PhD Qualifying Exam – July 2022

Manufacturing Processes-II

Maximum marks: 100 Time : 3 hours

- This is an Open Book, Open Notes and No internet Examination. You are expected to follow the instructions provided to you meticulously and submit your answer book accordingly.
- Answer any 5 questions. Each question carries 20 marks
- Make suitable assumptions, if required and mention them.

1. During deformation of material in machining, the shear strain, (γ) is a function of shear angle, ($\emptyset$) and rake angle, (α).
   a. Derive the expression for shear strain in orthogonal machining. [5 Marks]
   b. Find the expression for shear angle as a function of (α) for the minimum shear strain condition. [10 Marks]
   c. Prove that the expression for chip ratio, r, as a function of (α) for minimum shear strain condition is: [5 Marks]

$$r = \frac{\sin\left(\frac{\pi}{4} + \frac{\alpha}{2}\right)}{\cos\left(\frac{\pi}{4} - \frac{\alpha}{2}\right)}$$

2. This question contains two parts: 2a and 2b. Both parts are independent of each other.
   a. For the orthogonal cutting of a particular work material, μ is the coefficient of friction at tool-chip interface and r is the cutting ratio. Assume that rake angle is zero. Show that the ratio of material shear strength (τ_s) to the specific cutting energy (u) is given by: [10 Marks]

$$\frac{\tau_s}{u} = \frac{(1 - \mu\, r)r}{1 + r^2}$$

   b. Surface roughness of the machined cylindrical surface was measured using a line profilometer (see Fig 1). The raw data of the surface heights collected by the profilometer is given in the table below. The X-axis direction is along the direction of travel of the profilometer and Z-axis is normal to surface.

      Based on the data, find

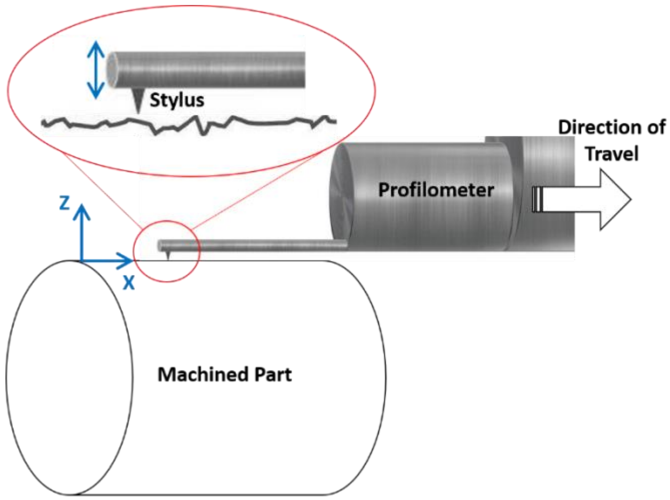
      i. If there is any form error in the raw measurement data. Justify your answer. [2 Marks]

ii. Find arithmetic mean roughness (Ra) of the surface. [4 Marks]

iii. Find surface straightness. [2 Marks]

iv. Comment on an estimate of cylindricity of the machined component. [2 Marks]

Show all the steps and state assumptions, if any.



Profilometer Raw Data

#	X [mm]	Z (Height) [mm]
1	0.00	4.05
2	0.20	4.21
3	0.40	3.58
4	0.60	2.30
5	0.80	2.66
6	1.00	2.17
7	1.20	2.64
8	1.40	1.80

Figure 1 : Question 2b

3. This question contains two parts: 3a and 3b. Both parts are independent of each other.

   a. Design the general type of GO and NOT GO gauges for a 40 mm shaft and hole pair designated as 40 D8/h9, given that: [15 Marks]

      $i = 0.453D^{1/3} + 0.001D$

      40 mm lies in the diameter range of 30-50 mm

      IT8 = 25i and IT9= 40i

      Upper and lower deviations for shafts are given in the table below

      Gauge tolerance = 10% of work tolerance

      Wear allowance = 10% of gauge tolerance

Upper deviation (es)		Lower deviation (ei)	
Shaft designation	In µm (for D in mm)	Shaft designation	In µm (for D in mm)
SHAFTS	$= -(265 + 1.3D)$ for $D \leq 120$	j5–j8	No formula
		(For js two deviations are equal to IT ± 2)	
a	$= -3.5D$ for $D > 120$	k4–k7	$= +0.6\sqrt[3]{D}$
		For grades ≤k3 to ≥k8	= 0
b	$= -(140 + 0.85D)$ for $D \leq 160$	m	= +(IT7 − IT6)
	$= -1.8D$ for $D > 160$	n	$= +5D^{0.34}$
		p	= + IT7 + 0 to 5
c	$= -52D^{0.2}$ for D + IT7 + 0 to 40	r	= Geometric mean of ei values for p and s
	$= -(95 + 0.8D)$ for $D > 40$		= +IT8 + 1 to 4 for $D \leq 50$
d	$= -16D^{0.44}$	s	= +IT7 + $0.4D$ for $D > 50$
e	$= -11D^{0.41}$	t	= +IT7 + $0.63D$
f	$= -5.5D^{0.41}$	u	= +IT7 + D
g	$= -2.5D^{0.34}$	v	= +IT7 + $1.25D$
		x	= +IT7 + $1.6D$
h	= 0	y	= +IT7 + $2D$
		z	= +IT7 + $2.5D$
		za	= +IT8 + $3.15D$
		zb	= +IT9 + $4D$
		zc	= +IT10 + $5D$

b. In deep hole drilling of metals using electrochemical machining, what kind of electrolytes are preferred? Provide an explaination. [5 Marks]

4. A manufacturing plant produces certain parts by drilling a through hole of diameter D at the center of aluminium blocks having a geometry of a cube with an edge length l. The process is carried out at a constant rotational speed of the drill equal to N. Identical drill bits of semi point angle θ and diameter D are used at varying feed rates f (m/rotation). The cost of a drill bit is R, and the labor and overhead charges are L and B per hour, respectively. Once a tool is worn out, it is replaced with a new one. The tool changing time is t_c. The relationship between the tool life t (in minutes) and the cutting parameters is given by the generalised Taylor's equation $vt^n a^p w^q = C$, where v (m/min) is the cutting speed, a is the uncut chip thickness and w is the width of cut. Both a and w are expressed in meters, and C is a constant. Derive an expression for the optimal feed rate (f) for maximum productivity. Assume any missing information and clearly outline the assumptions (if any). [20 Marks]

5. In an ultrasonic finishing operation, a 20 mm diameter titanium tool is used to finish a copper plate. The tool vibrates with a frequency of 20 kHz, at an amplitude of 40 μm (from mean position). An abrasive slurry containing 5 μm SiC particles at a concentration of 40% by volume is used. When the mean gap between the tool and workpiece is 50 μm, it was observed that the indentation per particle is 1 nm and the etch rate of the surface is 10 nm/s. The impact efficiency is observed to be a function of the minimum tool workpiece gap (h_{min}), given by $\beta =$

$\exp\left((\mathrm{d}-\mathrm{h}_{\min})/10\mathrm{d}\right)$, where *d* is the particle diameter. Calculate the etch rate of the surface in (nm/s) if the mean gap is increased to 60 μm. [20 Marks]

Given:

Density— SiC= 3.21 g/cc, Cu=8.96 g/cc, Ti= 4.5 g/cc,

Flow Stress — Cu= 100 MPa, Ti=450 MPa

Hint: Use the grain throwing model of ultrasonic machining

6. This question contains two parts: 6a and 6b. Both parts are independent of each other.

a. Consider a system where certain external events occur at random time intervals (i.e. the time-between-occurrence of these events is a random variable). Let there be two such external events namely E1 and E2, with their time-between-occurrence having Exponential probability density functions as $f_1(t)$ and $f_2(t)$ respectively. The mean time-between-occurrence for E1 and E2 can be taken as 100 hr and 50 hr respectively.
Occurrence of E1 can further trigger two events E3 and E4 with a probability of 0.5 and 0.3 respectively. Occurrence of E2 can further trigger two events E5 and E6 with a of 0.8 (i.e. P[E5|E2] = P[E6|E2] = 0.8) provided E3 or E4 has occurred less than 100 hr before. However, if E3 and E4 have not occurred less than 100 hr before, then the probability values for occurrence of E5 and E6 given that E2 has occurred are 0.3 (i.e. P[E5|E2] = P[E6|E2] = 0.3).
Explain in brief the theory and procedure (with an example and a schematic) behind random number generation using the inverse transform method and write the procedure for Simulating the occurrence of E3, E4, E5 and E6 for a given time period and demonstrate the method for a **single simulation run** for a 1000 hr interval and calculate the occurrence rates of E3, E4, E5 and E6. [10 marks]

b. A process produces units in batches of size 100. Consider an acceptance sampling plan which takes a random sample of size 10 from each batch and if more than 1 defective unit is found in the sample, the entire batch of 100 units will be rejected. Assume that the process producing these units has a defect rate of 10% (i.e. probability of a unit being defective is 0.1) when it is in an 'in-control' state. However, the inspection process used to check the sample is not perfect and has a 0.90 probability of detecting a defective unit (probability of declaring a good unit as defective can be assumed to be zero). At a random instance the process enters an 'out-of-control' state and starts producing 20% defective units.
Explain in detail the procedure for simulating the outcome of a sequence of batches to demonstrate the type 1 (wrongly rejecting a batch from an in-control process) and type 2 error (wrongly accepting a batch from an out-of-control process) for the sampling plan.
Demonstrate the method for one batch each from 'in-control' and 'out-of-control' states.
[10 marks]

7. Consider a $n \times n$ chessboard. The knight is a piece in the game of chess, representing a knight (armored cavalry). The knight move is unusual among chess pieces. When it moves, it can move to a square that is two squares horizontally and one square vertically, or two squares vertically and one square horizontally. The complete move therefore looks like the letter L.
Knight's tour problem involves starting from a given square on a $n \times n$ chessboard and traversing the entire chessboard in n^2 moves such that the knight visits every square exactly once and returns to it's original starting position. A knight's tour is given in the following for an 8×8 chessboard.

Formulate the Knight's Tour problem on an n n chessboard as a linear (integer) program. [20 Marks]

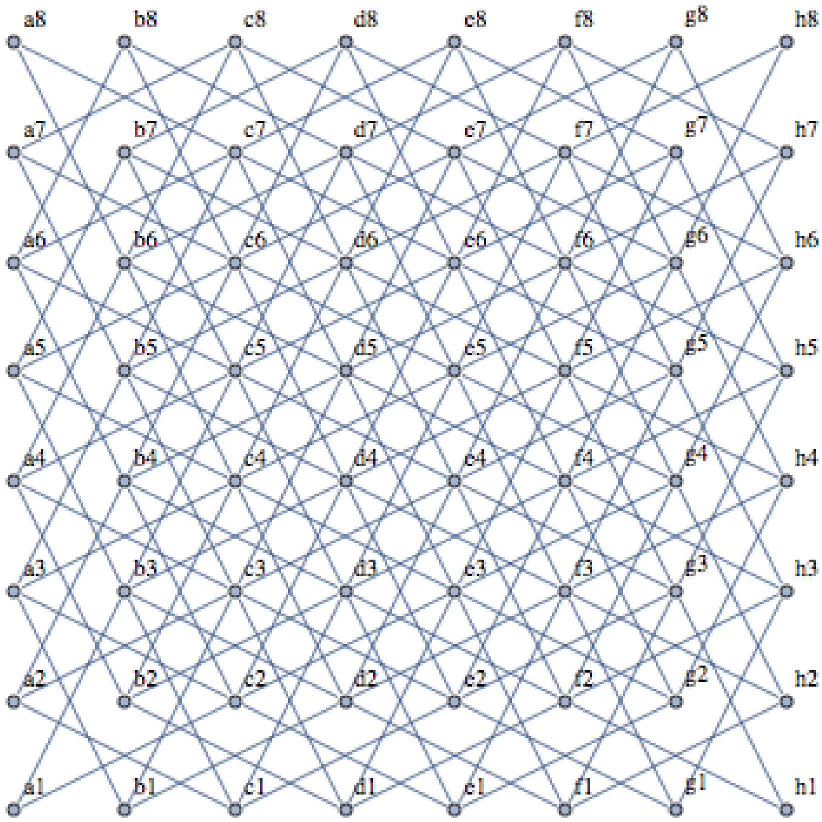


Figure Q7: Knight's tour in 8×8 chess board