Manufacturing Processes II

PhD Qualifying Exam - Jan 2020

Maximum Marks: 100 | 22 January 2020 | Duration: 3 hrs

Instructions:

- Make suitable assumptions, if required and mention them.
- Books and notes are NOT allowed.
- ONE formulae sheet of A4 size is allowed. Write your roll number on it and attach it to the answer book.

Questions:

1. i. For a certain tool-life test carried out at two speeds, a flank wear was measured at 5-min intervals and the data is tabulated below. If 0.75mm wear land is taken as the criteria for failure, estimate the life at a speed of 72 m/min for the same cutting conditions. **[6]**

Time (min)	Flank wear land (mm) For 60 m/min	Flank wear land (mm) For 80 m/min
5	0.375	0.575
10	0.525	0.775
15	0.650	1.05
20	0.800	1.30

   ii. Two tools are being considered to achieve higher production rate. The tool life equations are: $VT^{0.1} = 60$ and $VT^{0.16} = 80$. If tool changing time for both the tools was 3 min, which tool should be used? **[4]**

2. In milling operation, a 4-fluted end mill of diameter 75 mm is used to machine a 200 mm wide sidewall on a steel workpiece (See Fig. 1). The axial depth of cut is 80 mm and the radial depth of cut is 5 mm. Recommended maximum uncut chip thickness is 0.2 mm and the cutting velocity is 100 m/min. The length of the end-mill is 200 mm up to clamping point of the tool holder. The specific cutting energy and Young's modulus for the steel are 0.08 W/cm^3/min and 400 kN/mm^2. **[15]**

   i. Calculate the material removal rate and power required for this operation

   ii. Calculate the cutting force. If the radial force is 30% of cutting force find the deflection of the end-mill at the tip.

   Note: The end-mill can be considered as a cantilever with a point load (F) at the end. The deflection of the cantilever is given by $\frac{Fl^3}{3EI}$ where $I = \frac{\pi D^4}{64}$.

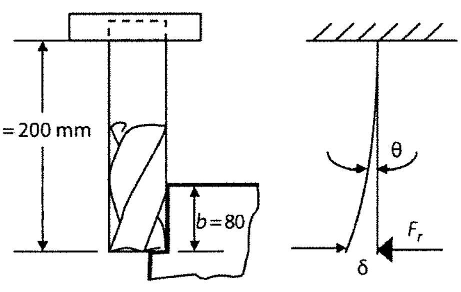

Fig 1: Question 2

3. i. During turning of an alloy steel a carbide tool with a normal rake angle of $-5°$ and side cutting edge angle of $15°$ is used. The force dynamometer reads tangential and axial forces to be 280 N and 130 N, respectively. Calculate radial force, frictional force and coefficient of friction at the chip-tool interface. **[7]**

   ii. Two single point cutting tools P and Q have signatures 5-5-6-6-8-30-0 and 5-5-7-7-8-15-0 (both ASA standard), respectively. They are used to turn components under the same machining conditions. If the feed per revolution is 0.4 mm, what is the uncut chip thickness and peak-to-valley and arithmetic mean surface roughness expected for the tools P and Q? Assume that the tool is mounted such that its axis is perpendicular to the work axis. **[8]**

4. In ultrasonic machining process (see Fig. 2), the average material removal rate (MRR) is calculated using grain hammering model. Use the basic fundamentals to derive the material removal rate given by: **[10]**

$$MRR = K_1 K_2 K_3 (d_g)^{1/4} f \left(\frac{4aF_{avg}}{\pi \sigma_w K_2 (1+\lambda)} \right)^{3/4}$$

F_{avg}: Average force applied by the tool
d_g: Diameter of the abrasive grain
f: Number of cycles per second (frequency)
a: Max. amplitude of the ultrasonic tool
N: Number of impacts per cycle
σ_w, σ_t: Fracture strengths of the workpiece and tool
λ: Ratio of fracture strength of tool to that of workpiece = $\frac{\sigma_w}{\sigma_t}$
K_1, K_2, K_3: Constants
$K_2 = N d_g^2$
K_3: Number of effective abrasive grains below the tool

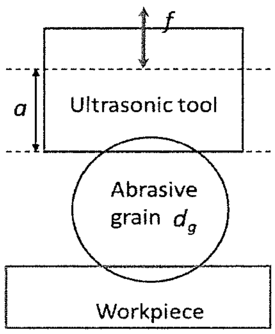

Fig 2: Question 4

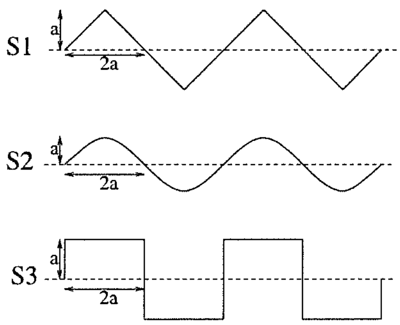

Fig 3: Question 5

5. Evaluate R_a (arithmetic mean roughness) for the three different surfaces shown in Fig. 3 in terms of a. Given that the profile of S2 is sinusoidal. Which of these surfaces is the most preferred for convective heat transfer applications? Give reasons. **[10]**

6. i. How is the cylindricity error different from the run out error? **[2]**

   ii. Cylindrical shafts up to an accuracy of ± 0.05 mm are made by the turning process. An interference fit is designed for a 20 mm nominal size hole. What will be the allowance if the minimum and maximum interferences are 0.04 mm and 0.08 mm, respectively. **[2]**

   iii. Why is low-pressure working environment preferred in electron beam machining? **[2]**

iv. In electric discharge machining (EDM) process, why is the tool erosion lesser than the workpiece erosion under standard polarity? **[2]**

v. Knowing that a spark is generated in EDM process, is it possible to use inflammable dielectrics like kerosene? Justify. **[2]**

7. A glass plate of length 8 mm and thickness 1 mm is to be cut using abrasive jet machining with a jet diameter equal to 1 mm. The workpiece is integrated to a XY CNC stage. SiC particles of size (d_a) 50 μm are used with air as the carrier gas. The abrasive flow rate ($\dot{m}$) is 5 g/min, velocity (v_a) is 200 m/s, density of SiC (ρ_a) is 3.2 gm/cc, flow strength of glass (σ_w) is 3 GPa, glass density (ρ_w) is 2.23 g/cc. Calculate the minimum time required to cut the workpiece along its length in a single pass, and the corresponding velocity of the XY stage. Assume abrasive particles to be spherical in shape. **[15]**
Use the following formulae:
The depth of crater generated by a single abrasive particle of mass m_a is given by: $\delta = \sqrt{\frac{m_a v_a^2}{\pi d_a \sigma_w}}$
The volume of crater generated by a single abrasive particle is given by: $V_c = \frac{1}{2}\pi d_a \delta^2$
Hint: Use the number of particles required to remove the material along the cut and correlate it with mass flow rate and velocity of the stage.

8. Electrochemical machining (ECM) process was used to reduce the diameter of a copper cylindrical rod of radius r. A hollow cylinder made of iron with an internal radius of R ($R > r$) was used as the tool. A potential difference of V was applied between the tool and the workpiece (See Fig. 4). A $NaNO_3$ solution with an electrolytic conductivity, k_e was used. In order to ensure uniform machining, the tool and the workpiece were placed coaxially, submerged in a bath of the electrolyte. Derive an expression for the instantaneous rate of change of the workpiece radius, dr/dt.
Given: Density of copper is ρ_{cu}, gram atomic weight of copper is A (in grams), valency exhibited by copper is n, and Faraday's constant is F. Assume the lengths of the both workpiece and cylinder , $l \gg R$.
Use the following formulae:
Faraday's law: material removal rate, $\dot{m} = \eta\frac{AI}{nF}$, where I is current, and η is current efficiency.
Ohm's law: $J = k_e\frac{\partial\psi}{\partial r}$, where J is current per unit area, ψ is the electric potential.
Laplace equation: $\nabla^2\psi = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial\psi}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2\psi}{\partial\theta^2} + \frac{\partial^2\psi}{\partial z^2} = 0$ **[15]**

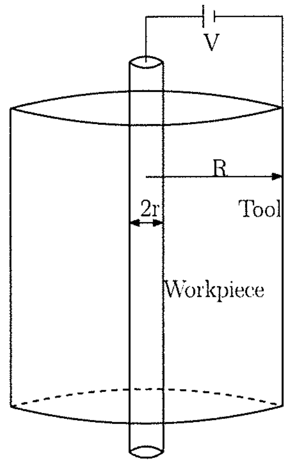

Fig 4: Question 8