Version Final

MET2
MANUFACTURING ENGINEERING TRIPOS PART IIA

Monday 28 April 2014 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

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) Describe the main factors in machine tool design and operation that can lead to dimensional error in the machining of a part.

(ii) What are the consequences of designing a machine tool with low stiffness and how can these be addressed? [25%]

b) (i) What properties of the work material have a significant influence on the success of a machining operation?

(ii) What criteria would you use to assess the success or otherwise of a particular machining operation for a specific workpiece material? [20%]

c) Titanium is commonly used in aerospace applications.

(i) Discuss the characteristics of titanium that make it difficult to machine.

(ii) Describe the composition and physical attributes of a cutting tool material that would be most suitable for machining titanium. [20%]

d) Consider the arrangement shown in Fig. 1 in which a long section of a titanium bar, with length L_w, is being reduced from diameter D_1 to D_2 by turning on a lathe in a number of passes.

(i) Calculate the total machining time, material removal rate, and the power required where D_1 = 100 mm, D_2 = 94 mm, $O = A$ = 5 mm, L_w = 80 mm, cutting velocity V_c = 500 mm s^{-1}, feed speed S_o = 1 mm rev^{-1}, and depth of cut per pass t = 1 mm. Assume the specific energy for cutting titanium alloy is 3.5 J mm^{-3}.

(ii) How might you improve the accuracy of your approach? [35%]

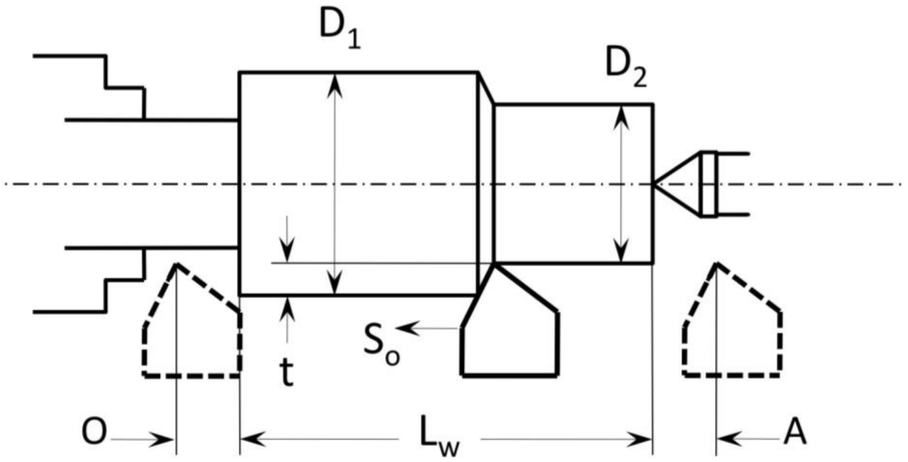

Fig.1

2 (a)

(i) With the aid of an appropriate diagram identify the principal forces acting on the workpiece during an orthogonal machining operation and describe what is meant by each force. Define the cutting ratio, r, shear plane angle, ϕ, and rake angle, α.

(ii) Which of the principal forces can be measured and how would you measure them?

(iii) Why is it important to have knowledge of the force components in machining operations? [35%]

b) Using your knowledge of the orthogonal cutting process, derive the following expression:

$$r = \frac{\sin \phi}{\cos(\phi - \alpha)}$$

where r is the cutting ratio, ϕ is the shear plane angle, and α is the rake angle. [15%]

c) In two tests on the turning of Al 7050, a number of process parameters were recorded as shown in Table 1. In both tests the rake angle was set at 8^{o}, the cutting velocity was 1500 m min^{-1}, and the width of the cut was 2 mm. The density of the material is 0.0028 g mm^{-3}.

(i) For each test, calculate the cutting ratio r, the shear plane angle ϕ, the shear force F_S, and the power consumed W.

(ii) Comment on the sensitivity of the power requirements to the parameters r and ϕ. [50%]

Test No:	**Feed rate (mm/rev)**	**Chip Length (mm)**	**Chip Mass (g)**	**F_c (N)**	**F_t (N)**
1	0.05	87.85	0.04	101	32
2	0.15	168.06	0.18	250	41

Table 1

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

3 (a) The IEC 61131-3 standard specifies five different approaches to PLC programming.

(i) Why is it important to have standardised approaches to PLC programming? [10%]

(ii) Contrast three of the approaches specified by the IEC 61131-3 standard, identifying the main features and advantages in each case. [15%]

(b) Petri nets and other modelling tools are often used in conjunction with PLC programming approaches. Why is PLC programming on its own generally insufficient for planning and developing a PLC-based control system for a complex manufacturing cell? [15%]

(c) An automated production cell is being developed to produce a simple gear box. It will comprise two machining stations machining cover parts A and B respectively and an assembly station in which two gears C and D are inserted into cover part A and then cover part B is screwed into place to complete the gear box. There are three buffer storage areas: one for the blanks for parts A and B, a WIP buffer for the machined parts A and B and a further buffer for the complete gearboxes. Each has a limited capacity. A single robot manages the movement of parts between the buffers and the machining and assembly stations.

(i) Describe a Petri Net-based modelling approach that you could use to plan the control logic for this system as a precursor to generating a suitable PLC programme. Comment on how your approach applies to the specific features of this production cell. [20%]

(ii) Indicate how you could ensure that the control logic allows no more than five components at any time in the WIP buffer and further ensures that the material handling robot operates without deadlock. [20%]

(iii) What additional factors need to be considered when a Petri Net model of a process is used to generate PLC programme code for automatic control? [20%]

 (TURN OVER

4 (a) A corrective maintenance strategy is currently used for a particular type of machine tool component in a factory, but the factory manager is interested in adopting a preventative maintenance strategy.

What are the factors that must be taken into account when deciding between preventative maintenance and corrective maintenance strategies? [10%]

(b) The factory manager collected historical data on 1500 failures of that type of component. Analysis indicated that the time to failure was distributed as shown in Table 2.

Time to failure	0-1 months	1-2 months	2-3 months	3-4 months
No of Failed Components	250	250	500	500

Table 2

The manager also obtained the following cost data. The total cost of preventative replacement of the component, c_p, is £100. The total cost of replacement, after failure c_f, is £200, which includes a penalty cost.

Assume that the time taken to replace the component is negligible and let *f(t)* be the probability density function of the failure times of the component and *F(t)* be the cumulative probability density function of the failure times of the component.

(i) Clearly explaining your derivations, develop an expression for the total expected replacement cost per unit time, *c*, as a function of replacement age, t_p,

(ii) Calculate the optimal replacement age, t_{po}, for this component type. State any assumptions you make. [60%]

(c) Assume now that the time taken for preventative replacement of the component is in fact T_p and the time taken for replacement after failure is T_f.

(i) Explain how this would affect your answers in part (b).

(ii) Under what circumstances would you expect replacement times T_p and T_f to significantly influence the optimal replacement age for a component? [30%]

END OF PAPER