MANUFACTURING ENGINEERING TRIPOS PART I

Friday 25 April 2003 9 to 12

Paper P1

DESIGN AND MANUFACTURE

*Answer not more than **four** questions of which not more than **one** may be taken from each section **A, B, C** and **D**.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

SECTION A

*Answer **not more than one** question from this section.*

1 (a) The component in Fig. 1 shows a sketch design for a stainless steel 'bayonet mount' to join a lens to a movie camera. The mount must provide precise location between the lens and the camera to ensure that the optical axes of both are aligned.

(i) The spigot 'A' (nominal diameter 54.0 mm) interfaces with the camera and must have a close clearance fit. Specify the tolerances for the spigot and its mating hole.

(ii) What potential manufacturing errors might inhibit the assembly of spigot 'A' into its mating part? [25%]

(b) The mount locates to the lens via diameter 'C'. How would you tolerance this feature to ensure that the lens and camera axes are aligned? [15%]

(c) The mount is screwed to the lens through the eight holes 'B'. Using sketches where appropriate, indicate how you would dimension these holes. [15%]

(d) Explain what is meant by 'run-out' and 'total run-out'. What advantages do they have over other methods of specifying tolerances. [15%]

(e) Explain the relationship between manufacturing process capability and engineering tolerances. [15%]

(f) The first batch of 100 mounts has been produced and inspected. Dimension 'E' has a mean value of 5.01, with a standard deviation of 0.03. Calculate and comment on the Cpk value. [15%]

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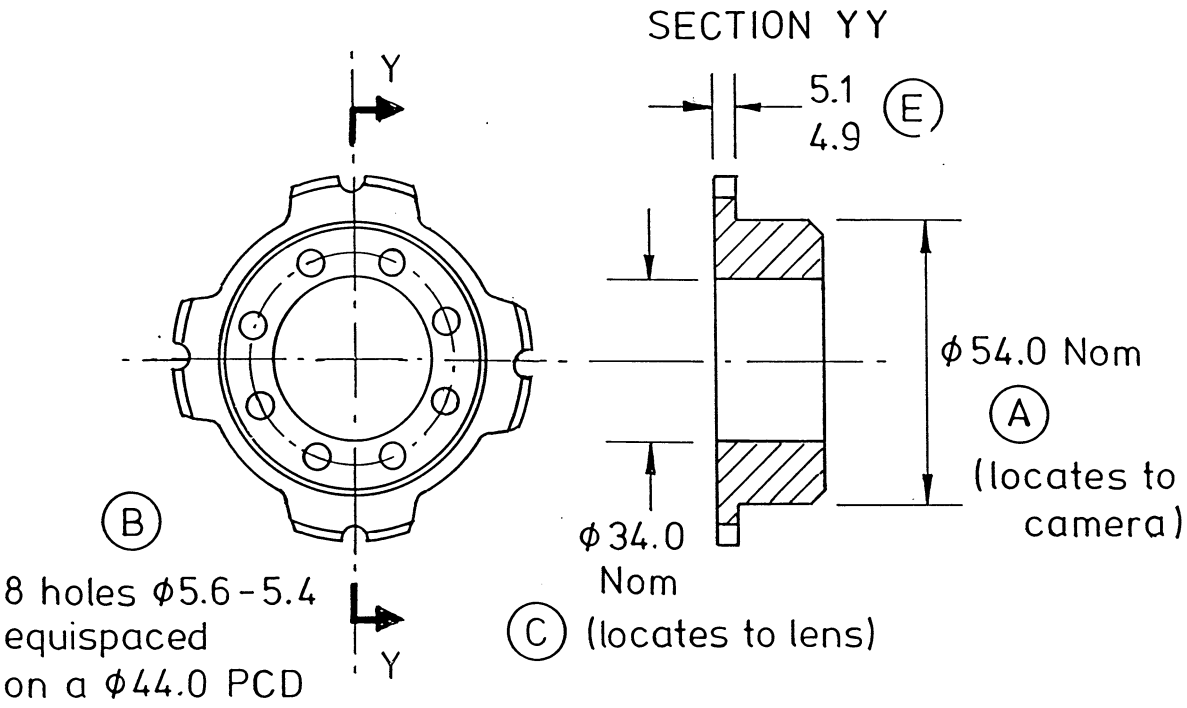
SECTION YY
Y
5.1
4.9
E
φ54.0 Nom
A
(locates to camera)
B
8 holes φ5.6 - 5.4
equispaced
on a φ44.0 PCD
φ34.0
Nom
C
(locates to lens)
Y

Fig. 1

2 (a) Bicycle Accessories Limited (BAL) has commissioned your product design consultancy to develop some original concepts for a new range of cycle lights. How could you use the Kano model and methodology to help generate a product specification? [35%]

(b) During your research, you have noticed that the company's existing range of cycle lights is diverse, with little overall coherence. The current lighting systems include:

- Traditional bulb lights, battery power, different front and rear lights, low and high power options. Tend to be the lowest price.
- LED lights, battery power, different front and rear lights. Mid and low price options.
- Halogen lights, battery power, different front and rear lights, low and high power options. Highest price products.
- Separate add-on battery packs, large and small capacity.
- Dynamo lights, front and rear fittings, hub and wheel dynamo.

Product rationalisation is necessary and you believe that a platform strategy may be appropriate. Describe the platform strategy options available and indicate how these might apply to BAL's cycle light range. [35%]

(c) You have developed a concept for a fully integrated 'handlebar control system', which combines a trip computer, direction indicators, front lights, and brake and gear controls into a single sealed unit. What advantages to the company and to end users might this integrated solution have over the traditional modular approaches? [30%]

SECTION B

*Answer **not more than one** question from this section.*

3 An organisation wishes to set up a web-based order system for its customers. This will enable them to: specify what they want to order; confirm availability, price and delivery date; and complete the payment. Your company has been asked to design the software necessary to achieve this and you are the engineer responsible for managing the project team.

(a) (i) Identify three primary tasks involved in fulfilling this project.

(ii) What are the skills required for each task?

(iii) How would you divide the responsibilities across the team involved? [35%]

(b) For each of the three primary tasks, what tests would you specify to ensure the quality of each element of software? [30%]

(c) (i) Describe how you might develop a working tool that would enable the necessary tasks to be specified clearly.

(ii) How might you use the tool to define and cost each work task, establish priorities and make choices about inclusion and exclusion of possible different features of the software?

(iii) How would you use the tool to monitor progress during the project? [35%]

4 Fig. 2 illustrates a preliminary design for a table for an aircraft seat, intended to fold away into the arm rest of the seat. The design is sketched as an assembly of standard details illustrating the general idea, but is to be simplified to reduce its manufacturing cost.

(a) List the degrees of freedom and ranges of movement, which are required to achieve the fold-away function. Explain why each degree of freedom is necessary. [20%]

(b) How would you identify the primary and secondary components? [10%]

(c) Identify each primary component in the preliminary design and explain what it does. [30%]

(d) State the function of each secondary component and suggest how each of these functions might be achieved by creating a feature on a neighbouring primary component. Describe how your simplified design would be assembled. Use sketches as appropriate. [40%]

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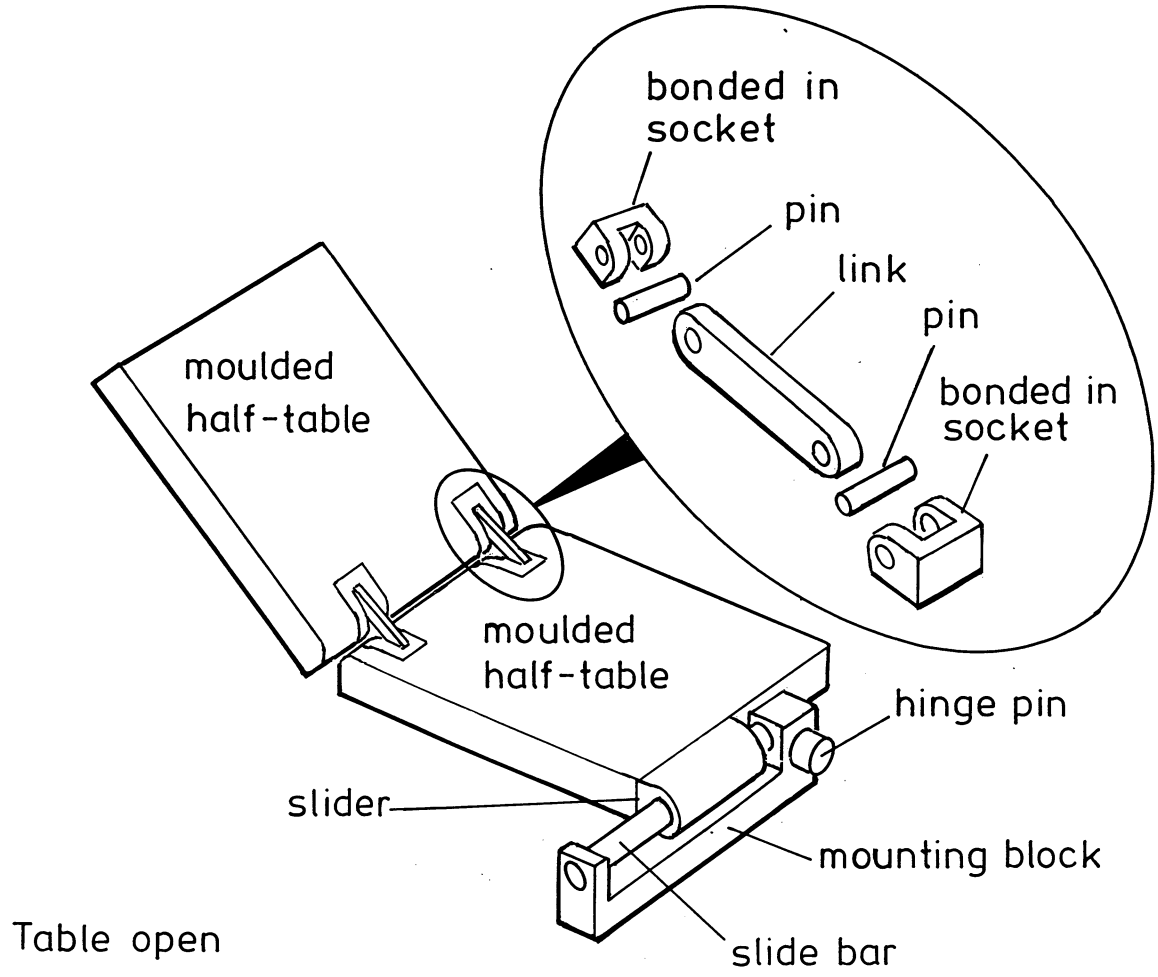
bonded in socket
pin
link
pin
bonded in socket
moulded half-table
moulded half-table
hinge pin
slider
mounting block
slide bar
Table open

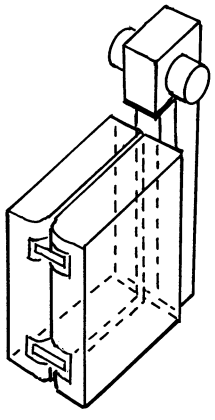
Folded away

Fig. 2

SECTION C

*Answer **not more than one** question from this section.*

5 (a) (i) Describe two work measurement techniques that can be used to set accurate time standards for manual manufacturing operations. [35%]

(ii) Show how 'standard time' is derived from 'observed time'. [15%]

(b) An engineer repeatedly measures the time taken for a worker to assemble a product, with the following results;

1st observed time	49.5 s.
2nd observed time	48.8 s.
3rd observed time	54.1 s.
4th observed time	53.7 s.
5th observed time	47.5 s.

Over a period of 10 days, a foreman carries out 400 random observations of the same worker, and notices that he is working productively on 298 occasions. During this period the worker attends for 70 hours and produces 3400 assembled products. From this the foreman deduces the basic time required to assemble the product.

Calculate 95% confidence limits for the time to perform the assembly operation using (i) the engineer's time study and (ii) the foreman's sample. [35%]

(iii) Comment on the difference between the times and explain the possible reasons for this. [15%]

6 You have been asked to plan *in detail* the layout of a new factory. Describe the stages that you would go through, the factors that you would take into account at each stage, and the analytical tools and techniques that you would use. [100%]

SECTION D

*Answer **not more than one** question from this section.*

7 (a) Briefly discuss the causes of vibration in machine tools and how one might counter them. [30%]

(b) Draw a block diagram to illustrate how closed loop control can be used to counter the effects of unexpected external vibration forces on machine tool position. Label your diagram carefully to describe each component and signal. [20%]

(c) The frequency plots in Fig. 3 illustrate the flexibility of a machine tool.

(i) If an external vibration force has an amplitude of 5 kN at 113 rad. s^{-1}, determine (approximately) the amplitude of the resulting deflection at the tool tip. [10%]

(ii) If K represents a proportional-integral negative feedback controller of the form:

$$K = K_i / s + K_p$$

which acts on the error between desired and actual tool position, determine the amplitude of the resulting deflection at the tool tip with the feedback controller in place

The controller gains are given by
Integral: $K_i = 6$;
Proportional: $K_p = 3$; [30%]

(iii) What would be the effect of increasing the value of K_i to 30? [10%]

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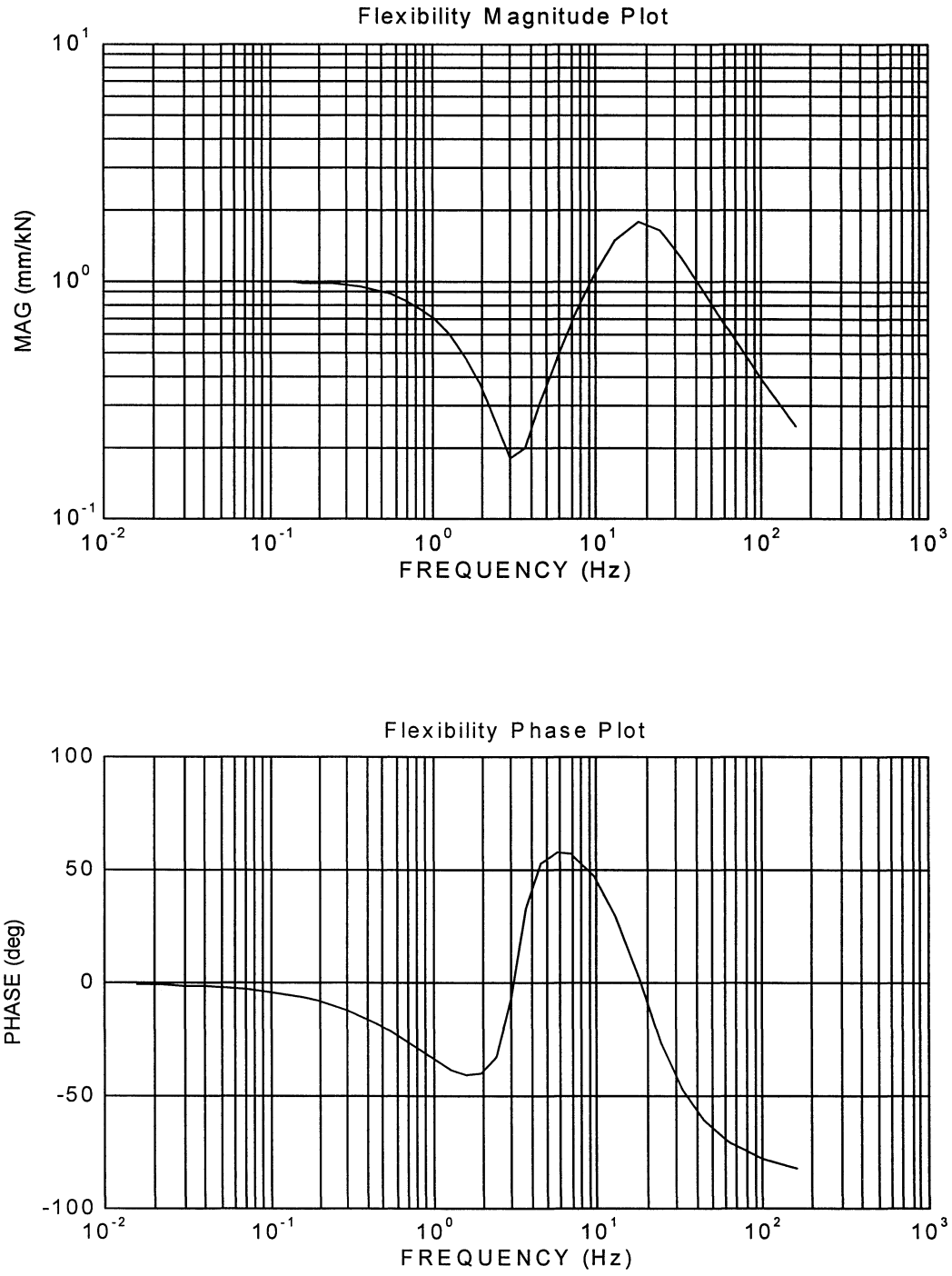
Flexibility Magnitude Plot
MAG (mm/kN)
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
FREQUENCY (Hz)
Flexibility Phase Plot
PHASE (deg)
100
50
0
-50
-100
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
FREQUENCY (Hz)

Fig. 3

8 (a) Token bus and Ethernet are two common access procedures or protocols for communications on Local Area Networks in manufacturing plants. Contrast the underlying principles behind the two and indicate where each is commonly used. [30%]

(b) A manufacturing plant producing and assembling specialised components for a number of customers has evolved as a set of relatively autonomous operations over a ten year period. Each of the operations is cellular in nature and is relatively well controlled, involving PLC based machining and assembly sequencing. CNC machines are used throughout the plant. (The PLCs and CNC machines are from a number of different supplier companies.) Statistical process control (SPC) procedures are used to monitor product quality in line with customer tolerances, and this data is collected, recorded and plotted manually within the individual operations. Scheduling is performed manually for each individual operation, as is order management and materials ordering, although it is perceived that there would be a benefit in expanding this activity to exploit synergies across the business. Finally, the company has recently invested in a powerful business level information system running on a main-frame computer in order to manage business level transactions and monitoring. The plant management perceives that there is a significant benefit to be extracted by the integration of production level information from all of the different plant operations with the newly installed system.

(i) Sketch the 'decision hierarchy' involved in running this plant indicating the frequency of decisions being made and the volumes of data required to make the decisions. [20%]

(cont.

(ii) Provide a specification for the communications network, ensuring that the specification includes:

- Communication levels, media used, protocols and justification for each.
- Necessary computing (hardware) systems with appropriate justification.
- A diagram outlining the overall information architecture you are recommending.

Clearly state any assumptions you have made about the existing production and information systems. [50%]

END OF PAPER