MANUFACTURING ENGINEERING TRIPOS PART IIA

Monday 30 April 2012 9 to 10.30

PAPER 2

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

*Answer not more than **two** questions, **one** from each of sections **A** and **B**.*

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

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

There are no attachments

STATIONERY REQUIREMENTS
8 page answer booklet x 2
Rough work pad

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

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

Final Version

SECTION A

Answer one question from this section.

1 (a) Tool wear is inevitable in conventional metal cutting processes. Discuss the three principal types of gradual tool wear that can occur and explain the effects they each have on the cutting process. [35%]

(b) Discuss the significance of the 'wear curve' and explain how it can be used to predict tool life in metal cutting operations. [35%]

(c) A steel ring of outside diameter 600 mm and internal diameter of 200 mm is being face machined in a single pass on a CNC lathe. The machine maintains a constant feed rate of 0.25 mm/rev as the ring is being machined. From previous tests, when V = 50 m/min, the Tool Life, T, is found to be 60 minutes, and n = 0.3. Given Taylor's empirical tool life relationship, $V T^n = C$ (where C is a constant), determine the number of components that can be machined per tool for a tool life of 50 minutes. [30%]

2 (a) When analysing an orthogonal cutting operation the following parameters need to be considered:

Cutting Force, F_c;
Thrust force, F_t;
Resultant force, R;
Shear force on the shear plane, F_S;
Friction force along the rake face, F_F;
Normal force to the rake face, F_N;
Normal force to the shear plane, F_n;
Shear angle, ϕ;
Rake angle, α; and
Mean friction angle, β;.

(i) Draw a force diagram to show the relationship between these parameters.

(ii) Explain why the cutting force, F_c, increases with depth of cut and decreasing rake angle.

(iii) With appropriate diagrams, show how the use of a cutting fluid can affect the magnitude of the thrust force, F_t, in orthogonal cutting. [40%]

(b) A cutting test on a steel bar was performed and the following values were noted:- F_c = 680 N; F_t = 380 N; and α= 10°, Calculate the coefficient of friction between the tool and the chip, μ, for this cutting operation. [30%]

(c) In a turning operation, the spindle speed is set to 1400 rpm in order to cut a straight 27 mm diameter workpiece. The cutting force is measured as 1900 N. If the efficiency of the machine tool for the operation is 0.90, what is the gross power requirement of the operation? [30%]

SECTION B

Answer one question from this section.

3 (a) The Petri Net in Fig. 1 models the material flow for an existing production line. Parts A and B are first machined in separate CNC machines, and finished parts are stored in separate Work-in-Progress (WIP) buffer areas. Finally, both parts are transferred for assembly.

The production line has to be modified to incorporate the following factors:

- Add a material handling robot, which is used to load parts to, and unload parts from, both CNC machines.

- Limit the space in WIP Buffer 1 to ten parts.

Redraw this Petri Net to incorporate the required changes, ensuring smooth deadlock-free operation. Clearly explain, in each case, the reason for the introduction of each new place, transition and arc. [30%]

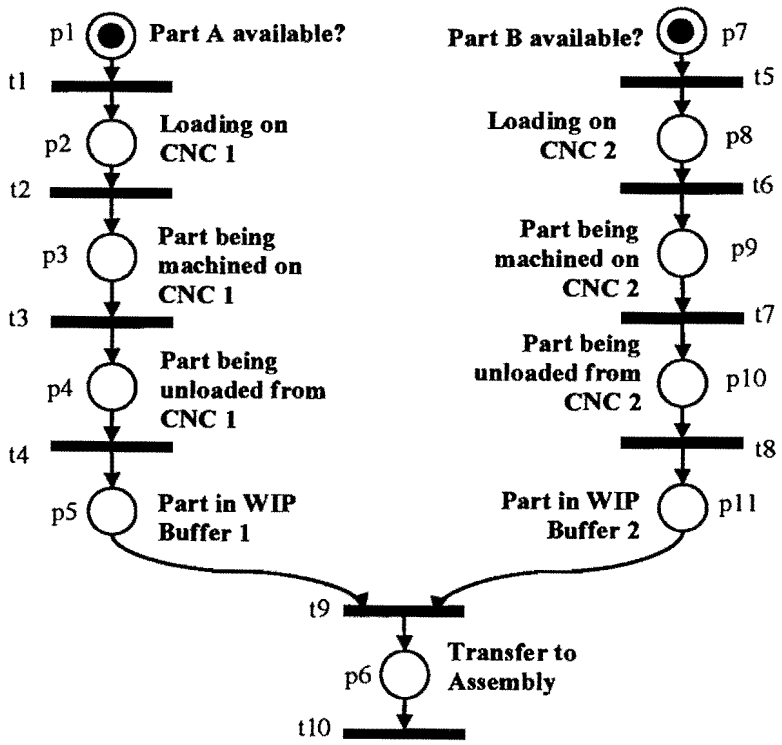

Fig. 1

(b) Describe how the interface between Petri Nets and physical systems can be achieved in cell automation. [20%]

(c) A hydraulic pump used in one of the CNC machines becomes less efficient with usage. The annual operating cost $c(t)$ is given by the following equation:

$$c(t) = A - Be^{-kt}$$

where, A = £3000, B = £2000, k = 0.35/year, and t is the age of the pump in years. The average cost of replacing the pump is £2000.

(i) Neglecting the time taken to perform a replacement, calculate the optimal replacement interval for the pump. [30%]

(ii) Discuss how you might incorporate the time needed for replacement in your calculation. [20%]

4 (a) Describe the basic functions common to adaptive-control systems. Discuss two types of adaptive-control systems used to control manufacturing operations. [30%]

(b) The relationship between applied force (in kN), $U(j\omega)$ and tool position (in mm), $Y(j\omega)$ for a machine tool is given in the frequency domain by

$$G(j\omega) = \frac{Y(j\omega)}{U(j\omega)} = \frac{0.1\omega_n^2}{-\omega^2 + 2c\omega_n\omega j + \omega_n^2}$$

where c, the damping factor, is 0.3, and ω_n, the natural frequency, is 100 rad/s. The machine tool is subject to a harmonic load disturbance of amplitude 0.077 kN at 12 Hz.

(i) Determine the impact of this harmonic load disturbance in terms of the resulting tool position. [20%]

(ii) Reducing static (steady-state) deflection is important. A negative proportional-feedback controller with gain k is used to reduce the impact of disturbance. Determine the value of gain k, such that the level of steady-state position deflection from the load disturbance is reduced by 50% compared to the open-loop system. [20%]

(c) A conveyor in a manufacturing line is controlled by a Programmable Logic Controller (PLC), which uses a momentary push button as input to turn the conveyor on when the button is pressed the first time and to turn it off when pressed again. Develop a ladder logic code to implement this logic in the PLC. [30%]

END OF PAPER