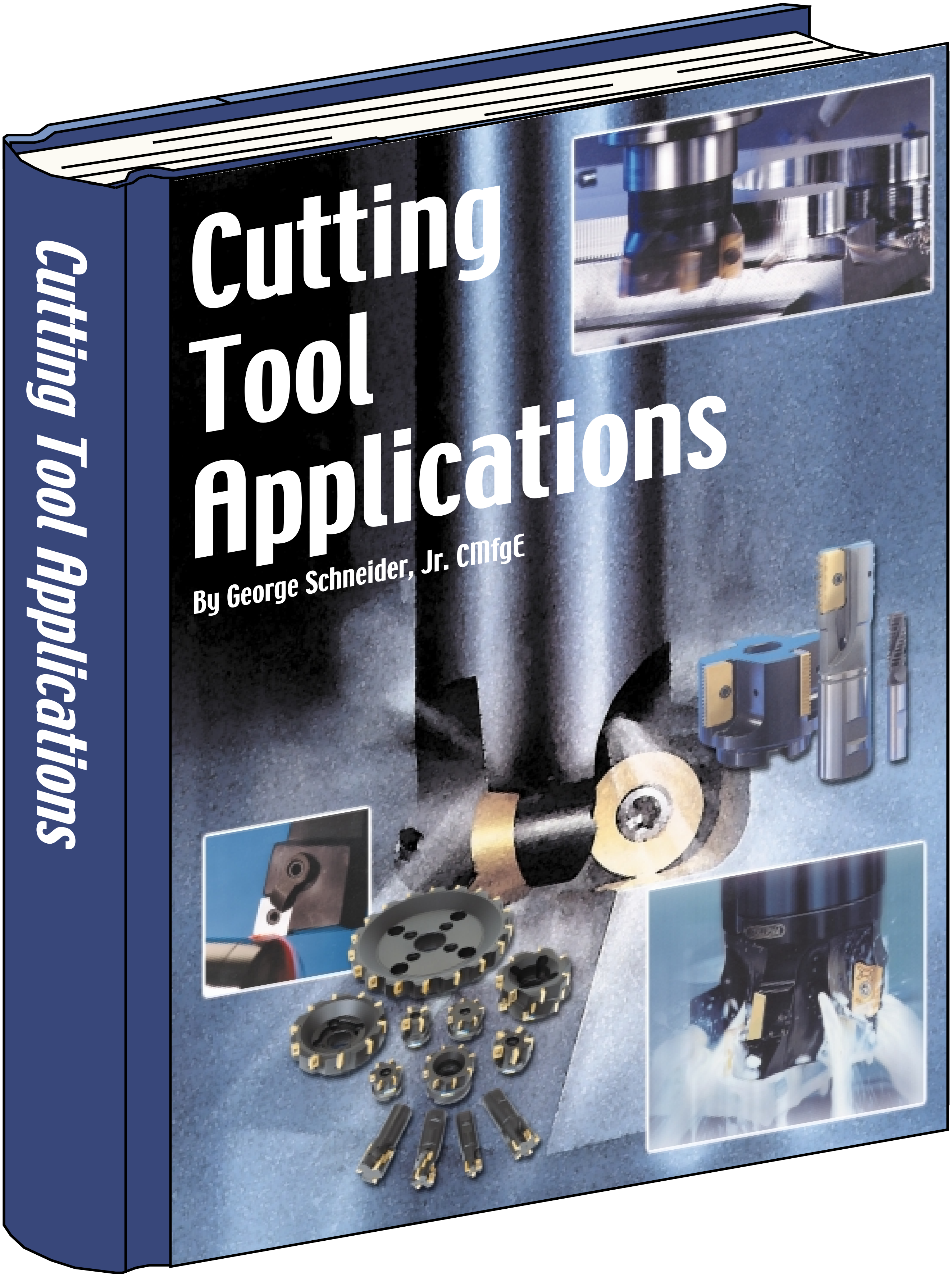
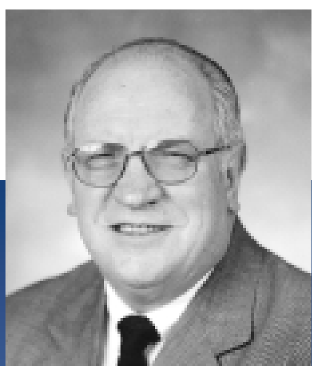

Cutting Tool Applications
Cutting
Tool
Applications
By George Schneider, Jr. CMfgE



**George Schneider, Jr. CMfgE**
Professor Emeritus
Engineering Technology
Lawrence Technological University

Former Chairman
Detroit Chapter ONE
Society of Manufacturing Engineers

Former President
International Excutive Board
Society of Carbide & Tool Engineers

Lawrence Tech. Univ.: http://www.ltu.edu

Prentice Hall: http://www.prenhall.com

# Chapter 2

# Metal Removal Methods

## 2.1 Introduction

The process of metal removal, a process in which a wedge-shaped tool engages a workpiece to remove a layer of material in the form of a chip, goes back many years. Even with all of the sophisticated equipment and techniques used in today's modern industry, the basic mechanics of forming a chip remain the same. As the cutting tool engages the workpiece, the material directly ahead of the tool is sheared and deformed under tremendous pressure. The deformed material then seeks to relieve its stressed condition by fracturing and flowing into the space above the tool in the form of a chip. A turning tool holder generating a chip is shown in Figure 2.1.

*FIGURE 2.1 A turning toolholder insert generating a chip. (Courtesy Kennametal Inc.)*

## 2.2 Cutting Tool Forces

The deformation of a work material means that enough force has been exerted by the tool to permanently reshape or fracture the work material. If a material is reshaped, it is said to have exceeded its plastic limit. A chip is a combination of reshaping and fracturing. The deformed chip is separated from the parent material by fracture. The cutting action and the chip formation can be more easily analyzed if the edge of the tool is set perpendicular to the relative motion of the material, as shown in Figure 2.2. Here the undeformed chip thickness t1 is the value of the depth of cut, while t2 is the thickness of the deformed chip after leaving the workpiece. The major deformation starts at the shear zone and diameter determines the angle of shear.

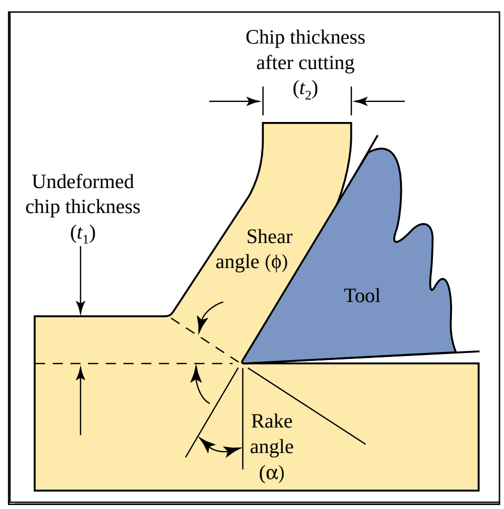



*FIGURE 2.2 Chip formation showing the deformation of the material being machined.*

A general discussion of the forces acting in metal cutting is presented by using the example of a typical turning operation. When a solid bar is turned, there are three forces acting on the cutting tool (Fig. 2.3):

**Tangential Force:** This acts in a direction tangential to the revolving workpiece and represents the resistance to the rotation of the workpiece. In a normal operation, tangential force is the highest of the three forces and accounts for about 98 percent of the total power required by the operation.

**Longitudinal Force:** Longitudinal force acts in the direction parallel to the axis of the work and represents the resistance to the longitudinal feed of the tool. Longitudinal force is usually about 50 percent as great as tangential force. Since feed velocity is usually very low in relation to the velocity of the rotating workpiece, longitudinal force accounts for only about 1 percent of total power required.

**Radial Force**: Radial force acts in a radial direction from the center line of the workpiece. The radial force is generally the smallest of the three, often about 50 percent as large as longitudinal force. Its effect on power requirements is very small because velocity in the radial direction is negligible.

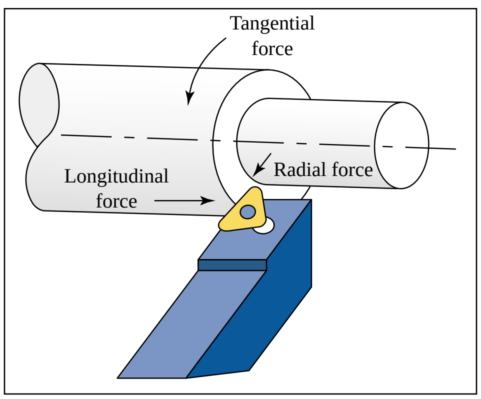



***FIGURE 2.3Typical turning operation showing the forces acting on the cutting tool.***

## 2.3 Chip Formation and Tool Wear

Regardless of the tool being used or the metal being cut, the chip forming process occurs by a mechanism called plastic deformation. This deformation can be visualized as shearing. That is when a metal is subjected to a load exceeding its elastic limit. The crystals of the metal elongate through an action of slipping or shearing, which takes place within the crystals and between adjacent crystals. This action, shown in Figure 2.4 is similar to the action that takes place when a deck of cards is given a push and sliding or shearing occurs between the individual cards.

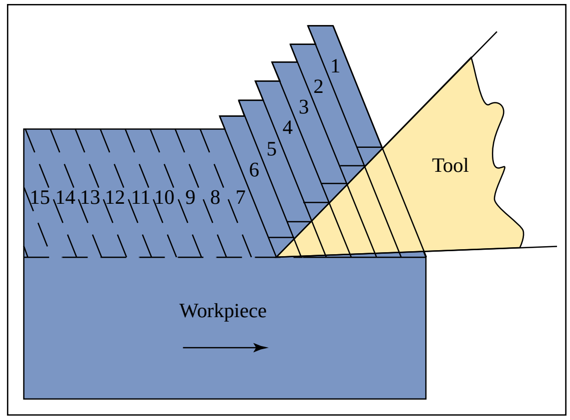



***FIGURE 2.4 Chip formation compared to a sliding deck of cards.***

Metals are composed of many crystals and each crystal in turn is composed of atoms arranged into some definite pattern. Without getting into a complicated discussion on the atomic makeup and characteristics of metals, it should be noted, that the slipping of the crystals takes place along a plane of greatest ionic density.

Most practical cutting operations, such as turning and milling, involve two or more cutting edges inclined at various angles to the direction of the cut. However, the basic mechanism of cutting can be explained by analyzing cutting done with a single cutting edge.

Chip formation is simplest when a continuous chip is formed in orthogonal cutting (Fig. 2.5a). Here the cutting edge of the tool is perpendicular to the line of tool travel, tangential, longitudinal, and radial forces are in the same plane, and only a single, straight cutting edge is active. In oblique cutting, ( Fig. 2.5b), a single, straight cutting edge is inclined in the direction of tool travel. This inclination causes changes in the direction of chip flow up the face of the tool. When the cutting edge is inclined, the chip flows across the tool face with a sideways movement that produces a helical form of chip.

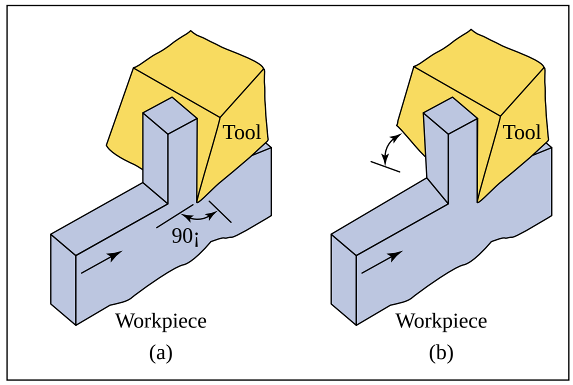



***FIGURE 2.5 Chip formation showing both (a) orthogonal cutting and (b) oblique cutting.***

### 2.3.1 Chip Formation

Metal cutting chips have been classified into three basic types:

- discontinuous or segmented
- continuous
- continuous with a built-up edge.

All three types of chips are shown in Figure 2.6 a,b,and c.

**Discontinuous Chip - Type 1:** Discontinuous or segmented chips are produced when brittle metal such as cast iron and hard bronze are cut or when some ductile metals are cut under poor cutting conditions. As the point of the cutting tool contacts the metal, some compression occurs, and the chip begins

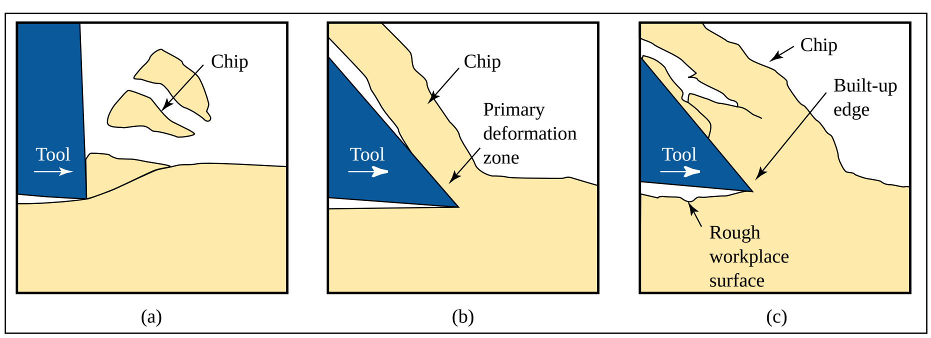



***FIGURE 2.6 Types of chip formations: (a) discontinuous, (b) continuous, (c) continuous with built-up edge (BUE).***

flowing along the chip-tool interface. As more stress is applied to brittle metal by the cutting action, the metal compresses until it reaches a point where rupture occurs and the chip separates from the unmachined portion. This cycle is repeated indefinitely during the cutting operation, with the rupture of each segment occurring on the shear angle or plane. Generally, as a result of these successive ruptures, a poor surface is produced on the workpiece.

**Continuous Chip - Type 2:** The Type 2 chip is a continuous ribbon produced when the flow of metal next to the tool face is not greatly restricted by a built-up edge or friction at the chip tool interface. The continuous ribbon chip is considered ideal for efficient cutting action because it results in better finishes.

Unlike the Type 1 chip, fractures or ruptures do not occur here, because of the ductile nature of the metal. The crystal structure of the ductile metal is elongated when it is compressed by the action of the cutting tool and as the chip separates from the metal. The process of chip formation occurs in a single plane, extending from the cutting tool to the unmachined work surface. The area where plastic deformation of the crystal structure and shear occurs, is called the shear zone. The angle on which the chip separates from the metal is called the shear angle, as shown in Figure 2.2.

**Continuous Chip with a Built-up Edge (BUE)- Type 3:** The metal ahead of the cutting tool is compressed and forms a chip which begins to flow along the chip-tool interface. As a result of the high temperature, the high pressure, and the high frictional resistance against the flow of the chip along the chip-tool interface, small particles of metal begin adhering to the edge of the cutting tool while the chip shears away. As the cutting process continues, more particles adhere to the cutting tool and a larger build-up results, which affects the cutting action. The built-up edge increases in size and becomes more unstable. Eventually a point is reached where fragments are torn off. Portions of these fragments which break off, stick to both the chip and the workpiece. The build-up and breakdown of the built-up edge occur rapidly during a cutting action and cover the machined surface with a multitude of built-up fragments. These fragments adhere to and score the machined surface, resulting in a poor surface finish.

**Shear Angle:** Certain characteristics of continuous chips are determined by the shear angle. The shear angle is the plane where slip occurs, to begin chip formation (Figure 2.2). In Figure 2.7 the distortion of the work material grains in the chip, as compared to the parent material, is visible. Each fracture line in the chip as it moves upward over the tool surface can be seen, as well as the distorted surface grains where the tool has already passed. In certain work materials, these distorted surface grains account for work hardening.

Regardless of the shear angle, the compressive deformation caused by the tool force against the chip, will cause the chip to be thicker and shorter than the layer of workpiece material removed. The work or energy required to deform the material usually accounts for the largest portion of forces and power involved in a metal removing operation. For a layer of work material of given dimensions, the thicker the chip, the greater the force required to produce it.

Heat in Metal Cutting: The mechanical energy consumed in the cutting area is converted into heat. The main sources of heat are, the shear zone, the interface between the tool and the chip where the friction force generates heat, and the lower portion of the tool tip which rubs against the machined surface. The interaction of these heat sources, combined with the geometry of the cutting area, results in a complex temperature distribution, as shown in Figure 2.8.

The temperature generated in the shear plane is a function of the shear energy and the specific heat of the material. Temperature increase on the tool face depends on the friction conditions at the interface. A low coefficient of friction is, of course, desirable.

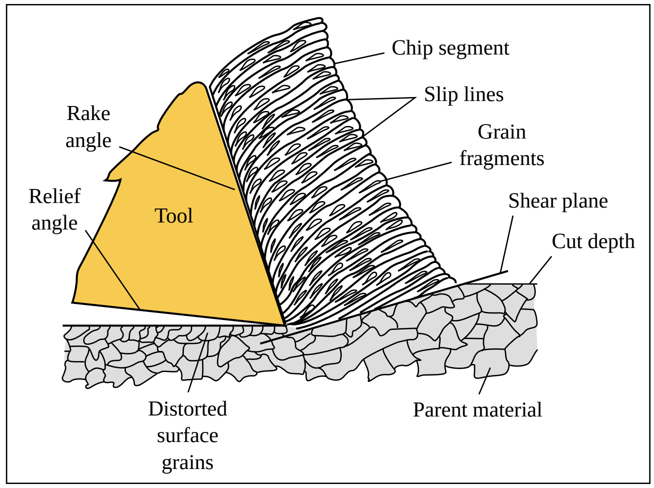



***FIGURE 2.7 Distribution of work material during chip formation.***

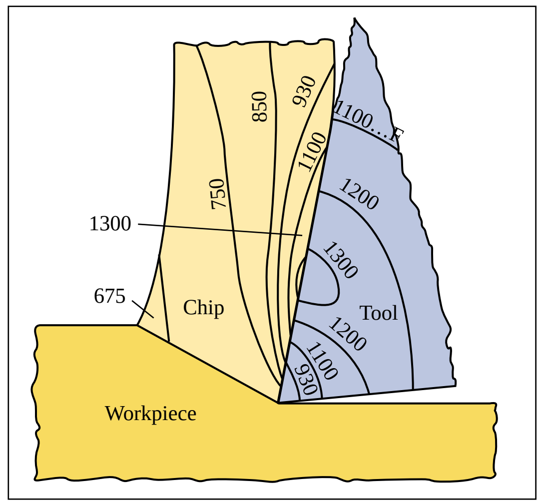



***FIGURE 2.8 Typical temperature distribution in the cutting zone.***

Temperature distribution will be a function of, among other factors, the thermal conductivities of the workpiece and the tool materials, the specific heat, cutting speed, depth of cut, and the use of a cutting fluid. As cutting speed increases, there is little time for the heat to be dissipated away from the cutting area and so the proportion of the heat carried away by the chip increases.

In Chapter 3 - Machinability of Metals - this topic is discussed in more detail.

## 2.3.2 Cutting Tool Wear

Cutting tool life is one of the most important economic considerations in metal cutting. In roughing operations, the tool material, the various tool angles, cutting speeds, and feed rates, are usually chosen to give an economical tool life. Conditions giving a very short tool life will not be economical because tool-grinding, indexing, and tool replacement costs will be high. On the other hand, the use of very low speeds and feeds to give long tool life will not be economical because of the low production rate. Clearly any tool or work material improvements that increase tool life without causing unacceptable drops in production, will be beneficial. In order to form a basis for such improvements, efforts have been made to understand the behavior of the tool, how it physically wears, the wear mechanisms, and forms of tool failure.

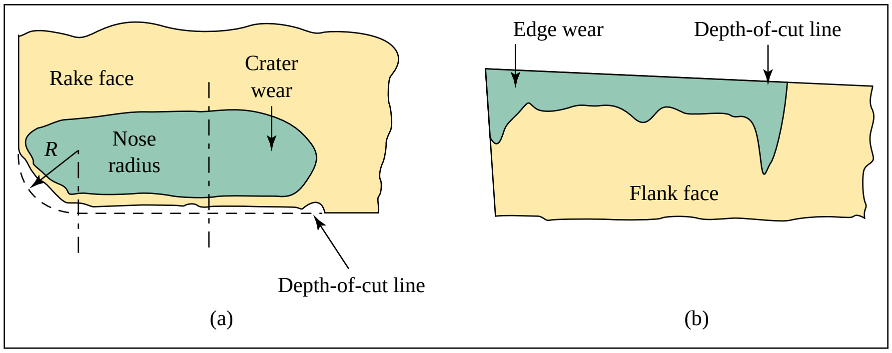



*FIGURE 2.9 Carbide insert wear patterns: (a) crater wear, (b) edge wear.*

While the tool is engaged in the cutting operation, wear may develop in one or more areas on and near the cutting edge:

**Crater Wear:** Typically, cratering occurs on the top face of the tool. It is essentially the erosion of an area parallel to the cutting edge. This erosion process takes place as the chip being cut, rubs the top face of the tool. Under very high-speed cutting conditions and when machining tough materials, crater wear can be the factor which determines the life of the tool. Typical crater wear patterns are shown in Figures 2.9 and 2.10a. However, when tools are used under economical conditions, the edge wear and not the crater wear is more commonly the controlling factor in the life of the tool

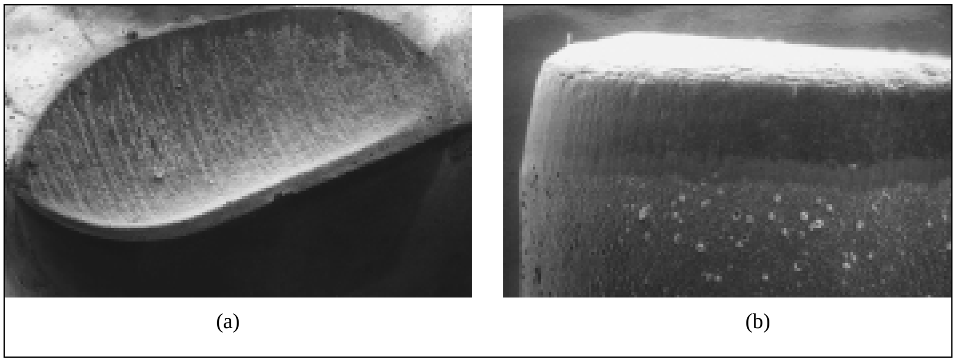



*FIGURE 2.10 Carbide insert wear patterns: (a) crater wear, (b) edge wear. (Courtesy Kennametal Inc.)*

**Edge Wear:** Edge wear occurs on the clearance face of the tool and is mainly caused by the rubbing of the newly machined workpiece surface on the contact area of the tool edge. This type of wear occurs on all tools while cutting any type of work material. Edge wear begins along the lead cutting edge and generally moves downward, away from the cutting edge. Typical edge wear patterns are shown in Figures 2.9 and 2.10b. The edge wear is also commonly known as the wearland.

**Nose Wear:** Usually observed after a considerable cutting time, nose wear appears when the tool has already exhibited land and/or crater wear. Wear on the nose of the cutting edge usually affects the quality of the surface finish on the workpiece.

Cutting tool material in general, and carbide tools in particular, exhibit different types of wear and/or failure:

**Plastic Deformation:** Edge depression and body bulging appear, due to excessive heat. The tool loses strength and consequently flows plastically.

**Mechanical Breakage:** Excessive force may cause immediate failure. Alternatively, the mechanical failure (chipping) may result from a fatigue-type failure. Thermal shock also causes mechanical failure.

**Gradual Wear:** The tool assumes a form of stability wear due to interaction between tool and work, resulting in crater wear. Four basic wear mechanisms affecting tool material have been categorized as:

**Abrasion:** Because hard inclusions in the workpiece microstructure plow into the tool face and flank surfaces, abrasion wear predominates at relatively low cutting temperatures. The abrasion resistance of a tool material is proportional to its hardness.

**Adhesion:** Caused by formation and subsequent destruction of minute welded junctions, adhesion wear is commonly observed as built-up edge (BUE) on the top face of the tool. This BUE may eventually disengage from the tool, causing a crater like wear. Adhesion can also occur when minute particles of the tool surface are instantaneously welded to the chip surface at the tool-chip interface and carried away with the chip.

**Diffusion:** Because of high temperatures and pressures in diffusion wear, microtransfer on an atomic scale takes place. The rate of diffusion increases exponentially with increases in temperature.

**Oxidation:** At elevated temperature, the oxidation of the tool material can cause high tool wear rates. The oxides that are formed are easily carried away, leading to increased wear.

The different wear mechanisms as well as the different phenomena contributing to the attritious wear of the cutting tool, are dependent on the multitude of cutting conditions and especially on the cutting speeds and cutting fluids.

Aside from the sudden premature breakage of the cutting edge (tool failure), there are several indicators of the progression of physical wear. The machine operator can observe these factors prior to total rupture of the edge.

The indicators are:
• Increase in the flank wear size above a predetermined value.
• Increase in the crater depth, width or other parameter of the crater, in the rake face.
• Increase in the power consumption, or cutting forces required to perform the cut.
• Failure to maintain the dimensional quality of the machined part within a specified tolerance limit.
• Significant increase in the surface roughness of the machined part.
• Change in the chip formation due to increased crater wear or excessive heat generation.

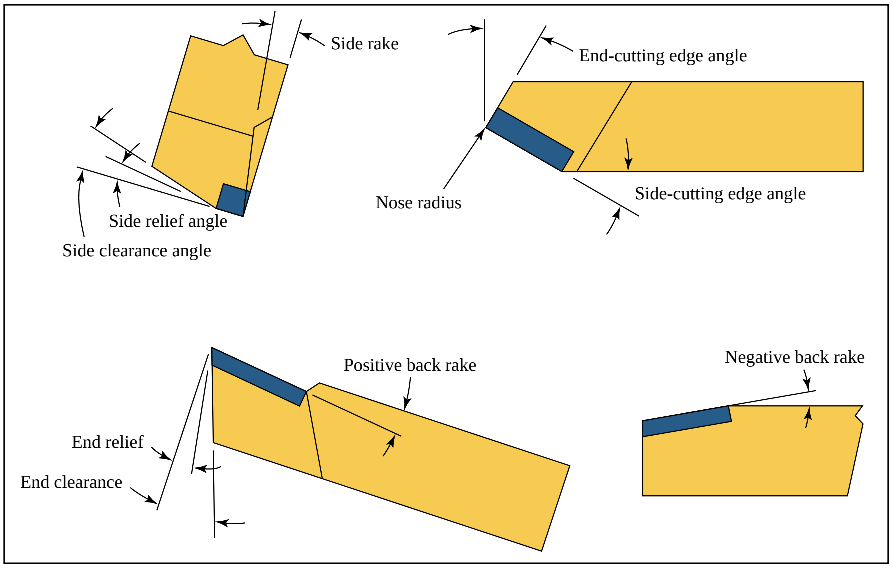



*FIGURE 2.11 Terminology used to designate the surfaces, angles, and radii of single-point tools.*

## 2.4 Single Point Cutting Tools

The metal cutting tool separates chips from the workpiece in order to cut the part to the desired shape and size. There is a great variety of metal cutting tools, each of which is designed to perform a particular job or a group of metal cutting operations in an efficient manner. For example, a twist drill is designed to drill a hole of a particular size, while a turning tool might be used to turn a variety of cylindrical shapes.

### 2.4.1 Cutting Tool Geometry

The shape and position of the tool, relative to the workpiece, have an important effect on metal cutting. The most important geometric elements, relative to chip formation, are the location of the cutting edge and the orientation of the tool face with respect to the workpiece and the direction of cut. Other shape considerations are concerned primarily with relief or clearance, i.e., taper applied to tool surfaces to prevent rubbing or dragging against the work.

Terminology used to designate the surfaces, angles and radii of single point tools, is shown in Figure 2.11. The tool shown here is a brazed-tip type, but the same definitions apply to indexable tools.

### T & P TO PLACE FIG. 2.11 HERE

**The Rake Angle**: The basic tool geometry is determined by the rake angle of the tool as shown in Figure 2.12. The rake angle is always at the top side of the tool. With the tool tip at the center line of the workpiece, the rake angle is determined by the angle of the tool as it goes away from the workpiece center line location. The neutral, positive, and negative rakes are seen in (a), (b), and (c) in Figure 2.12. The angle for these geometries is set by the position of the insert pocket in the tool holder. The positive/negative (d) and double positive (e) rake angles are set by a combination of the insert pocket in the tool holder and the insert shape itself.

There are two rake angles: back rake as shown in Figure 2.12, and side rake as shown in Figure 2.13. In most turning and boring operations, it is the side rake that is the most influential. This is because the side rake is in the direction of the cut.

Rake angle has two major effects during the metal cutting process. One major effect of rake angle is its influence on tool strength. An insert with negative rake will withstand far more loading than an insert with positive rake. The cutting force and heat are absorbed by a greater mass of tool material, and the compressive strength of carbide is about two and one half times greater than its transverse rupture strength.

The other major effect of rake angle is its influence on cutting pressure. An insert with a positive rake angle reduces cutting forces by allowing the chips to flow more freely across the rake surface.

**Negative Rake:** Negative rake tools

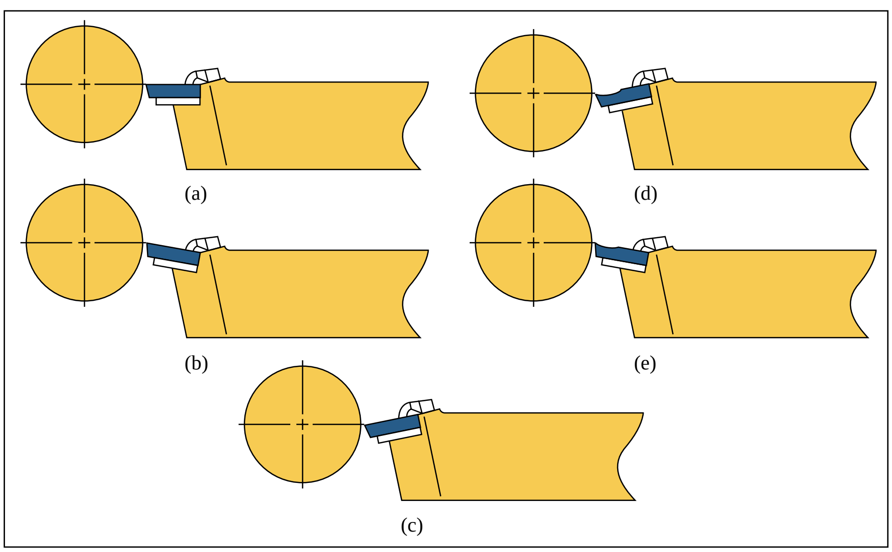



*FIGURE 2.12 With the cutting tool on center, various back rake angles are shown: (a) neutral, (b) positive, (c) negative, (d) positive/negative, (e) double positive.*

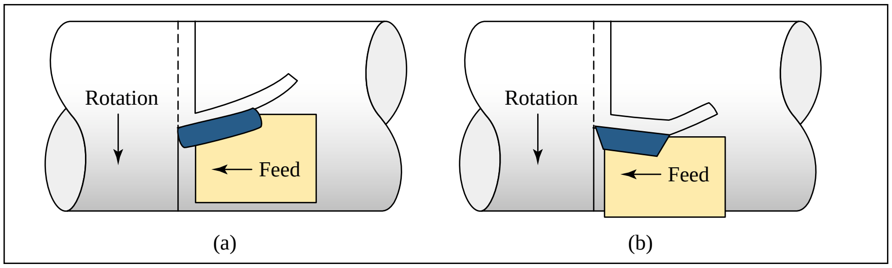



*FIGURE 2.13 Side-rake-angle variations: (a) negative, (b) positive.*

should be selected whenever workpiece and machine tool stiffness and rigidity allow. Negative rake, because of its strength, offers greater advantage during roughing, interrupted, scaly, and hard-spot cuts. Negative rake also offers more cutting edges for economy and often eliminates the need for a chip breaker. Negative rakes are recommended on insert grades which do not possess good toughness (low transverse rupture strength)

Negative rake is not, however, without some disadvantages. Negative rake requires more horsepower and maximum machine rigidity. It is more difficult to achieve good surface finishes with negative rake. Negative rake forces the chip into the workpiece, generates more heat into the tool and workpiece, and is generally limited to boring on larger diameters because of chip jamming.

**Positive Rake:** Positive rake tools should be selected only when negative rake tools can't get the job done. Some areas of cutting where positive rake may prove more effective are, when cutting tough, alloyed materials that tend to 'work-harden', such as certain stainless steels, when cutting soft or gummy metals, or when low rigidity of workpiece, tooling, machine tool, or fixture allows chatter to occur. The shearing action and free cutting of positive rake tools will often eliminate problems in these areas.

One exception that should be noted when experiencing chatter with a positive rake is, that at times the preload effect of the higher cutting forces of a negative rake tool will often dampen out chatter in a marginal situation. This may be especially true during lighter cuts when tooling is extended or when the machine tool has excessive backlash.

**Neutral Rake:** Neutral rake tools are seldom used or encountered. When a negative rake insert is used in a neutral rake position, the end relief (between tool and workpiece) is usually inadequate. On the other hand, when a positive insert is used at a neutral rake, the tip of the insert is less supported, making the insert extremely vulnerable to breakage.

**Positive/Negative Rake:** The positive/negative rake is generally applied using the same guidelines as a positive rake. The major advantages of a positive/negative insert are that it can be used in a negative holder, it offers greater strength than a positive rake, and it doubles the number of cutting edges when using a two-sided insert.

The positive/negative insert has a ten degree positive rake. It is mounted in the normal five degree negative pocket which gives it an effective five degree positive rake when cutting. The positive/negative rake still maintains a cutting attitude which keeps the carbide under compression and offers more mass for heat dissipation. The positive/negative insert also aids in chip breaking on many occasions, as it tends to curl the chip.

**Double Positive Rake:** The double positive insert is the weakest of all inserts. It is free cutting, and generally used only when delicate, light cuts are required which exert minimum force against the workpiece, as in the case of thin wall tubing, for example. Other uses of double positive inserts are for very soft or gummy work materials, such as low carbon steel and for boring small diameter holes when maximum clearance is needed.

**Side Rake Angles:** In addition to the back rake angles there are side rake angles as shown in Figure 2.13. These angles are normally determined by the tool manufacturers. Each manufacturer's tools may vary slightly, but usually an insert from one manufacturer can be used in the tool holder from another. The same advantage of positive and negative geometry that was discussed for back rake, applies to side rake. When back rake is positive so is side rake and when back rake is negative so is side rake.

**Side and End Relief Angles:** Relief angles are for the purpose of helping to eliminate tool breakage and to increase tool life. The included angle under the cutting edge must be made as large as practical. If the relief angle is too large, the cutting tool may chip or break. If the angle is too small, the tool will rub against the workpiece and generate excessive heat, and this will in turn, cause premature dulling of the cutting tool.

Small relief angles are essential when

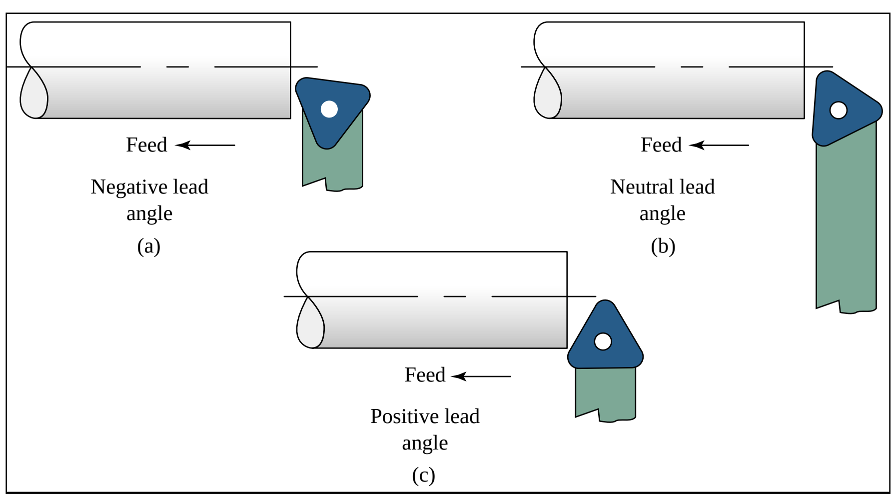



*FIGURE 2.14 Lead-angle variations: (a) negative, (b) neutral, (c) positive.*

machining hard and strong materials, and they should be increased for the weaker and softer materials. A smaller angle should be used for interrupted cuts or heavy feeds, and a larger angle for semi-finish and finish cuts.

**Lead Angle:** Lead angle (Fig. 2.14) is determined by the tool holder which must be chosen for each particular job. The insert itself can be used in any appropriate holder, for that particular insert shape, regardless of lead angle.

Lead angle is an important consideration when choosing a tool holder. A positive lead angle is the most commonly used and should be the choice for the majority of applications. Positive lead angle performs two main functions:

- It thins the chip
- It protects the insert

The undeformed chip thickness decreases when using a positive lead angle.

Positive lead angles vary, but the most common lead angles available on standard holders are 10, 15, 30 and 45 degrees. As seen in Figure 2.15, the volume of chip material is about the same in each case but the positive lead angle distributes the cutting force over a greater area of the tool's edge. This allows a substantial increase in feed rate without reducing the tool life because of excessive loading. The greater the lead angle, the more the feed rate can be increased.

Positive lead angle also reduces the longitudinal force (direction of feed) on the workpiece. But positive lead angle increases the radial force because the cutting force is always approximately perpendicular to the cutting edge (Fig. 2.16). This may become a problem when machining a workpiece that is not well supported. Care must be taken in cases where an end support, such as a tail stock center is not used.

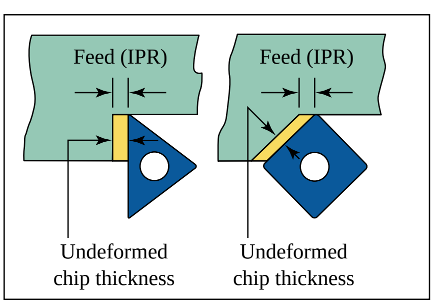



*FIGURE 2.15 Lead angle vs. chip thickness. A positive lead angle thins the chip and protects the insert.*

A heavy positive lead angle also has a tendency to induce chatter because of a greater tool contact area. This chatter is an amplification of tool or workpiece deflection resulting from the increased contact. In this situation it is appropriate to decrease the positive lead angle.

A positive lead angle protects the tool and promotes longer tool life. As shown in Figure 2.17 the tool comes in contact with the workpiece well away from the tool tip, which is the weakest point of the tool. As the tool progresses into the cut, the load against the tool gradually increases, rather than occurring as a sudden shock to the cutting edge. The positive lead angle also reduces the wear on the cutting edge caused by a layer of hardened material or scale, by thinning the layer and spreading it over a greater area. These advantages are extremely beneficial during interrupted cuts. Another way that positive lead angle helps to extend tool life is by allowing intense heat build-up to dissipate more rapidly, since more of the tool is in contact with the workpiece.

Neutral and negative lead angle tools also have some benefits. A neutral angle offers the least amount of tool contact, which will sometimes reduce the tendency to chatter, and lowers longitudinal forces. This is important on less stable workpieces or set-ups. Negative lead angles permit machining to a shoulder or a corner and are useful for facing. Cutting forces tend to pull the insert out of the seat, leading to erratic size control. Therefore, negative lead angles should be avoided if at all possible.

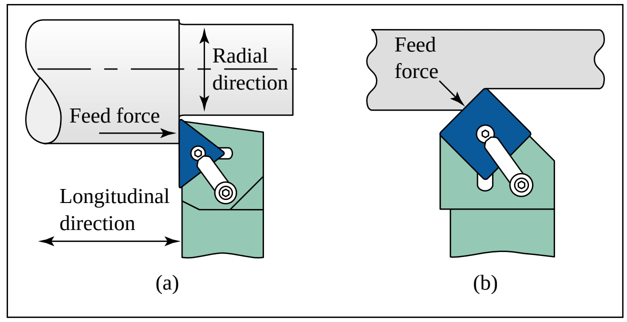



*FIGURE 2.16 Lead angles and their effects on longitudinal and radial cutting cutting-tool feed forces.*

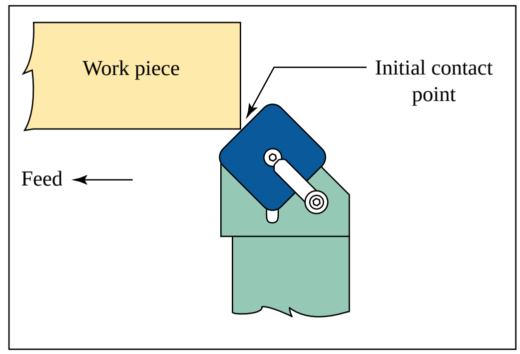



*FIGURE 2.17 Gradual feed/workpiece contact protects the cutting tool by slowing increasing the load.*

## 2.4.2 Edge Preparation

Edge preparation is a step taken to prolong tool life or to enhance tool performance. There are four basic approaches to edge preparation:

- Edge hone
- Edge "L" land
- Edge chamfer
- Combinations of the above

Many inserts, including carbide, ceramic, etc., are purchased with a standard edge preparation, normally an edge hone. The primary purpose of edge preparation is to increase the insert's resistance to chipping, breaking, and wear. Figure 2.18 illustrates the basic edge preparations.

Tool materials such as carbide and ceramic are very hard and brittle. Therefore, a lead sharp cutting edge on inserts made of these materials is extremely prone to chipping and breaking. Once a cutting edge is chipped, the wear rate is greatly accelerated or breakage occurs. A prepared edge eliminates the sharp edge and provides other benefits such as redistributing cutting forces.

**Edge Hone:** The edge hone is by far the most commonly used edge preparation. Many inserts are automatically provided with an edge hone at the time of purchase, especially larger inserts that will be exposed to heavy cutting. An edge hone on a ground or precision insert must usually be specially requested. A standard light hone in the United States usually has a radius of 0.001 to 0.003 inch; A standard heavy hone has a radius of 0.004 to 0.007 inch. Heavier

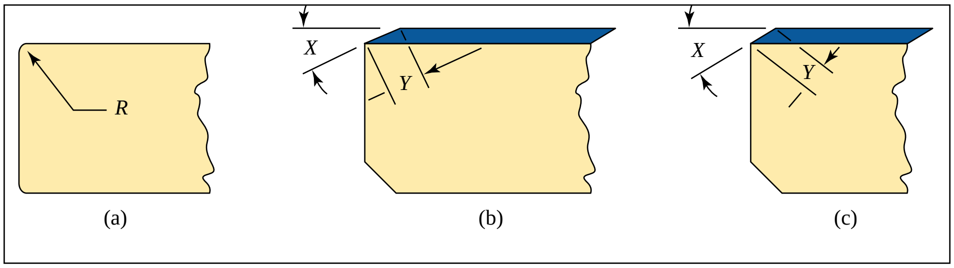



*FIGURE 2.18 The three basic edge preparations are (a) edge hone, (b) L land, (c) edge chamfer.*

hones are available on request. The heavier the hone, the more resistance an edge has to chipping and breaking, especially in heavy roughing cuts, interrupted cuts, hard spot cuts, and scaly cuts.

It is standard practice of all manufacturers to hone inserts that are to be coated before the inserts are subjected to the coating process. The reason for this is that during the coating process, the coating material tends to build up on sharp edges. Therefore it is necessary to hone those edges to prevent build-up.

**'L' Land:** The 'L' land edge preparation adds strength to the cutting edge of an insert. Essentially, the 'L' land amplifies the advantages of negative rake by diverting a greater amount of cutting force into the body of the insert. The 'L' land amplifies this condition because the included angle at the insert's edges is 110 degrees as opposed to 90 degrees. The 'L' land is particularly beneficial when engaging severe scale, interruptions, and roughing.

The 'L' land configuration is normally 20 degrees by two thirds of the feedrate. The feedrate should exceed the land width by about one third. This is not a hard and fast rule, but it does serve as a good starting point. If the land width is greater than the feedrate, severe jamming of the chips, excessive high pressures, and high heat will likely occur, resulting in rapid tool failure.

Something other than a 20 degree land angle may be considered, with varying land width. Some experimentation may prove beneficial, however, if the land angle is varied from 20 degrees it should probably be less rather than more than 20 degrees to keep from jamming the chips.

An 'L' land is normally used only on negative, flat top inserts placed at a negative rake angle. To use an 'L' land on a positive or a positive/negative insert would defeat the purpose of positive cutting action.

**Chamfer:** A chamfer is a compromise between a heavy hone and an 'L' land. A chamfer will also increase an insert's resistance to chipping and breaking. In a shop situation a chamfer is easier and quicker to apply than a heavy hone, because it can be applied with a grinder rather than a hand hone. When a chamfer is applied it should be very slight, 45 degrees by 0.005 to 0.030 inch.

Normally a chamfer presents a negative cutting situation which can result in some problems. The area of application for chamfers is limited and caution must be exercised. A slight chamfer is often used on a hard and brittle tool for making a very light finishing cut on hard work material. In this instance, the chamfer will strengthen the cutting edge.

Combinations: Any time that a sharp edge can be eliminated the life of an insert will likely be extended. When an 'L' land or chamfer is put on an insert, it will make a dramatic improvement in performance, but the 'L' land or chamfer will leave some semi-sharp corners. To get the maximum benefit from an 'L' land or chamfer, it will help to add a slight hone to each semi-sharp corner. This will be of significant value in extending tool life, particularly when a large 'L' land is used.

**Nose Radius:** The nose radius of an insert has a great influence in the metal cutting process. The primary function of the nose radius is to provide strength to the tip of the tool. Most of the other functions and the size of the nose radius are just as important. The choice of nose radius will affect the results of the cutting operation; however, inserts are provided with various standard radii and, in most cases, one of these will meet each specific cutting need.

The larger the radius, the stronger the tool tip will be. However, a large radius causes more contact with the work surface and can cause chatter. The cutting forces will increase with a large radius for the same reason, increased contact with the work surface. When taking a shallow cut, a depth approximately equal to the radius or less, the radius acts as a positive lead angle, thinning the chip. A large radius will allow the cutting heat to dissipate more quickly into the insert body, reducing the temperature build-up at the cutting edge.

One of the most important influences of a large radius is that of surface finish. The larger the radius, the better the surface finish will be at an equal feedrate. A larger radius will allow a faster feedrate and yet obtain a satisfactory finish. During a finishing cut, the feedrate should not exceed the radius if a reasonable surface finish is required.

### 2.4.3 Chip Breakers

Breaking the chip effectively when machining with carbide tools is of the utmost importance, not only from the production viewpoint, but also from the safety viewpoint. When machining steel at efficient carbide cutting speeds, a continuous chip flows away from the work at high speed.

If this chip is allowed to continue, it may wrap around the toolpost, the workpiece, the chuck, and perhaps around the operator's arm. Not only is the operator in danger of receiving a nasty laceration, but if the chip winds around the workpiece and the machine, he must spend considerable time in removing it. A loss of production will be encountered. Therefore it is imperative that this chip be controlled and broken in some manner.

With the advent of numerial control (NC) machining and automatic chip handling systems, the control of chips is becoming more important than ever. The control of chips on any machine tool, old or new, helps to avoid jam-ups with tooling and reduces safety hazards from flying chips. There is a great deal of research and development being conducted in chip control, much of which has been very successful.

There are two basic types of chip control being used with indexable insert tooling: the mechanical chip breaker,

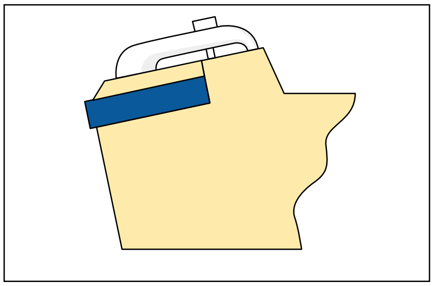


*FIGURE 2.19 Mechanical chip breaker.*

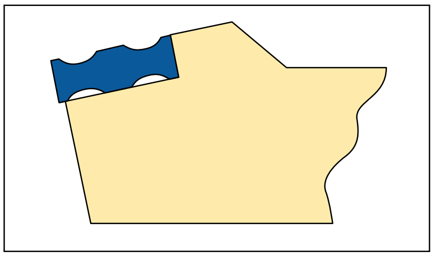


*FIGURE 2.20 Sintered chip breaker.*

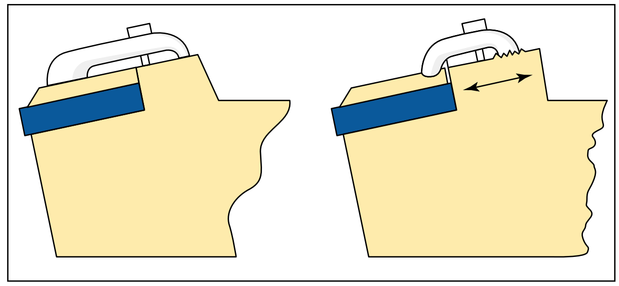


*FIGURE 2.21 Solid and adjustable chip breaker.*

Figure 2.19, and the sintered chip breaker, Figure 2.20. Mechanical chip breakers are not as commonly used as sintered chip breakers. There are more parts involved with the mechanical chip breaker, which increases the cost, and the chip breaker hampers changing and indexing the insert. However, mechanical chip breakers are extremely effective in controlling chips during heavy metal removing operations.

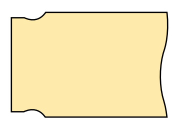
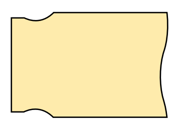
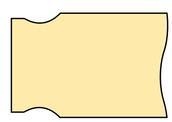
There are two groups of mechanical chip breakers, solid and adjustable as shown in Figure 2.21. Solid chip breakers are available in various lengths and angles, to suit each metal cutting application. The adjustable chip breaker can eliminate the need for stocking various sizes of solid chip breakers.

Sintered chip breakers are available in many different configurations, some designed for light feeds, some for heavy feeds, and still others for handling both light and heavy feeds. Figure 2.22 shows examples of the various sintered chip breaker configurations available from a single manufacturer. There are single sided and double sided designs of sintered chip breaker inserts.

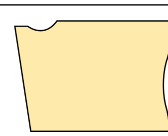
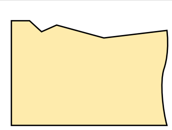
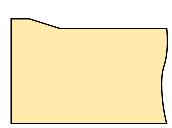
Many of the designs will significantly reduce cutting forces as well as control chips. Normally it would be more economical to use a double sided insert because of the additional cutting edges available. However, this is not always true. While a double sided insert is more economical under moderate and finish cutting conditions because of its additional cutting edges, a single sided design will justify itself, from a cost standpoint, through more effective chip control and reduced cutting forces in certain situations. Figure 2.23 shows five common insert styles with sintered chip breakers.

Figure 2.22 illustrates that a single sided insert is flat on the bottom as com-

Double-Sided General-Purpose Groove Geometries

| | | |
|---|---|---|
| .004—.020 ipr feed range |  | Offers excellent mix of low cost per cutting edge and effective chip control. Designed for general-purpose use at low feed rates. |
| .005—.065 ipr feed range |  | Offers excellent mix of low cost per cutting edge and effective chip control. Designed for general-purpose use at medium feed rates |
| .012—.070 ipr feed range |  | Offers excellent mix of low cost per cutting edge and effective chip control. Designed for general-purpose use at high feed rates |

Single-Side Low Force Groove Geometries

| | | |
|---|---|---|
| .005—.045 ipr feed range |  | Offers lower cutting forces than general-purpose grooves in medium feed range applications. Insert has 11¡ clearance angle for use in positive rake tool holder. |
| .006—.050 ipr feed range |  | Generates about 25% less cutting force than general-purpose chip grooves. Designed for medium-feed applications where force reduction, particularly in the radial direction, is important. |
| .012—.078 ipr feed range |  | Generates about 25% less cutting force than general-purpose chip grooves. Designed for ultra-high-feed applications where force reduction is important. |

Double-Sided Low Feed Groove Geometries

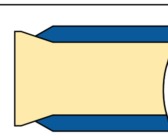
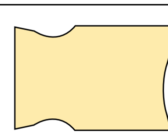
| | | |
|---|---|---|
| .003—.024 ipr feed range |  | Offers excellent chip control at ultra-low feed rates. Positive/negative design provides some force reducing advantages. Low cost per cutting edge. |
| .004—.032 ipr feed range |  | Positive/negative design provides lower cutting forces than general-purpose grooves in low- to medium-feed range. Offers low cost per cutting edge than other force-reducing geometries. |

***FIGURE 2.22 Various sintered chip breaker configurations, with application recommendations.***

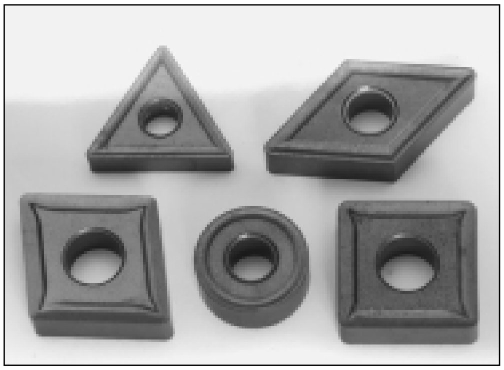


*FIGURE 2.23 Five common insert shapes with various sintered chip-breaker configurations. (Courtesy American National Carbide Co.)*

pared to a double sided insert. This flat bottom provides a single sided insert with better support under the cutting edge in a severe cutting situation. The single sided insert, because of its added support, has the ability to remove larger amounts of material with greater ease and efficiency, making it more economical to use. Another reason the single sided insert may be more economical is that, under heavy machining conditions, it is rare that all of the cutting edges of a double sided insert can be used. The intense thermal and mechanical shock to the insert will normally damage it to the point where the opposite cutting edge is not usable and in a sense, wasted. Figure 2.24 a,b shows two square inserts with special purpose chip breakers.

Statistics have proven that under severe conditions a single sided insert is more often the most economical choice because its higher efficiency will remove more metal in less time.

Additionally, if half of the available cutting edges of a double sided insert are unusable, for reasons stated before, then the more efficient single sided insert, having essentially the same number of usable cutting edges, is the most economical insert to use.

There are many other configurations of chip breaker designs than the ones shown in Figure 2.22. Each manufacturer has its own. The recommended application areas are generally listed in each manufacturer's catalog. However, for specific recommendations and special applications, it is best to consult the manufacturer.

Figure 2.25 shows the various types of chips that are encountered every day. Examining the chips that are coming off a workpiece will give a lot of information as to how well the job is going, how tool wear is progressing, and why premature tool failure or short tool life is occurring.

**Straight Chips:** Straight chips are usually the most troublesome. They string out all over the machine tool, they get snarled in the tool, workpiece, and fixturing, they cause tooling to break, they jam up chip handling equipment, they are difficult to remove, and they are dangerous, especially when they begin to whip around. Soft gummy low carbon and tough steels usually cause this type of chip. One of the quickest ways to eliminate the straight chip, is to increase the feedrate, because a thicker chip breaks more easily. Other ways to eliminate straight chips are to decrease the lead angle, which would also thicken the chip, increase the speed, use a negative rake tool, or use a chip breaker insert.

**Snarling Chips:** Snarling chips are continuous chips much the same as straight chips. They are generally caused by the same conditions as straight chips and create the same problems. It stands to reason, therefore, that to correct a snarling chip situation, the same methods would be used as with straight chips. In addition, cooling the chips with a flood or mist coolant as they come off the tool, will frequently help to break them.

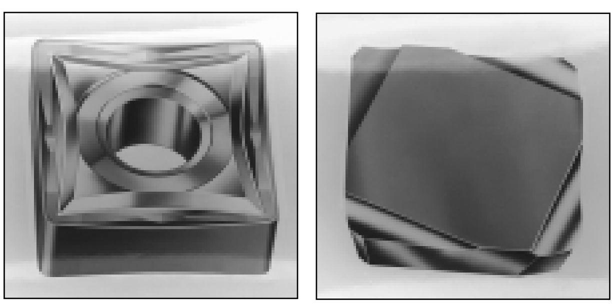


*FIGURE 2.24 Two square inserts with one-sided special-purpose chip breakers. (Courtesy Iscar Metals, Inc.)*

**Infinite Helix Chips:** Infinite helix chips are chips that are near the breaking point. The problems this type of chip creates are similar to those created by straight chips. Infinite helix chips are common when machining very ductile material, such as leaded or resulfurized steels, and other soft materials. They will most often occur when making light cuts with positive rake tools. Using a sintered chip breaker insert, that will force the natural chip flow direction to change, is often effective in breaking the infinite helix chip. An increase in feed or speed will also help break the chip.

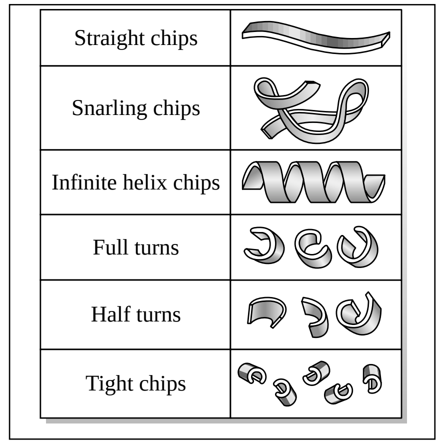



*FIGURE 2.25 Various types of chip formations.*

**Full Turn Chips:** Full turn chips are not usually a problem so long as they are consistent and without occasional stringers. A consistent full turn chip is near the ideal half turn chip.

**Half Turn Chip:** If there is such a thing as a perfect chip, it is the half turn or '6' shape chip. This is the chip shape that the machinist strives for in his cutting operation. The half turn chip is known as the classic chip form. The 'Half turn' or just about perfect chip is shown in Figure 2.26.

**Tight Chips:** Tight chips do not present a problem from a handling or inter-

*FIGURE 2.26 Half-turn chip or "perfect" chip. (Courtesy Kennametal Inc.)*

facing point of view, but these tight chips are a sign that poor tool life or premature tool failure may occur. The tight chip is formed by very high pressure and causes intense heat, deflection of the tool and workpiece, and rapid tool failure. A tight chip is a jammed chip, meaning that its flow path is overly restricted. Causes include; too high a feed rate, too negative a rake angle, improper chip breaker selection or setting, or a worn insert.

Many times a straight, snarled or infinite helix chip will be generated at the start of a cutting operation, when the insert is new. As the insert begins to wear, the chip gradually becomes well shaped and properly broken. It may even progress into a tight chip and eventually cause catastrophic tool failure. This is caused by a type of insert wear known as cratering.( see Figures 2.9a and 2.10a) In cratering, a groove is worn into the insert causing a false chip breaker groove to be formed. This is a definite sign of a problem, such as the insert is not of the correct carbide grade, is not the correct geometry, or that the cutting speed may be too fast.

## 2.5 Indexable Type Tooling

One of the more recent developments in cutting tool design is the indexable insert which is mechanically held in a toolholder. Inserts are available in several thicknesses and a variety of sizes and shapes. The round, square, triangle, and diamond account for the greatest percentage. Many other shapes, including the parallelogram, hexagon, and pentagon, are used to meet specific machining requirements. Each shape has its advantages and limitations since the operational, as well as the economical factors must be considered in tooling selection. The most common insert shapes were shown in Figure 2.23.

### 2.5.1 Indexable Insert Shapes

Indexable inserts have certainly established their position and potential in the metal working industry. The elimination of regrinding, accuracy of tool geometry, reduced inventory tool costs, and down time for tool changes, are some of the advantages resulting from the use of this tooling.

There are four basic shapes and a variety of special shapes. Because approximately 95 percent of all machining is done with the four basic shapes, these are the ones of interest here. The four basic shapes are:

- square
- triangle
- diamond
- round

These shapes are available in many different configurations for almost any job. Each shape can be obtained for positive, negative, or positive/negative rake, with or without chip breaker grooves, with or without holes, with various edge preparations, in various tolerances, and in various radii and sizes. A variety of insert shapes and configurations are shown in Figure 2.27

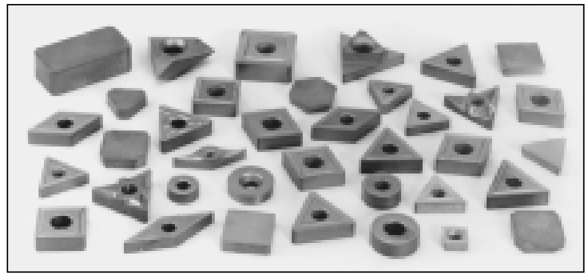


*FIGURE 2.27 Various insert shapes, with and without holes, with and without chip breakers. (Courtesy American National Carbide Co.)*

Choosing a particular shape or insert requires a great deal of planning and thought. The choice of insert shape must be based on such factors as the workpiece configuration and tolerance, workpiece material, amount of material to be removed, machine tool capability, and economics.

The insert shape also has an influence on insert strength. As shown in Figure 2.28, the greater the included angle at the insert tip, the greater the strength. The round insert and the 100 degree corner of the first diamond shaped insert are shown as the strongest. Because of the higher cutting forces and the possibility of chatter, these inserts are more limited in use than the square shape. Therefore, for practical purposes, the square insert is the strongest for general use. Triangle and diamond inserts should only be used when a square cannot be used, such as when machining to a corner or a shoulder.

**The Round Insert:** Round or button inserts give a good finish at heavy feeds, and they are also ideal for forming inside corner radii. Their shape provides the greatest geometric strength, and they offer the maximum number of indexes when light cuts are being taken. The solid button type which is held in place by means of a clamp, generally has edges at 90 degrees to the surfaces for use in negative rake holders, thereby providing cutting edges on both sides of the insert. The CDH button type is made in larger sizes and has a counterbored hole. This button has clearance and is normally held in the toolholder with neutral rake. A typical application is for tracing or contouring, where the tool must generate forms which require a large portion of the cutting edge to be in the cut.

Round inserts have their limitations, however, since the large nose radius thins the chips and increases the forces between the tool and workpiece for a given size cut. Very high radial forces are usually incurred as compared with normal cutting, particularly at normal feed rates. Chatter and deflection often result, especially when machining long-chip materials. For this reason, button inserts are applied with greater success on cast iron and the other short-chip, low-strength materials, although heavy feed rates will often improve the cutting action on ductile materials.

**The Square Insert:** Square inserts provide four or eight cutting edges, depending on the design of the toolholder. Positive rakes mean that relief angles must be ground on the insert, thereby eliminating the use of one side.

Square inserts are preferred for most machining jobs, where the workpiece and tool design relationships allow their use. Their shape provides strength close to that of the round insert, but with the economy of four or eight cutting edges, and also permits a reduction in the side cutting edge angle and the problem related to the chip-thinning action of the round. Economical tool application dictates the use of an insert shape which gives the maximum number of cutting

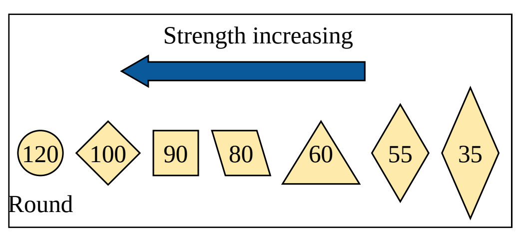



*FIGURE 2.28 Various insert shapes as related to strength.*

edges and is compatible with the machining operation. If the operation requires machining to a square shoulder, the square insert would be eliminated because of the design of an 'A' style tool. Since end cutting edge angle (ECEA) is required so that the tool will clear the machined surface, something less than a 90 degree included angle between the side and end of the tool is mandatory.

**The Triangular Insert**: Owing to design and application requirements, one of which has just been pointed out, the triangular insert has assumed an important place in indexable tooling. The triangle provides three or six cutting edges, depending on whether relief angles are required on the insert for use in a positive rake holder. The 60 degree included angle is not as strong as the 90 degree of the square, or the radius of the button, yet many machining operations are performed satisfactorily with triangular inserts. Turning to a shoulder, plunging and contouring, and numerous other operations require a generous end cutting edge angle which the triangle can provide. The 60 degree included angle is also suitable for threading operations.

Because of its fewer cutting edges and lower strength, the triangular insert and holder should only be used when other geometric shapes will not meet the job requirements.

**The Pentagon Insert:** A pentagon or five-sided insert is a means of providing one or two more cutting edges per insert, and the extra edges are the main reason for this design. There is, of course, a strength advantage over the square and triangle in the 108 degree included angle. As in the case of the square, the pentagonal shape sets up certain design and application limitations. The tool must always cut with a side cutting edge angle (SCEA), which thins the chip and improves tool life. However, SCEA cannot always be used owing to the requirements of the finished part's shape or because the increased radial forces cause chatter and deflection of the workpiece. The minimum SCE angle which can be used is 24 degrees. This then leaves 6 degrees end cutting edge (ECE) angle. An SCEA of 33 degrees results in 15 degrees of ECEA which is the same as that used on standard 'B' style tools and is quite adequate.

**The Diamond Insert:** The trend in lathe design is toward machines which generate the form on the workpiece. This is accomplished by guiding the tool so it faces, plunges, turns, and forms radii, chamfers, and machines other configurations. In order for a tool to satisfy the requirements of these complex maneuvers, it must meet certain design standards. Since the tool often plunges along an angle, a great amount of ECEA is needed. Back facing is also a common operation on such setups, and this requires negative SCEA.

The diamond insert was developed specifically for tracing operations. The industry's standard marking system includes designations for diamond inserts with included angles of 86, 80 55, and 35 degrees. By far the most popular size is the 55 degree included angle diamond. This geometry apparently meets the requirements of most tracing operations. When the insert is positioned in the toolholder and tool block so that it cuts with 3 degree negative SCEA, it will back face with depths of cut up to 0.020 inch and in most toolholders will be able to plunge at an angle of 20 degrees with adequate clearance.

Holding the insert securely in the holder so that duplication of workpiece size to tolerances specified is achieved, has been a problem. The tendency for the insert to twist in the pocket on turning and plunging operations, and to be pulled out of the pocket on back facing operations, has resulted in design changes by some manufacturers. Diamond tracer inserts are made in regular and elongated shapes. The elongated diamond provides greater resistance to the twisting action set up by the cutting forces.

Further developments are still being made in tracer inserts and holders so that they will meet the exacting requirements of tracing operations better. In some designs the diamond shaped insert, either regular or elongated, is locked into the pocket with an eccentric pin. This gives a positive holding action and locates the insert against the back walls of the pocket, minimizing the chances for movement during the contouring operations.

The selection of a tool for a tracing operation should begin with an analysis of the requirements of the contouring operations. The tool selected should be the one which provides the strongest geometric shape and still meets the contouring requirements. Many tracing jobs can be done satisfactorily with a triangular insert. If no back facing is included in the operations, no negative SCEA is needed and a standard 'A' style tool can be used. In some cases it is possible to use a tool designed to cut with SCEA. Generally, better tool life will be realized with lower cost per cutting edge, when tools without negative SCEA can be used.

**The Parallelogram Insert:** The parallelogram-shaped insert provides some advantages which make its use justified in certain applications. When a long side cutting edge is needed, it is sometimes more economical and advantageous from a machining standpoint, to use a parallelogram rather than a square or triangle.

The parallelogram also permits the construction of an 'A' style tool with greater geometric strength than is possible with a triangular insert. A limitation of the parallelogram design is the number of usable cutting edges. A negative rake insert can be used on two corners in a right or left-hand holder. To use the remaining two cutting edges, the opposite hand holder is required. Unless all four corners can be used, the use of the parallelogram insert may not be economically justifiable.

**The Hexagonal Insert:** A versatile tool makes use of a hexagonal shaped insert. Turning, facing, and chamfering can all be done from a number of positions. Its shape provides strong cutting edges as in the case of the pentagon, but also necessitates cutting with considerable SCEA. The number of usable cutting edges in this design makes it a most economical insert where it can be applied.

**The On-Edge Insert:** The on-edge insert concept (Fig. 2.29), has only been in use for a short time, but is becoming more common. The on-edge insert was first developed for milling operations. The main reason for its development was to provide the strength needed to withstand the constant interruption of milling cuts. The on-edge concept is now becoming more popular for turning inserts as well.

The main use of the on-edge insert is for rough cutting when cutting forces are high and the interruptions are often

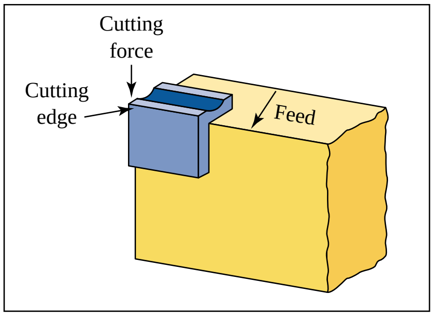



*FIGURE 2.29 On-edge turning tool design.*

severe.

The extra thickness of the on-edge insert offers more protection from heat and shock damage to the opposite side cutting edge during heavy roughing, than is common with standard inserts. A milling cutter section with on-edge inserts is shown in Figure 2.30.

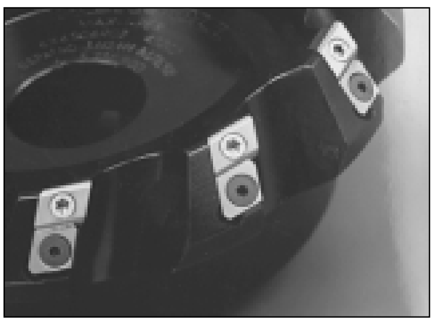


*FIGURE 2.30 On-edge milling cutter section. (Courtesy Ingersoll Cutting Tool Co.)*

## 2.5.2 Indexable Inserts – Classes and Sizes

Inserts are commercially available with various degrees of dimensional tolerances, such as the inscribed circle of a triangle, the measurement across the flats of a square or elongated diamond, thickness, nose radii, and tangency. All these dimensions, and several other factors, contribute to the ability of an insert to be accurately indexed and to machine a given material to a specific size. The need for inserts with different tolerances depends not so much on the dimensional size of the finished part, but more on how the insert is to be used in the machining operation.

**Unground Inserts**: Through improved manufacturing techniques, many carbide producers can supply inserts that are to the required specifications, thus eliminating the grinding operation. Cutting edges produced by this method are not only metallurgically sound in structure, but are also honed to give them geometric increase in strength.

**Utility Inserts**: This type of insert is ground on the top and bottom faces only.

*FIGURE 2.31 Carbide-insert honing equipment. (Courtesy American National Carbide Co.)*

**Precision Inserts:** These are ground all over and to close tolerances.

**Honed Inserts:** The development of production honing techniques for inserts has made standard inserts available to the machining industry in the prehoned condition. These inserts have the advantage of not only having the cracked crystal layer removed from the cutting edge area, but also from the cutting tool surfaces. Lighter finishing cuts taken with finishing grades of carbide should have small amounts of honing performed on the cutting edge. Roughing grades should, conversely, be honed heavily. Carbide Insert Honing Equipment is shown in Figure 2.31.

**Insert Size:** The size of an insert is determined by its inscribed circle (I.C.). Every insert has an I.C. regardless of the insert shape (Fig. 2.32). The I.C. is designated in fractions of an inch in the United States, normally in 1/8 inch increments. The thickness of the insert is designated by its actual thickness in increments of 1/16 inch, and the nose radius is designated in increments of 1/64 inch.

The thickness of the insert is usually standard to a particular I.C. Sometimes however, a choice of thickness will be available. In these situations, the thickness that is appropriate to the amount of cutting force that will be applied is the optimum choice. If a thin insert is chosen, a thicker shim should be used to keep the cutting edge at the workpiece centerline.

## 2.5.3 Indexable Insert Identification System

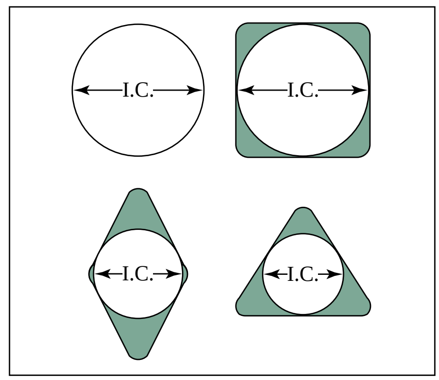



*FIGURE 2.32 The size of an insert is determined by its inscribed circle (I.C.).*

A standard marking system, proposed by the Cemented Carbide Producers Association and approved by the American National Standards Institute (ANSI), has been adopted by the cemented carbide manufacturers. A new identification and numbering system became necessary, due to the addition of an expanded range of types and sizes of inserts incorporating a wide variety of detail. Under this new system, the insert number, with the manufacturer's grade of carbide, is all that is needed to describe the insert. (See Fig. 2.33). The eight sequences of marking indexable inserts are:

- Shape
- Size
- Thickness
- Clearance Angle
- Cutting Point
- Class
- Other Conditions
- Type

**Insert Economics:** The cost of carbide and other tool materials as well as

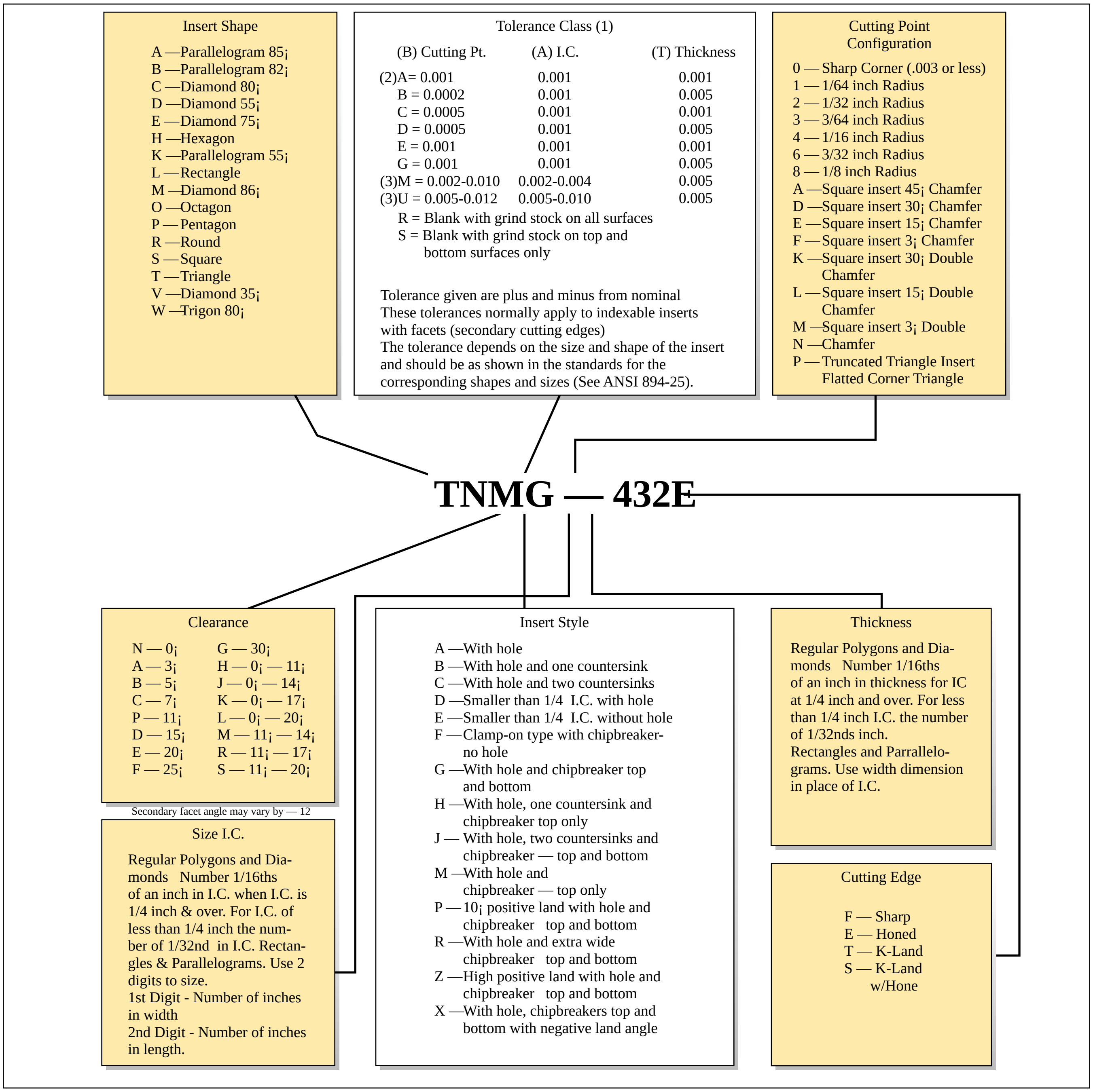



***FIGURE 2.33 Standard Identification System for indexable inserts. (Courtesy Cemented Carbide Producers Association)***

the cost of preparing these materials into cutting tools is relatively high and continuing to increase. Therefore, it is most important to choose tool inserts wisely. Here are some important things to consider when making the choice:

• Chose a shape that offers the most cutting edges.

*Examples:*
*A negative insert has twice as many cutting edges as a positive insert.*
*A square insert has 25 percent more cutting edges than a triangle insert.*
*A double sided chip breaker insert has twice as many cutting edges as a single sided insert.*

• *Choose an I.C. appropriate to the amount of material to be removed.*

*Examples:*
*A 1 inch I.C. square insert for a 1/4 inch depth of cut would be wasteful, because a large piece of expensive carbide would be used where a smaller piece would achieve the same result.*

• Choose an insert tolerance that is appropriate to the job being done. In most cases an unground utility grade will do the job. The closer the tolerance, the higher the cost. Tight insert

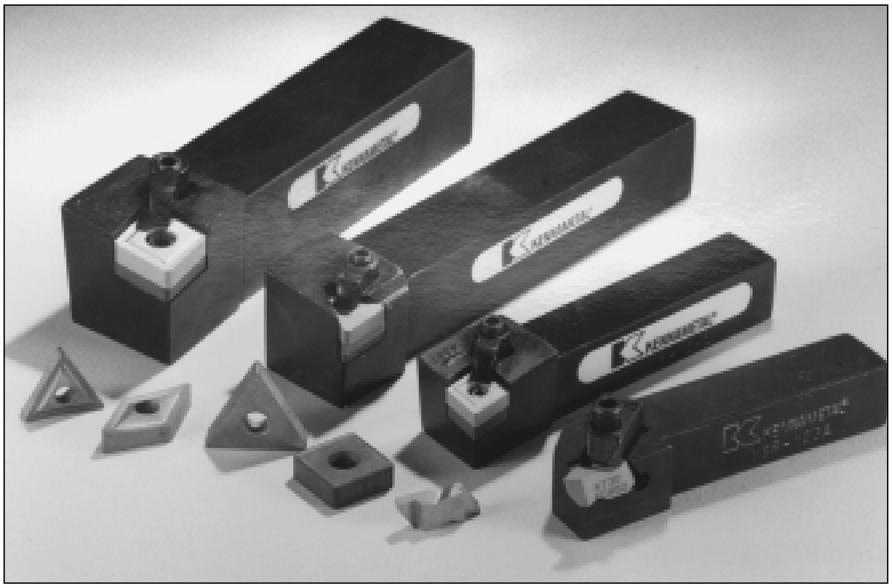


*FIGURE 2.34 Four toolholders with various insert styles and sizes (Courtesy Kennametal Inc.)*

tolerances are normally required only when the indexability of an insert is critical.

*Example:*
*A 'C' tolerance insert used for finishing to a workpiece tolerance of plus or minus 0.010 inch would not be necessary. An 'M' or even a 'U' tolerance insert would be satisfactory.*

• Choose a single sided insert when conditions make its efficiency more economical.

*Example:*
*A heavy roughing cut has made the second side of a less efficient double sided insert unusable because of heat and shock damage.*

### 2.5.4 Mechanical Tool Holders

The revolution of the indexable insert has resulted in the availability of a wide range and variety of tool holders. A number of tool holders with inserts are shown in Figure 2.34.

To select or recommend the best holder for every machining application would be a formidable task. The practice in many manufacturing plants is to standardize on one or two designs, so that a minimum of repair parts and accessories need to be carried in inventory. There are basic designs and construction elements common to all holders.

• The Shank
• The Seat
• The Clamp or Locking Device

Turning toolholders have been standardized as shown in Figure 2.35.

**The Shank:** The shank is the basic element of the toolholder and its purpose is to hold and present the cutting edge to the workpiece. It usually has drilled and tapped holes, slots and cutouts, and it must provide a firm support for the carbide cutting edge. Generally shanks are made of high-carbon or low-alloy steel, heat treated to give physical properties that will resist thread damage, chip erosion and deformation under the tool-block clamping

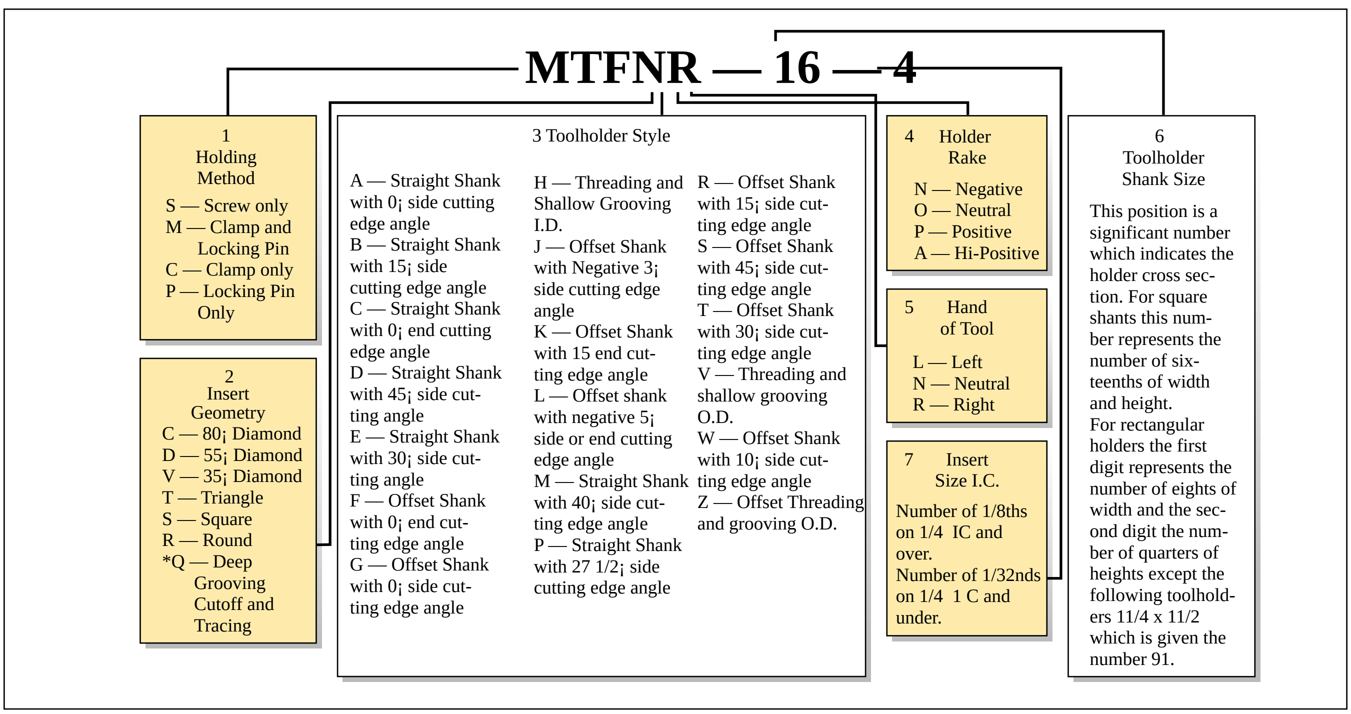



*FIGURE 2.35 Standard identification system for turning toolholders. (Courtesy Cemented Carbide Producers Association)*

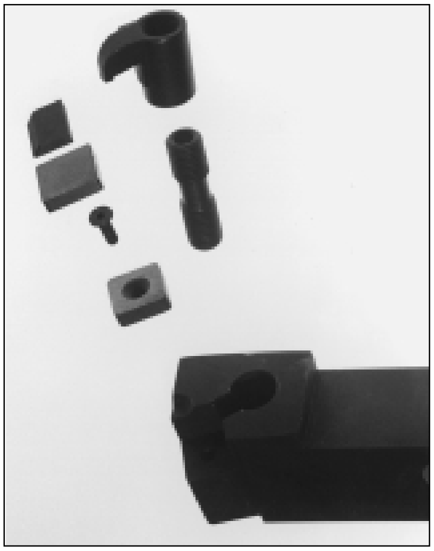


*FIGURE 2.36 Tool shank with basic components. (Courtesy Kennametal Inc.)*

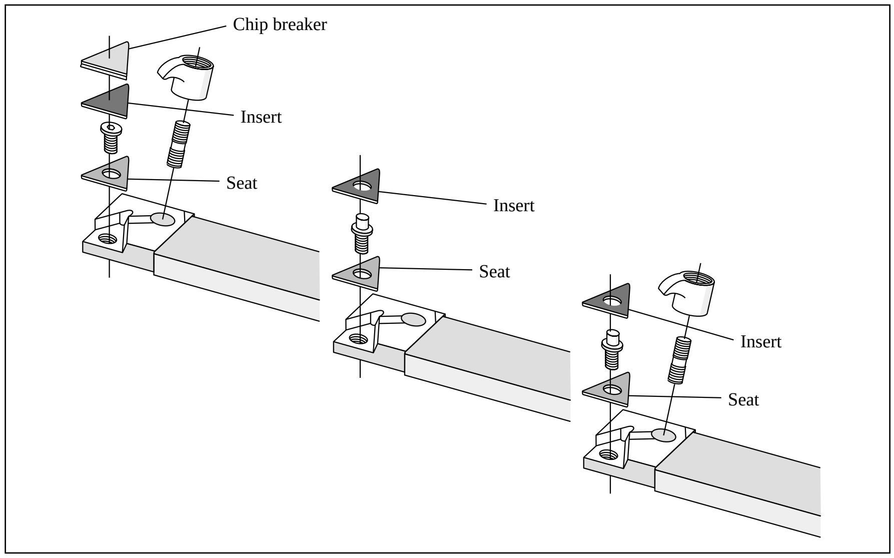



*FIGURE 2.37 Schematic drawing of various insert-locking positions.*

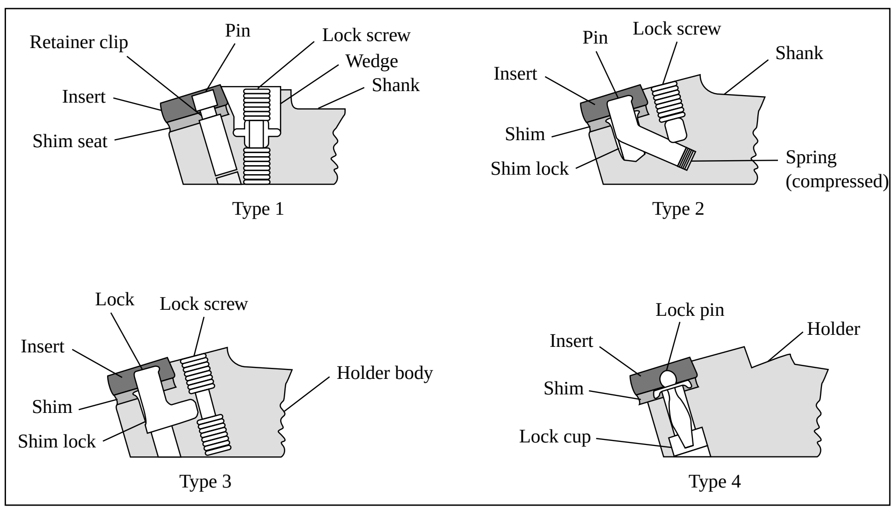



*FIGURE 2.38 Various pin-type holder-locking options.*

screws. Some designs and sizes which do not make use of a carbide seat are made of high alloy steel to resist deformation under the insert.

The machined area for the seat and insert is one of the most critical areas and must be flat to provide the proper support for the carbide seat and insert. Common practice is to relieve the inside corner for seat and insert clearance. The intersections of the sides and bottom of the pocket usually have a small radius, since sharp corners may be the source of cracks during heat treatment. A tool shank with basic components is shown in Figure 2.36.

**The Seat:** Most toolholders for indexable inserts use a carbide seat or pad as support for the insert. Cemented tungsten carbide has a high compressive strength, is hard, and can be ground to a smooth flat surface. While hardened steel has been used, and still is in some designs, a strong preference for carbide seats prevails.

The seats shown in Figure 2.37 are typical and will serve to illustrate the basic design. The periphery is chamfered at one face to clear any radius in the steel shank pocket area. If the seat or pad is held in place by a screw, the hole will be deeply countersunk so that the head of the screw will be well below the surface. If the screw head projects above the seat surface and the insert is clamped down on it, breakage of the latter could result.

The seat is attached to the shank only for convenience and to prevent its loss when inserts are removed and replaced, or if the holder is used vertically as in a vertical turret lathe or upside down as in the rear tool post of a turret lathe.

Seat flatness is one of the most critical requirements of tool holders. Application tests have shown that an out-of-flatness condition, of as little as 0.001 inch, can result in insert breakage. Regardless of the design of the toolholder selected, the pocket and seat flatness specifications should be carefully examined and the highest standards insisted upon.

The Clamp or Locking Device: Many clamping and locking arrangements have been developed for holding the insert in a toolholder and there is probably no one best method or design, since specific application requirements vary so greatly. There are a number of features and construction elements, however, which warrant consideration and should influence the selection of a toolholder (Fig. 2.38).

The main function of the clamping mechanism is to hold the insert securely in position and many methods of doing

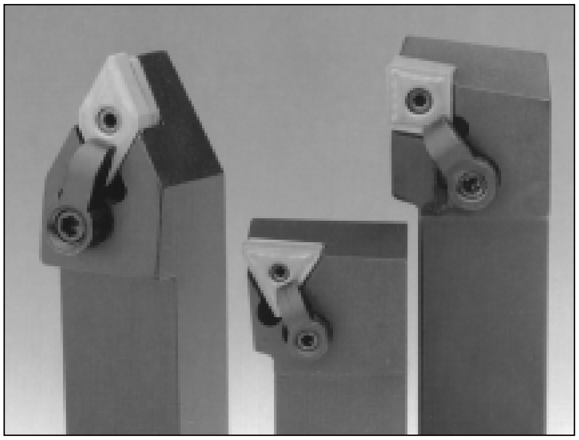


*FIGURE 2.39 Three toolholders in which inserts are held by both pins and clamps. (Courtesy Sandvik Coromant Corp.)*

so are in use. On normal turning and facing operations, the insert in most styles of toolholders is held in the pocket by the cutting pressures, and the load on the clamp is very light except as affected by the chip. Tracing and threading operations change the direction and amount of the load applied to the insert, and there is more tendency to twist or pull the insert out of the pocket. The ability of the clamping mechanism, to perform satisfactorily under such conditions, should be carefully evaluated. The use of a pin or lever mechanism has been incorporated in some designs to give a more positive holding action against the insert.

The suitability of the clamp design to the machine toolholding blocks and to the workpiece configuration should be considered. Bulky club heads, high clamps on clamping screws, or intricate adjusting mechanisms may be in the way, especially when tools must be ganged up, or when machine and workpiece clearances are small. A toolholder which is not easily accessible and must be removed from the machine so the insert can be indexed or the chip breaker adjusted, should not be considered suitable for the application. A number of tool holders are shown in Figure 2.39 where indexable inserts are being held by both pins and clamps.

Tools which are positioned upside down should have a wrench socket in the lower end of the clamping screw so that it can be easily reached. Chipbreaker plates and clamp parts should be secured so that they will not be dropped in the chip pan when loosened for insert changing.