PhD Qualifying Exam – Jan 2019

Manufacturing Processes-II

Maximum marks: 100 Time : 3 hours

- Books and notes are Not allowed. Only One A4 sheet of handwritten formulae is permitted. The formula sheet must be attached to the answer book.
- Make suitable assumptions, if required and mention them.

1. a) Surface roughness profile of a component is represented by $y = 1 - \sin(\theta)$, where y is the profile height in microns and $\theta \in [0, \pi]$. Calculate the Arithmetic Average (R_a) and RMS (R_q) parameters of the surface profile. (You can use the digitized profile if you wish).
   b) Explain in brief (Any Two Only) [6]

   - Significance of providing Inclination Angle on cutting tools
   - Difference between Cylindricity and Concentricity geometric tolerances
   - Size of a GO gage for inspecting a Shaft $20^{-0.010}_{-0.040}$ mm. Assume Gage Tolerances to be 10% of part tolerances. Neglect wear tolerance. Draw a neat sketch. [6]

2. In a machine shop, cylindrical shafts of 40 mm diameter, 250 mm long are turned on a lathe using a feed of 0.2 mm/rev. The tool life equation is $VT^{0.1} = 150$, where V is the cutting speed in m/min and T is the tool life in min. Tool changing time is 2 mins.

   a) Which spindle speed should be set up to achieve maximum productivity?
   b) The shop engineer has permitted to set up spindle speed varying by $+/-5$ % from the optimum value. Calculate the number of parts produced during the useful life of the cutting tool by such speed setting. Compare the results with those corresponding to the optimum speed setting. [8]

3 A surface with roughness resembling a sinusoidal profile has peak-to-valley (PV) roughness of 10 microns. It is to be electrochemically finished. The ECM is carried out using 10 V DC supply and electrolyte with conductivity 0.2 $ohm^{-1}cm^{-1}$. The process is started when the perfectly flat tool electrode is 10 microns away from the peak point of the work surface. The workpiece material is pure Fe (gram atomic weight, 56 and density 7.86 g/cm^3) and is dissolved as Fe^{2+}. Assume Faraday's constant to be 96500.

   a) What is the largest possible feedrate that can be used?
   b) If the tool electrode is maintained stationary (i.e. without any feed), plot the evolution of the PV roughness of the workpiece surface over time. (take at least 5 data points)
   c) Calculate the time required to machine the surface in order to reduce the PV roughness to 5 microns approximately.

d) Is it practically possible to polish the surface flat (PV ~ few nm) using the above machining strategy? Explain your answer. [14]

4. a) Explain how the tool electrode electrical conductivity affects the machined surface integrity during EDM process [2]

b) For given USM parameters, which of the material, glass or tungsten carbide (WC), is more sensitive to the grit size from the point of view of surface finish obtained. [2]

c) Which are the two most effective process parameters that affect the material removal rate in Ultrasonic machining? [2]

5. Orthogonal cutting experiments have been conducted to investigate the machining performance of PCBN tools in machining high strength materials. The tool catalogue mentions that the maximum allowable temperature for PCBN tool material is 800°C and the corresponding Brinell hardness (HB) at that temperature is 1800 kg/mm^2. Assume that the maximum allowable shear stresses at tool-chip interface is $\frac{1}{12}$ HB of the PCBN. The machining conditions are as follows: uncut chip thickness, t_0 = 0.25 mm, chip thickness, t_c = 0.75 mm, width of cut, w = 2.5 mm, rake angle, $\alpha = 0°$. The coefficient of friction at the tool-chip interface is 0.3. The tool-chip contact length (l) is determined by the following equation:

$$l = \frac{t_0 \sin\theta}{\cos(\theta + \alpha - \phi)\sin\phi}$$

where θ is the angle between the shear plane and the resultant force, ϕ is the shear angle.

a) Find the maximum allowable shear strength of the material that can be cut using that tool. [10]

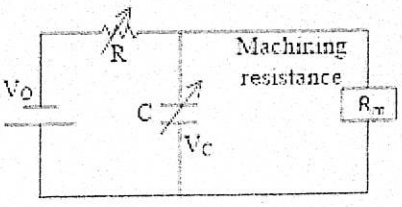
b) Find the specific cutting energy of this material. [5]

c) Why does the temperature increase with an increase in the cutting velocity? How will the cutting forces change if the cutting velocity is continuously increased? Explain the reason. [5]

6. a) Resistance-capacitance (RC) based electric circuit is frequently used to control the electrical spark duration in the commercial electro-discharge machining.

In one such application (refer the EDM circuit diagram), the machining resistance is R_m. V_o , V_c and V_d represent the supplied open source voltage, charging voltage and discharge voltage, respectively. t_c and t_d are the charging and discharging durations.

Using the basic first-principle fundamentals, **derive** the expression of discharge voltage (V_d) in terms of open source voltage (V_o), variable resistance (R) and capacitance (C), charging duration (t_c) and discharging durations (t_d). [8]



b) What is the "etch selectivity" in photochemical etching? [2]

7. A through-hole having the shape of a regular pentagon (5 sides) of 10 mm side length is machined in a 10 mm thick alloy plate by square pulse ECM process. An aqueous solution of 10% $NaNO_3$ is used as electrolyte, which results in the average conductivity of 0.05 $\Omega^{-1}mm^{-1}$.

A steady state gap of 2 mm is maintained throughout the process. In the pulse mode, a peak voltage of 25V is applied during the ECM process. The duty cycle and pulse frequency is 60% and 100Hz, respectively. The overall over-potential and the current efficiency is 5V and 90%, respectively.

Total time taken to form through-hole is 17.5 min. If the % (by weight) of Iron is 65, find the percentage of Aluminum and Nickel in the alloy.

Details of material present in the alloy (of Iron, nickel and aluminum) is as follows: Gram atomic weight of Iron, Aluminum and Nickel are 56, 27 and 60, while their density (mg/mm^3) is 8, 2.7 and 9, respectively. The valence of Iron, Aluminum and Nickel are 2, 3 and 2. Faraday constant is 96500 C. [8]

b) Why is low–pressure environment recommended in electron beam machining? [2]

8. In a finish-surface-grinding operation on a horizontal-spindle surface grinder, the length of the workpiece is 100 mm and its width 50 mm. The cross-feed is applied every stroke of the worktable and is set at 0.25 mm. The back engagement (depth of cut) is 0.1 mm, and the table traverse speed is 250 mm/sec. The grinding wheel diameter is 150 mm. Calculate:

a) Total machining time considering approach length and an over-travel of 5 mm. [8]
b) The maximum metal removal rate. [3]
c) The maximum power consumption in watts (W) if the specific cutting energy for the conditions employed is 25 GJ/m^3. [3]
d) The maximum tangential force for a grinding rotational frequency of 60 rev/sec. [6]

*****Paper Ends*****