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| Benha  University | Faculty of Engineering | | | |
| Mechanical Engineering Dept. (Manufacturing Div.) | | 3rd Year | |
| M 1371 | **Theory of Metal Cutting** |  | |
| Instructor: | Dr. Ashraf Hassan  Training Building, Room # 404 | | Facebook:BHIT M481 Manufacturing Technology |

**SHEET No (1)**

**CUTTING TOOL MATERIALS**

1. Discuss the requirements of cutting tool materials. (P.9)
2. Discuss ferrous tool materials concerning: chemical composition, applications, cutting speeds used and temperatures allowed.
3. Discuss non-ferrous tool materials concerning: chemical composition, applications, cutting speeds used and temperatures allowed.
4. State the advantages of ceramic tool materials. (P.19-20)
5. State the disadvantages of ceramic tool materials.
6. Classify sintered carbide tool materials giving examples of each. (P.16)
7. Compare between the following tool materials:
8. High speed steel
9. sintered carbide
10. satellites
11. ceramics
12. diamond

Concerning:

1. chemical composition
2. applications
3. cutting speeds used
4. temperatures allowed

**Sheet No (2)**

**Mechanics of machining operations**

1. What effect has the undeformed chip thickness on the specific cutting energy? Show your answer on a graph stating the reason. (P.32-33)
2. Discuss the different types of chip. (P.28)
3. Derive the equation for the normal force acting at the chip/tool interface (10th wk 2004)
4. Discuss the theory of Lee and Schaffer with a neat sketch. (P.42).
5. Derive an expression for the specific cutting energy ps in terms of the shear angle φ and the mean shear strength of the work material τs in orthogonal cutting. Assume that the shear angle relationship of ernest and merchant applies, i.e.,

2φ + β – γne = π /2

1. In an orthogonal turning operation the resultant cutting force, was 200 Kg. If the cutting force is 120 Kg and the rake angle, γ=15°, the cutting ratio, r = 0.6, calculate: the normal force Ft , the shear angle and draw a circular force diagram and derive the equation of friction force Ff. (2.b Jan 2005)
2. In an orthogonal turning operation of a steel tube of outside diameter 66 mm and inside diameter 60 mm using HSS tool having 15° rake angle, the feed rate used is 0.2 mm/rev and the cutting speed is 36 m/min., the chip thickness is 0.6 mm. If the shear stress of steel is 600 MN/m2 and the relationship between the shear angle (φ), the mean friction angle at tool chip interface (β) and the rake angle (α) is in the following form: φ + β – α = π/4. Determine: (2. Jan 2006 )

(a) The cutting and thrust components of the resultant cutting force.

(b) The motor power in KW if the efficiency of the lathe used is 70% [no 20 sheet M. Riad].

1. In an orthogonal cutting test on mild steel the following results were obtained:

ac = 0.25 mm Fc = 900 N

a0 = 0.75 mm Ft = 450 N

aw = 2.5 mm γne = 0

lf = 0.5 mm

Calculate:

(a) The mean angle of friction on the tool face β.

(b) The mean shear strength of the work material τs, in meganewtons per square meter (MN/m2).

(c) The mean frictional stress on the tool face τf, in meganewtons per square meter (MN/m2).

1. In an orthogonal cutting test the following conditions were noted:

Width of chip (width of cut) = 2.5 mm.

Working normal rake = -50.

Undeformed chip thickness = 0.25 mm.

Cutting force = 900 N.

Chip thickness = 1.0 mm.

Thrust force = 900 N calculate:

(a) The shear angle.

(b) The mean shear strength of the work material in meganewton per square meter (MN/m2).

1. In an orthogonal cutting operation the following data were available: (10th wk 2004)

Material: medium carbon steel

Main cutting force: 120 Kg

rake angle, γ=15°

depth of cut = 0.4 mm

cutting speed: 20 m/min

thrust force: 60 Kg

chip thickness= 0.6 mm

w.p. diameter: 80mm

Calculate:

1. friction force,
2. the length of the shear plane,
3. w.p. rotational speed,
4. the shear angle
5. shear force
6. the cutting ratio,
7. the resultant cutting force
8. Draw Merchant Circle of forces.
9. In an orthogonal turning operation the following data were calculated: [no 2 sheet M. Riad]

Main cutting force: 1130 N

rake angle, γ=10°

cutting speed: 150 m/min

chip thickness= 0.45 mm

feed = 0.25 mm/rev

thrust force: 295 N

width of cut = 2.5 mm

Calculate:

1. friction force,
2. velocity of the chip along tool face,
3. the shear angle
4. shear stress
5. the cutting ratio,
6. specific cutting energy
7. During machining of a medium carbon steel with a 10 deg rake angle cutting tool, the following observations have been made: [no 3 sheet M. Riad]

Main cutting force: 1600 N

depth of cut = 2 mm

cutting speed = 200 m/min

chip thickness= 0.4 mm

feed = 0.25 mm/rev

thrust force: 850 N

Calculate:

1. shear force
2. normal force on the shear plane,
3. friction force
4. normal force on the tool face
5. specific cutting energy
6. In an orthogonal turning operation of a tube the following data were given: [no 5 sheet M. Riad]

main cutting force = 1850 N

rake angle, γ=10°

rotational speed = 210 rpm

tube inside diameter = 67 mm

feed = 0.25 mm/rev

thrust force = 1150 N

tube outside diameter= 73 mm

length of continuous chip for one revolution of workpiece= 88 mm

Calculate:

1. friction force,
2. the shear angle
3. shear stress
4. the cutting ratio,
5. specific cutting energy
6. The diameter of a bar was reduced from 70 mm to 67 mm by means of a tool having a rake angle of 10.5°. The process was performed under orthogonal cutting conditions with spindle speed of 500 rpm, and 0.3 mm/rev feed. The chip thickness ratio was found to be 0.4. Calculate the friction energy and find the coefficient of friction between the chip and the rake face of the tool, and compare its value with the results obtained when using Merchant theory and Lee and Schaffer theory. The shear stress of the machined material is 780 MN/m2, while its specific cutting energy is 3000 MN/m2. [no 8 sheet M. Riad]
7. A planer tool has a rake angle of 11° is set to operate with a depth of cut 1.2 mm and cutting speed of 15 m/min. The chip is 6 mm wide and thickness of chip after cutting is 4.45 mm. If the material being cut is Killed steel having a shear strength of 520 MN/m2, and the coefficient of friction is found to be 0.94. Determine the amperes of the lead wires to the motor, knowing that the efficiency of the motor is 85% and that of planer 70% and the voltage is 380 V. [no 9 sheet M. Riad]
8. A tube of 75 mm outside diameter, 65 mm inside diameter is face turned on a lathe, rake angle of 15°. Length of continuous chip for one revolution of workpiece= 71 mm, feed=0.2 mm/rev, tangential component of cutting force =1130 N, Axial component of cutting force =760 N ( as measured by force dynamometer). Calculate coefficient of friction, friction angle and shear angle. [no 10 sheet M. Riad]
9. In orthogonal turning operation, the following data were given: tube outside diameter=93 mm, inside diameter=87 mm, mean shear strength=700 MN/m2, rake angle of 10°. Spindle speed= 150 rpm, mean chip thickness=0.5 mm, volume of chip for one revolution of workpiece= 2.2 mm3. Assume that the shear angle relationship of Ernest & Merchant applies, Calculate [no 14 sheet M. Riad]
10. Coefficient of friction,
11. Machining time of 200 mm length
12. shear strain
13. specific cutting energy
14. A lathe running idle consumes 325 W. When cutting an alloy steel at 24 m/min the power input raises to 2580 W. Find the cutting force, the torque at the spindle speed of 1200 rpm. Calculate the efficiency of the lathe at such conditions. [no 16 sheet M. Riad]
15. The power required to turn medium carbon steel is around 3.8 J/mm3. If the maximum power at the machine spindle is 3.75 KW. Find the maximum rate of metal removal, also find for the cutting speed of 40 m/min, and feed rate of 0.25 mm/rev, the deph of cut and cutting force which will occur when the metal removal is at the maximum value. [no 18 sheet M. Riad]
16. In facing a tubular workpiece of a steel material on a lathe the following data were available: [no 19 sheet M. Riad]

rake angle, γ=15°

feed rate = 0.25 mm/rev

cutting speed: 78 m/min

chip thickness= 0.75 mm

mean coefficient of friction=0.8

outer diameter = 66mm

inner diameter = 60mm

shear flow strength of material=600 MN/m2

Calculate:

1. Specific power consumption
2. The motor power if the friction at the machine elements consumes 40% of the power input.
3. the thrust force,
4. the cutting force

**SHEET (3)**

**Temperatures in metal cutting**

1. Draw typical temperature contours in a cutting tool and show the effect of coolants on these contours. (P.105)
2. State the advantages and disadvantages of cutting fluids. (P.104)
3. It was found from experiments where the chips produced during shaping of mild steel that the cutting conditions were as follows:

cutting speed = 1 m/s.

undeformed chip thickness = 0.5 mm.

width of chip = 5 mm.

working normal rake = 450.

cutting force = 6000 N.

thrust force = 0.

chip thickness = 1.2 mm.

width of cut aw = 2.5 mm

length of contact between chip and tool lf = 0.75 mm

thermal conductivity = 43.6 J/s m °K

specific heat capacity = 502 J/Kg °K

density = 7200 Kg/m3 & w.p. room temperature = 22 °C

width of sec deformation zone / chip thickness w0 = 0.2.

Calculate the max temperature along the tool face

1. Show that, when cutting metal orthogonally with a tool of zero rake angle, the rate of heat generation, ps, in the shear zone is given by:

ps = Fc v (1-μrc)

where

Fc = cutting force

v = cutting speed

μ = mean coefficient of friction on the tool face.

rc = cutting ratio

* + 1. For the same conditions, calculate the mean shear-zone temperature rise θs when the metal has a specific cutting energy of 2.8 GN/m2, μ = 1.0, rc = 0.2, and 10 percent of the shear zone heat is conducted into the workpiece. Assume, for the work material, that ρ = 7200 kg/m3 and c= 500 J/kgK
    2. What would be the value of θs if the cutting speed were doubled and the proportion of shear-zone heat conducted into the workpiece remained the same?

1. In an orthogonal turning operation, a solid bar of 40 mm is required to be reduced to 33 mm using a feed of 0.2 mm/rev and a spindle speed of 504 rpm. The following data are relevant:(3 Jan 2005)

cutting force = 1500 N

cutting ratio = 0.4

thermal conductivity= 58 J/sm °K

density = 7800 Kg/m3

contact length = 0.9 mm

width of cut = 2.5 mm

thrust force = 700 N

rake angle = 8°

specific heat = 570 J/Kg. °K

room temperature = 25 °C

sticking length= 0.6 mm (no use)

w0 = 0.2

Calculate the maximum temperature along the rake face.

**Sheet No (4)**

**Tool life**

1. Show with the aid of a neat sketch the effect of the clearance angle on tool wear. (P.22)
2. In a repeated use of a twist drill for drilling brass alloy, the tool life, estimated in time units, was found to be 30 min at cutting speed, V=20 m/min. What will be the speed that attains a tool life of 45 min, the constant n = 0.2. (2. Jan 2006 )
3. A single point cutting tool has a rake angle equal to zero and a clearance angle of 20. By what percentage would the life of the tool between regrinds be increased if a clearance angle of 80 were provided? (Assume the tool is reground after a specified amount of flank wear has taken place and the rate of wear of the tool normal to the wear land is constant).
4. Given the following data for a cutting process: (2. Jan 2005 )

|  |  |  |  |
| --- | --- | --- | --- |
| V (m/min) | 731 | 642 | 514 |
| T (min) | 20 | 30 | 60 |

Compute the C and n values for Taylor tool life equation and calculate the tool life in minutes for a cutting speed of 580 m/min.

**Sheet No (5)**

**Surface roughness**

1. Discuss the factors affecting machinability of metals and alloys. (P.25)
2. Mention the factors that contribute to the natural surface roughness. (P.203)
3. A turning tool with a sharp corner and a major cutting edge angle of 600 is to be used at a feed of 0.05 mm, what minor edge angle should be provided to obtain an arithmetical mean? Surface roughness under ideal conditions of 3 μm?
4. What corner radius should be ground on a tool with a rounded corner to give an arithmetical mean surface roughness of 10 μm when turning under ideal conditions with a feed of 0.25 mm?
5. A 150-mm-diameter slab-milling cutter has 10 teeth and is used at a feed speed of 1.5 mm/s. Estimate the "ideal" arithmetical mean surface roughness when the rotational frequency of the cutter is 3s-1.

**Sheet No (6)**

**Economics of machining operations**

1. A batch of 1000 components is to be rough-turned to 80 mm diameter for 300 mm of their length using a feed of 0.25 mm per revolution. The Taylor tool-life equation for the particular carbide tool-workpiece combination was found by experiment, to be:

vt 0.25 = 28

where v is the cutting speed, in meters per second (m/s) and t is the tool life, in seconds (s). If the cost per cutting edge for the particular throw-away type insert tool is $0.50 (including the tool depreciation and cost of resetting the cutting edge) and the total machine rate, including operator costs, is $8.00 /hr, calculate:

1. the tool life, in seconds, to give minimum production costs.
2. the cutting speed, in meters per second, that will result in this optimum tool life.
3. the total production time in kilo seconds, assuming that the time taken to load and unload a component is 1 min, that the time taken to reset a cutting edge is 30 s, and that the initial set-up time for the batch is 1 hr.
4. the total production cost, in dollars (LECT 0)
5. A tool used in a turning operation is of the brazed-carbide-tip type. Its cost is $10.00, and on the average it can be reground ten times. The cost of regrinding is $1.00. The lathe cost $20000 and is used for 8 hr per day, 5 days per week, 50 weeks per year. Its cost is to be amortized over 10 years, and the machine overheads are 100 percent. The operator's wage is $5.00 /hr, and operator overheads are 100 percent. The relation between cutting speed and tool life for the conditions employed is:

vt 0.25 = 28

Where v is the cutting speed, in meters per second (m/s), and the tool life, in seconds (s).

The tool changing time is 4 min, and the handling time per component is 5 min. The cutting distance per component is 200 m. Calculate:

1. The minimum production cost, in dollars ($).
2. The minimum production time, in seconds (s).
3. For the conditions of prob.2 calculate the tool life, in seconds (s), and cutting speed, in meters per second (m/s), for maximum rate of profit and the corresponding production cost and production time. (Assume that the machine shop receives $4.00 for each component.)
4. For single-shift working in particular turning operation, the cost of the labor and machine time in resetting a cutting edge is $0.20, the cost of each throw-away insert having four cutting edges is $0.80, and the depreciation of the insert holder per insert is $0.08. The initial cost of the lathe was $20000, which is amortized for 5 years. Machine running costs including labor and overheads but neglecting depreciation are estimated at $6.00 /hr. If the Taylor tool-life index for the carbide inserts is 0.25, calculate, for minimum second (m/s), if the machine is to be used on a:

* Single-shift, 40 hr/wk basis
* Double-shift, 80 hr/wk basis

Assume 50 working weeks per year, a cutting speed for 60 s tool life of 7.6 m/s, and a nonproductive time for loading and unloading a component of 3 min