**PhD Qualifying Exam – April 2020**

**Manufacturing Processes-II**

Maximum marks: 100 Time: 3 hours

- This is an Open Book Examination. You are expected to follow the instructions provided to you meticulously and submit your answer book accordingly.
- Make suitable assumptions, if required and mention them.
- Answer any 5 questions.
- If you answer more than 5 questions, the best 5 answers (in terms of marks obtained) will be chosen for the final total.

| | | |
|---|---|---|
| 1. | a) A 1 m diameter disc having an 80 mm diameter hole in the center are to be faced on a vertical boring machine with a feed of 0.25 mm/rev and a back engagement (depth of cut) of 5 mm. The machine has an automatic control device by which the cutting speed is continuously adjusted to allow maximum power utilization at the cutting tool of 3 kW. However the maximum rotational frequency of the spindle is limited to 42 rev/min. If the specific cutting energy for the work material is 2.27 GJ/m3 and it takes 600 sec to unload a machined disc, load an un-machined disc and return the tool to the beginning of the cut. Calculate the total time for machining the disc in kiloseconds (ksec). | [12] |
| | b) Show that for orthogonal cutting with a zero rake angle tool ($\alpha = 0^o$), the rate of heat generation $P_s$ in the shear zone is given by $$P_s = F_c V(1-\mu r)$$ Assume all the workdone in the shear plane contributes to heat generation. ($F_c$ = Cutting force, $V$ = Cutting velocity, $\mu$ = coefficient of friction, $r$ = chip thickness ratio) Show all the steps. | [8] |
| 2. | a) Assume that in orthogonal cutting operation, the frictional force, F is given by $F = K\tau_s A_0$ where K is a constant, $\tau_s$ is the material shear strength and $A_0$ can be either (a) uncut chip area; (b) cut chip area. If the rake angle is α and the shear angle is φ, prove that the average coefficient of friction, μ for: If $A_0$ = cut chip area: $\mu = \frac{K\cos^2(\varphi-\alpha)}{1+K\cos(\varphi-\alpha).\sin(\varphi-\alpha)}$ | [10] |

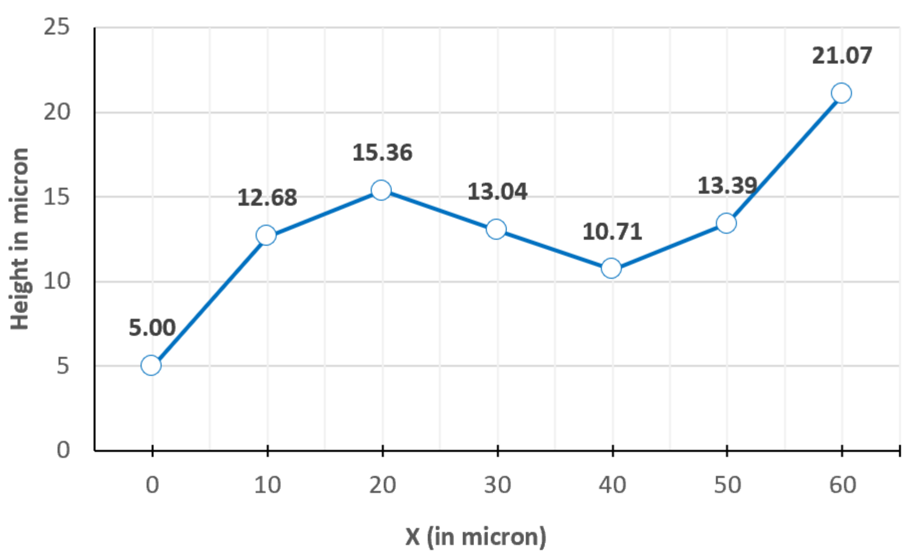
b) From tool-life tests with a disposable-insert carbide tool and carbon steel workpiece, the tool life was found to be 11.6 ksec for a cutting speed of 1 m/sec and 363 sec for a speed of 2 m/sec.

The cost of the insert is INR 400/-, and it has four cutting edges. Indexing time is 10 sec, and insert replacement time is 30 sec.

i) For a machine and labor rate of INR 2000/- per hour, and 100% overheads, what is the tool life for minimum cost? [8]

ii) What cutting speed will give this tool life? [2]

3. a) A profilometer was used to measure the surface roughness of a machined component. The raw data of the surface heights collected by the profilometer are plotted below. X-axis shows the direction along which the data was collected (at intervals of 10 microns), while the Y-axis shows the surface heights. Based on the date, find (a) peak-to-valley roughness, and (b) arithmetic mean roughness (Ra). Show all the steps and assumptions, if any. [10]




b) Evaluate the following for a hold and shaft assembly with nominal diameter of 8 mm, and fit specified as H7g6 [10]

i) tolerances on shaft and hole

ii) maximum material limit of shaft and hole

iii) maximum and minimum clearance for the assembly

iv) allowance for the assembly

v) type of fit (i.e., clearance, interference or transition)

Supporting data:

The various steps specified for the diameter steps are as follows: 1–3, 3–6, 6–10, 10–18, 18–30,

| IT5 | IT6 | IT7 | IT8 | IT9 | IT10 | IT11 | IT12 | IT13 | IT14 | IT15 | IT16 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7i | 10i | 16i | 25i | 40i | 64i | 100i | 160i | 250i | 400i | 640i | 1000i |

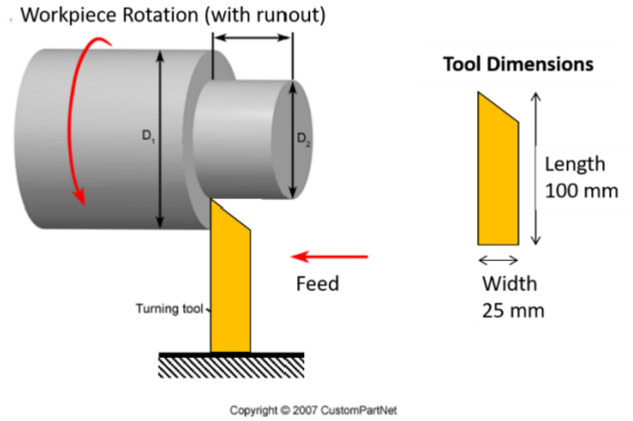
$D = \sqrt{D_{max} \times D_{min}}$ $\quad i = 0.453D^{1/3} + 0.001D \;\; (\mu\text{m})$ , where, D is in mm

| **Upper deviation (es)** | |
|---|---|
| Shaft designation | In μm (for *D* in mm) |
| a | $= -(265 + 1.3D)$ for $D \leq 120$ |
| | $= -3.5D$ for $D > 120$ |
| b | $= -(140 + 0.85D)$ for $D \leq 160$ |
| | $= -1.8D$ for $D > 160$ |
| c | $= -52D^{0.2}$ for D + IT7 + 0 to 40 |
| | $= -(95 + 0.8D)$ for $D > 40$ |
| d | $= -16D^{0.44}$ |
| e | $= -11D^{0.41}$ |
| f | $= -5.5D^{0.41}$ |
| g | $= -2.5D^{0.34}$ |
| h | $= 0$ |

4. a) Turning operation is carried out using a solid HSS tool of dimensions 100 mm x 25 mm x 25 mm (See figure below). The workpiece rotates at 600 RPM and has a runout due to which the tool experiences periodic force in feed direction with an amplitude ($F_0$) of 1000 N. The tool material has density of 8000 Kg/m3 and elastic modulus of 200 GPa. Damping coefficient (‘c’) is 30 Ns/m. [10]

i) What is the vibrational amplitude ($x_0$) of the tool in the feed direction?

ii) What rotational speed must be avoided to prevent the tool vibrations becoming unstable?




(Hint: Assume the force experience by the tool is sinusoidal with frequency same as the rotational frequency of the workpiece. Assume tool to be a rectangular beam fixed at one end. The equation for tool displacement (x) can be written as $m\ddot{x} = F_0 \sin(wt) - c\dot{x} - kx$)

b) In an electrochemical machining process, the tool is grounded and the workpiece is given a pulsed voltage of +*V* (in volts). The pulse on-time and off-time are $t_{on}$ and $t_{off}$, respectively. The workpiece is a thin plate of thickness '*H* '. The initial inter-electrode gap was set to '*d* '. The electrolyte conductivity is '*K*'. Atomic mass of workpiece is '*M*' and its valency is '*Z*'. The machining is performed without giving any feed to the tool or workpiece. Derive an expression for the time required to drill a through hole. Assume current efficiency to be '*h*'. Note: Assume any missing info. Merely writing formulae will not fetch any marks. [10]

5. a) A nanosecond pulsed fiber laser having a wavelength of 1064 nm and a beam diameter of 10 mm is used to drill a through hole on a polycarbonate plate of thickness 1 mm. The laser generated pulses of duration of 20 ns (nanoseconds) and pulse repetition rate of 100 Hz, each having an energy of 1 mJ. Calculate the time required to drill a through hole. [15]

Given that the depth of material removed or ablation depth per pulse (d) can be calculated using the following expression:

$$\delta = \frac{1}{\alpha} ln(F/F_{th}) \qquad \text{(per pulse)}$$

where, a is the absorption coefficient, *F* is the applied laser fluence, and $F_{th}$ is the threshold laser fluence of ablation or the fluence at which material removal starts, below which there will be no material removal. Laser fluence is defined as energy density or energy per unit area (J/m²). For polycarbonate: $\alpha = 1.2 \times 10^6\ m^{-1}$ and $\mathrm{F_{th}} = 10^6\ \mathrm{J/m^{-2}}$

b) A 2 mm titanium plate is cut using wire-EDM process. The wire moves at a speed of 3 mm/s and the kerf width is 0.5 mm. Assume that 70% of the energy generated from the discharge goes into the workpiece. Calculate the power required. State your assumptions clearly. [5]

Properties of Titanium:

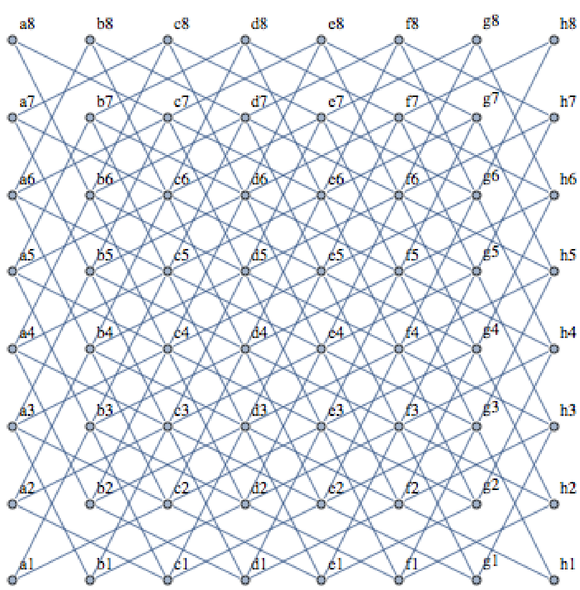
Thermal conductivity = 21.9 W/m-K

Specific heat = 520 J/kg-K

Latent heat of fusion = 295 KJ/kg.

Density = 4.5 g/cc

6. Consider a n x 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. [20]




Knight's Tour in 8 x 8 chessboard

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| | Knight's tour problem involves starting from a given square on a n x n chessboard and traversing the entire chessboard in n*n moves such that the knight visits every square exactly once and returns to the original starting position. A knight's tour is given in the following for an 8 x 8 chessboard.<br><br>Formulate the Knight's Tour problem on an n x n chessboard as a linear (integer) program. (Please clearly write all your parameters, decision variables, objective function and constraints) | |
| 7. | **a)**<br>Consider a time interval *(a, b)* such that the system starts empty and returns to empty.<br>Let $N_{a,b}$ be the number of jobs that arrive to the system during the interval *(a, b)*.<br>Let $T_i^a$ be the arrival time of the $i^{th}$ job and $A(t)$, for $t \geq 0$, be the total number of arrivals during the time interval [0,t]<br>Also let $T_i^d$ be the departure time of the $i^{th}$ job and $D(t)$, for $t \geq 0$, be the total number of departures during the time interval [0,t].<br><br>Using the above terms, derive the Little's law | [5] |
| | Also show how the Constant Work-In-Process (CONWIP) production control mechanism can be implemented for a 3-station serial production line. Consider the following for a steady state condition,<br>Arrival rate (λ) at machine 1 = 10 jobs/hr,<br>Average processing time for machine 1 = 4 min/job,<br>Average process time for machine 2 = 5.5 min/job,<br>Average process time for machine 3 = 4.5 min/job. | [5] |
| | **b)**<br>Consider a component that gets subjected to shock loading. Every time a shock occurs, the amount of damage (wear) caused is a random variable that can be assumed to have an exponential distribution with mean as 0.2 mm.<br>The time between arrivals of shocks is also a random variable and can be assumed to have a Weibull distribution with shape parameter = 1.5 and scale parameter = 500 hr. The component will have to be discarded if the number of shocks exceed 3 or the cumulative wear exceeds 0.5 mm. | |

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| | First, explain the method and the theory behind random number generation using inverse transform and then simulate the arrival of shocks and wear of the component over a period of 1500 hr for just one simulation run to determine if the component would fail during the run. | [7] |
| | If the time between arrivals and wear magnitude are both exponential, write the analytical function to estimate the probability of survival till time ‘t’ | [3] |

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