MET2
MANUFACTURING ENGINEERING TRIPOS PART IIA

Friday 29 April 2022 9.00 to 10.40

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 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 at the start of the exam.

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

You may not remove any stationery from the Examination Room.

SECTION A

1 (a) Machining economics is an important topic to consider when planning production operations.

(i) In machining operations, explain why high production rates do not necessarily mean low production costs. [10%]

(ii) Discuss the three main types of tool wear encountered in machining operations and their impact on the process. [15%]

(iii) Briefly describe three measures can you take to extend tool life. [15%]

(b) The average production cost of a component can be written as.

$$C_{pr} = Mt_l + Mt_m + M\frac{N_t}{N_b}t_c + \frac{N_t}{N_b}C_t$$

where M is the machine and operator charge rate, t_l is the time to load and unload the part, t_m is the time to machine the part, t_c is the time to replace a worn tool, N_t is the total number of tools used in an entire batch, N_b is the number of parts in the batch, and C_t is the cost of each tool.

(i) A cylinder of diameter 150 mm is rough turned to a diameter of 142 mm over a length of 200 mm. The following conditions apply, C_t = £20, M = £80/h, t_l = 26 s, t_c = 3 min. The maximum feed for the cutting tool is 0.35 mm with a maximum depth of cut of 2 mm. Taylor's tool life conditions are, n = 0.2, with T = 60 s, and V 4 m/s. Calculate the average production cost for cutting speeds of 1.2, 1.6, and 2.0 m/s. Comment on the trends you observe. [40%]

(ii) What methods could you employ to monitor tool wear? [20%]

2 (a) (i) If softer materials like aluminium and copper are easier to machine, and materials tend to soften with increasing temperature, why is it undesirable to allow temperatures to rise in machining operations? [10%]

(ii) Explain how cutting fluids can influence the magnitudes of the thrust force F_t, and cutting force F_c. Use diagrams to support your answer. [15%]

(iii) Why is it important to have knowledge of the magnitude and direction of the thrust force F_t? Under what conditions can this force be upward? [15%]

(b) A machining operation is being carried out with the conditions shown in Table.1.

Undeformed chip thickness t_o	0.6 mm
Chip width w	2.54 mm
Cutting ratio r	0.3
Cutting speed v	91 m/min
Rake angle α	0°
Cutting force F_c	890 N
Thrust force F_t	667 N
Workpiece density ρ	7.8 g/cm^3
Workpiece specific heat capacity C_p	502 J/kg°C

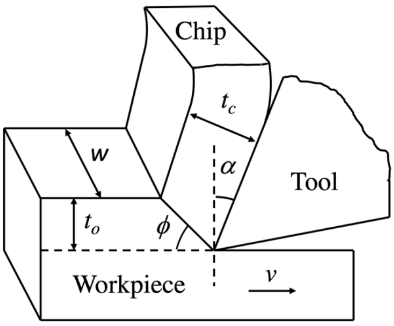
Table 1

You may assume the following: the sources of heat are from the shear plane and tool-chip interface; the thermal conductivity of the tool is zero and there is no loss of heat to the environment; the temperature of the chip is uniform throughout.

(i) Determine the total power dissipated in the shear zone. [30%]

(ii) If the average temperature rise of the chip is 135 °C, what is the percentage of total power dissipated in the shear zone that is lost to the workpiece? Comment on your answer. [30%]

Merchant's Cutting Model



t_0	undeformed chip thickness
t_c	deformed chip thickness
α	rake angle
ϕ	shear angle
v	cutting speed
w	chip width

Forces in orthogonal cutting

R	Resultant force
F_t	Thrust force
F_c	Cutting force
F	Friction force
N	Normal force
F_s	Shear force
N_s	Normal force to shear plane
β	Friction angle

Forces on the shear plane

$$F_s = F_c \cos\phi - F_t \sin\phi$$

$$N_s = F_t \cos\phi + F_c \sin\phi$$

Forces on the tool-chip interface

$$F = F_c \sin\alpha + F_t \cos\alpha$$

$$N = F_c \cos\alpha - F_t \sin\alpha$$

Merchant's shear angle relationship

$$\emptyset = 45 + \frac{\alpha}{2} - \frac{\beta}{2}$$

SECTION B

3 (a) (i) What is *handshaking* in the context of an automated production operation?

(ii) Why is handshaking used?

(iii) What are the benefits and downsides of handshaking?

[20%]

(b) A system involving two robots and a conveyor has been developed in a warehouse for extracting priority goods from the main conveyor system. The system is illustrated in Fig 1 in which available priority boxes are received by the loading robot and placed on the conveyor at position A. On detecting the box at A, the conveyor motor is turned on and the box proceeds to position B. On detecting the box at B, the conveyor motor is turned off and the box is retrieved by the unloading robot. For additional safety both robots must have returned to their home position before the conveyor starts, and the conveyor must be confirmed idle before either robot can operate. Only one box at a time can be processed by this system. Inputs to and outputs from the controlling PLC are as follows:

Inputs

I0: Priority box available for loading (external signal)
I1: Loading robot in home position
I2: Box detected at input – Position A
I3: Box detected at output – Position B
I4: Unloading robot in home position
I5: Conveyor stationary

Outputs

O1: Conveyor motor on
O2: Loading robot on
O3: Unloading robot on

(i) Identify the states of each robot, the conveyor and the box.

(ii) Determine the valid states of the system that a box moves through and sketch a state machine diagram. Annotate your diagram with the system inputs and outputs given above.

(iii) Generate Ladder Logic that could be used on the PLC controlling the system.

[50%]

(c) Stating any assumptions, describe the additional considerations required for the system in b) to allow the conveyor to handle two boxes at a time, so that a box can be loaded to the conveyor at the same time as another is being unloaded. The conveyor is assumed to be long enough that the two robots will be able to operate independently.

[30%]

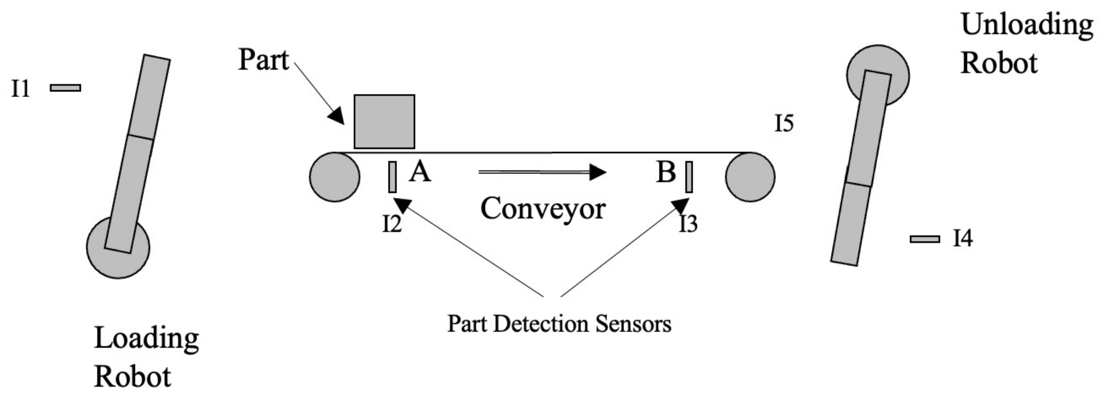


Fig.1

4 (a) Explain what is meant by the term *digital manufacturing* and discuss the reasons for its development over the last ten years. [15%]

(b) A number of emerging digital technologies have been associated with the recent digital manufacturing developments. For three such emerging technologies:

(i) Describe their main features and benefits; [25%]

(ii) Identify new manufacturing solutions that they enable; [10%]

(iii) Discuss how each technology might align with one (or more) of the three dimensions associated with Industry 4.0.

[10%]

(c) An aerospace parts company is giving its machining operations an overhaul. A greater customisation of product lines is planned and hence smaller product batches, the use of multiple tools and different machine settings, and an increased number of production changeovers are expected. Further, a diversification of suppliers with more stringent delivery requirements is proposed which is expected to impact the quality of raw materials, and lead to more frequent, just-in-time deliveries.

(i) Making reasonable assumptions about the nature of the existing industrial automation and control facilities, what new digital solutions might be required to support these new developments? Justify the solutions you suggest. [20%]

(ii) Identify where emerging digital technologies (as well as more developed technologies) might be required to support the suggested solutions.

[20%]

END OF PAPER

THIS PAGE IS BLANK