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B.E. MECHANICAL ENGINEERING FOURTH YEAR FIRST SEMESTER EXAMINATION 2025

METAL CUTTING AND MACHINE TOOLS

Time: 3 Hours Full Marks: 100

Assume any relevant data, if necessary. Symbols in the Question Paper carry their usual meanings. Figures in the margin indicate full marks. All Parts of any one question must be answered together.

Answer the following Questions

1. a) Name different systems used to describe and designate the cutting tool geometry. Draw a single-point turning tool and visualize its different rake angles, clearance angles and cutting edge angle in machine reference or ASA system.
b) Describe, with the help of proper diagrams and deriving simple equations, how the rake angles of single-point turning tool can be converted from ASA system to ORS (orthogonal rake system)
(CO1) 2+8+10=20

OR

2. a) Draw a single-point turning tool and show its different rake angles, clearance angles and cutting edge angles in orthogonal rake system (ORS). State the purposes of tool angle's conversion and name two methods that are used to convert tool angles from one system to another.
b) Determine the values of orthogonal rake angle (γ_0), the inclination angle (λ) of the main cutting edge and the maximum rake angle (γ_m) of the turning tool specified in the ASA system as 10°, −10°, 8°, 6°, 15°, 30°, 0 (inch). (CO1) 8+2+10=20

3. a) State the differences among abrasion wear, adhesion wear and diffusion wear in respect of cutting tool wear. Show schematically and briefly explain the pattern of growth of flank wear (V_B) and crater wear (K_T and K_B) with the progress of machining time.
b) Determine the values of the constant 'C' and the exponent 'n' of Taylor's tool life equation for a cutting condition, if the life of the tool increases from 30 min to 60 min due to reduction of cutting velocity from 200 m/min to 160 m/min. (CO2) (6+4)+10=20

OR

4. a) Explain Taylor's tool life equation and the modified Taylor's tool life equation. State the role of the machining process parameters on tool life.
b) The following equation for tool life is given for a turning operation:
$$V.T^{0.13}.f^{0.77}.d^{0.37}=C$$
A 60 minutes tool life was obtained while cutting at V=30 m/min, f=0.3 mm/rev. & d=2.5 mm. Determine the change in tool life if the cutting speed, feed & depth of cut are increased by 20% individually & also taken together. (CO2) (6+4)+10=20

5. a) Prove that in metal cutting
i) $\xi = \frac{1}{r} = \frac{\cos(\varphi-\alpha)}{\sin\varphi}$
ii) $\varepsilon = \cot\varphi + \tan(\varphi - \alpha)$, where, φ= shear plane angle, α= Rake angle, r= Chip thickness ratio, ξ =chip reduction coefficient, ε=shear strain.
b) During an orthogonal machining operation on mild steel, the results obtained are:
Uncut thickness (t_1)= 0.25mm, Chip thickness (t_2)= 0.75mm, Width of cut (w) = 2.5mm, Rake angle (α)=0^0, Cutting force (F_C)= 950N, Thrust force (F_T)= 475N
i) Determine the coefficient of friction between the tool and the chip.
ii) Determine the ultimate shear stress τ_s of the work material. (CO3) (7+5)+8=20

OR

6. a) Draw a Merchant's circle diagram and derive expressions to show relationships among the different forces acting on the cutting tool and coefficient of friction.

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b) Mild steel is being machined at a cutting speed of 210 m/min with a tool of rake angle 10^0 The width of cut and uncut chip thickness are 3 mm and 0.2 mm respectively. If the average value of coefficient of friction between the tool and the chip is 0.5 and shear stress 400 N/mm^2. Determine: i) The shear angle, ii) Cutting and thrust components of machining force. Use Merchant's first solution. (CO3) 10+10=20

7. a) Classify types of machine tool kinematic structures and explain their basic differences using suitable block diagrams.
b) Illustrate with examples the difference between
i) stepped drive and stepless drive.
ii) positive drive and non-positive drive in respect of machine tools.
c) A drilling machine having nine spindle speeds in GP is to be designed for drilling holes of diameter in between 6 mm and 30 mm at cutting velocity in between 20 m/min and 50 m/min. Determine the standard values of all those nine spindle speeds. (CO4) 6+4+10=20

OR

8. a) Why are centre lathes provided with large number of spindle speeds?
b) Design a speed gear box for a Centre Lathe requiring six spindle speeds with common ratio φ=1.25 ($\cong 2^{1/3}$) The design of the gear box should include i) drawing the gearing diagrams, ii) Ray diagram, iii) number of teeth of all the gears. (CO4) 4+16=20

9. a) Describe briefly the basic working principle of numerical control of machine tools. State the functions of DPU (data processing unit) and CLU (control loop unit) of numerical control system of machine tools.
b) Distinguish between point to point and continuous path system.
c) The worktable of a positioning system is driven by a ball screw whose pitch =6.0mm. The screw is connected to the output shaft of a stepper motor through a gearbox whose ratio is 5:1. (five turns of the motor to one turn of the screw). The stepper motor has 48 step angles. The table must move a distance of 250 mm from its present position at a linear velocity = 500 mm/min. Determine i) how many pulses are required to move the table the specified distance, ii) the required motor speed and pulse rate to achieve the desired table velocity. (CO5) (3+3)+4+10=20

OR

10. a) State the advantages of CNC machine tools over NC machine tools. Why re-circulating screws are used in CNC machines?
b) Three through holes of 16 mm diameter are to be drilled in a 10 mm thick steel plate as shown in Fig.1. The left bottom corner (point A) of the pre-machined plate or any other suitable point may be taken as the reference point in XY plane. Write a part program considering all dimensions in mm. (G and M codes are given in Table 1). (CO5) (5+3)+12=20

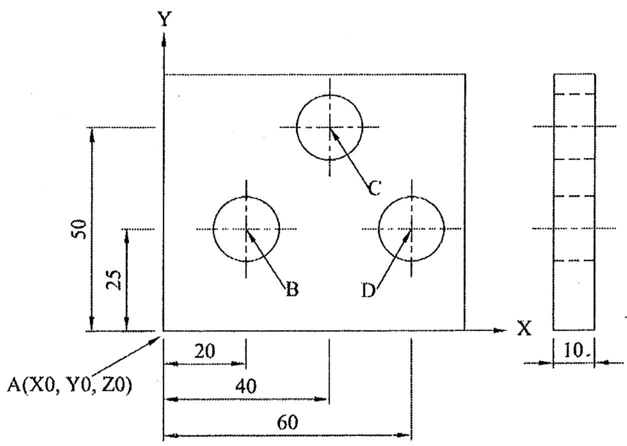

Fig.1 A plate to be drilled in CNC Drilling Machine

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Table 1: ISO Standard G Codes and M Codes

G-codes for preparatory functions

G00 - Point-to-point positioning, rapid traverse
G01 - Linear interpolation
G02 - Circular interpolation, clockwise (CW)
G03 - Circular interpolation, anti-clockwise (CCW)
G04 - Dwell
G05 - Hold/delay
G06 - Parabolic interpolation
G08 - Acceleration of feed rate
G09 - Deceleration of feed rate
G10 - Linear interpolation for 'long dimensions' (10–100 inches)
G11 - Linear interpolation for 'short dimensions' (up to 10 inches)
G17 - XY plane designation
G18 - ZX plane designation
G19 - YZ plane designation
G20 - Circular interpolation, CW for 'long dimensions'
G21 - Circular interpolation, CW for 'short dimensions'
G30 - Circular interpolation, CCW for 'long dimensions'
G31 - Circular interpolation, CCW for 'short dimensions'
G33 - Thread cutting, constant lead
G34 - Thread cutting, linearly increasing lead
G35 - Thread cutting, linearly decreasing lead
G40 - Cutter compensation – cancels to zero
G41 - Cutter radius compensation – offset left
G42 - Cutter radius compensation – offset right
G43 - Cutter compensation – positive
G44 - Cutter compensation – negative
G53 - Deletion of zero offset
G54–G59 - Datum point/zero shift
G60 - Target value, positioning tolerance 1
G61 - Target value, positioning tolerance 2, or loop cycle
G62 - Rapid traverse positioning
G63 - Tapping cycle
G64 - Change in feed rate or speed
G70 - Dimensioning in inch units
G71 - Dimensioning in metric units
G80 - Canned cycle cancelled
G81–G89 - Canned drilling and boring cycles
G90 - Specifies absolute input dimensions
G91 - Specifies incremental input dimensions
G92 - Programmed reference point shift
G94 - Feed rate/min (inch units when combined with G70)
G95 - Feed rate/rev (metric units when combined with G710)
G96 - Spindle feed rate for constant surface feed
G97 - Spindle speed in revolutions per minute

M-codes for miscellaneous functions

M00 - Program stop, spindle and coolant off
M01 - Optional programmable stop
M02 - End of program – often interchangeable with M30
M03 - Spindle on, CW
M04 - Spindle on, CCW
M05 - Spindle stop
M06 - Tool change
M07 - Coolant supply No. 1 on
M08 - Coolant supply No. 2 on
M09 - Coolant off
M10 - Clamp
M11 - Unclamp
M13 - Spindle on, CW + coolant on
M14 - Spindle on, CCW + coolant on
M15 - Rapid traverse in + direction
M16 - Rapid traverse in – direction
M19 - Spindle stop at specified angular position
M30 - End of Program, Machine stop, Rewind tape (on tape controlled machine)
M31 - Interlock by-pass
M32–M35 - Constant cutting velocity
M40–M45 - Gear change; otherwise unassigned
M50 - Coolant supply No. 3 on
M51 - Coolant supply No. 4 on
M55 - Linear cutter offset No.1 shift
M56 - Linear cutter offset No.2 shift
M60 - Piece part change
M61 - Linear piece part shift, location 1
M62 - Linear piece part shift, location 2
M68 - Clamp piece part
M69 - Unclamp piece part
M71 - Angular piece part shift, location 1
M72 - Angular piece part shift, location 2
M78 - Clamp non-activated machine bed-ways
M79 - Unclamp non-activated machine bed-ways