CUTTING TOOL MATERIALS TOOL WEAR, TOOL LIFE, SURFACE FINISH AND MACHINABILITY

23MOT201- Manufacturing and Measurement Techniques
Unit -2 Metal Forming and Metal Cutting Processes
II Year /III Semester
Mechanical and Mechatronics Engineering

CUTTING-TOOL MATERIALS

PROPERTIES REQUIRED FOR CUTTING TOOLS

- One of most important components in machining process
- Performance will determine efficiency of operation
- Two basic types (excluding abrasives)
  - Single point and multiple point
- Must have rake and clearance angles ground or formed on them

CUTTING-TOOL MATERIALS

- Tools are generally made of these seven materials
  - High-speed steel
  - Cast alloys (such as stellite)
  - Cemented carbides
  - Ceramics
  - Cermets
  - Cubic Boron Nitride
  - Polycrystalline Diamond

CUTTING TOOL PROPERTIES

- **Hardness**
  - Cutting tool material must be 1 1/2 times harder than the material it is being used to machine.

- **Capable of maintaining a red hardness during machining operation**
  - Red hardness: Ability of cutting tool to maintain sharp cutting edge
  - Also referred to as hot hardness or hot strength

CUTTING TOOL PROPERTIES

- **Wear Resistance**
  - Able to maintain sharpened edge throughout the cutting operation
  - Same as abrasive resistance
- **Shock Resistance**
  - Able to take the cutting loads and forces
- **Shape and Configuration**
  - Must be available for use in different sizes and shapes.

HIGH-SPEED STEEL

- May contain combinations of tungsten, chromium, vanadium, molybdenum, cobalt.
- Can take heavy cuts, withstand shock and maintain sharp cutting edge under red heat.
- Generally two types (general purpose)
  - Molybdenum-base (Group M)
  - Tungsten-base (Group T)
- Cobalt added if more red hardness desired.

CAST ALLOY

- Usually contain 25% to 35% chromium, 4% to 25% tungsten and 1% to 3% carbon
  - Remainder cobalt
- Qualities
  - High hardness
  - High resistance to wear
  - Excellent red-hardness
- Operate 2 ½ times speed of high-speed steel
- Weaker and more brittle than high-speed steel

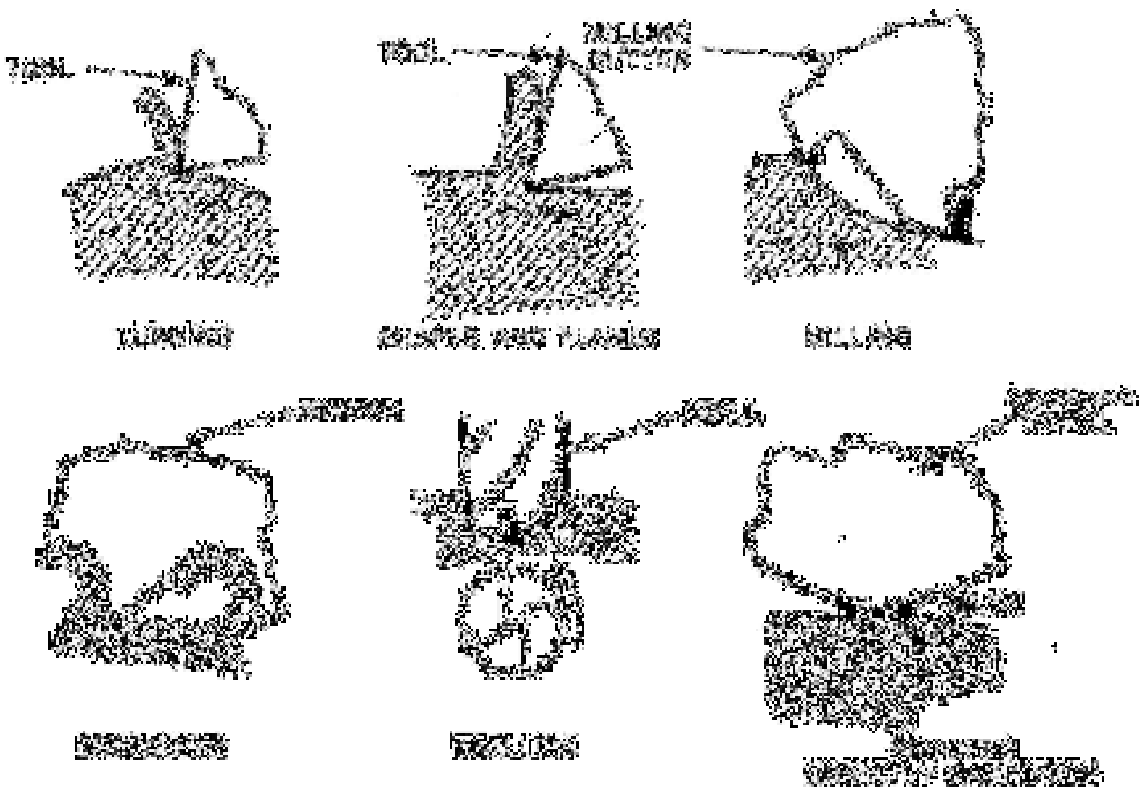
CARBIDE CUTTING TOOLS

- First used in Germany during WW II as substitute for diamonds
- Various types of cemented (sintered) carbides developed to suit different materials and machining operations
  - Good wear resistance
  - Operate at speeds ranging 150 to 1200 sf/min
- Can machine metals at speeds that cause cutting edge to become red hot without loosing harness

CEMENTED-CARBIDE APPLICATIONS

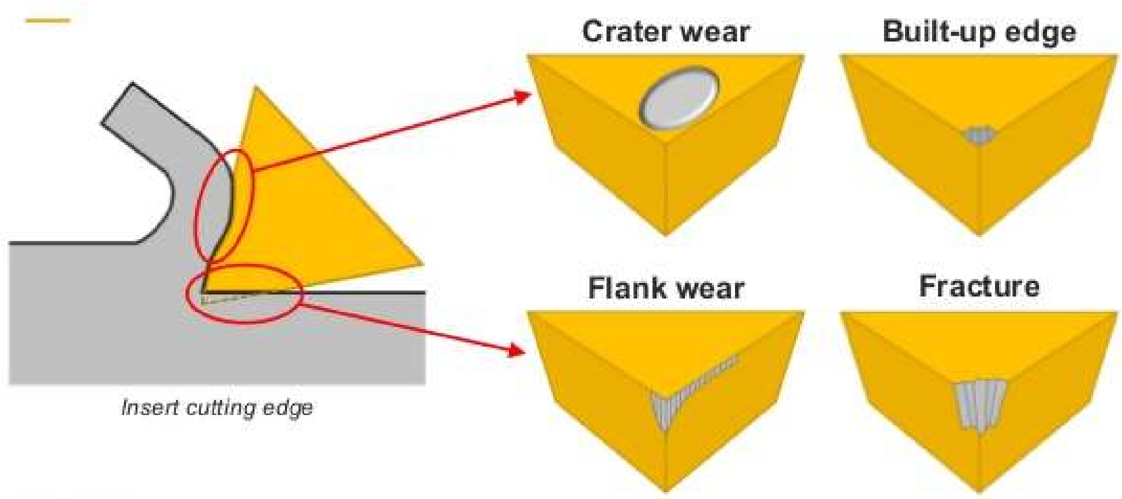
- Used extensively in manufacture of metal- cutting tools
  - Extreme hardness and good wear-resistance
- First used in machining operations as lathe cutting tools
- Majority are single-point cutting tools used on lathes and milling machines

METAL-CUTTING



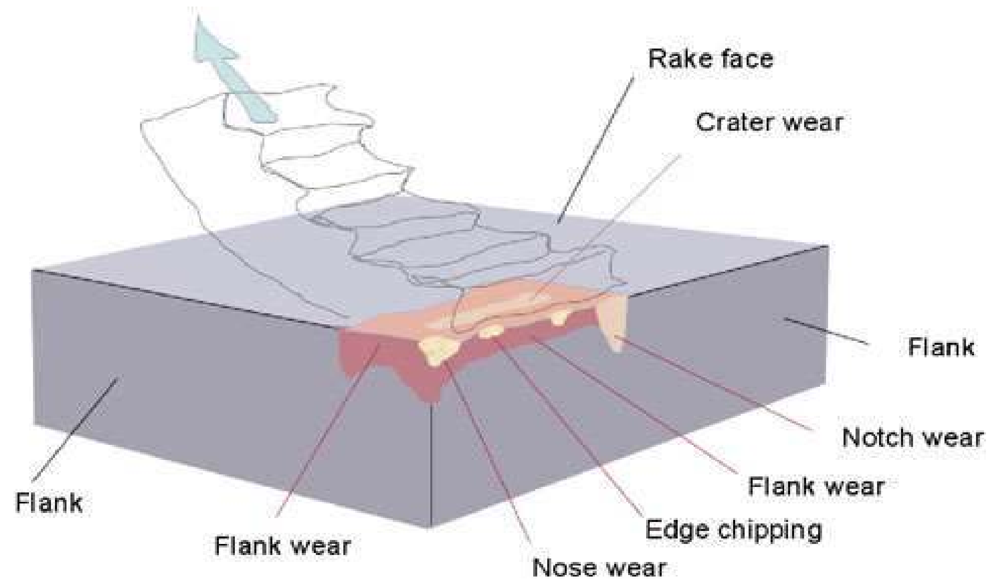
TOOL WEAR

- Wear is loss of material on an asperity or micro-contact, or smaller scale, down to molecular or atomic removal mechanisms. It usually progresses continuously.
- **Tool wear** describes the gradual failure of cutting tools due to regular operation. It is a term often associated with tipped tools, tool bits, or drill bit that are used with machine tools.



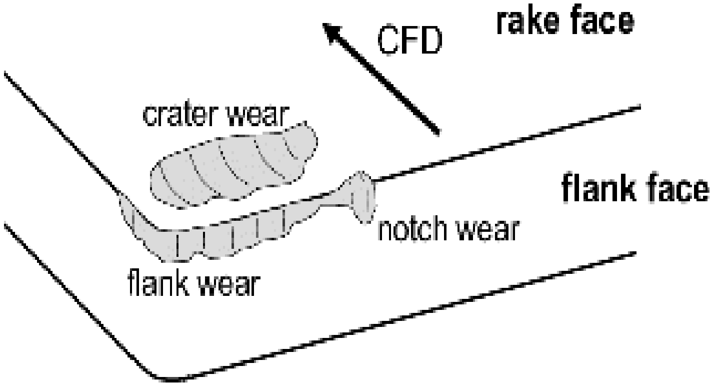
TYPES OF TOOL WEAR

- **Flank wear**
- **Crater wear**
- **Nose wear**



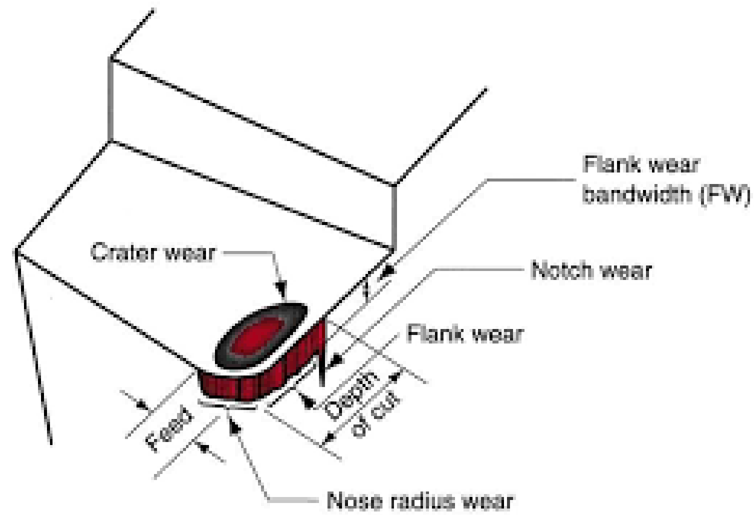
FLANK WEAR

- Flank wear occurs on the tool flank as a result of friction between the machined surface of the workpiece and the tool flank.
- Flank wear appears in the form of so-called wear land and is measured by the width of this wear land, Flank wear affects to the great extend the mechanics of cutting.
- Cutting forces increase significantly with flank wear.
- If the amount of flank wear exceeds some critical value (VB > 0.5~0.6 mm), the excessive cutting force may cause tool failure.



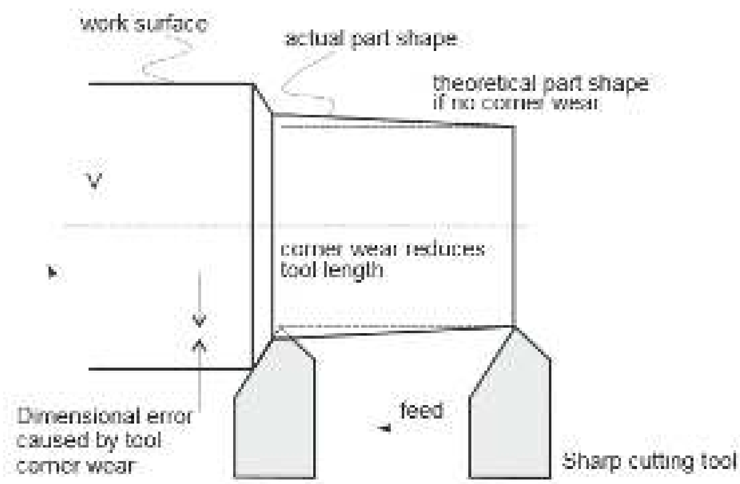
CRATER WEAR

- Crater wear consists of a concave section on the tool face formed by the action of the chip sliding
  on the surface.
- Crater wear affects the mechanics of the process increasing the actual rake angle of the cutting tool and consequently, making cutting easier.
- At the same time, the crater wear weakens the tool wedge and increases the possibility for tool breakage.
- In general, crater wear is of a relatively small concern.



NOSE WEAR

- Nose wear occurs on the tool corner.
- Can be considered as a part of the wear land and respectively flank wear since there is no distinguished boundary between the corner wear and flank wear land.
- We consider nose wear as a separate wear type because of its importance for the precision of machining.
- Nose wear actually shortens the cutting tool thus increasing gradually the dimension of machined surface and introducing a significant dimensional error in machining, which can reach values of about 0.03~0.05 mm.



Top view showing the effect of tool corner wear on the dimensional precision in turning

EFFECTS OF TOOL WEAR

Some General effects of tool wear include:

- Increased cutting forces
- Increased cutting temperatures
- Poor surface finish
- Decreased accuracy of finished part
- May lead to tool breakage
- Causes change in tool geometry

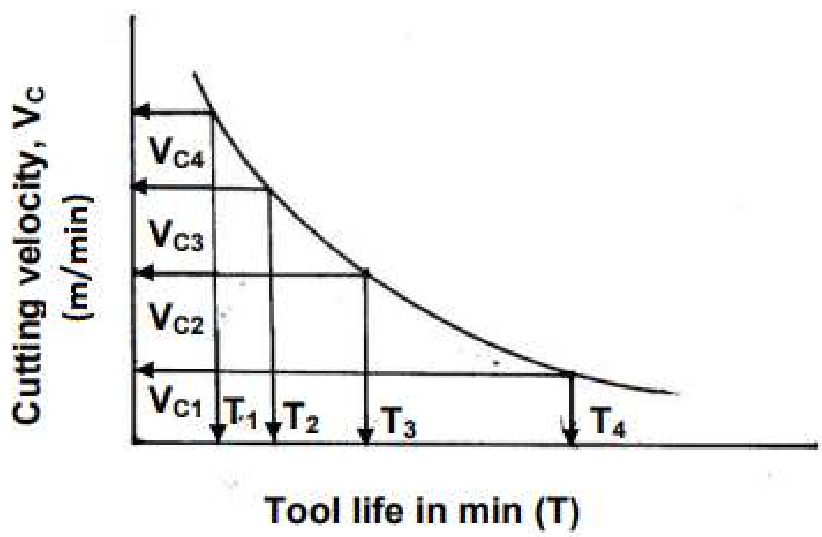
ASSESSMENT OF TOOL LIFE

There are three ways of assessment of tool life

- No. of pieces of work machined – This is used commonly when the tool operates continuously .
- Total volume of material removed –This is used commonly when the tool is used for high stock removal.
- Total length of cut

FACTORS AFFECTING TOOL LIFE

- Cutting speed
- Feed and depth of cut
- Tool geometry
- Tool material
- Work material
- Nature of cutting
- Rigidity of machine tool and work
- Use of cutting fluids



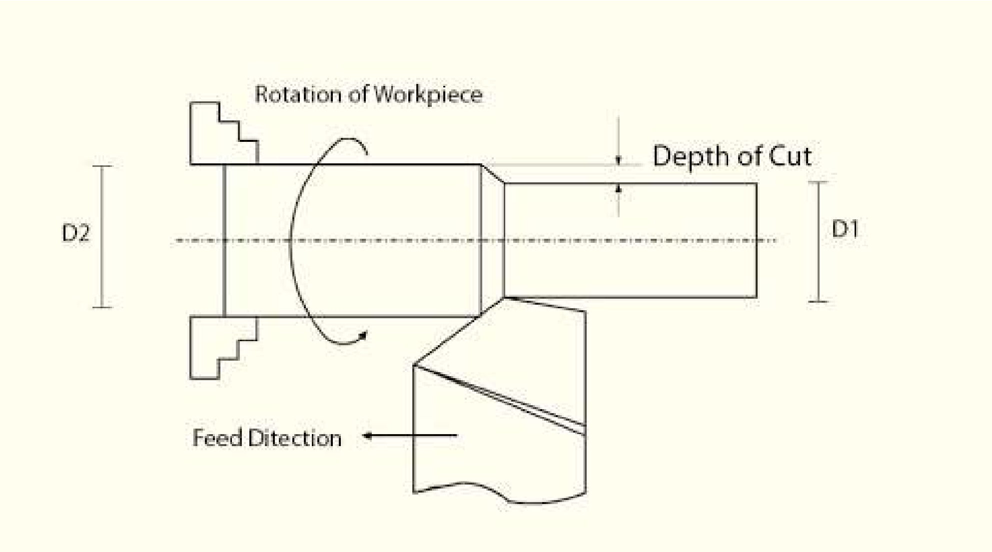
DEPTH OF CUT

Too small

- Loss of chip control
- Vibration
- Excessive heat
- Uneconomical

Too deep

- High power consumption
- Insert breakage
- Increased cutting force



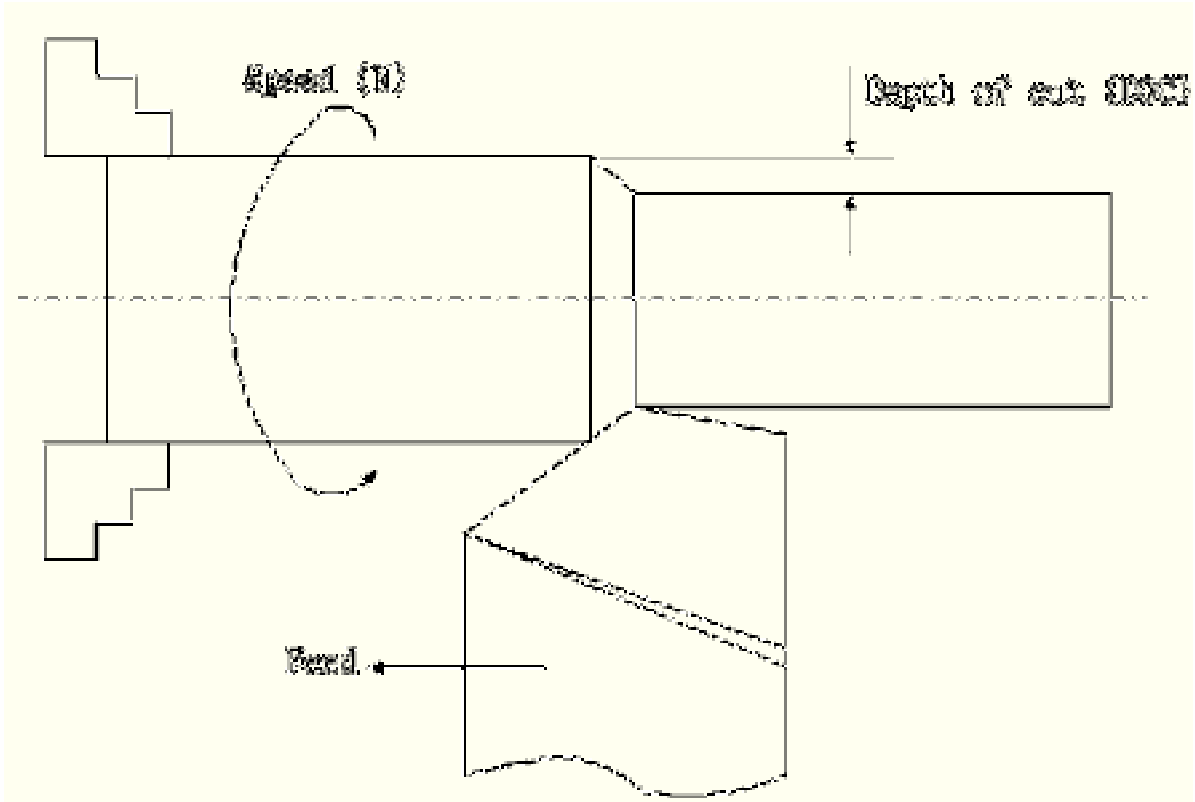
FEED RATE

Too light

- Stringers
- Rapid flank wear
- Build-up edge
- Uneconomical

Too heavy

- Loss of chip control
- Poor surface finish
- Crater wear/plastic deformation
- High power consumption



TOOL GEOMETRY

- **Rake angle :-** If it is increased in positive direction , the cutting force and amount of heat generated are reduced. This increases the life of the tool. But if it is increased too much , cutting edge is weakened and capacity to conduct heat also decreases.
- **Relief angle :-** These are provided on the cutting tool to prevent rubbing of tool flank with machined work surface. Thus it reduces the amount of heat generated and increases tool life.
- **Cutting edge angles :-** these angles affect tool wear. Up to a certain value of these angles, higher speed without an adverse affect on tool life can be used.

CUTTING FLUIDS

- Reduces heat generation at shear zone and friction zone (coolants)
  - High specific heat and thermal conductivity (water based coolants)
  - Effective at high cutting speeds
- Reduces friction between tool and chip (lubricants)
  - Effective at low cutting speeds
  - Oil-based lubricants
  - Low friction means low friction angle , which means shear angle decreases , which reduces heat.

MACHINABILITY

- Machinability is defined in terms of :-

1. Surface finish and surface integrity
2. Tool life
3. Force and power required
4. The level of difficulty in chip control

- Good machinability indicates good surface finish and surface integrity, a long tool life, and low force and power requirements
- **Machinability ratings (indexes)** are available for each type of material and its condition

FACTORS AFFECTING MACHINABILITY OF METALS

- Material of w/p- hardness, tensile properties, strain hardenability
- Tool material.
- Size and shape of the tool.
- Type of machining operation.
- Size, shape and velocity of cut.
- Type and quality of machine used
- Quality of lubricant used in machining
- Friction b/w chip & tool
- Shearing strength of w/p material

EVALUATION OF MACHINABILITY

- Tool life
- Form and size of chip and shear angle.
- Cutting forces and power consumption
- Surface finish
- Cutting temperature
- MRR per tool grind
- Rate of cutting under standard force
- Dimensional accuracy

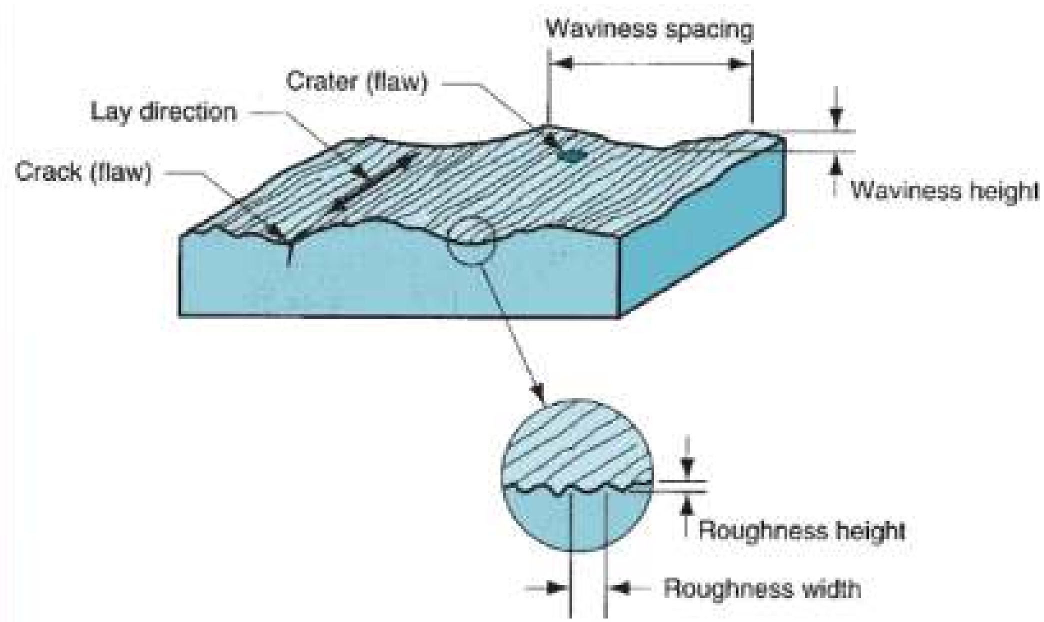
SURFACE FINISH

- An engineering component may be cast, forged, drawn, welded or stamped, etc.
- All the surfaces may not have functional requirements and need not be equally finished.
- Some surfaces (owing to their functional requirements) need additional machining that needs to be recorded on the drawing.

MEASUREMENT OF ROUGHNESS

The roughness may be measured, using any of the following :

1. Straight edge
2. Surface gauge
3. Optical flat
4. Tool marker's microscope
5. Profilometer
6. Profilograph
7. Talysurf



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