MANUFACTURING ENGINEERING TRIPOS PART I

Monday 28 April 2008 9 to 12

Paper P2

ORGANISATION AND CONTROL OF MANUFACTURING SYSTEMS

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

*Answers to sections **A, B, C** and **D** must appear in four separate booklets.*

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.*

There are no attachments.

STATIONERY REQUIREMENTS	SPECIAL REQUIREMENTS
8 page answer booklet x 4	Engineering Data Book
Rough work pad	CUED approved calculator allowed

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

Version 6

SECTION A

*Answer **one** question from this section.*

1 (a) A Programmable Logic Controller (PLC) is commonly used for control and coordination of automated production cell operations, and ladder logic is a standard approach for producing control instructions for PLCs.

(i) A latching function is a key element in most ladder logic programmes. Using an example, describe its use and explain how it is effectively generated in ladder logic code. [20%]

(ii) Using an example, explain how a counter is generated in ladder logic code. [20%]

(b) Petri Net modelling provides one approach for generating ladder logic code for an automated production cell. The Petri Net in Figure 1 models the material flow for an existing production line. Parts A and B are first machined in separate CNC machines, and finished parts are stored in separate Work-in-Progress (WIP) buffer areas. Finally, both parts are transferred for assembly.

The production line has to be modified to incorporate the following factors:

- Add a material handling robot, which is used to load parts to, and unload parts from, both CNC machines.

- Ensure that the material handling robot does not load the machines unless the machines are idle.

- Limit space in WIP buffer 1 to five parts. Ensure that the robot does not unload parts from CNC 1 unless there is space in this buffer.

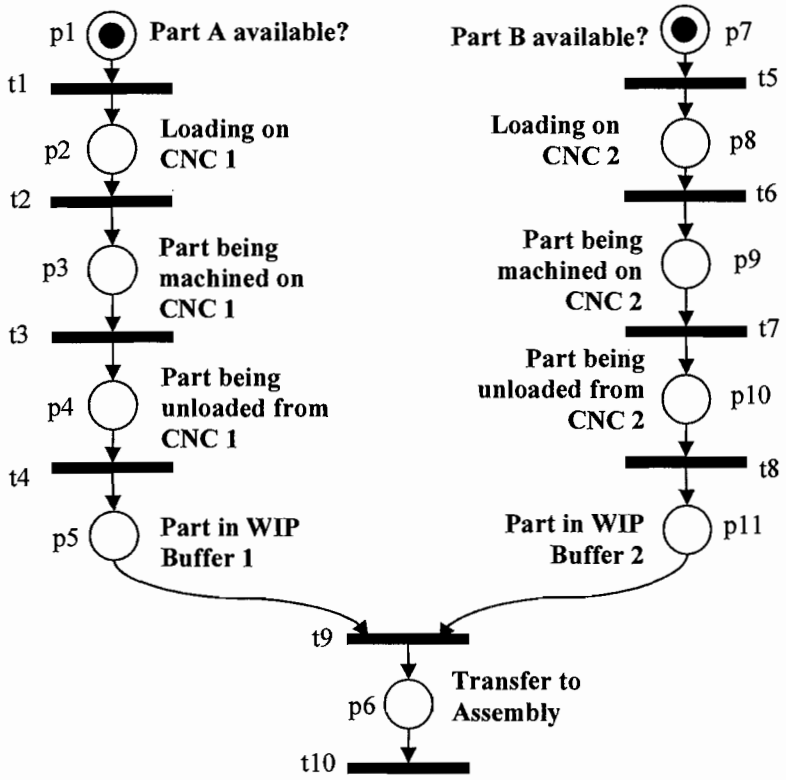

Fig. 1

(i) Redraw/extend this Petri Net to incorporate the required modifications. [45%]

(ii) Clearly explain, in each case, the reason for the introduction of each new place, transition and arc. [10%]

(iii) State the current marking of the Petri Net you have generated. [5%]

2 (a) Discuss the advantages and disadvantages of closed loop control systems as compared to open loop control systems. [20%]

(b) The block diagram shown in Figure 2 illustrates the effect of unexpected vibration forces on idealised machine tool operation and their influence on tool position. Note that the control action is presented here in terms of the force applied to the workpiece by the tool. The behaviour of the machine tool as a result of these vibrations is represented by its transfer function $G(j\omega)$, from vibrational force $F(j\omega)$ (in kN) to deflection $D(j\omega)$ (in mm) as follows:

$$G(j\omega) = \frac{D(j\omega)}{F(j\omega)} = \frac{\omega_n^2}{-\omega^2 + 2c\omega_n j\omega + \omega_n^2}$$

where c, the damping factor, is 0.3, and ω_n, the natural frequency, is 120 rad/s.

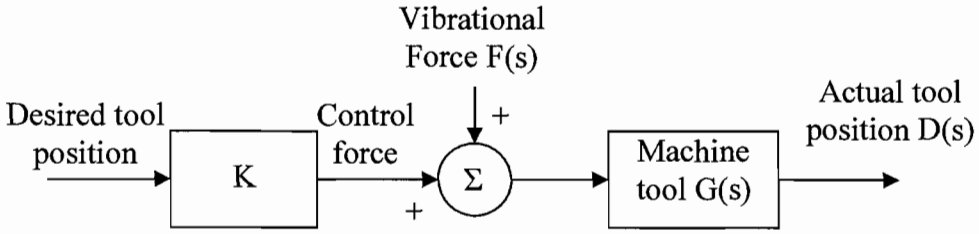

Fig. 2

(i) If the vibration has an amplitude of 1 kN at 14 Hz, determine (approximately) the amplitude of the resulting deflection at the tool tip. [30%]

(ii) Now, let K be a proportional negative feedback controller of gain K=2 which acts on the error between desired and actual tool position. Revise the block diagram to reflect this change. Also determine the amplitude of the resulting deflection at the tool tip with the feedback controller in place. [30%]

(iii) Discuss how you would design the machine tool so as to reduce the effects of such vibrations. [20%]

SECTION B

*Answer **one** question from this section.*

3 The Z-company is a manufacturer of telephone systems, which are assembled on a single assembly line with ten separate tasks, A-J. Table 1 gives the duration of each task, and the immediate precursors of each task. The company works 7.5 hours per day, with two 20 minutes breaks per day. The company operates 5 days per week. The total processing time from component production through assembly to shipping takes 17.4 hours.

Task	**Duration (minutes)**	**Precursors**
A	3	-
B	4	A
C	5	A
D	8	B,C
E	4	B
F	6	C
G	3	D,E
H	4	F,G
I	5	F
J	4	H,I

Table 1

(a) Balance this line for a weekly demand of 180 units, and show the tasks to be completed by each worker. Justify your approach and determine the minimum number of stations as well as the balancing loss for your solution. [40%]

(b) Towards the end of the year, the Z-company slides into financial trouble and the CEO demands a radical cut in operational cost. For this purpose, the entire inventory in the firm is counted. The work-in-progress inventory was counted at 140 units. The Operations Manager suggests a 50% reduction in inventory to meet the demands of the CEO. Is this possible? Justify your answer. [20%]

(c) The Operations Manager is further debating a cut in raw material stocks. Briefly explain the advantages and disadvantages of holding stock at the raw material end of the manufacturing operation. [40%]

4 A company wants to make improvements by reviewing its production scheduling for its main product, SuperTele, which sells at 20,000 units per annum. The setup cost is £60 per batch, and the value of each product to the company 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 the mathematical formula. Calculate the EBQ for this particular case. [40%]

(b) Due to an increase in labour cost, annual storage cost increases by £5 per unit. What happens to the EBQ, considering both storage cost and the cost of capital? What is the total annual cost in this case? [20%]

(c) Discuss the main advantages and disadvantages of the Economic Order Quantity (EOQ) model, and explain how it should be used in a manufacturing firm. [40%]

SECTION C

*Answer **one** question from this section.*

5 (a) When is it better for manufacturers to have high output rate rather than high flexibility? [20%]

(b) A manufacturer of quality beer expects monthly demand for the next year to be as shown in Table 2. The manufacturing process is dominated by time spent in the fermenting tank. For this beer, fermentation must occur in full 1000 litre tanks, and takes almost one month. After manufacture, the beer can be stored for up to one year without degradation. At the beginning of the year, the manufacturer has no beer in stock.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Demand in 1000 litres	2	3	4	6	7	9	11	12	9	7	5	9

Table 2

(i) If the manufacturer has enough capacity to meet demand during the month in which it is required, what is the average capacity utilisation of the plant? [25%]

(ii) If the manufacturer has only enough tanks to supply mean demand per month, what is the average stock held during the year? [25%]

(iii) What could the manufacturer do to improve his capacity management? [30%]

6 A manufacturing operation has two processes, A and B and makes two products, X and Y. Product X follows process route A-B, while product Y follows process route B-A. The process times and switchover times are shown in Table 3. The operation aims to make an equal number of each product, and always operates a first-in-first-out scheduling rule. The operation has unlimited demand and a secure supply of raw materials, so there is always work waiting for both machines.

Process	Process time for product X (secs)	Process time for product Y (secs)	Switchover time from one product to the other (secs)
A	20	60	200
B	50	30	300

Table 3

(a) With a batch size of one for each product, and assuming that operations must begin with a switchover, calculate the average process utilisation of the operation. Also calculate the output rate (capacity) in units of either X or Y produced per hour. [25%]

(b) Calculate the process utilisation and capacity with batch sizes of 5 and 20. [15%]

(c) Draw an activity cycle diagram for the process, stating any assumptions you make. [20%]

(d) At time 0, process A is about to switchover to processing product X and process B is about to switchover to processing product Y. List the time and nature of the first 10 events that occur in a discrete event simulation of the operation. Assume that the batch size is one, and that the two processes always alternate between the two products. [20%]

(e) Briefly discuss how the operations manager should decide on an appropriate batch size for the operation. [20%]

SECTION D

*Answer **one** question from this section.*

7 An automotive component company based in the UK is proposing to establish a new production facility to service three key customers, A, B, and C, who require highly reliable just-in-time deliveries. The daily demand from each customer and the grid references for the location of their factories are given in Table 4. Three possible locations, L1, L2, and L3, for the new production facility are under consideration. The grid references for these sites are given in Table 5.

	X coordinate	Y coordinate	Demand
Customer A	10	50	60
Customer B	40	20	40
Customer C	50	10	50

Table 4

	X coordinate	Y coordinate
Location L1	20	30
Location L2	30	50
Location L3	40	20

Table 5

(a) Calculate the Euclidean load-distance for each location and the Centre of Gravity for the three customer locations to identify the best location for the new production facility. [50%]

(b) Discuss the factors, other than distance, that may influence the automotive company's choice of where to locate the new production facility within the UK. [15%]

(c) Many companies have recently been relocating production facilities offshore. Using specific examples where possible, explain the factors they may need to consider when choosing where to set up such facilities for the first time. Also discuss how they might decide between the different possible locations. [35%]

8 (a) Explain the concept of risk pooling and the demand conditions under which it is likely to be of most and least benefit. [15%]

(b) Compare and contrast the different distribution strategies that a company may employ in terms of risk pooling, transportation costs and holding costs. Discuss, with examples the types of business for which each strategy is appropriate. [25%]

(c) Describe, with examples, four different types of retailer-supplier partnerships and explain the reasons why a company might choose each type. [25%]

(d) How does Collaborative Planning Forecasting Replenishment (CPFR) differ from other forms of retailer-supplier partnerships? What challenges does CPFR pose for both parties? [15%]

(e) Discuss the reasons why companies may participate in retail-supplier partnerships with retailers, and the risks to which it may expose them. [20%]

END OF PAPER