Version DCM/6

MET2
MANUFACTURING ENGINEERING TRIPOS PART IIA

Monday 27 April 2015   9 to 10.30

Paper 2

Module 3P2: OPERATION AND CONTROL OF PRODUCTION MACHINES AND SYSTEMS

Answer ***two*** *questions, one from each of sections* ***A*** *and* ***B.***

Answers to sections ***A*** *and* ***B*** *must appear in two 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.*

Write your candidate number ***not*** *your name on the cover sheet.*

STATIONERY REQUIREMENTS
8 page answer booklet x 2
Rough work pad

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Engineering Data Book

10 minutes reading time is allowed for this paper.

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

SECTION A

Answer **one** question from this section.

1 (a) Statistical Process Control (SPC) is commonly applied in the precision machining industry.

(i) Explain what is meant by the following terms:

statistical process control;
chance causes of variation;
assignable causes of variation.

[15%]

(ii) Explain, with reasons, why control charts are widely used in the precision machining industry.

[10%]

(b) A precision machine shop wishes to establish a procedure for using a control chart during a turning operation for a particular part. Describe the detailed steps to be taken when setting up and implementing a control chart for this operation, including any appropriate metrological methodologies.

[25%]

c) Table 1 presents a typical dataset collected for a turning operation performed on 15 disc-shaped parts sampled over two production shifts using a different operator on each shift. For each part, the operator recorded the maximum diameter and the minimum diameter. The diameter of the part is required to be between 147.25 and 147.15 mm.

(i) Plot a control chart for this operation.

(ii) What information does this chart give to the operator regarding the process and the part? How can this information be used to keep the process stable and within specification?

(iii) Explain how the data can be used to determine the roundness of the part.

(iv) Define the *process capability index*, C_p. What is its value here?

[50%]

(Cont.

Operator	Shift	Part No	Maximum diameter (mm)	Minimum diameter (mm)
A	1	1	147.216	147.201
A	1	2	147.217	147.195
A	1	3	147.224	147.216
A	1	4	147.232	147.215
A	1	5	147.232	147.228
A	1	6	147.245	147.224
A	1	7	147.208	147.180
A	1	8	147.181	147.173
B	2	9	147.208	147.192
B	2	10	147.199	147.188
B	2	11	147.208	147.193
B	2	12	147.206	147.194
B	2	13	147.211	147.197
B	2	14	147.209	147.192
B	2	15	147.219	147.199

Table 1 Process data for a precision turning operation

 (TURN OVER

2 (a) Explain what is meant by the terms *surface roughness* and *waviness*. Discuss how these can be influenced in machining operations, and why they are difficult to control.

[20%]

(b) Describe methods by which cutting force can be measured in a turning operation. Explain how cutting force measurement provides information about machining performance.

[20%]

(c) An orthogonal cutting operation was performed under the following conditions. Depth of cut = 0.15 mm, width of cut = 5 mm, chip thickness = 0.2 mm, cutting speed = 2 m/s, rake angle = 15^{o}, cutting force = 500 N, thrust force = 200 N, and shear velocity = 2.17 m/s.

(i) Draw a diagram showing the forces acting on the workpiece and their directions.

(ii) Calculate the percentage of total power that is dissipated in the shear zone. Estimate its sensitivity to a change in rake angle.

(iii) Waviness is observed on the machined surface to a height of 50 μm. What is the likely cause of this effect? Calculate the impact this waviness will have on cutting ratio, shear angle and the percentage of total power that is dissipated in the shear zone. What changes to the process parameters would you make to minimise this effect?

[60%]

SECTION B

Answer **one** question from this section.

3 (a) Under which circumstances would you choose to use a Selective Compliance Assembly Robot Arm (SCARA) instead of an anthropomorphic robot arm? Your answer should include a comparison of different performance measures and should suggest typical applications for which each robot arm is suited.

[30%]

(b) A SCARA robot is to be used in an assembly cell for auto insertion of components into a housing. The relationship between applied force, $U(j\omega)$ (kN), and end-effector position, $Y(j\omega)$ (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 100 rad/s. The robot arm is subject to a harmonic load disturbance of amplitude 0.077 kN at 75 rad/s. The tolerance on vertical position is ± 10 μm.

(i) Determine the impact of this harmonic load disturbance on the end-effector position. Is the impact of this load disturbance acceptable? Comment on the ability of the system to tolerate additional disturbances at or near this frequency.

[30%]

(ii) 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. Draw a diagram of the closed-loop system and write a closed-loop transfer function relating load disturbance and end-effector deflection.

[15%]

(iii) 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 for the closed-loop system is reduced by 50% compared to the open loop system. Comment on the effect that the value of k has on the damping of the system.

[25%]

4 (a) (i) Define what is meant by *deadlock* in a fully automated production environment and explain why it is generally undesirable.

[15%]

(ii) A robot is being used to unload parts from a machining centre. Machined parts are temporarily stored in a buffer (with a capacity of two parts) prior to being moved (by the same robot) to an assembly operation. Use a petri net to illustrate how deadlock can arise in this system. On a separate petri net show how deadlock can be avoided.

[20%]

(b) (i) What are the key issues to be considered when preparing a petri net model for use in an automated machining operation?

[15%]

(ii) Fig. 1 illustrates an automated cell for assembling a simple two part meter box. The loading operation of the cell involves a robot moving parts A and B from separate part buffers into one of two assembly jigs on a turntable before a separate robot screws them together. An incomplete petri net model for the loading operation is given in Fig. 2. Stating any assumptions, complete the petri net model of the loading operation and demonstrate how it can be made ready to be used for the automation of the loading operation.

[30%]

(iii) A PLC programmed with ladder logic is being used to control the loading operation. Generate appropriate rungs of ladder logic for the completed petri net developed in part (b) (ii).

[20%]

(Cont.

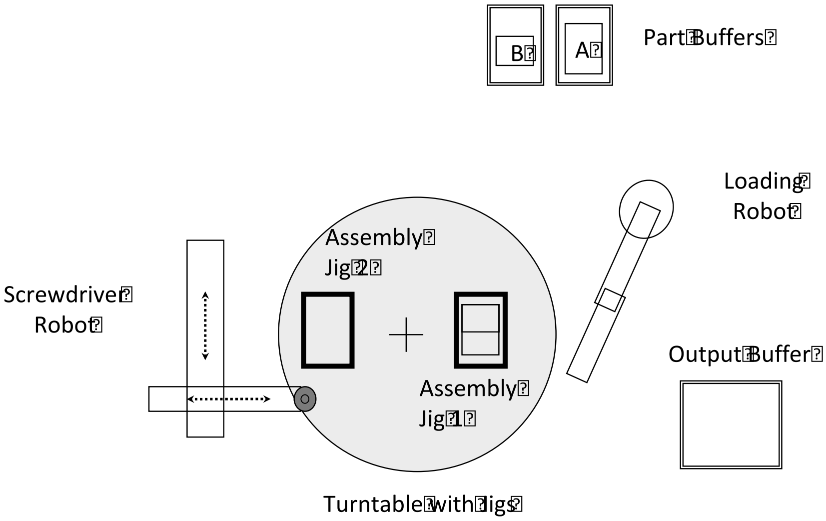

Fig. 1

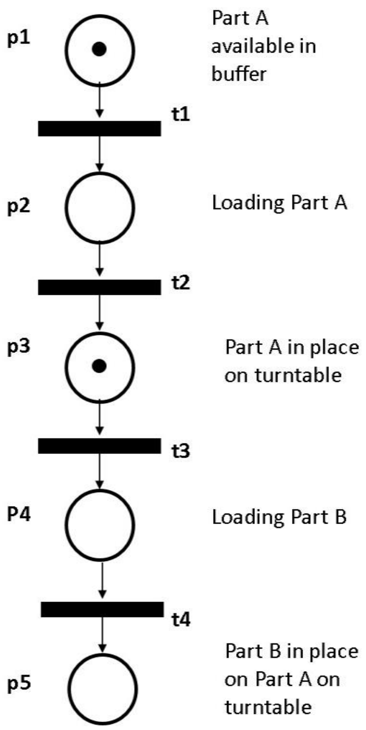

Fig. 2

END OF PAPER

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