MANUFACTURING ENGINEERING TRIPOS PART I

Monday 26 April 2004 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.*

There are no attachments.

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 3

1 (a) The diagram in Fig. 1 outlines the typical decision requirements for a manufacturing plant:

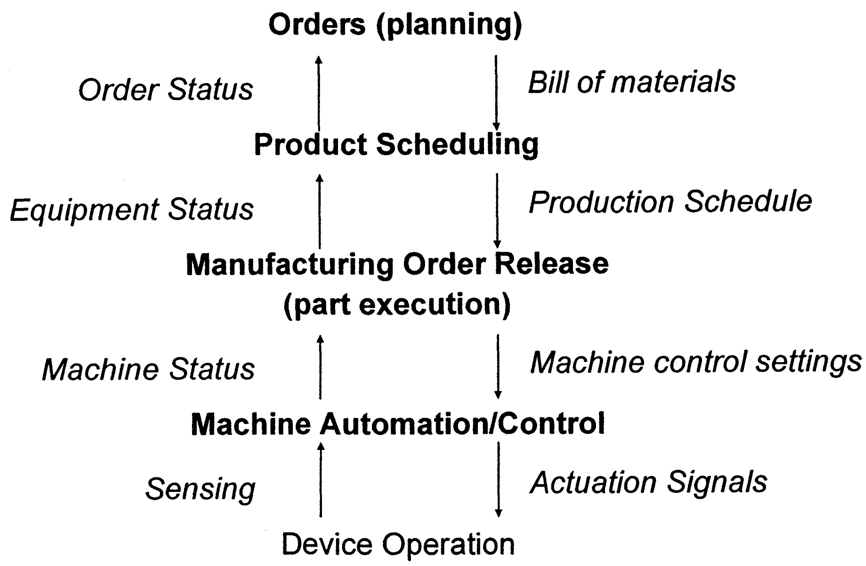

Fig. 1

(i) For each of the decision levels in Fig. 1, comment on the different information processing requirements, and hence explain why a hierarchical approach is generally taken to computer integration. [20%]

(ii) For each of the decision levels in Fig. 1, outline the typical computer and communications systems used. [20%]

(b) A new manufacturing cell comprising machining and assembly operations, a robot and a part storage facility has been planned. The individual robots and machine tools are supplied with their own controllers. The cell will be fully automated and integrated within the existing factory operations.

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(i) What steps would be required to fully automate this cell? [15%]

(ii) Describe the typical requirements for communications between machines within the cell, commenting in particular on:

- characteristics of this type of communication;
- typical hardware;
- access procedures;
- relevant standards;
- topology. [30%]

(iii) What is the benefit in using standards when specifying a communications system of this type? [15%]

2 (a) Ladder logic is a standard approach for producing control instructions for automated systems.

(i) State diagrams are often used in the design of ladder logic programmes. Explain what is meant by a state diagram and how it is helpful in ladder logic design. [20%]

(ii) A latching function is a key element in most ladder logic programmes. Describe its use and explain how it is generated in ladder code, using an example to illustrate this. [15%]

(b) Triggered by an external input signal, a robotic arm provides parts to a machining operation from a storage buffer. The arrangement is described in Fig. 2. PLC based control logic is required to manage this operation.

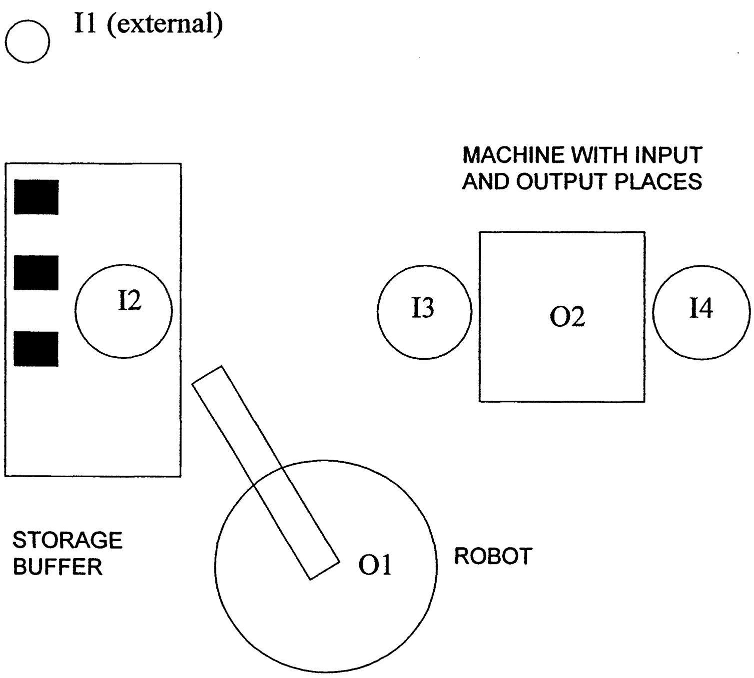

Fig. 2

(cont.

The characteristics of this system are as follows:

- Each time the external input signal triggers the start of the operation, a single part is machined.
- Both the robot and the machine have only two possible conditions: "operating" or "idle".
- The robot and the machine cannot operate simultaneously.
- The robot can only operate if there is a part available in the storage buffer, and no part in the machine's input position.
- The machine can only operate if there is a part available in the machine's input position, and not one available in the machine's output position.
- Completed parts are removed manually when an operator is available.

The inputs to, and outputs from, the proposed control system are respectively:

I1 – external start (momentary signal);
I2 – indicator that there is a part in the storage buffer;
I3 – indicator that there is a part at machine input;
I4 – indicator that there is a part at machine output;
O1 – actuation signal to start the robot;
O2 – actuation signal to start the machine.

(i) Specify an appropriate set of states and associated state values for the system. [15%]

(ii) Draw a state diagram for the operation which includes all allowable combinations of state values and specifies which of the above inputs are required for each transition. [15%]

(iii) Using the state diagram or otherwise, generate representative ladder logic for the control of this system. [20%]

(iv) It is proposed that this system be integrated into a continuous production environment, and the possibility of the robot loading simultaneously while the machine is operating is now being considered. Describe the type of changes to the ladder logic that would be required to enable this possibility. [15%]

3 A company produces service parts for ice-cream vending machines. The demand for the parts is 50 units per month. The fixed cost of ordering raw material is £1,500 regardless of the order size, and the value of each part is £450. The company uses an annual interest rate of 10% to account for the cost of capital, and a further 12% for the annual cost of storage.

(a) State the basic assumptions underpinning the Economic Order Quantity (EOQ) model, and derive the mathematical formula. Calculate the EOQ for the company. [45%]

(b) The Operations Manager assumes that the cost of storage is negligible, and only considers the cost of capital in his calculations. What happens to the EOQ in this case, and what are the implications for the total annual cost? [15%]

(c) Describe the main advantages and key problems associated with the EOQ model. [40%]

4 (a) Describe the main reasons for holding inventory in a manufacturing system. [30%]

(b) You are the operations manager of a bicycle manufacturing company. The manufacturing process has four main production stages – frame welding, painting, assembly, and packing – all of which together take 800 minutes in total. A workday has 7.5 hours, and the average daily demand is 1,600 units. Each bicycle sells for £200. Current work-in-progress (WIP) inventory levels for all production stages combined are at 4,800 units. The company works 200 days per year.

(i) A recent study suggests cutting WIP inventory by 50% in order to save costs. Is this feasible? Explain. [35%]

(ii) How much could you improve your annual inventory turns in percent, if you reduced the WIP level to the minimum level? [15%]

(iii) The marketing department has found that sales are very seasonal, with many more bicycles being sold over the summer than during the winter. Currently, the demand is forecast using a simple moving average. Discuss why a simple exponential smoothing forecast might work better. What value of smoothing constant *alpha* would you recommend? [20%]

5 A manufacturer of heavy engineering boilers needs to deliver 10, 10 and 20 boilers respectively during Weeks 3, 4 and 9. It is currently the end of Week 0. It takes two weeks to assemble the boiler from a number of sub-assemblies. This includes two of sub-assembly A, each of which takes one week to make, and requires 12 of component B and 20 of component C. Current stocks are 4 boilers, 7 of sub-assembly A, 60 of component B and 900 of component C. Current stocks and scheduled receipts (which arrive at the beginning of the week) are shown inTable 1.

	Current Stock	Scheduled receipts
Boiler	4	2 in each of weeks 2 & 6
Sub Assembly A	7	8 in each of weeks 3, 5 & 8
Component B	60	60 in each of weeks 2, 5 & 8
Component C	900	500 in each of weeks 1, 5 & 9

Table 1

(a) Calculate the net requirements for components B and C using an approach based on a Materials Requirement Planning (MRP) system. [40%]

(b) Based on your answer to (a) and assuming that this product represents the bulk of the business of this company, do you think that this manufacturing process is well-managed? Explain your answer and suggest how you would improve it. [30%]

(c) Would you recommend the implementation of Just In Time practices to this company? Justify your answer. [30%]

6 An ideal 'Just in Time' production system would have a batch size of one, no stock and full utilisation of all resources.

(a) What are the implications of this ideal for the design of the whole production system? [40%]

(b) Why might a factory manager choose to move away from this ideal? [30%]

(c) What should a company with relatively low stock-holding costs learn from the 'Just in Time' approach? [30%]

7 (a) Identify three different types of computer models that may be used to solve distribution problems and explain the advantages and disadvantages of each. [25%]

(b) A manufacturing company operates three factories in Glasgow, Leeds and Nottingham to supply customers located in Birmingham, Derby, Liverpool and York. The output of the Glasgow factory is 600 units per month, the output of the Leeds factory is 700 units per month and the output of the Nottingham factory 300 units per month. The demand from customers is 500 units per month at Birmingham, 200 units per month at Derby, 300 units per month at Liverpool and 600 units per month at York. The distance in miles between each factory and each customer location is given in Table 2:

	Birmingham	Derby	Liverpool	York
Glasgow	292	270	216	210
Leeds	110	70	81	25
Nottingham	49	95	99	80

Table 2

(i) Show that the distribution of units in Table 3 is optimal using the Northwest Corner method. [40%]

	Birmingham	Derby	Liverpool	York
Glasgow	200	0	300	100
Leeds	0	200	0	500
Nottingham	300	0	0	0

Table 3

(ii) Calculate the saving that the manufacturing company will make on its monthly transport bill if it adopts the optimal solution in Table 3, compared to the initial Northwest corner allocation. Transport costs are £0.01 per unit per mile. [20%]

(c) Why may methods to solve distribution problems sometimes fail to identify the optimal solution? Explain how this failure can be avoided. [15%]

8 (a) Developing an integrated supply chain involves compromise.

(i) Describe the key objectives of each of the different parties involved in developing an integrated supply chain. [25%]

(ii) Identify which objectives conflict, and therefore examine the trade-offs that may be required to meet them. [25%]

(b) Explain, with examples, how computer-based information systems may be used to improve performance against objectives in the face of these trade offs. [50%]

END OF PAPER