MACHINE TOOLS & OPERATIONS Course

Module # 3. Cutting Tool Materials
What is cutting tool?

Cutting tool is any tool that is used to remove material from the workpiece by means of shear deformation. Cutting may be accomplished by single-point or multipoint tools. Single-point tools are used in turning, shaping, plaining and similar operations, and remove material by means of one cutting edge. Milling, grinding and drilling tools are often multipoint tools. Each grain of abrasive functions as a microscopic single-point cutting edge and shears a tiny chip.

Cutting tools must be made of a material harder than the material which is to be cut, and the tool must be able to withstand the heat generated in the metal-cutting process. Also, the tool must have a specific geometry, with clearance angles designed so that the cutting edge can contact the workpiece without the rest of the tool dragging on the workpiece surface. The angle of the cutting face is also important, as is the flute width, number of flutes or teeth, and margin size.

In order to have a long working life, all of the above must be optimized, plus the speeds and feeds at which the tool is run.
Types of cutting tools

- Cutting tools
  - Single point
  - Multipoint
There are three types of single point cutting tools:
(a) Solid tool (typical of HSS)
(b) Brazed insert (one way of holding a cemented carbide insert; and
(c) Mechanically clamped insert, used for cemented carbides, ceramics, and other very hard tool materials
Cutting Tool Materials

- Required properties
  - Higher hardness
  - Hot hardness
  - Wear resistance
  - Toughness
  - Low friction
  - Better thermal characteristics
PROPERTIES OF CUTTING TOOL MATERIALS

- Wear Resistance, necessary to enable the cutting tool to retain its shape and cutting efficiency

- Hot hardness, to retain the cutting ability and hardness that may be lost due to high temperature developed at the tool–chip interface

- Toughness, to withstand the force due to cutting and to absorb shocks and to prevent chipping of the fine cutting edge.
Introduction

- Cutting Tool Characteristics:
  1. Maintaining hardness, strength, and wear resistance at elevated temperatures. This property ensures that the tool does not undergo any plastic deformation and thus retains its shape and sharpness.
  2. Toughness and impact strength (or mechanical shock resistance), so that impact forces on the tool that are encountered repeatedly in interrupted cutting operations or forces due to vibration and chatter during machining do not chip or fracture the tool.
  3. Thermal Shock resistance to withstand the rapid temperature cycling encountered in interrupted cutting.
  4. Wear resistance so that an acceptable tool life is obtained before replacement is necessary.
  5. Chemical stability to avoid or minimize any adverse reactions, adhesion, and tool-chip diffusion.
• **Tool Materials Categories:**
  1. High-speed steels
  2. Cast-cobalt alloys
  3. Carbides
  4. Coated tools
  5. Alumina-based ceramics
  6. Cubic boron nitride
  7. Silicon-nitride-base ceramics
  8. Diamond
  9. Whisker-reinforced materials
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<th>Characteristics</th>
<th>High-speed steels</th>
<th>Cast-cobalt alloys</th>
<th>Uncoated carbides</th>
<th>Coated carbides</th>
<th>Ceramics</th>
<th>Polycrystalline cubic boron nitride</th>
<th>Diamond</th>
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<td>Hot hardness</td>
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<td>Tool material cost</td>
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<td>Depth of cut</td>
<td>Light to heavy</td>
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<td>Light to heavy</td>
<td>Light to heavy</td>
<td>Very light for single-crystal diamond</td>
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<tr>
<td>Processing method</td>
<td>Wrought, cast, HIP* sintering</td>
<td>Cast and HIP sintering</td>
<td>Cold pressing and sintering</td>
<td>CVD or PVD†</td>
<td>Cold pressing and sintering or HIP sintering</td>
<td>High-pressure, high-temperature sintering</td>
<td>High-pressure, high-temperature sintering</td>
</tr>
</tbody>
</table>

*Source: After R. Komanduri.
†Hot-isostatic pressing.
‡Chemical-vapor deposition, physical-vapor deposition.
## TABLE 22.3

### General Operating Characteristics of Cutting-Tool Materials

<table>
<thead>
<tr>
<th>Tool materials</th>
<th>General characteristics</th>
<th>Modes of tool wear or failure</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-speed steels</td>
<td>High toughness, resistance to fracture, wide range of roughening and finishing cuts,</td>
<td>Flank wear, crater wear</td>
<td>Low hot hardness, limited hardenability, and limited wear resistance</td>
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<tr>
<td></td>
<td>good for interrupted cuts</td>
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<tr>
<td>Uncoated carbides</td>
<td>High hardness over a wide range of temperatures, toughness, wear resistance, versatile</td>
<td>Flank wear, crater wear</td>
<td>Cannot use at low speeds because of cold welding of chips and microchipping</td>
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<tr>
<td></td>
<td>and wide range of applications</td>
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<tr>
<td>Coated carbides</td>
<td>Improved wear resistance over uncoated carbides, better frictional and thermal properties</td>
<td>Flank wear, crater wear</td>
<td>Cannot use at low speeds because of cold welding of chips and microchipping</td>
</tr>
<tr>
<td>Ceramics</td>
<td>High hardness at elevated temperatures, high abrasive wear resistance</td>
<td>Depth-of-cut line notching, microchipping, gross fracture</td>
<td>Low strength, and low thermo-mechanical fatigue strength</td>
</tr>
<tr>
<td>Polycrystalline cubic boron nitride (cBN)</td>
<td>High hot hardness, toughness, cutting-edge strength</td>
<td>Depth-of-cut line notching, chipping, oxidation, graphitization</td>
<td>Low strength, and low chemical stability at higher temperature</td>
</tr>
<tr>
<td>Diamond</td>
<td>High hardness and toughness, abrasive wear resistance</td>
<td>Chipping, oxidation, graphitization</td>
<td>Low strength, and low chemical stability at higher temperatures</td>
</tr>
</tbody>
</table>

*Source: After R. Komanduri and other sources.*
High-Speed Steel Toolbits

- 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
High Speed Steel (HSS)

Highly alloyed tool steel capable of maintaining hardness at elevated temperatures better than high carbon and low alloy steels

- One of the most important cutting tool materials
- Especially suited to applications involving complicated tool geometries, such as drills, taps, milling cutters, and broaches
- Two basic types (AISI)
  1. **Tungsten-type**, designated T-grades
  2. **Molybdenum-type**, designated M-grades
High Speed Steel Composition

- Typical alloying ingredients:
  - Tungsten and/or Molybdenum
  - Chromium and Vanadium
  - Carbon, of course
  - Cobalt in some grades

- Typical composition (Grade T1):
  - 18% W, 4% Cr, 1% V, and 0.9% C
Production of WC

Blended WC powder, produced by mixing WC (94%) with Cobalt (6%) in a ball milling press

Carbide blending equipment, Ball mill
HIGH SPEED STEELS

- Two basic types of HSS:
  1. Molybdenum (M series)
     - Up to about 10% Mo, with Cr, Vn, W, Co as alloying elements
  2. Tungsten (T series)
     - 12% -18% W, with Cr, Vn, and Co as alloying elements
     - M series generally has higher abrasion resistance than T series, undergoes less distortion during heat treating, and is less expensive
CAST-COBALT ALLOYS

- 38%-53% Co, 30%-33% Cr, and 10%-20%W
- High hardness, good wear resistance, can maintain their hardness at elevated temperatures
- They are not as tough as HSS and are sensitive to impact forces

**Stellite Tools**

- These alloys are cast and ground into relatively simple tool shapes.
- used only for special applications that involve deep continuous roughing cuts at relatively high feeds and speeds, as much as twice the rates possible with HSS
Cast Alloy

- Usually contain 27% to 32% chromium, 14% to 19% tungsten and 1% to 3% carbon
  - Remainder cobalt (about 40 to 50%)

- 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
Cermets

- These sintered hard inserts are made by combining ‘cer’ from ceramics like TiC, TiN and (or) TiCN and ‘met’ from metal (binder) like Ni, Ni-Co, Fe etc.
- Since around 1980, the modern cermets providing much better performance are being made by TiCN (TiCN- Titanium Carbonitrides) which is consistently more wear resistant, less porous and easier to make.
- The term cermets is short form of ceramics in metallic binder.
• The grains are made of TiCN (in place of WC) and Ni or Ni-Co and Fe as binder (in place of Co)
• Harder, more chemically stable and hence more wear resistant
• More brittle and less thermal shock resistant
• Wt% of binder metal varies from 10 to 20%
• Cutting edge sharpness is retained unlike in coated carbide inserts
• Can machine steels at higher cutting velocity than that used for tungsten carbide, even coated carbides in case of light cuts.
Cemented carbide

Definition and properties
Cemented carbide is a powder metallurgical material;
- Composite of tungsten carbide (WC) particles and a binder rich in metallic cobalt (Co).
- Cemented carbides for metal cutting applications consist of more than 80% of hard phase WC.
- The cemented carbide body is formed, either through powder pressing or injection moulding techniques, into a body, which is then sintered to full density.
COATED TOOLS

- Because of their unique properties, such as lower friction and higher resistance to cracks and wear, coated tools can be used at high cutting speeds, reducing both the time required for machining operations and costs.
- Coated tools can have tool lives 10 times longer than those of uncoated tools.
COATED TOOLS - Coating Materials

- Coatings thickness of 2-15 μm, are applied on cutting tools and inserts by the following techniques:
  1. Chemical-vapor deposition (CVD), including plasma-assisted
  2. Physical-vapor deposition (PVD)
- Coatings for cutting tools, as well as dies, should have the following general characteristics:
  1. High hardness at elevated temperatures
  2. Chemical stability to the workpiece material
  3. Low bonding to the substrate to prevent flaking or spalling
  4. Little or no porosity
- Honing of the cutting edges is an important procedure for the maintenance of coating strength; otherwise, the coating may peel or chip off at sharp edges
COATED TOOLS - Coating Materials

Titanium Nitride coating (gold in color):
  • low friction coefficient, high hardness, resistance to high temp, and good adhesion to the substrate.
  • perform well at higher cutting speeds and feeds
  • Flank wear is significantly lower than that of uncoated tools
  • do not perform as well at low cutting speeds because the coating can be worn off by chip adhesion

Titanium Carbide coatings:
  • on tungsten-carbide inserts have high flank-wear resistance in machining abrasive materials
DIAMOND

- Low friction
- High wear resistance
- Ability to maintain sharp edge
- Used when good surface finish and dimensional accuracy are req. (soft non-ferrous & abrasive non-metallic materials)
- Low rack angles are generally used > strong cutting edge
- Used at high speed
- Most reasonable for light uninterrupted finishing cut
- Diamond is not recommended for machining plain carbon steels or titanium, because of its strong chem. Affinity
Cubic Boron Nitride

- Next to diamond, cubic boron nitride (CBN) is hardest material known
- Fabrication into cutting tool inserts same as SPD: coatings on WC-Co inserts
- **Applications**: machining steel and nickel-based alloys
- SPD and CBN tools are expensive
Tool Nomenclature

Shank: The portion of tool bit which is not ground to form cutting edges and is rectangular in each portion.

Face: The surface against which chips slide upwards.

Base: Base of the tool is under side of the shank.
TOOL PARTS

FACE and RAKE SURFACE
The surface along which chip move upward called rake surface

FLANK and RELIEF SURFACE
The other surface which is avoid rubbing with machined surface is called flank or relief surface

SHANK
It forms the main body of a solid tool and it is the part of tool which is gripped in the tool holder
The 7 Parameters

6 Angles and 1 Nose radius

- BACK RAKE ANGLE
- SIDE RAKE ANGLE
- END RELIEF ANGLE
- SIDE RELIEF ANGLE
- END CUTTING EDGE ANGLE
- SIDE CUTTING EDGE ANGLE
- NOSE RADIUS
FIGURE 22-11 Standard terminology to describe the geometry of single-point tools.
CUTTING THE SECTION PERPENDICULAR TO THE BASE AND PARALLEL TO WIDTH
Tool Geometry

Terms adopted by ASME
A Clay Example

- Carving or bending clay to demonstrate the concept.
- Metal carving and bending are similar, but with clay –
  Rather than it bunching up, it curls up, it’s softer.

Steeper rake angle – note that the clay is bunching up on the outside curve because it’s being bent quite a lot – metal chips do that too.

Machining and CNC Technology
The Function of Clearance

- Clearance is a simple issue
- It relieves behind the cutting edge such that only the edge touches without rubbing the heel of the bit on the newly cut surface.

Machining and CNC Technology
➢ SIDE RAKE ANGLE
➢ SIDE RELIEF ANGLE
SIDE RAKE ANGLE

It is the angle between the face of the tool and the base of the shank or holder.

SIDE RELIEF ANGLE

It is the angle between the portion of the side flank immediately below the side cutting edge and a line drawn through this cutting edge perpendicular to the base.
CUTTING THE SECTION PARALLEL TO THE BASE
- END CUTTING ANGLE
- SIDE CUTTING ANGLE
END CUTTING EDGE ANGLE

It is the angle between end cutting edge & line Normal to tool shank.

SIDE CUTTING EDGE ANGLE

It is the angle which prevents interference as the tool enters the work material.
CUTTING THE TOOL PARALLEL TO ITS LENGTH AND PERPENDICULAR TO THE BASE
- BACK RAKE ANGLE
- END RELIEF ANGLE
**BACK RAKE ANGLE**
It is the angle between face of the tool & plane parallel to base

**END RELIEF ANGLE**
The angle between front surface of the tool & line normal to base of the tool is known as a front clearance angle
Rake Angles

• Back-Allows the tool to shear the work and form the chip.
• Back rake angle: The angle which measures the slope of the face of the tool from the nose towards the rear.
• It can be positive or negative
  ✓ Positive = reduced cutting forces, limited deflection of work, tool holder and machine
  ✓ Negative = typically used to machine harder metals-heavy cuts (if the slope of the face is downward from the nose)
• The side and back rake angle combine to form the “true rake angle”
Rake Angle

• Larger positive rake angles
  ✓ Reduce compression and less chance of a discontinuous chip
  ✓ Reduce forces
  ✓ Reduce friction
  ✓ Result = A thinner, less deformed.
Negative Rake Angle

- Typical tool materials which utilize negative rakes are:
  - Carbide
  - Diamonds
  - Ceramics

- These materials tend to be much more brittle than HSS but they hold superior hardness at high temperatures.

- The negative rake angles transfer the cutting forces to the tool which help to provide added support to the cutting edge.
(a) positive rake  (b) zero rake  (c) negative rake

Fig. 3.2  Three possible types of rake angles
BACK RAKE ANGLE

It is the angle between face of the tool & plane parallel to base

* Positive
  Top face slopes downward away from point

* Negative
  Top face slopes upward away from point

* Neutral
Rake Angle

• Small to medium rake angles cause:
  ✓ high compression
  ✓ high tool forces
  ✓ high friction
  ✓ result = Thick, highly deformed, hot chips
Notice the length of these red lines as the rake becomes more negative.

Positive  Neutral  Negative
NOSE ANGLE or LIP ANGLE or WEDGE ANGLE or KNIFE ANGLE or CUTTING ANGLE
NOSE ANGLE

It is the angle between face and flank. The angle is maximum when clearance and rake angle are minimum. Larger lip angles allow high depth of cut, high cutting speed, work on hard materials.
Cutting-Tool Nomenclature

- **Base**: Bottom surface of tool shank
- **Flank**: Surface of tool adjacent to and below cutting edge
- **Shank**: Body of toolbit or part held in toolholder
Cutting-Tool Nomenclature

- Nose radius: radius to which nose is ground
  - Size of radius will affect finish
    - Rough turning: small nose radius (.015in)
    - Finish cuts: larger radius (.060 to .125 in.)
- Point: end of tool that has been ground for cutting purposes
Cutting-Tool Nomenclature

- Cutting edge: leading edge of that does cutting
- Face: surface against which chip bears as it is separated from work
- Nose: Tip of cutting tool formed by junction of cutting edge and front face
Lathe Toolbit Angles and Clearances

- **End Cutting Edge Angle**
- **Top View**
- **Side Rake**
- **Nose Radius**
- **End View**
- **Side Rake Angle**
- **Angle of Keenness**
- **Side Relief Angle**
- **End Relief Angle**
Lathe Cutting-tool Angles

Negative rake: face of cutting tool contacts metal first and chip moves up the face of the toolbit
Positive Rake Angle

• Considered best for efficient removal of metal
  – Creates large shear angle at shear zone
  – Reduces friction and heat
  – Allows chip to flow freely along chip-tool interface

• Generally used for continuous cuts on ductile materials not too hard or abrasive
Cutting-Tool Terms

- **Front, End, Relief (Clearance)**
  - Allows end of cutting tool to enter work
- **Side Relief (Side)**
  - Permits side of tool to advance into work
Characteristics of a Drill Point

Cutting-point angles for standard drill

Chip formation of a drill
Nomenclature of a Plain Milling Cutter
Milling Cutter
Nomenclature of an End Mill

- Radial Rake Angle
- Primary Clearance Angle
- Secondary Clearance Angle
- Tooth Face
- Cutting Edge
- Flute
- Land
Nomenclature of an End Mill

- Cutting Edge
- Tooth Face
- Helix Angle
Objectives

• Use the nomenclature of a cutting-tool point
• Explain the purpose of each type of rake and clearance angle
• Identify the applications of various types of cutting-tool materials
• Describe the cutting action of different types of machines
Cutting Tools

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

• Lathe toolbits generally made of five materials
  – High-speed steel
  – Cast alloys (such as stellite)
  – Cemented carbides
  – Ceramics
  – Cermets

• More exotic finding wide use
  – Borazon and polycrystalline diamond
Lathe Toolbit Properties

• Hard
• Wear-resistant
• Capable of maintaining a red hardness during machining operation
  – Red hardness: ability of cutting tool to maintain sharp cutting edge even when turns red because of high heat during cutting
• Able to withstand shock during cutting
• Shaped so edge can penetrate work
Cemented-Carbide Toolbits

- Capable of cutting speeds 3 to 4 times high-speed steel toolbits
- Low toughness but high hardness and excellent red-hardness
- Consist of tungsten carbide sintered in cobalt matrix
- Straight tungsten used to machine cast iron and nonferrous materials (crater easily)
- Different grades for different work
Coated Carbide Toolbits

- Made by depositing thin layer of wear-resistant titanium nitride, titanium carbide or aluminum oxide on cutting edge of tool
  - Fused layer increases lubricity, improves cutting edge wear resistance by 200%-500%
  - LOWERS breakage resistance up to 20%
  - Provides longer life and increased cutting speeds
- Titanium-coated offer wear resistance at low speeds, ceramic coated for higher speeds
Ceramic Toolbits

• Permit higher cutting speeds, increased tool life and better surface finish than carbide
  – Weaker than carbide used in shock-free or low-shock situation

• Ceramic
  – Heat-resistant material produced without metallic bonding agent such as cobalt
  – Aluminum oxide most popular additive
  – Titanium oxide or Titanium carbide can be added
Diamond Toolbits

• Used mainly to machine nonferrous metals and abrasive nonmetallics

• Single-crystal natural diamonds
  – High-wear but low shock-resistant factors

• Polycrystalline diamonds
  – Tiny manufactured diamonds fused together and bonded to suitable carbide substrate
Factors When Choosing Type and Rake Angle for Cutting Tool

• Hardness of metal to be cut
• Type of cutting operation
  – Continuous or interrupted
• Material and shape of cutting tool
• Strength of cutting edge
Shape of Chip

• Altered in number of ways to improve cutting action and reduce amount of power required

• Continuous straight ribbon chip can be changed to continuous curled ribbon
  – Changing angle of the keeness
    • Included angle produced by grinding side rake
  – Grinding chip breaker behind cutting edge of toolbit
Crater wear occurs as result of chips sliding along chip-tool interface, result of built-up edge on cutting tool. When flank wear is .015 to .030 in. need to be reground.

Nose wear occurs as result of friction between nose and metal being machined. Occurs on side of cutting edge as result of friction between side of cutting-tool edge and metal being machined.
Factors Affecting the Life of a Cutting Tool

- Type of material being cut
- Microstructure of material
- Hardness of material
- Type of surface on metal (smooth or scaly)
- Material of cutting tool
- Profile of cutting tool
- Type of machining operation being performed
- Speed, feed, and depth of cut
Assume cutting machine steel: If rake and relief clearance angles correct and proper speed and feed used, a continuous chip should be formed.
PowerPoint to accompany

Technology of Machine Tools
6th Edition

Krar • Gill • Smid

Operating Conditions
and Tool Life
Unit 30
Objectives

- Describe the effect of cutting conditions on cutting-tool life
- Explain the effect of cutting conditions on metal-removal rates
- State the advantages of new cutting-tool materials
- Calculate the economic performance and cost analysis for a machining operation
Operating Conditions

• Three operating variables influence metal-removal rate and tool life
  – Cutting speed
  – Feed rate
  – Depth of cut
Reduction in Tool Life

Operating Conditions

- Cutting Speed + 50%: 90%
- Feed Rate + 50%: 60%
- Depth of Cut + 50%: 15%
General Operating Condition Rules

• Proper cutting speed most critical factor to consider establishing optimum conditions
  – Too slow: Fewer parts produced, built-up edge
  – Too fast: Tool breaks down quickly

• Optimum cutting speed should balance metal-removal rate and cutting-tool life

• Choose heaviest depth of cut and feed rate possible
Objectives

- Identify and state the purpose of the two main types of carbide grades
- Select the proper grade of carbide for various workpiece materials
- Select the proper speeds and feeds for carbide tools
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
Blending

• Five types of powders
  – Tungsten carbide, titanium carbide, cobalt, tantalum carbide, niobium carbide
• One or combination blended in different proportions depending on grade desired
• Powder mixed in alcohol (24 to 190 h)
• Alcohol drained off
• Paraffin added to simplify pressing operation
Compaction

• Must be molded to shape and size
• Five different methods to compact powder
  – Extrusion process
  – Hot press
  – Isostatic press
  – Ingot press
  – Pill press
• Green (pressed) compacts soft, must be presintered to dissolve paraffin
Presintering

- Green compacts heated to about 1500° F in furnace under protective atmosphere of hydrogen
- Carbide blanks have consistency of chalk
- May be machined to required shape
  - 40% oversize to allow for shrinkage that occurs during final sintering
Sintering

- Last step in process
- Converts presintered machine blanks into cemented carbide
- Carried out in either hydrogen atmosphere or vacuum
  - Temperatures between 2550° and 2730° F
- Binder (cobalt) unites and cements carbide powders into dense structure of extremely hard carbide crystals
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
Types of Carbide Lathe Cutting Tools

- **Brazed-tip type**
  - Cemented-carbide tips brazed to steel shanks
  - Wide variety of styles and sizes

- **Indexable insert type**
  - Throwaway inserts
  - Wide variety of shapes: triangular, square, diamond, and round
    - Triangular: has three cutting edges
  - Inserts held mechanically in special holder
Grades of Cemented Carbides

• Two main groups of carbides
  – Straight tungsten carbide
    • Contains only tungsten carbide and cobalt
    • Strongest and most wear-resistant
    • Used for machining cast iron and nonmetals
  – Crater-resistant
    • Contain titanium carbide and tantalum carbide in addition to tungsten carbide and cobalt
    • Used for machining most steels
Cutting Speeds and Feeds

• Important factors that influence speeds, feeds, and depth of cut
  – Type and hardness of work material
  – Grade and shape of cutting tool
  – Rigidity of cutting tool
  – Rigidity of work and machine
  – Power rating of machine
Cutting Fluids—Types and Applications

Unit 34
Objectives

- State the importance and function of cutting fluids
- Identify three types of cutting fluids and state the purpose of each
- Apply cutting fluids efficiently for a variety of machining operations
Cutting Fluids

- Essential in metal-cutting operations to reduce heat and friction
- Centuries ago, water used on grindstones
- 100 years ago, tallow used (did not cool)
- Lard oils came later but turned rancid
- Early 20th century saw soap added to water
- Soluble oils came in 1936
- Chemical cutting fluids introduced in 1944
Economic Advantages to Using Cutting Fluids

• Reduction of tool costs
  – Reduce tool wear, tools last longer

• Increased speed of production
  – Reduce heat and friction so higher cutting speeds

• Reduction of labor costs
  – Tools last longer and require less regrinding, less downtime, reducing cost per part

• Reduction of power costs
  – Friction reduced so less power required by machining
Heat Generated During Machining

- Heat find its way into one of three places
  - Act as disposable heat sink

Too much, cutting edge will break down rapidly, reducing tool life

Too much, work will expand
Heat Dissipation

• Ideally most heat taken off in chips
• Indicated by change in chip color as heat causes chips to oxidize
• Cutting fluids assist taking away heat
  – Can dissipate at least 50% of heat created during machining
Characteristics of a Good Cutting Fluid

1. Good cooling capacity
2. Good lubricating qualities
3. Resistance to rancidity
4. Relatively low viscosity
5. Stability (long life)
6. Rust resistance
7. Nontoxic
8. Transparent
9. Nonflammable
Types of Cutting Fluids

• Most commonly used cutting fluids
  – Either aqueous based solutions or cutting oils
• Fall into three categories
  – Cutting oils
  – Emulsifiable oils
  – Chemical (synthetic) cutting fluids
Oil Categories

• Sulfurized mineral oils
  – Contain .5% to .8% sulfur
  – Light-colored and transparent
  – Stains copper and alloys

• Sulfochlorinated mineral oils
  – 3% sulfur and 1% chlorine
  – Prevent excessive built-up edges from forming

• Sulfochlorinated fatty oil blends
  – Contain more sulfur than other types
Inactive Cutting Oils

• Oils will not darken copper strip immersed in them for 3 hours at 212°F
• Contained sulfur is natural
  – Termed inactive because sulfur so firmly attached to oil – very little released
• Four general categories
  – Straight mineral oils, fatty oils, fatty and mineral oil blends, sulfurized fatty-mineral oil blend
Emulsifiable (Soluble) Oils

• Mineral oils containing soaplike material that makes them soluble in water and causes them to adhere to workpiece
• Emulsifiers break oil into minute particles and keep them separated in water
  – Supplied in concentrated form (1-5 /100 water)
• Good cooling and lubricating qualities
• Used at high cutting speeds, low cutting pressures
Functions of a Cutting Fluid

• Prime functions
  – Provide cooling
  – Provide lubrication

• Other functions
  – Prolong cutting-tool life
  – Provide rust control
  – Resist rancidity
Functions of a Cutting Fluid: Cooling

- Heat has definite bearing on cutting-tool wear
  - Small reduction will greatly extend tool life
- Two sources of heat during cutting action
  - Plastic deformation of metal
    - Occurs immediately ahead of cutting tool
    - Accounts for 2/3 to 3/4 of heat
  - Friction from chip sliding along cutting-tool face
- Water most effective for reducing heat (rust)
Functions of a Cutting Fluid: Lubrication

• Reduces friction between chip and tool face
  – Shear plane becomes shorter
  – Area where plastic deformation occurs correspondingly smaller

• Extreme-pressure lubricants reduce amount of heat-producing friction

• EP chemicals of synthetic fluids combine chemically with sheared metal of chip to form solid compounds (allow chip to slide)
Cutting-Tool Life

- Heat and friction prime causes of cutting-tool breakdown
- Reduce temperature by as little as 50°F, life of cutting tool increases fivefold
- Built-up edge
  - Pieces of metal weld themselves to tool face
  - Becomes large and flat along tool face, effective rake angle of cutting tool decreased
Application of Cutting Fluids

- Cutting-tool life and machining operations influenced by way cutting fluid applied
- Copious stream under low pressure so work and tool well covered
  - Inside diameter of supply nozzle $\frac{3}{4}$ width of cutting tool
  - Applied to where chip being formed
Milling

- **Face milling**
  - Ring-type distributor recommended to flood cutter completely
  - Keeps each tooth of cutter immersed in cutting fluid at all times
- **Slab milling**
  - Fluid directing to both sides of cutter by fan-shaped nozzles ¾ width of cutter