MANUFACTURING ENGINEERING TRIPOS PART I

Monday 2 May 2005 9 to 12

Paper P2

ORGANISATION AND CONTROL OF MANUFACTURING SYSTEMS

*Answer not more than **four** questions.*

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.*

Attachments:
Log-log paper (1 sheet)

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

1 A new Selective Compliance Assembly Robot Arm (SCARA) is to be used in an assembly cell for auto insertion of high precision components.

(a) As with machining processes, position accuracy in robot assembly is clearly critical.

(i) Identify three categories of sources of position disruption that might occur for this robot.

(ii) Explain what steps can be taken during the physical construction and installation of the robot to ensure that the position disruption problems identified above are minimised in the factory environment.

[30%]

(b) The relationship between applied force, $U(j\omega)$ (in kN), and end-effector position, $Y(j\omega)$ (in mm), for the robot's vertical axis is given in the frequency domain by

$$\frac{Y(j\omega)}{U(j\omega)} = G(j\omega) = \frac{0.1\omega_n^2}{-\omega^2 + 2c\omega_n \omega j + \omega_n^2}$$

where c, the damping factor, is 0.3, and ω_n, the natural frequency, is given by $\omega_n = 100$ rad/s. The robot arm is subject to a harmonic load disturbance of amplitude 0.077 kN at 75 rad/s. Determine the impact of this harmonic load disturbance in terms of the resulting end-effector position.

[30%]

c) It is known that feedback control can reduce the impact of disturbances. Hence the vertical axis of the robot is to be equipped with a simple, proportional-feedback controller, k, which uses a measure of the end-effector position to adjust load.

(i) Sketch the closed-loop system and write a closed-loop transfer function relating load disturbance and end-effector deflection.

(ii) Reducing static (steady-state) deflection is also important. Determine a value of k such that the level of steady-state position deflection from load disturbance is reduced by 50% compared to the open-loop system.

[40%]

2 A small production cell is being built which involves machining and sub-assembly processes for a range of parts. The physical equipment for the cell – which includes machining, materials handling, fixturing and part storage facilities – has already been specified, and a plan for the physical layout of the equipment and their interconnections provided. The cell may need to operate stand-alone – that is, without operator assistance. You are tasked with the development of an automatic control system for the cell.

(a) Stating any assumptions, outline the tasks you would need to complete in carrying out this development, referring particularly to the following areas:

(i) automating the operations of the individual pieces of equipment;
(ii) ensuring effective communications within the cell; and
(iii) coordinating the production cell as a whole.

[30%]

(b) Describe three programming tools that could be used, stating in each case:

(i) the area of the development in part (a) that the tool applies to;
(ii) how a program is developed;
(iii) any limitations of the tool.

[30%]

(c) There is a need to ensure that a part on a particular conveyor section (Section 1) can only pass to the subsequent conveyor section (Section 2) when section 2 is clear of all other parts. Using diagrams or otherwise, show how this might be guaranteed through the design of the automation logic for the cell coordination. What other issues would need to be addressed?

[40%]

3 A computer manufacturer offers two main products: product A is a standard desktop geared at the college market, which is characterised by a high demand throughout the year; product B is a top-end laptop geared at the professional market, which is characterised by a high sensitivity to competitors' activity, and hence shows considerable sales fluctuations throughout the year. The company has a make-to-forecast (MTF) production strategy.

(a) Outline the key differences between the simple exponential smoothing forecast and the simple moving average. For which type of application is each forecasting method best suited?

[20%]

(b) The demand pattern for both products A and B for weeks 1-15 is given in Table 1, along with two sets of exponentially smoothed forecast data for each product. Variables α_1 and α_2 represent the smoothing constants used in the forecasts for each product.

Week	**Product A**			**Product B**		
	Demand (in 100s of units)	Forecast (using α_1)	Forecast (using α_2)	Demand (in 100s of units)	Forecast (using α_1)	Forecast (using α_2)
1	11	-	-	3	-	-
2	12	-	-	8	-	-
3	9	11.50	11.10	2	5.50	3.50
4	10	10.25	10.89	1	3.75	3.35
5	13	10.13	10.80	5	2.38	3.12
6	11	11.56	11.02	6	3.69	3.30
7	12	11.28	11.02	7	4.84	3.57
8	10	11.64	11.12	4	5.92	3.92
9	12	10.82	11.01	2	4.96	3.92
10	8	11.41	11.10	2	3.48	3.73
11	10	9.71	10.79	6	2.74	3.56
12	11	9.85	10.71	7	4.37	3.80
13	12	10.43	10.74	5	5.69	4.12
14	8	11.21	10.87	8	5.34	4.21
15	12	9.61	10.58	4	6.67	4.59

Table 1

(cont.

(i) Calculate the values of smoothing constants α_1 and α_2 that have been used.

(ii) Which of the two values, α_1 or α_2, would you recommend for product A, and which for product B? Explain your choice.

[40%]

(c) Currently, both products A and B are made to forecast, and sold through large retail chains. The manufacturer is considering adopting an assemble-to-order (ATO) strategy.

(i) Outline the key advantages and disadvantages of an ATO strategy in comparison with the current make-to-forecast (MTF) approach for products A and B.

(ii) What product characteristics are required for a successful ATO strategy?

[40%]

4 A beverage manufacturer produces a range of soft drinks. All products are bottled in sequential batches on a central bottling machine. A new brand, is being introduced, and the projected annual demand is 10,000 crates per annum. The setup cost is £180 per batch, and the value of each crate of beverage is £15. The company uses an annual interest rate of 10% to account for the opportunity cost of capital.

(a) State the basic assumptions underpinning the Economic Batch Quantity (EBQ) model, and derive an appropriate formula for the EBQ. Calculate the EBQ for this case.

[25%]

(b) Briefly explain the Period Order Quantity (POQ) model, and calculate the POQ for the case above. What production pattern does the result suggest?

[20%]

(c) In the above calculations, the Operations Manager has omitted the annual cost of £3 per crate for storage in the warehouse by only considering the cost of capital. How does the EBQ change if both storage cost and cost of capital are considered? What is the total annual cost in this case?

[20%]

(d) After an operational audit, senior management wants to reduce inventory in order to reduce cost. The total processing time for the three main production steps of mixing, bottling and packaging is 23 hours, and the output is 50 crates per day. Current work-in-progress (WIP) levels are at 125 crates, and the factory works in two shifts of 7 hours per day. Use Little's Law to determine to what extent the inventory level can be reasonably lowered. Comment on any limitations of this approach.

[35%]

5 A manufacturing company is setting up a new factory and considering two options for the key processing equipment:

Processing Option 1: A single machine A directly feeding a single machine B;
Processing Option 2: Four machines C in parallel, directly feeding any one of four machines D in parallel.

The product produced by the route A-B is identical to that produced by the route C-D. The factory works for eight hours per day. Processing and setup times for the four machine types are given in Table 2:

Processing Option	Machine	Process time (seconds)	Setup time (seconds)
1	A	6	1500
	B	8	1000
2	C	40	50
	D	50	20

Table 2

(a) For both processing options above, calculate the daily capacity of the new factory, for the cases where batch size is 10 and 1000. State any assumptions you make.

[30%]

(b) For both processing options, and for both batch sizes:

(i) Calculate the utilisation rate for all four machine types, defined as the % of time in which the machine is processing. State any assumptions you make.

(ii) Explain why your results differ for the two batch sizes.

[20%]

(c) Discuss the effect of variations in processing times on the performance of both options.

[20%]

(d) Which of the processing options would you recommend to meet a fluctuating demand? Justify your answer.

[30%]

6 (a) Briefly describe the main principles of the Toyota Production System (TPS).

[25%]

(b) Describe three different ways in which a task may be standardised, giving an example for each. [25%]

(c) Discuss the appropriateness of the Toyota Production System:

(i) In a job shop with 1000 different products each having unique processing routes.

(ii) For short life-cycle products such as mobile phone hand-sets or fashionable clothing.

(iii) In an integrated steel plant.

[50%]

7 It has been argued that the internet enables the increasing use of markets in business relationships. At the same time, there is a growing emphasis on partnership and collaboration in supply chain relationships, many of which make use of the internet.

(a) Explain the reasons behind these two developments.
[30%]

(b) Describe, using an example in each case:

(i) two ways in which the internet has led to an increase in the use of markets in the supply chain;

(ii) two ways in which the internet supports partnership and collaboration in the supply chain.
[40%]

(c) What explanations can you offer for these apparently contradictory developments?
[30%]

8 A company is considering three possible sites for a new warehouse to serve four existing factories. The grid references for the four factories, F1, F2, F3 and F4 and the daily production output of each are given in Table 3. The grid references for the three candidate warehouse sites, S1, S2 and S3 are given in Table 4.

	X coordinate	Y coordinate	Output
F1	300	180	200
F2	400	400	70
F3	200	360	240
F4	100	270	160

Table 3 - Factory Locations and Output

	X coordinate	Y coordinate
S1	240	240
S2	120	350
S3	320	380

Table 4 - Proposed Warehouse Locations

(a) Different approaches exist for determining the best location of the proposed warehouse. Load-distance and Centre of Gravity are two such approaches.

(i) Using Euclidean distance, calculate the Load-distance for each warehouse S1, S2 and S3.

(ii) Calculate the Centre of Gravity for the four production sites.

(iii) Based on this information, which warehouse site would you recommend? Justify your answer.

[50%]

(cont.

(b) Why might the solutions from these methods not necessarily provide the best location for the new warehouse?

[20%]

(c) (i) Describe two other types of distribution problem and methods that may be used to solve each of them.

(ii) Under what circumstances would a simulation-based solution method be most suitable?

[30%]

END OF PAPER