MET2
MANUFACTURING ENGINEERING TRIPOS PART IIA

Monday 8 May 2017   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
3P2 Data Sheet

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)

(i) List the principal error generating processes that occur during the operations of a machine tool. Describe the impact of each on machining accuracy. [10%]

(ii) List the three classes of machine tool vibration and describe their origins. [10%]

(b) (i) Explain what is meant by the terms *roughness*, *lay* and *waviness* in the context of surface finish. Briefly describe *two* methods by which surface finish can be measured. [20%]

(ii) Which machining parameters have the greatest influence on surface finish and why? [10%]

(c) A company wishes to compare dry cutting with cutting using a fluid for a typical cutting operation. A workpiece is being machined at a cutting speed $V = 12.95$ m s^{-1}, depth of cut $t_0 = 0.3$ mm, width of cut $w = 2.5$ mm, with a rake angle $\alpha = +5^o$. Without coolant, the total power requirement for the operation is 3.73 kW. The coefficient of friction in dry cutting is 0.3. The thrust force F_t is found to be zero when using the fluid.

(i) Determine the following:

- the cutting force without using the fluid;
- the shear strength of the work piece material;
- the cutting force when using the fluid. [35%]

(ii) Comment on the effect of cutting fluid on cutting force and discuss the influence that cutting fluid has on surface quality. [15%]

2 (a)

(i) Why does the temperature of a cutting tool have an important effect on its performance?

(ii) List the three main sources of heat in a mechanical cutting operation in decreasing order of their heat generating capacity.

(iii) Sketch a set of curves showing how the heat generated from the three sources is dissipated as a function of cutting speed.

(iv) Where is the maximum temperature located during orthogonal cutting? Explain why this is so. [35%]

(b) An orthogonal cutting operation is carried out on mild steel under the following conditions: rake angle $\alpha = +10°$; cutting speed $V = 2$ m s^{-1}; undeformed chip thickness $t_0 = 0.25$ mm; width of cut $w = 2.54$ mm; deformed chip thickness $t_c = 0.83$ mm. The cutting and thrust forces are: $F_c = 890$ N and $F_t = 667$ N. The temperature of the chip is uniform. The workpiece specific heat capacity = 0.49 kJ kg^{-1} K^{-1} and the density of the workpiece = 8,050 kg m^{-3}.

(i) What percentage of total power is dissipated in the shear zone? [35%]

(ii) If the temperature rise in the chip is 350K, what is the power lost to the workpiece? Comment on your results. Ignore heat transfer to the tool and to the environment. State your other assumptions. [30%]

SECTION B

Answer **one** question from this section.

3 (a) Describe the role played by state machines in the development of PLC code for automated production operations. [20%]

(b) A two part meter box as shown in Fig. 1 is being assembled by robots in a cell shown in Fig. 2. Robot 1 is used for part movement and placement, and Robot 2 is used for inserting two screws which hold the two parts together. A PLC will be used to coordinate the routines of the two robots. Assume that both robots are initially idle, are not permitted to operate at the same time, and the robots return to idle after completing each task. The system operates as follows. The operation begins when a part (Part A) is present in Part A Buffer and a momentary start button is pressed by the operator. Robot 1 picks up the part and moves it into place in the screwing fixture. Only when Part A is in place on the screwing fixture can the robot then collect a part (Part B) from Part B Buffer, assuming one is available, and place it in position on top of part A. Once parts A and B are in position, and Robot 1 is returned to idle mode, Robot 2 then completes the screwing operation to form the meter box. Once this is completed and Robot 2 is returned to idle mode, Robot 1 then removes the finished meter box to the Finished Product Buffer (which has ample capacity) and Robot 1 is returned to idle mode.

The signals from the operation to the control system are:

- i1 - part A detected in Part A Buffer;
- i2 - part B detected in Part B Buffer;
- i3 - part A detected in Screwing Fixture;
- i4 - part B detected in Screwing Fixture;
- i5 - idle confirmation signal from Robot 2;
- i6 - idle confirmation signal from Robot 1;
- i7 - momentary start button.

(i) Robot 1 has four operating states (Idle, Collect Part A, Collect Part B, Remove Finished Box) and Robot 2 has two operating states (Idle, Screwing). Identify the allowable combined operating states that the two robots can have during this operation. [10%]

 (cont.

(ii) Represent the automation logic using a state machine diagram for the assembly operation. Identify each different state, state transition requirements and appropriate signals to the equipment. Clearly state any assumptions you make. Describe how you could use your diagram for producing Ladder Logic code. [40%]

(iii) If the Finished Product Buffer was to be amended so that it can only hold a limited number of completed meter boxes, what changes would you make to the assembly cell specification in Fig. 2 and to the automation logic you have suggested in part (ii)? [30%]

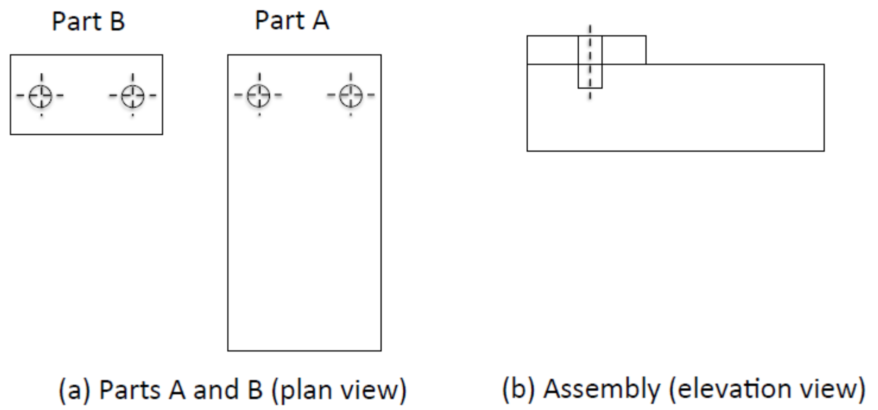

Fig. 1

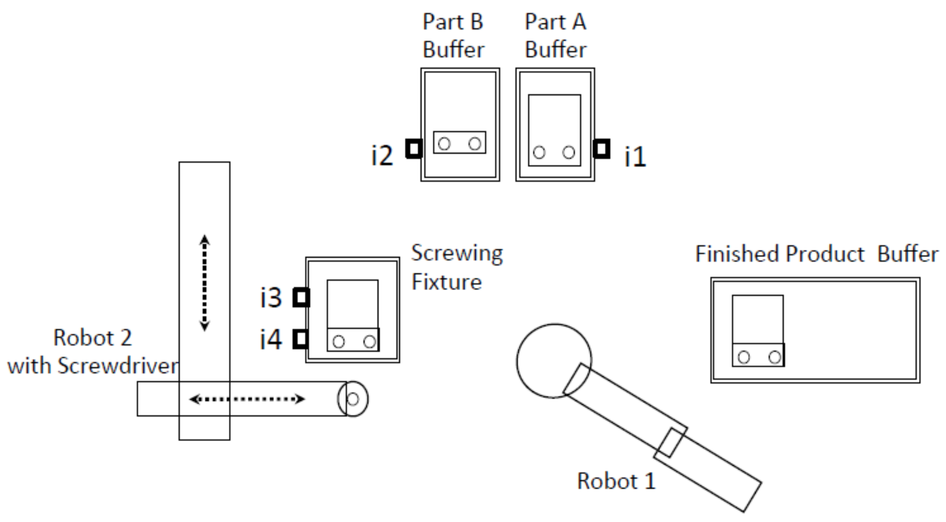

Fig. 2

4 (a) Explain the term *hazard rate* in the context of equipment reliability. [20%]

(b) A production machine in a factory has three critical components A, B and C. The machine will cease to operate if any of those components fail. Statistical analysis of failures of the components revealed a constant hazard rate for all the components. The results of the failure analysis and the current age of each component is as follows.

- Component A: fails once every 50 hours; current age – 5 hours
- Component B: fails once every 1000 hours: current age – 995 hours
- Component C: fails once every 200 hours: current age – 100 hours

What is the probability that the machine will successfully complete an operation that takes 5 hours? [20%]

(c) The operating cost function $c(t)$, of the machine in pounds is given by $c(t) = 5000 + 1600t$, where t denotes the time elapsed in years since the machine was replaced. The replacement cost of the machine is £500,000.

(i) Assuming that the time taken to carry out the replacement is negligible, how often should the machine be replaced? [40%]

(ii) Discuss the implications of a non-negligible replacement time for calculating the optimal replacement interval. [20%]

END OF PAPER