PART A (ANSWER ALL QUESTIONS)

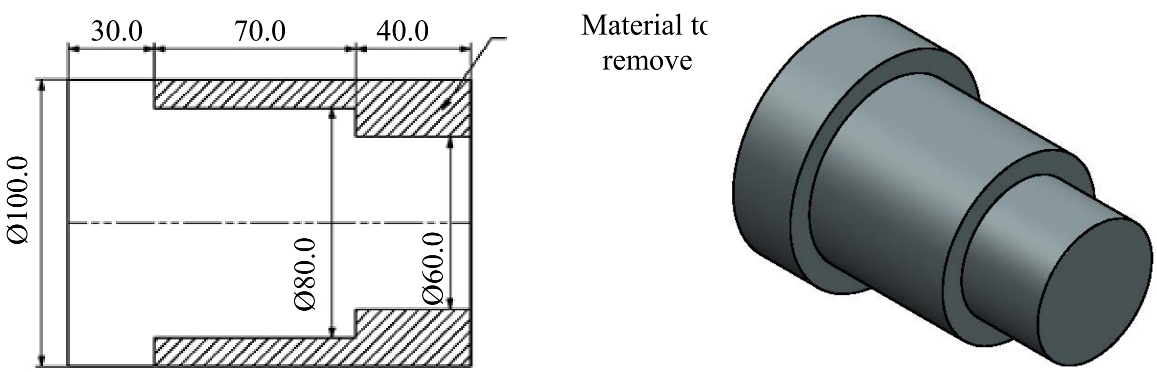
QUESTION 1 (20 MARKS)

A. Component shown in Figure Q1A will be machined using a lathe machine with two (2) steps. The first step of these components will be machined along 110.0 mm (70.0 mm + 40.0 mm) to reduce the diameter of Ø100.0 mm to Ø80.0 mm. The second (2) step is to reduce the size of the diameter of Ø80.0 mm to Ø60.0 mm with a length of 40.0 mm. Calculate cutting time for the entire machining process using cutting conditions included:

Given:

i. Cutting Speed = 80.0 m/min
ii. Feed rate = 0.8 mm/rev
iii. Depth of Cut = 2.0 mm/passes

(6 marks)



(a) Detail dimension

(b) Final product

Figure Q1A: Detail dimension and Final Product

Solution:

Given:

i. V = 80.0 m/min
ii. *f* = 0.8 mm/rev
iii. DOC = 2.0 mm/passes

The turning will be done in 2 steps. In first step a length of (70 + 40) = 110 mm will be reduced from Ø100 mm to Ø80 mm and in second step a length of 40 mm will be reduced from Ø80 mm to Ø60 mm.

STEP 1: To turn from Ø100 mm to Ø80 mm, for 110 mm long.

$$N = \frac{1000 \times V}{\pi \times D} = \frac{1000 \times 80}{\pi \times 100} = 255 \text{ RPM}$$

$$\text{Number of passes} = \frac{\text{Depth of material to be removed}}{\text{Depth of Cut}} = \frac{100 - 80}{2 \times 2} = 5$$

Time required $= \frac{L}{f \times N} \times 5 = \frac{110 \times 5}{0.8 \times 255}$ = 2.7 min

STEP 2: To turn from Ø80 mm to Ø60 mm, for 40 mm long.

$N = \frac{1000 \times V}{\pi \times D} = \frac{1000 \times 80}{\pi \times 80}$ = 318 RPM

Number of passes $= \frac{\text{Depth of material to be removed}}{\text{Depth of Cut}} = \frac{80 - 60}{2 \times 2}$ = 5

Time required $= \frac{L}{f \times N} \times 5 = \frac{40 \times 5}{0.8 \times 318}$ = 0.79 min

Total Time = 2.7 + 0.79 = 3.48 minit.

B. A cylindrical riser is to be designed for a sand casting mold. The height of the cylinder is to be 1.25 times its diameter. The casting is a steel rectangular plate with dimensions 15.0 cm x 25.0 cm x 4.0 cm. If the metal is cast iron, and the mold constant = 3.26 min/cm^2, determine the dimensions (height and diameter) of the riser so that it will take 30% longer for the riser to solidify. The Figure Q1B below shown the sand casting mold.

(8 marks)

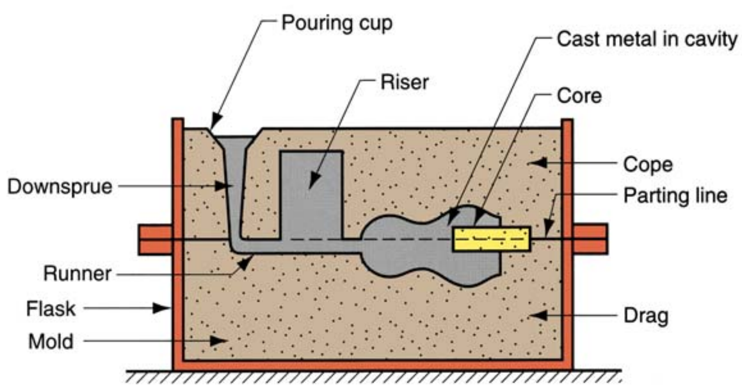


Figure Q1B: Sand casting mold.

SOLUTION:

PRODUCT:

Casting Volume (V) = W x L x T = 15 x 25 x 4 = 1500 cm^3

Casting area (A) = 2(W x L) + 2(W x T) + 2(T x L)
= 2(15 x 25) + 2(15 x 4) + 2(25 x 4) = 1070 cm^2

(V/A) = 1500/1070 = 1.4

Casting solidification time T_{TS} = 3.26 (1.4)^2 = 6.41 min

RISER:

Riser solidification time T_{TS} = 1.3 (6.41) = 8.33 min

Riser Volume (V) = $\frac{\pi D^2}{4}$ x H = $\frac{\pi D^2}{4}$ x 1.25D = 0.3125 πD^3

Riser area (A) = $\frac{2\pi D^2}{4}$ + πDH = 0.5πD^2 + 1.25πD^2 = 1.75 πD^2

(V/A) = 0.3125 πD^3 / 1.75 πD^2 = 0.1786 D

Riser solidification time T_{TS} = 3.26 $(0.1786D)^2$ = 8.33 min

3.26 $(0.1786D)^2$ = 8.33 min

D = **9.0 cm**

H = 1.25 x 9.0
= **11.2 cm**

C. A blanking operation is to be performed on 3.5 mm thick Cold Rolled Steel with allowance, 0.075. The part is circular with diameter, 100 mm.

Determine:

iv. The appropriate punch and die sizes for this operation.
v. The blanking force required if the steel has a shear strength = 325 MPa and the tensile strength = 450 MPa.

(6 marks)

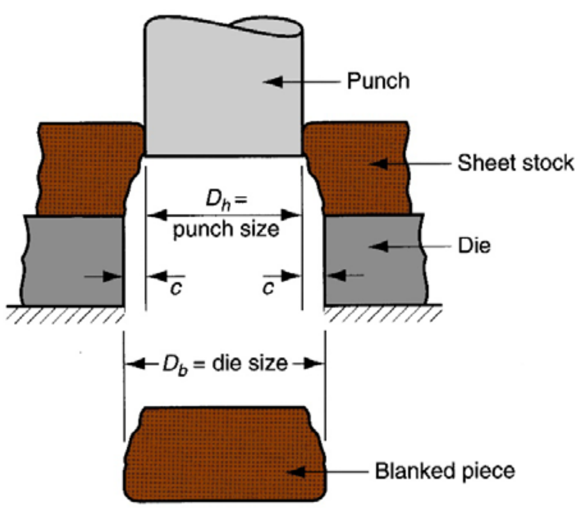


Figure Q1C: Schematic diagram of the die and punch for shearing and blanking process.

SOLUTION:

Given:

i. Thickness (t) = 3.5mm
ii. Allowance (a) = 0.075 (Cold Rolled Steel)
iii. Part Size (D) = Ø100 mm
iv. Shear strength = 325 MPa
v. Tensile strength = 450 MPa.

- Clearance can be calculated by:

  $c = at$

  $c = 0.075 \times 3.5$

  $c = 0.2625$ mm

  - Know *blank* of diameter D_b = Die diameter = **Ø100 mm**

  - Blanking punch diameter, $D_h = D_b - 2c$

    $D_h = 100 - 2(0.2625)$

    $D_h =$ **99.48 mm**

- Cutting Forces: (Shearing process)

  $F = \tau\, t\, \ell$

  $F = 325 \times 3.5 \times \pi\,(100)$

  F= 357,356 N

QUESTION 2 (20 MARKS)

A. Define what is sustainable manufacturing?

(4 marks)

Answer:

Sustainable manufacturing is defined as the creation of manufacturing products that us materials and processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound

Or similar answer/terminology

B. In the hierarchy of recycling, differentiate what is meant by; (i) Reuse, (ii) Recycle, and (iii) Reduce. Gives **ONE (1)** example on how the application of (i), (ii), and (iii).

(6 marks)

Answer:

Reuse - Item then can be used again within the safe use period such as plastic bottle, plastic food container; Items that can be used over and over such as glass bottle, used clothings, for same purpose or use the m somewhere else,

Recycle - Items that can be collected to the recycling center, sorted and process as become raw material; ie, plastic bottles, metals, glass etc:

Reduce – Item amounts, quantity or cost that can be reduced by using methods and responsibility. Parts that can be done by metal forming are using less material compare to machining, etc..(for example).

C. Describe **THREE (3)** reasons why manufacturers have to pay more attention to sustainable manufacturing issues in the design and production of new products.

(3 marks)

Answer:

Sustainability is the driver for innovation. Innovation promotes accelerated growth in manufacturing. Manufacturing is the engine for wealth generation and societal well-being. Product design shall include innovation in using recycle resources or reuse materials that it could be relatively high production cost saving. many percent

D. Discuss the possible target of sustainable manufacturing goals and the strategies to green manufacturing implemented in automotive manufacturing companies. You may discuss based on the approach that is achievable by these companies.

(7 marks)

Answer:
Sustainable manufacturing based on 6R

- Light materials/hybrid materials used, design fuel saving engine, redesign, electric/hybrid automobile concept
- Integrate digital product and process models throughout the product life cycle to ensure the success of the model based enterprise
- Green manufacturing based on 3R

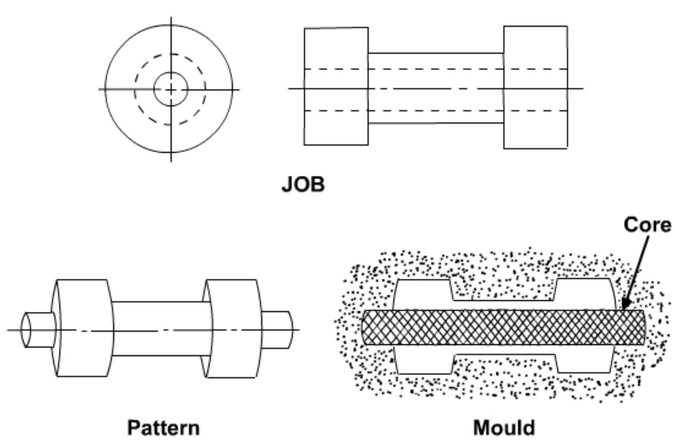
QUESTION 3 (20 MARKS)

A. With the aid of sketches, explain what is meant by core and "core print" and then explain the function of each of them.

(4 marks)

Answer:
SKETCH core (1 mark), SKETCH core print (1 mark)
Castings are often required to have holes, recesses, etc. of various sizes and shapes. These impressions can be obtained by using cores. So where coring is required, provision should be made to support the core inside the mold cavity. Core prints are used to serve this purpose. The core print is an added projection on the pattern and it forms a seat in the mold on which the sand core rests during pouring of the mold. The core print must be of adequate size and shape so that it can support the weight of the core during the casting operation. Depending upon the requirement a core can be placed horizontal, vertical and can be hanged inside the mold cavity. A typical job, its pattern and the mold cavity with core and core print is shown

(1 mark each for description about core and core print)



B. Describe **THREE (3)** desirable mould properties and characteristics for sand casting.

(3 marks)

Answer:

i. *Strength* - to maintain shape and resist erosion
ii. *Permeability* - to allow hot air and gases to pass through voids in sand
iii. *Thermal stability* - to resist cracking on contact with molten metal
iv. *Collapsibility* - ability to give way and allow casting to shrink without cracking the casting

(1 mark each, ½ mark if no description)

C. Table Q3A below shows three (3) different products, each of them are produced by different casting processes. Based on the process characteristics given;
[Note: You may choose only **ONE (1)** product]

i. Name an appropriate casting process for producing the chosen product
ii. Give **ONE (1)** logical reason on why the casting process is chosen
iii. With the aid of sketches, explain the principles of the chosen casting operation
iv. Describe the steps of pattern making in order to produce the chosen products

(7 marks)

Table Q3A: Metal casting products and process characteristics

Product	Characteristic
 (a) Crankshaft	i. Most widely used casting process, accounting for a significant majority of total tonnage cast ii. Parts ranging in size from small to very large
 (b) Impeller	i. It is a precision casting process - capable of castings of high accuracy and intricate detail. ii. The pattern assembly called a 'tree.'
 (c) Exhaust manifold	i. The patterns are made in a dry unbounded sand ii. Uses a mold of sand packed around a type of material, which vaporizes when molten metal is poured into the mold.

Answer:

Selection of process should be based on the given process characteristics

Product A

(i) Sand Casting (1 mark)

(ii) Any reason/advantages relate with sand casting (1 mark)

(iii) SKETCH (1 mark)

- There are seven basic steps in making sand castings:
    i. Obtaining the casting geometry
    ii. Pattern-making
    iii. Core-making
    iv. Molding
    v. Melting and pouring
    vi. Cleaning & inspection
    vii. Heat treatment & post processing
- Description about the process of sand casting

(2 marks)

(iv) - The mold is made by packing some readily formed aggregate material, such as molding sand, around the pattern. When the pattern is withdrawn, its imprint provides the mold cavity, which is ultimately filled with metal to become the casting.

- If the casting is to be hollow, as in the case of pipe fittings, additional patterns, referred to as cores, are used to form these cavities.
- Making draft, shrinkage allowance

(1 mark)

Product B

(i) Lost Wax casting or investment casting (1 mark)

(ii) Any reason/advantages relate with investment casting (1 mark)

(iii) SKETCH (1 mark)

- Description about the process of investment casting
- A pattern made of wax is coated with a refractory material to make mold, after which wax is melted away prior to pouring molten metal
- It is a precision casting process - capable of castings of high accuracy and intricate detail

(2 marks)

(iv) - Wax is made of plastic injection method or 3D printing device

- Wax is heated and arrange into a form of 'tree'

(1) wax patterns are produced

(2) several patterns are attached to a sprue to form a pattern tree

(3) the pattern tree is coated with a thin layer of refractory material

(4) the full mold is formed by covering the coated tree with sufficient refractory material to make it rigid

(5) the mold is held in an inverted position and heated to melt the wax and permit it to drip out of the cavity

(6) the mold is preheated to a high temperature, which ensures that all contaminants are eliminated from the mold; it also permits the liquid metal to flow more easily into the detailed cavity; the molten metal is poured; it solidifies

(7) the mold is broken away from the finished casting - parts are separated from the sprue

(2 marks)

Product C

(i) lost‑foam process, lost pattern process, evaporative‑foam process, and full‑mold process (1 mark)

(ii) Any reason/advantages relate with lost-foam casting (1 mark)

(iii) SKETCH (1 mark)

- Description about the process of lost foam casting
- Uses a mold of sand packed around a polystyrene foam pattern which vaporizes when molten metal is poured into mold
- Polystyrene foam pattern includes sprue, risers, gating system, and internal cores (if needed)
- Mold does not have to be opened into cope and drag sections

(2 marks)

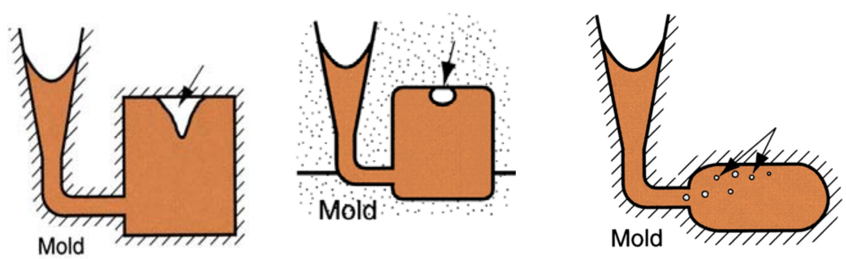
(iv) - Polystyrene is made similar like plastic injection method or 3D printing device

(1) pattern of polystyrene is coated with refractory compound
(2) foam pattern is placed in mold box, and sand is compacted around the pattern
(3) molten metal is poured into the portion of the pattern that forms the pouring cup and sprue. As the metal enters the mold, the polystyrene foam is vaporized ahead of the advancing liquid, thus allowing the resulting mold cavity to be filled.

(2 marks)

D. The defects in Figure Q3A are among the defects occurred in metal casting products. Give the main reason such defect may occur and explain how the defect can be avoided or minimised.

(6 marks)



(a) Shrinkage (b) Sand blow (c) Cold shot

Figure Q3A: Metal casting defects

Answer:

a) Reason - depression in surface or internal void caused by solidification shrinkage that restricts amount of molten metal available in last region to freeze
How to avoid - The general technique for eliminating shrinkage porosity is to ensure that liquid metal under pressure continues to flow into the voids as they form.
Design or use a proper riser.

b) Reason - Balloon-shaped gas cavity caused by release of mold gases during pouring
How to avoid - Make adequate provision for evacuation of air and gas from the mold cavity; Increase permeability of mold and cores.

c) Reason - Metal splatters during pouring and solid globules form and become entrapped in casting
How to avoid - improving pouring conditions and protecting the mold openings against metal splashing.

QUESTION 4 (20 MARKS)

A. Explain briefly, **TWO (2)** differences of between cold working and hot working in metal forming processes.

(4 marks)

Answer:

- Hot working is performed above the re-crystallization temperature of the material. According to American Society for metals, re-crystallization temperature can be defined as the approximate minimum temperature at which complete re-crystallization of a cold worked metal occurs within a specified time. During hot working, a metal is in a plastic state and is easily formed. The forces required to deform the metal are definitely lesser than cold working. Some mechanical properties of the metal are improved due to hot working because at elevated temperatures, metal microstructures are rebuilding continually through the re-crystallization process which allows for much higher deformation.
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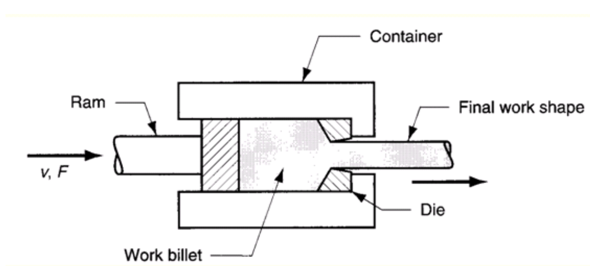
B. In a cold extrusion operation, there are **TWO (2)** types of extrusion methods, both the processes named forward extrusion and backward extrusion. Explain with the help of sketches both processes.

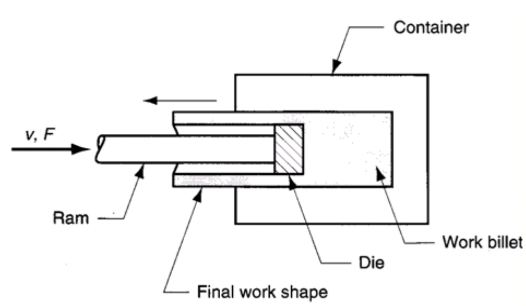
(6 marks)

Answer:

- **FORWARD EXTRUSION** In this process, the metal moves in the same direction as the punch, and very high reductions in cross-sectional area can be produced in one operation. The length of the extrusion depends upon the material, lubrication, and the space in the press beyond the die orifice.
- **BACKWARD EXTRUSION** generally involves the production of a relatively thin-walled heavy-bottomed cup, by forcing a punch rapidly into a closed-bottom die containing a cylindrical slug of metal, causing the metal to flow upward around the punch, between it and the die.



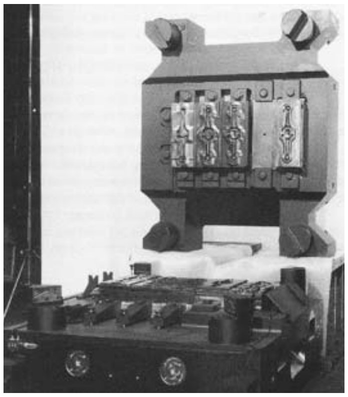
FORWARD EXTRUSION



BACKWARD EXTRUSION

C. Explain with the help of sketches in detail on how a drop forging will produce parts in Figure Q4A. State also **ONE (1)** major factor why forging maybe subjected to one or more subsequent operations.

(4 marks)



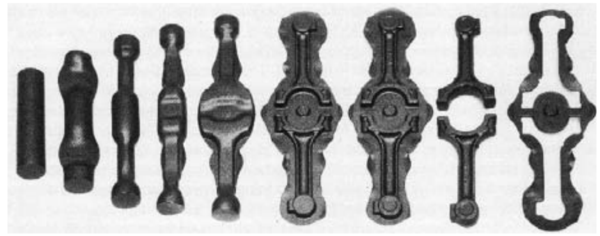
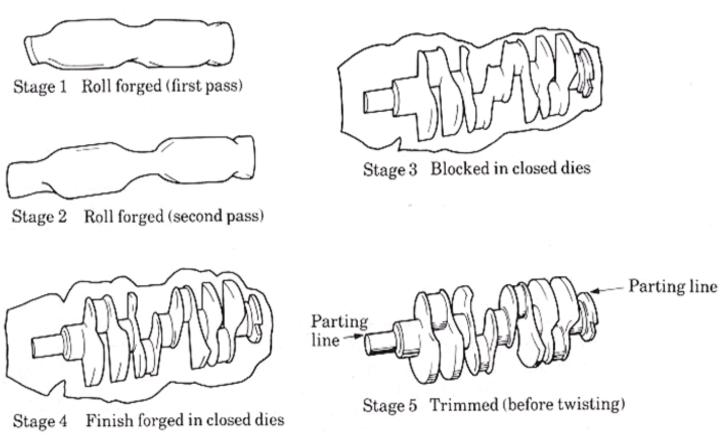


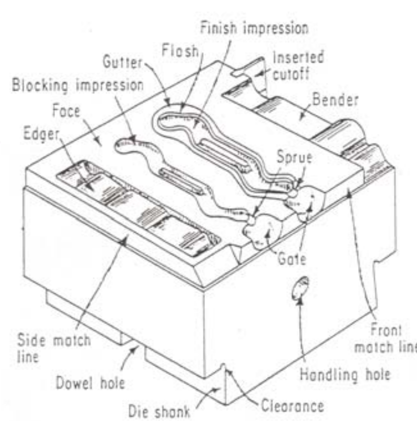
Figure Q4A: Die forging and forming stages of connecting rod using forging process.

Answer:

- The open die forging is easy and flexible, but it is less practical to be used for high volume production mainly because of the slow process. These can be overcome by using the closed die forging or drop forging. Heated metal is inserted to the lower part of the die, then clamp with the upper die on top and hammered. The then melted metal will flow and filled the cavity or the design of the die until it is fully filled. This will caused a very find grain structure and no air-trapped in it. In this process, the size of the work piece inserted in between the die is important. Because it determined the ability to fill the die sufficiently without leaving any void that contributed to air-trap in the end. Precise positioning of the work piece on the die is also another important factor. Die design and also the usage of lubricant in this process will increase the efficiency and effectiveness in aiding the metal flow in the die. Other than all these, this process also produced a reasonably low scrap, which is at the level of 20-45%.

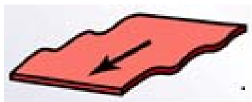
- The number of forging steps required to change a bar or biller forging stock into the shape of a structural member may vary from one or two steps to a series of many operations. The sequences of operations depends upon the size and shape of the part to be forged, the forgeability of the metal composition, the properties to be developed in the part, and the tolerances and other special requirements that may prevail. The use of impressive dies is the basis in producing drop forgings that are commercial duplicates of each other. These dies compain cavities or pockets, termed "impressions" of the part to be made, and in the drop-forging operation the impressions are filled with hot plastic metal.





D. Explain the main reason of occurring the defects shown in Figure Q4B that occurred during the rolling process and suggest a solution.

(6 marks)



(a)

Wavy Edges

(b)

Alligatoring

(c)

Edge Cracks

Figure Q4B: Defects in Rolling process

Answer:

(a) Earring is the formation of wavy edges at the ope end of the drawn cup. These are usually trimmed. The anisotropy of a particular sheet metal blank is the predominant source of earing.

(b) Alligorating or opening crack, If there is any metallurgical weakness in the metal (due to the presence of inclusions) along the centre line of the slab, fracture will occur. This results in the separation of the layer giving rise to opening of the slab which looks like an alligator mouth in opening position.

(c) Eade Cracks, The length of the center portion increases but the edges are prevented due to frictional force. As a result the material gets rounded off. The edges are strained in tension leading to edge cracking along the width of the slab.

PART B: ANSWER ONLY ONE (1) OF TWO (2) QUESTIONS.
(QUESTION 5 OR QUESTION 6)

QUESTION 5 (20 MARKS)

A. Based on your knowledge on the advantages and disadvantages of machining process, explain **FOUR (4)** situations where machining process will be the best process selection.

(4 marks)

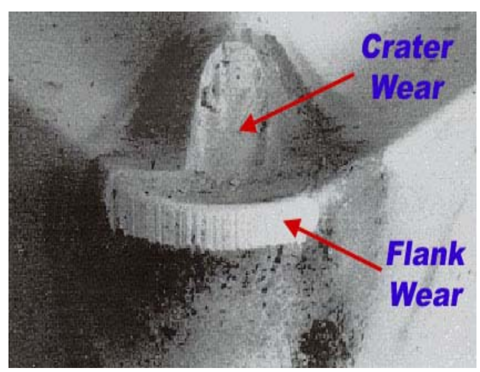
Answer:

	ADVANTAGES	DISADVANTAGES
1.	Improved quality - Repeatable accuracy as human error is reduced	Removal of material – become scrapped and waste
2.	Manufacturing flexibility – To accommodate frequent job changes and design changes	Machining is relatively a slow process
3.	Accuracy - Highest of all manufacturing processes, close tolerances can be achieved.	Need highly skilled operators
4.	Low cost tooling - Cutting tools are mass produced in standardized shapes/geometry	High capital cost – machine, cutters, work-holders, jigs and fixtures
5.	Any complex shape can be machined by combining several machining operations in sequences	Not suitable for high volume production

B. In metal cutting operations there are **TWO (2)** types of wear that occur on cutting tools which the flank wear and crater wear;

Answer:

vi. Explain with a sketch of both types of that wears.

(a)	<u>Crater wear:</u> Tool wear characterized by a concave depression in the rake face of the cutting tool adjacent to the cutting edge. Crater wear is also called cratering. (1 mark)	 (1 mark)
(b)	<u>Flank wear:</u> Tool wear resulting in the gradual wearing away of the cutting edge. Flank wear is mostly caused by abrasion, is predictable, and is the most desired form of tool wear. (1 mark)	

vii. Provide **TWO (2)** effects of the both wears during metal cutting operations.

	Type of wear	Effect
(a)	Crater wear:	• Increased cutting forces • Increased cutting temperatures • Decreased tool life (1 mark)
(b)	Flank wear:	• Poor surface finish • Decreased accuracy of finished part (1 mark)

(5 marks)

C. In the cutting process, referring to Figure Q5A, rake angle can be used to control the chip thickness. Discuss how controlling rake angle can play an important role on the cutting tool life.

(4 marks)

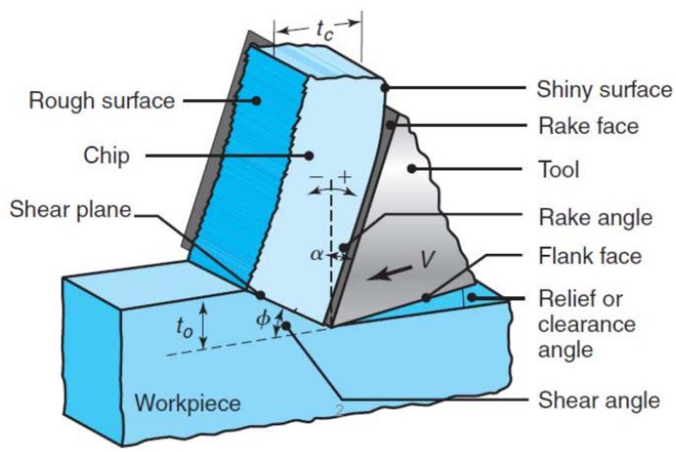


Figure Q5A: Merchant model of orthogonal cutting.

Answer:

Rake Angle (α): This is the angle between the tool face and the plane normal to the surface of the cut and pressing through the tool cutting edge. Generally three types of rake angle considered, i.e. positive rake angels, negative rake angles & zero rake angles. A zero rake angle is the easiest to manufacture, but has a larger crater wear when compared to positive rake angle as the chip slides over the rake face.

Generally, positive rake angles:

- Make the tool more sharp and pointed. This reduces the strength of the tool, as the small included angle in the tip may cause it to chip away.
- Reduce cutting forces and power requirements.
- **Helps in the formation of continuous chips in ductile materials.**
- **Can help avoid the formation of a built-up edge.**

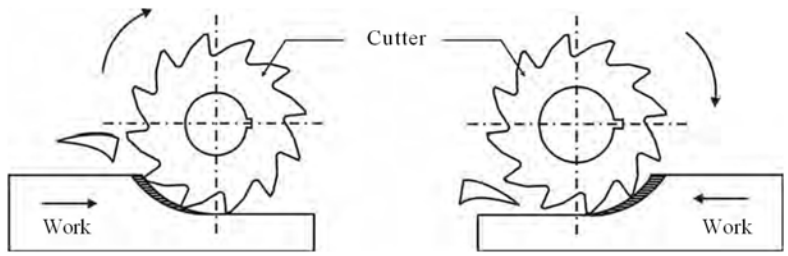
Negative rake angles, by contrast:

- Make the tool more blunt, increasing the strength of the cutting edge;
- Increase the cutting forces;
- Can increase friction, resulting in higher temperatures;
- Can improve surface finish.

(4 marks

D. Discuss **TWO (2)** advantages of down milling as compared to up milling (Figure Q5B) and why down milling is less recommended when using an old milling machine?

(5 marks)



(a) Up/Conventional Milling (b) Down/Climb Milling

Figure Q5B: Illustration of up and down milling

Answer:

Advantage of down milling as compared to up milling (4 marks)

	DOWN MILLING	UP MILLING
1.	In down milling most of heat diffuse to the chip does not change the work piece properties.	In this process, heat is diffuse to the work piece which causes the change in metal properties.
2.	In this, tool wear is less compare to the up milling, due to the cutter rotate with the feed.	In up milling, tool wear is more because the tool runs against the feed.
3.	Tool life is high.	Tool life is low.
4.	The cutting chips fall down behind the tool. This gives better surface finish	The cutting chips fall down in front of the cutting tool which again cut the chips cause less surface finish
5.	In down milling, downward force act on work piece normal zig and fixture required.	Due to upward force by tool, high strength zig and fixture required to hold the work piece.
6.	In this process heat does not diffuse in the work piece, so simple cutting fluid is required.	High quality cutting fluid is required because heat diffuse in the work piece.
7.	It required low cutting force.	It required high cutting force compare to down milling.

Why down milling is less recommended when using an old milling machine? (1 marks)

There is a problem with climb milling, which is that it can get into trouble with backlash if cutter forces are great enough. The issue is that the table will tend to be pulled into the cutter when climb milling. If there is any backlash, this allows leeway for the pulling, in the amount of the backlash. If there is enough backlash, and the cutter is operating at capacity, this can lead to breakage and potentially injury due to flying shrapnel. For this reason, many shops simply prohibit climb milling at all on any manual machines that have backlash. Some machines even came equipped with a "backlash eliminator" whose primary purpose was to enable climb milling and its attendant advantages.

E. Describe **TWO (2)** effects of cutting fluids on the chip formation that influence the cutting operation.

(2 marks)

Answer:

1) Cutting fluids influence friction at the tool-chip inter-face, thus affecting the shear angle and chip thickness. These, in turn, can influence the type of chip produced.
2) With effective cutting fluids the built-up edge can be reduced or eliminated.
3) Aid the cutting process by lubricating the interface between the tool's cutting edge and the chip. By preventing friction at this interface, some of the heat generation is prevented. This lubrication also helps prevent the chips from being welded onto the tool, which would interfere with subsequent cutting.

QUESTION 6 (20 MARKS)

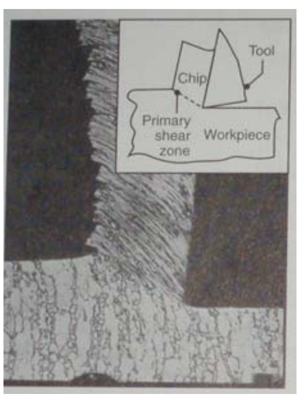
A. In turning, there are **THREE (3)** types of chip is formed.

viii. With the aid of appropriate sketches, list and briefly explain each type of chip.

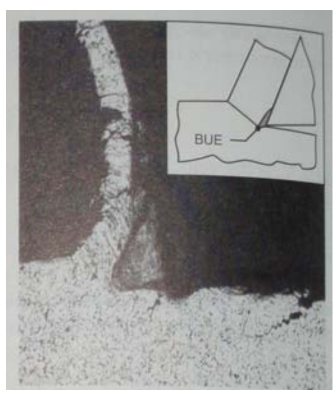
ix. List **TWO (2)** factors that influence the formation of chips as previously listed.

(6 marks)

Answer:



Continuous Chips



Built-up Edge

Discontinuous Chips

- **Continuous chips**;
  Continuous "ribbon" chips of metal that flows up the chip/tool zone. Usually considered the ideal condition for efficient cutting action. Continuous chips are usually formed at high rake angles and/or high cutting speeds. Continuous chips are less likely to form if the work-piece is brittle. A good surface finish is generally produced. However, continuous chips are not always desirable, particularly in automated machine tools, because they tend to get tangled around the tool, and the operation has to be stopped to clear away the chips. This problem can be alleviated by using *chip breakers*. Conditions which favor this type of chip,
  - **Ductile work,**
  - **Fine feeds,**
  - **Sharp cutting tools,**
  - **Larger rake angles,**
  - **High cutting speeds, and**
  - **Proper coolants.**

- **Built-up edge (BUE)**;
  Same process as continuous, but as the metal begins to flow up the chip-tool zone, small particles of the metal begin to adhere or weld themselves to the edge of the cutting tool. As the particles continue to weld to the tool it effects the cutting action of the tool. This type of chip is common in softer non-ferrous metals and low carbon steels. The problems with this chips is,
  - **Welded edges break off and can become embedded in work piece,**
  - **Decreases tool life, and**
  - **Can result in poor surface finishes.**

  A Built-up edge (BUE) may form at the tip of the tool during cutting. The BUE consists of layers of material from the work-piece that are gradually deposited on the tool. The BUE then becomes unstable and eventually breaks up. Some BUE material is carried away on the tool side of the chip; the rest is deposited randomly on the work-piece surface. BUE is most likely to form if the work-piece is highly plastic. BUE can result in the formation of a poor surface finish. The tendency for BUE to form can be reduced by increasing the rake angle and therefore decreasing the depth of cut.

- **Discontinuous chips**.
  Discontinuous chips consist of segments that may be firmly or loosely attached to each other. These chips occur when machining hard brittle materials such as cast iron. Brittle failure takes place along the shear plane before any tangible plastic flow occurs. As tool contacts work, some compression takes place. As the chip starts up the chip-tool interference zone, increased stress occurs until the metal reaches a saturation point and fractures off the work piece. Conditions which favor this type of chip,
  - **Brittle work material,**
  - **Small rake angles on cutting tools,**
  - **Coarse machining feeds, and**
  - **Low cutting speeds.**

B. The cutting tool materials must possess a number of important properties to avoid excessive wear, fracture failure and with stand high temperatures during metal cutting operation. The list below shows **TWO (2)** characteristics of the cutting tool materials should have, to produce good machining quality.

   x. Hardness.
   xi. Toughness.

   Briefly explain the importance of these characteristics and list any **FOUR (4)** types of cutting tool materials.

   (6 marks)

Answer:

Hardness — harness and strength of the cutting tool must be maintained at elevated temperatures, also called hot hardness

Toughness — toughness of cutting tools is needed so that tools don't chip or fracture, especially during interrupted cutting operations.

(a) **Tool steels -** Used to make some drills, taps, reamers, etc. Low cost equals low tool life.
(b) **High speed steel** (HSS) - can withstand cutting temperatures up to 1100F. Have improved hardness and wear resistance, used to manufacture drills, reamers, single point tool bits, milling cutters, etc. HSS cutting tools can be purchased with additional coatings such as TiN which add additional protection against wear.
(c) **Cobalt -** one step above HSS, cutting speeds are generally 25% higher.

(d) **Carbides -** Most widely used cutting tool today. Cutting speeds are three to five times faster than HSS. Basic composition is tungsten carbide with a cobalt binder. Today a wide variety of chemical compositions are available to meet different applications. In addition to tool composition, coatings are added to tool materials to increase resistance to wear.

(e) **Ceramics** - Contain pure aluminum oxide and can cut at two to three times faster than carbides. Ceramic tools have poor thermal and shock resistance and are not recommended for interrupted cuts. Caution should be taken when selecting these tools for cutting aluminum, titanium, or other materials that may react with aluminum oxide.

(f) **Cubic Boron Nitride** (CBN) **-** This tool material maintains its hardness and resistance to wear at elevated temperatures and has a low chemical reactivity to the chip/tool interface. Typically used to machine hard aerospace materials. Cutting speeds and metal removal rates are up to five times faster than carbide.

(g) **Industrial Diamonds -** diamonds are used to produce smooth surface finishes such as mirrored surfaces. Can also be used in "hard turning" operations to eliminate finish grinding processes. Diamond machining is performed at high speeds and generally fine feeds. Is used to machine a variety of metals.

C. In the cutting process, referring to Figure Q6A**,** rake angle can be used to control the chip thickness. Discuss how controlling rake angle can play an important role on the cutting tool life.

(4 marks)

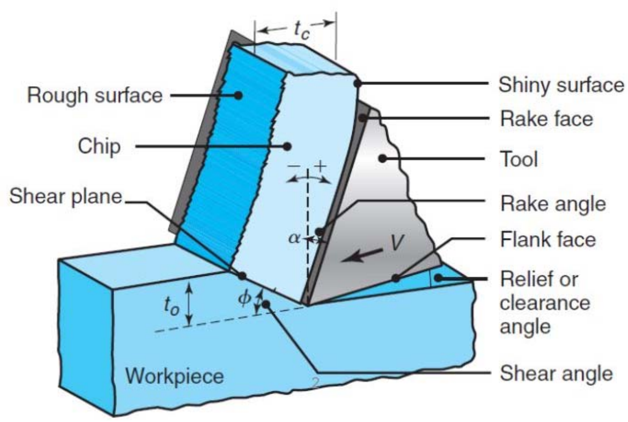


Figure Q6A: Merchant model of orthogonal cutting

Answer:

Rake Angle (α): This is the angle between the tool face and the plane normal to the surface of the cut and pressing through the tool cutting edge. Generally three types of rake angle considered, i.e. positive rake angels, negative rake angles & zero rake angles. A zero rake angle is the easiest to manufacture, but has a larger crater wear when compared to positive rake angle as the chip slides over the rake face.

Generally, positive rake angles:

- Make the tool more sharp and pointed. This reduces the strength of the tool, as the small included angle in the tip may cause it to chip away.
- Reduce cutting forces and power requirements.
- **Helps in the formation of continuous chips in ductile materials.**
- **Can help avoid the formation of a built-up edge.**

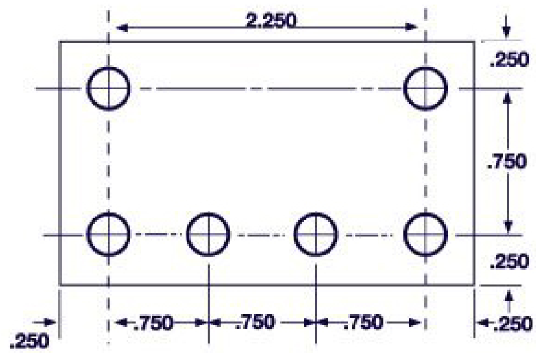
Negative rake angles, by contrast:

- Make the tool more blunt, increasing the strength of the cutting edge;
- Increase the cutting forces;
- Can increase friction, resulting in higher temperatures;
- Can improve surface finish.

D. In a numerical controlled system, the phrase machine coordinate system refers to the physical limits of the motion of the machine in each of its axes. With the help of sketches, describe what is the absolute and incremental coordinates?

(4 marks)

Answer:



CNC machine will use either incremental coordinates or absolute coordinates to determine this movement. With incremental coordinates, a new location is calculated from the current position. Once the tool reaches the new location, it becomes the base for the next position. In other words, the current position always acts as the origin for the next position. A potential problem with incremental coordinates is that an error can be carried from one dimension to the next. While absolute coordinates are measured from the fix datum.

APPENDIX /LAMPIRAN

E. For turning:

$$V_c = \pi N D_0$$
$$MRR = V_c f d$$
$$t = l/fN$$
$$P = MRR\mu = F_c V_c$$
$$v = fN$$

F. For casting, Chrovinov's rule:

$$T_{TS} = C_m (V/A)^n$$

G. For Sheet Metal:

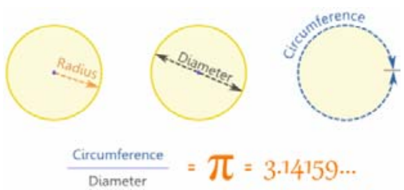
- Recommended clearance can be calculated by:

$$c = at$$

- For a round *blank* of diameter D_b:
  - Blanking punch diameter = $D_b - 2c$
  - Blanking die diameter = D_b
  - where c = clearance
- For a round *hole* of diameter D_h:
  - Hole punch diameter = D_h
  - Hole die diameter = $D_h + 2c$
  - where c = clearance
- Cutting Forces:

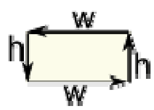
$$F = \sigma t \ell$$
or
$$F = \tau t \ell$$

H. Circular:



- Perimeter = $2\pi r$ or πD
- Area = πr^2 or $\pi D^2/4$

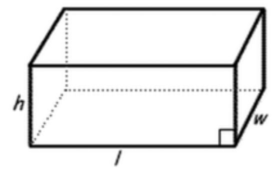
I. Rectangular:



- Perimeter = 2(w x h)
- Area = w x h

J. Rectangular Prism:

Surface Area $A = 2(wh + lw + lh)$



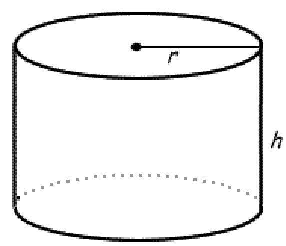
Volume $V = lwh$

K. Cylinder:

Surface Area: We will need to calculate the surface area of the top, base and sides.

Area of the top is πr^2
Area of the bottom is πr^2
Area of the side is $2\pi r h$

Therefore the Formula is: $A = 2\pi r^2 + 2\pi r h$



Volume $V = \pi r^2 h$