11}	0.7	
Polymethylmethacrylate PMMA	50-70	3	1.2	1.5	50-90	0.2	>10^{12}	1.6	"Perspex"
Polyamide (nylon) PA (g)	50-90	1-3	1.1	1.6	80-150	0.22	>10^{10}	2.5	
Polyacetal (Polyoxymethylene) POM	65	3	1.4	1.4	30-35	0.25	>10^{11}	2.0	"Kematal"
Acrylonitrile-butadiene styrene ABS	20-40	2	1-1.1		60-100		>10^{15}	1.2	
Polyethylene terephthalate PET (g)	70-170 (1)	2.3	1.3	1.3	20 (1)		>10^{19}	2.2	"Melinex"/"Mylar" (1) Oriented film
Polycarbonate PC (g)	60-70	2.8	1.2		70	0.15	10^{16}	2.4	
THERMOSETTING POLYMERS									
Epoxy and polyester: 'GRP', 'DMC', 'SMC'	90-130	20-30	1.5-2.0	1.7	15-30	0.2-0.4	>10^{16}	1.7	'Glass fibre reinforced plastics'
Phenol, urea, melamine- formaldehyde (g)	30-50	5-8	1.4-2.0	1.7	30-45	0.2	>10^{12}	1.1-2.4	

(g) With glass fibre filler, UTS and E increased by x2 to x3, density by +0.2

Note: Polymers exhibit creep at room temperature. The given values for σ and E are for short-term loading only.

RUBBERS					Max usable temp. (°C)				
Natural (polyisoprene)	20		0.9-1.2	1.9-1.4	85	0.13-0.16	10^{6}-10^{16}	0.5	Soft →Hard
Polyurethane	25	0.001 to	1.1		85			3.0	
Neoprene (polychloroprene)	20	1.0 as	1.2		95			2.0	
Nitrile	15	required	1		115			1.0	
Fluorocarbon	15		1.8		290			35.0	

WOOD pine	20-100	15 (1) 1 (2)	0.5	2.8	3-5 (1) 35-60 (2)	0.15	10^{10} (dry)	0.4	(1)along grain (2)across grain
GLASS crown	30-90	70	2.5	0.7	8.5	1	>10^{9}	1.0	
CONCRETE	15-70(1)	15-40	2-2.5	0.8-1.2	10-20	1.5-2.5	10^{2}-10^{9}	0.25	(1) compressive (cube)

FLUIDS	Viscosity	Bulk Modulus			Coefficient of volumetric expansion			Relative cost	
	η (10^{-3} Pa·s)	k (Pa)			β (10^{-3} K^{-1})			(€·m^{-3})	
WATER pure	1 (1)	2.2x10^{9}	1	4.19	0.2	0.67	5x10^{3}	0.2	(1) tap water at 20°C
sea	1		1.03	3.9			1		
OIL engine (10W50)	300 (1) 20 (2)	1.7x10^{9}	0.9	2	1	0.15	>10^{10}	400	(1)at 20°C (2)at 100°C
AIR at 20°C, 10^5 Pa	0.02	10^{5}	1.2x10^{-3}	1	3.7	0.032	→∞		
HYDROGEN at 20°C, 10^5 Pa	0.009	10^{5}	0.084x10^{-3}	14	3.7	0.14	→∞	2	

ACOUSTIC PROPERTIES*	Density (kg·m^{-3})	Longitudinal velocity (m·s^{-1})	Shear velocity (m·s^{-1})
ALUMINIUM ("Duralumin")	2790	6320	3130
BRASS (70Cu 30Zn)	8640	4700	2100
COPPER	8930	5010	2270
IRON (Cast)	7220	4600	2600
LEAD	11200	200	700
MAGNESIUM	1738	5800	3000
NICKEL	8840	5600	3000
STEEL mild	7800	5900	3200
STEEL stainless	7890	5790	3100
TITANIUM	4510	6100	3100
TUNGSTEN	19400	5200	2900
ZINC	7000	4200	2400
AIR (@20°C and 1 atm)	1.2 x 10^{-3}	344	-
OIL	880	1700	-
WATER (@20°C)	1000	1480	-

ACOUSTIC PROPERTIES*	Density (kg·m^{-3})	Longitudinal velocity (m·s^{-1})	Shear velocity (m·s^{-1})
CARBON (Pressed graphite)	1800	2400	
EPOXY RESIN	1100	2440	
GLASS	2240	5100	2800
NYLON	1120	2600	1100
PERSPEX (PMMA)	1180	2700	1300
POLYETHYLENE	900	1950	540
POLYPROPYLENE	880	2660	
RUBBER (Neoprene)	1310	1600	
SILICON NITRIDE	3270	11000	6250
WOOD pine	450	3500	
PIEZOELECTRIC MATERIALS			Piezoelectric pressure (V·m·N^{-1})
LITHIUM NIOBATE	4700	7080	0.37
LEAD-ZIRCONATE-TITANATE (PZT)	7500	4440	0.24
PVDF	1800	2300	0.23
QUARTZ	2650	5750	0.58

*Shear velocity may be approximated to one half of the longitudinal velocity. All values shown vary with exact material composition. Many materials exhibit significant anisotropy.