Optimizing Insert Life 305
Class Outline

Objectives
The Economics of Insert Life
Tool Wear
Flank Wear
Premature Flank Wear
Crater Wear
Notch Wear
Built-Up Edge
Plastic Deformation
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Chipping
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Objectives

- Describe the economics of insert life.
- List the types of tool wear.
- Identify flank wear.
- Identify the variable that affects insert life the most.
- Identify crater wear.
- Identify notch wear.
- Identify a built-up edge.
- Identify plastic deformation.
- Identify thermal cracking.
- Identify chipping.
- Identify chip hammering.
- Identify fracture.
- Describe the role of the operator in extending insert life.

Figure 1. Carbide inserts are indexable and replaceable cutting tools with a geometric shape that provides multiple cutting surfaces.

Plastic Deformation

Figure 2. Plastic deformation is the shape distortion of an insert due to extreme conditions. (Courtesy of Kennametal.)
Figure 3. Identification of tool wear can be difficult, even with the assistance of measuring equipment.
Lesson: 2/15

The Economics of Insert Life

The life of an insert is an important economic consideration for a machine shop. Figure 1 shows inserts that have reached the end of their usable life. As Figure 2 suggests, manufacturing demands a careful balance of production costs and production output. Shop workers seek to prolong the life of inserts because they are relatively expensive, and any operation that uses inserts without regard to prolonging their usable life is wasting money. Plus, excessive efforts to prolong the life of an insert are also expensive. Grinding or indexing inserts takes time away from production, and if you are not making parts, you are not making money. High production at the expense of tool life may not be the best balance of output and cost.

On the other hand, cautious cutting strategies are also not economical. Conservative production strategies may save money on tooling, but any savings is lost on low production. Your goal should be to increase tool life and maintain acceptable levels of production. This balance of output and production cost is a key strategy for a successful manufacturing operation.

All inserts eventually wear out and fail. However, a crucial way to optimize insert life while keeping up acceptable levels of production is by identifying known problems that inserts experience and adjusting the variables that help defeat them. Your goal is to prolong the insert's life as long as possible and reach the most cost-effective balance of insert life and production. This class covers several known types of wear and their causes. You will learn how to identify tool wear that causes premature tool failure and make the appropriate corrections to optimize insert life.

Figure 1. These worn inserts are ready to be recycled.

Figure 2. Successful manufacturing is often a balance of production output and production cost.
Lesson: 3/15

Tool Wear

There are nine types of insert wear, which are listed in Figure 1. The first type is generally unavoidable but controllable, while the rest should be avoided entirely:

- **Flank wear** is the gradual abrasive wear of an insert's flank. Figure 2 shows the location of the flank. Flank wear is the most desirable form of tool wear because it occurs at a predictable rate.
- **Crater wear**, also called cratering, is the formation of a depression in the rake face behind the cutting edge of an insert.
- **Notch wear**, also called depth-of-cut notching, is the formation of a valley on the cutting edge at the depth-of-cut line.
- **Built-up edge** (BUE) is the pressure welding of workpiece and chip material to the flank and rake face of the tool.
- **Plastic deformation** is the shape distortion of an insert due to extreme pressure and temperatures.
- **Thermal cracking**, also called thermal fatigue, is the formation of small cracks and fissures perpendicular to the cutting edge of the tool.
- **Chipping**, also called frittering, is the breaking away of small particles from the cutting edge, flank, or rake face of the insert.
- **Chip hammering** is damage to the insert's rake face due to constant chiseling of long chips.
- **Fracture** is the sudden catastrophic failure of an insert due to a large portion of the insert breaking away. Fracture can be the end result of all the other wear types, though it can happen without prior wear or warning.

Notice that the most desirable form of wear, flank wear, is the result of the natural abrasion that occurs when two materials rub together. The remaining wear types are the result of extreme conditions like excessive pressures and temperatures, and unintended intense mechanical contact. In general, you want to control flank wear and avoid the other wear types entirely.

**Figure 1.** There are nine types of insert wear.

**Figure 2.** The three areas of an insert are the rake face, flank, and cutting edge.
Lesson: 4/15

**Flank Wear**

*Flank wear* is the most normal type of wear, which is caused by abrasion of the insert **flank**, as shown in Figure 1. Flank wear is also the most desirable type of wear. The goal is for every insert to eventually fail from flank wear. If each insert fails from flank wear, then you know that each insert has reached its maximum tool life.

Flank wear develops due to contact between the workpiece and the cutting edge during the cutting operation. This interaction gradually wears away the relief on the flank of the tool, causing the development of a **wear land**, as shown in Figures 2 and 3. Flank wear is most desirable because it provides the longest and most predictable tool life. In fact, you can measure the size of the wear land to predict how much longer an insert should last. Eventually, the wear land increases to the point of tool failure.

As you can see in Figure 4, flank wear develops differently over time. Flank wear usually follows the S-shaped pattern with three distinct zones:

- **Rapid wear** occurs in Area A because the point of contact between the insert and the workpiece is very small. During this "hone in" or "break in" period, material quickly wears from the point of contact and generates a measurable wear land.
- **Wear proceeds at a constant rate** in Area B, making flank wear predictable. The largest segment of insert life occurs in this area. Optimal machining involves keeping insert wear in this area as long as possible without sacrificing production. Cutting that is too aggressive can shorten the amount of time insert wear spends in this area.
- **The wear land reaches an increased size** in Area C. The cut generates excess heat and forces, which produce a constantly increasing rate of wear. Eventually, the cutting force exceeds the strength of the edge, and the insert breaks or deforms, ending its usable life. In almost all cases, the cutting edge should be replaced before flank wear enters this last area.

*Figure 1.* Flank wear is the most normal type of wear. (Courtesy of Kennametal.)

*Figure 2.* A wear land is the area of the edge that is abraded away during flank wear. (Courtesy of Kennametal.)

*Figure 3.* During flank wear, abrasion wears away the relief of the insert, which forms a wear land.
Figure 4. Flank wear can be tracked to three distinct areas.
Lesson: 5/15

Premature Flank Wear

Optimizing insert life involves controlling the amount of time your insert spends in Area B during flank wear. You can do this by carefully adjusting cutting variables such as speed, feed rate, and depth of cut (DOC) during machining. Together, these variables, shown in Figure 1, determine the rate of metal removal, and thus influence the rate of insert wear. As a rule, an equal change in any variable has an equal impact on the rate of metal removal. For example, if you want to decrease your metal removal rate by 50%, you can decrease your cutting speed, your feed rate, or DOC by 50 percent.

Each cutting variable has a different effect on tool life, however. In general, there are three guidelines regarding the relationship between cutting variables and tool life:

1. Tool life is least affected by DOC. Maximize DOC whenever possible to extend tool life.
2. Feed rate has the next highest impact on tool life. Maximize it only after you have maximized DOC.
3. Speed has the greatest impact on tool life. Speed is the variable you use to strike the balance between tool life and productivity. Set your speed only after you have maximized DOC and feed rate.

If you adjust the cutting variables as needed, you can maximize metal removal rates and prolong the life of the insert through predictable flank wear.

Figure 2 lists the common causes of rapid flank wear. Flank wear is only a problem if it occurs too rapidly. To eliminate rapid flank wear:

- Reduce the speed.
- Select an insert with a harder grade.
- Increase the clearance angle.
- Reduce edge hone.
- Reduce corner radius.
- Use a coated carbide insert, such as an aluminum oxide (Al₂O₃) coated grade, to counter diffusion.

Figure 1. Cutting variables include speed, feed, and depth of cut.

CAUSES OF PREMATURE FLANK WEAR

- Excessive cutting speed
- Poor wear resistance
- Low clearance angle
- High edge honing
- High corner radius
- Diffusion

Figure 2. The causes of premature flank wear.
Lesson: 6/15

Crater Wear

Sometimes, cutting conditions weaken inserts and increase the risk of other types of wear besides flank wear. One such case is **crater wear** or **cratering**, which is shown in Figure 1. Crater wear is the formation of a depression in the rake face behind the cutting edge of an insert. During cratering, elevated temperatures lead to a chemical breakdown in an area of the insert. The result is a **diffusion** of carbon atoms from the tool material into the chip. The chip flowing over the rake face of the tool easily wears away this softened insert material. Diffusion increases as the temperature increases. If left unchecked, crater wear can grow and expand until it fractures the insert.

Figure 2 lists the common causes of crater wear. Additionally, some combinations of insert and workpiece material are more likely to cause crater wear than others. Specifically, the use of **tungsten carbide** inserts for machining steel increases the risk of crater wear. During machining, the contact between the insert and the workpiece material may deplete the insert of carbon at the site of contact. High temperatures and the compromised wear resistance of the tool edge can also contribute to cratering. Occasionally, the wrong tool geometry or **rake angle** can contribute to cratering, premature insert wear, and insert failure.

To eliminate cratering, you can:

- Use harder **titanium carbide** (TiC) or **tantalum carbide** (TaC) inserts, or use a coated carbide grade insert such as **aluminum oxide** ($\text{Al}_2\text{O}_3$).
- Reduce the speed.
- Reduce the feed rate.
- Select a positive rake.
- Apply coolant properly.
Lesson: 7/15

Notch Wear

As you can see in Figures 1 and 2, notch wear, also called depth-of-cut notching, is the formation of a valley on the cutting edge at the depth-of-cut line. Notch wear occurs due to chemical and mechanical wear. Both the flank and rake surfaces of the insert may be affected. During notching, the hard surface of the workpiece abrades the trailing edge of the insert with a combination of adhesion and oxidation. The workpiece material that hits the leading edge may lead to chipping. Notch wear can lead to poor surface finish and eventual edge breakage.

Figure 3 lists the common causes of notch wear. Notch wear may appear as the result of oxidation of the insert and poor wear resistance. Often, carbide chemically reacts and forms an unstable oxide material when it is exposed to air at elevated temperatures. This soft oxide is prone to wear.

Mechanical forces may also cause notch wear due to competing forces at the cutting edge. The resistance of the workpiece material, especially if it has a work-hardened outer layer, may overpower the hardness of the insert at the depth of cut area. Castings and forgings generally have harder outer surfaces. Also, workpieces that work harden during machining also contribute to notch wear. Sometimes the wrong tool geometry and chip hammering may also factor into notch wear.

To eliminate notch wear:

- Choose a coated carbide insert such as aluminum oxide (Al₂O₃).
- Choose an insert with a harder grade.
- Reduce the speed.
- Use a positive rake angle.
- Use a larger lead angle.
- Adjust factors that contribute to chip hammering.

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**Figure 1.** Notch wear is the formation of a valley on the cutting edge at the depth-of-cut line due to chemical and mechanical wear. (Courtesy of Kennametal.)

**Figure 2.** Notching can appear due to poor wear resistance. (Courtesy of Kennametal.)

**Figure 3.** The causes of notching.
Lesson: 8/15

Built-Up Edge

The elevated temperatures and pressures of cutting operations can affect inserts in adverse ways. One way pressure and temperature can affect an insert is through the appearance of a built-up edge (BUE), which is shown in Figure 1. A BUE, sometimes called “build-up,” is the pressure welding of workpiece material to the flank and rake face of the insert. The extreme pressure and temperatures present during cutting can cause portions of the chip to adhere to the insert. The BUE is constantly changing because sections continuously shear off and re-build during cutting. The BUE blunts the insert edge and causes poor surface finish of the workpiece. A BUE can also cause sudden catastrophic failure of the insert if the BUE portion suddenly gives way.

Figure 2 lists the common causes of BUE. Sometimes a BUE can form because of low cutting speeds and negative rake angles. It may also appear when there is insufficient clearance between the workpiece and the cutting tool. Extreme heat generation is also to blame on some occasions. Sometimes, “sticky” ductile materials like some stainless steels and pure aluminum have a greater tendency to adhere to the insert during cutting.

To eliminate a BUE:

- Increase the cutting speed.
- Select a positive rake angle.
- Apply coolant properly.
- Use polished rake faces.

Figure 1. A built-up edge is the pressure welding of workpiece material onto the flank and rake face of the insert. (Courtesy of Kennametal.)

Figure 2. The causes of a built-up edge.
Lesson: 9/15

**Plastic Deformation**

Excessive temperatures and pressure during cutting can also cause **plastic deformation**. Sometimes called **thermal deformation**, plastic deformation is the shape distortion of an insert due to extreme conditions. If BUE is the distortion of the insert by the addition of workpiece material, plastic deformation is the distortion of the insert without the addition of any other material. If a BUE does not form, there still exists the chance that cutting conditions may distort the insert. Plastic deformation can lead to poor chip control and poor surface finish.

As you can see in Figure 1, during plastic deformation, the insert develops a downward slope on the rake face and around the nose radius. Bulges also develop near the rear edges of the slopes. If left unattended, plastic deformation results in fracture of the cutting edge.

Figure 2 lists the common causes of plastic deformation. As mentioned, high temperatures and extreme forces can cause stress that leads to deformation. A poor clearance angle and a large positive rake can also lead to plastic deformation. A low grade insert hardness can also cause deformation.

To eliminate plastic deformation:

- Reduce the speed.
- Reduce the feed rate.
- Select a harder grade insert with better resistance to deformation.
- Use a lower clearance angle.
- Use a less positive rake angle.

**Figure 1.** Plastic deformation is the shape distortion of an insert due to extreme conditions. (Courtesy of Kennametal.)

**Figure 2.** The causes of plastic deformation.

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CAUSES OF PLASTIC DEFORMATION

- Excessive speed
- Excessive feed
- Weak carbide insert grade
- Suboptimal clearance angle
- Suboptimal rake angle
Lesson: 10/15

Thermal Cracking

Temperature is an important factor in insert wear and failure. The thermal changes that occur during cutting can exert enormous stress on an insert. Thermal cracking, also called thermal fatigue, is the formation of small cracks or fissures perpendicular to the cutting edge of the tool, as shown in Figure 1. The fissures are caused by fatigue from inconsistent temperatures in the cut. The constant cycle of heating and cooling of insert material causes the molecules making up the insert to expand and contract. This expansion and contraction can cause fissures to appear on the cutting edge of an insert.

Figure 2 lists the common causes of thermal cracking. The causes of thermal cracking are cutting conditions that cause temperature variations along the insert. These conditions include intermittent cuts, an inconsistent supply of coolant, and variations in workpiece hardness. Milling involves intermittent cuts during which cutting edges of an insert repeatedly enter and exit the workpiece. During milling, the insert is heated during cutting and cooled during intervals between cuts. Coolant that is reaching the cutting area in varying amounts and inconsistencies in workpiece material can both cause temperature fluctuations.

Any effort to reduce temperature variation should decrease the risk of thermal cracking. To eliminate thermal cracking:

- Use a tougher insert grade.
- Reduce the speed.
- Improve the flow of coolant or discontinue coolant use entirely.
- Reduce chip load.
- Isolate jobs by workpiece hardness.

Figure 1. Thermal cracking is the formation of small cracks or fissures perpendicular to the cutting edge of the tool. (Courtesy of Kennametal.)

Figure 2. The causes of thermal cracking.

CAUSES OF THERMAL CRACKING

- Temperature fluctuations
- Poor use of coolant
- Intermittent machining
- Excessive speed
- Excessive chip load
Lesson: 11/15

Chipping

Chipping, also called frettering, is the breaking away of small particles from the insert. As you can see in Figure 1, chipping occurs because the insert does not have enough strength to withstand the intense mechanical contact with the workpiece. The ragged cutting edge is very inefficient and causes poor surface finish. The inefficient edge can increase cutting forces and temperature, which in turn can cause excessive flank wear and serious failure.

To the naked eye, chipping is sometimes mistaken for normal flank wear if the chips are small. A view of the insert under a 20x microscope reveals the rough, uneven surface characterized by chipping. By contrast, normal flank wear leaves a fine, regular wear pattern. Remember that chipping involves breaking away small portions, while flank wear involves a uniform abrading.

Figure 2 lists the common causes of chipping. As you can see, chipping may be caused by weakness of the tool, the variable shock loads of an intermittent cut, and an unstable setup. Unstable setups such as an excessively long toolholder or an unsupported workpiece can lead to chatter. Chipping may also occur as the result of poor tool geometry and other forms of insert wear like BUE.

To eliminate chipping:

- Choose a tougher insert grade.
- Choose an insert with a stronger geometry.
- Add a hone to insert edges to increase strength.
- Increase the speed.
- Reduce vibrations.
- Adjust any factors that contribute to BUE.

Figure 1. Chipping or frettering is the breaking away of small particles from the insert. (Courtesy of Kennametal.)

Figure 2. The causes of chipping.
Lesson: 12/15

Chip Hammering

During cutting, if chip formation is not ideal, inserts can be damaged. One way inserts can be damaged in this manner is through chip hammering, which is illustrated in Figure 1. Chip hammering is a form of mechanical wear that damages the insert’s rake face due to the constant chiseling action of long chips hitting the rake face. If cutting variables are not optimized during cutting, long chips can form that "hammer" at the part of the cutting edge that is not "in the cut." During chip hammering, both the rake face and the clamping mechanism can be damaged. Chip hammering is characterized by chipping on the rake face.

Figure 2 lists the common causes of chip hammering. One of the main causes is use of the wrong chipbreaker. A feed rate or depth of cut that is too low can also cause chip hammering. The workpiece material can also contribute. Usually ductile workpiece materials are more likely to cause chip hammering.

To eliminate chip hammering, you can:

- Use another chipbreaker.
- Increase the feed rate.
- Increase the depth of cut.
- Select a different insert geometry.
- Change the lead angle of the tool holder.
- Allow more space for chips to escape when using ductile workpiece materials.

Figure 1. Chip hammering is a form of mechanical wear that damages the insert’s rake face due to the constant chiseling action caused by long chips.

Figure 2. The causes of chip hammering.

CAUSES OF CHIP HAMMERING

- Poor chip control
- Excessively long chips
- Suboptimal feed
- Suboptimal lead angle
- Suboptimal clearance
- Suboptimal insert geometry
Lesson: 13/15

Fracture

The last type of wear is generally the most serious. As you can see in Figure 1, fracture is the sudden catastrophic failure of an insert due to a large portion of the insert breaking away. Fracture can be the end result of other forms of wear, but it can also occur without prior wear. In either case, mechanical fracture occurs when the cutting forces exceed the mechanical strength of the insert. Fracture is serious because once an insert is fractured, it can no longer be used. A fractured insert can also damage the machine, the toolholder, the workpiece, and even injure the operator.

Figure 2 lists the common causes of fracture. Fracture can be the final result of every other form of wear. You may have difficulty distinguishing chipping and fracture at first. However, remember that a chipped insert can still be used, while a fractured insert is immediately useless.

The most common forms of wear that are sources of fracture are flank wear and crater wear. Additionally, very hard and brittle insert grades and small inserts are naturally susceptible to fracture. Fracture can also occur if the insert is clamped incorrectly, if there is excessive vibration, or if there is an excessive load.

To reduce the chance of fracture:

- Change your worn insert before it fails.
- Use a tougher insert grade.
- Check the clamping of the insert in the workholding device.
- Reduce your cutting load by reducing feed rate and depth of cut.
- Choose an insert with a different shape or larger size.

Figure 1. Fracture is the sudden catastrophic failure of an insert due to a large portion of the insert breaking away.

Figure 2. The causes of fracture.
Lesson: 14/15

The Role of the Operator

A key to maximizing insert life is the proper identification of insert wear. Manufacturers seek to observe the development of tool wear over time to determine appropriate measures. As an operator, you can help identify wear and detect insert failure by observing your inserts on and off the machine and recording your observations. More importantly, you can improve the life of an insert by observing the recommendations set by engineering and programming personnel in your shop. These people should know the correct balance of productivity and tool life.

The life of an insert is dependent on many factors. In general, you should be able to run your machine for four hours without indexing inserts to a new edge most of the time. Under normal conditions, you should probably index your inserts at least once during a shift. However, there are exceptions. Certain conditions and materials will speed up the wear of your inserts. Likewise, if your inserts are inactive, or run very conservatively, they will not require indexing as frequently. When in doubt, consult your supervisor to determine when to index your inserts to a fresh edge.

To see wear on an insert, you need a well-lighted, 20-power (20x) microscope or a measuring device, like the machine in Figure 1. But even with the assistance of this equipment, identification of tool wear can be difficult. For example, edge deformation and chipping are often misidentified as flank wear. Since each type of wear demands unique corrective actions, proper identification is key. Improper identification and the application of the wrong corrective action can damage the insert even further.

Figure 1. Identification of tool wear can be difficult, even with the assistance of measuring equipment.
Lesson: 15/15

Summary

The life of an insert is a key economic consideration for a machine shop. Shop workers seek to prolong the life of inserts because they are relatively expensive. Any operation that uses inserts without regard to prolonging their usable life is wasting money. One way to balance production costs and output is by observing insert wear and preventing the premature failure of an insert. This is accomplished by recognizing the nine forms of wear and altering the conditions of machining to optimize the life of the insert. Flank wear is the gradual abrasive wear of an insert's flank. Flank wear is the most desirable form of tool wear because it occurs at a predictable rate.

Other types of wear are less desirable than flank wear. Crater wear is the formation of a depression in the rake face behind the cutting edge of an insert. Notch wear is the formation of a valley on the cutting edge at the depth-of-cut line. Built-up edge is the pressure welding of workpiece and chip material to the flank and rake face of the tool. Plastic deformation is the shape distortion of an insert due to extreme pressure and temperatures. Thermal cracking is the formation of small cracks and fissures perpendicular to the cutting edge of the tool. Chipping is the breaking away of small particles from the cutting edge, flank, or rake face of the insert. Chip hammering is damage to the insert's rake face due to constant chiseling of long chips.

Finally, fracture is the sudden catastrophic failure of an insert due to a large portion of the insert breaking away. This is the most serious type of failure because the insert is no longer useful, and it can even lead to damage or injury. Fracture can be the end result of all the other wear types, though it can happen without prior wear or warning. Your goal as an operator is to strive for flank wear. You must also identify and take measures to counteract other forms of wear.

**Figure 1.** Successful manufacturing is often a balance of production output and production cost.

**Figure 2.** Flank wear is the most normal type of wear. (Courtesy of Kennametal.)

**Figure 3.** A built-up edge is the pressure welding of workpiece material to the flank and rake face of the insert. (Courtesy of Kennametal.)
adhesion The build up of workpiece material on an insert during metal cutting.

aluminum oxide A common coating element for carbide tools that has excellent resistance to crater wear and notching.

built-up edge Adhesion of workpiece material to the cutting edge of an insert due to high temperatures and pressure welding. Built-up edge is a common cause of tool failure when machining soft, gummy metal.

chatter The occasional vibration between a workpiece and a cutting tool. Chatter decreases machining productivity, negatively impacts surface quality, and increases tool wear.

chip hammering Tool wear characterized by damage to the insert's rake face due to the constant chiseling action of long chips.

chip load The thickness of a chip generated during a machining operation.

chipbreaker A feature designed to prevent chips from forming into long pieces. Chipbreakers are either indentations on the surface of the cutting insert or another wafer clamped above the insert in the toolholder.

chipping Tool wear resulting in the loss of small slivers from the cutting edge of the tool. Chipping is also called frittering.

clearance An amount of space or distance between two objects.

clearance angle The angle designed to eliminate interference and provide adequate space between the cutting tool and the workpiece.

corner radius The rounded tip on the cutting edge of an insert. The greater the corner radius, the greater the degree of roundness at the tip. A zero degree corner radius creates a sharp point.

crater wear Tool wear characterized by a concave depression in the rake face of the cutting tool adjacent to the cutting edge. Crater wear is also called cratering.

cratering Tool wear characterized by a concave depression in the rake face of the cutting tool adjacent to the cutting edge. Cratering is also called crater wear.

depth of cut The distance that the cutting tool is plunged into the workpiece. Depth of cut is typically measured in millimeters or inches.

depth-of-cut Insert wear characterized by excessive localized damage on both the rake face and flank of the insert at the depth-of-cut line. Depth-of-cut notching is also called notch wear and notching.

diffusion The wearing away of material due to the exchange of atoms.

ductile Able to bend, stretch, or form without breaking. Ductile metals tend to produce long, continuous chips.

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edge hone A rounded and blunted cutting edge used to add strength.

feed rate The rate at which the cutting tool and the workpiece move in relation to one another. Feed is typically a linear movement.

fissures Small cracks perpendicular to the cutting edge of an insert that appear due to high temperatures.

flank The flat surface of an insert perpendicular to the rake face.

flank wear Tool wear resulting in the gradual wearing away of the cutting edge. Flank wear is mostly caused by abrasion, is predictable, and is the most desired form of tool wear.

fracture The catastrophic failure of the insert due to the separation of a large section. Fracture can happen without warning or as the result of other forms of insert wear.

frittering Tool wear resulting in the loss of small slivers from the cutting edge of the tool. Frittering is also called chipping.

hone A rounded and blunted cutting edge shaped by abrasives. The hone on a cutting edge increases edge strength.

indexing Rotating a carbide insert to present a new cutting edge. Once all the cutting edges are worn, the insert is replaced.

insert An indexable and replaceable cutting tool with a geometric shape that has multiple cutting surfaces.

intermittent cut Metal cutting during which one or more edges of the cutting tool are not in constant contact with the workpiece surface. Milling is an intermittent cutting operation.

lead angle The approach angle of the cutting edge as it enters the workpiece. The lead angle controls the direction of the radial and axial cutting forces.

mechanical wear Insert wear caused by intense physical contact between an insert and a workpiece.

notch wear Insert wear characterized by excessive localized damage on both the rake face and flank of the insert at the depth-of-cut line. Notch wear is also called notching and depth-of-cut notching.

oxidation A chemical reaction involving the addition of oxygen, the removal of hydrogen, or the removal of electrons from an element or compound.
plastic deformation Permanent deformation of the tool that occurs during metal cutting because of extreme pressure, extreme temperature, and intense mechanical contact. Plastic deformation is also called thermal deformation.

rake angle An angle describing the tilt of the face from the cutter axis or radius. Positive rake angles reduce cutting forces and encourage chip removal.

relief A clearance angle behind or below the cutting edge that allows the tool to be forced into the workpiece material.

speed The rate at which the cutting edge of the tool moves past the workpiece surface at the point of contact. Speed is typically a rotational movement.

tantalum A material used in carbide cutting tools that offers improved hot hardness and reduced thermal deformation.

tantalum carbide A material used in carbide cutting tools that offers improved hot hardness and reduced thermal deformation.

thermal cracking Insert wear characterized by small cracks and fissures caused by temperature fluctuations. Thermal cracking is also called thermal fatigue.

thermal deformation Permanent metal deformation that occurs during metal cutting because of extreme pressure, extreme temperature, and intense mechanical contact. Thermal deformation is also called plastic deformation.

thermal fatigue Insert wear characterized by small cracks and fissures caused by temperature fluctuations. Thermal fatigue is also called thermal cracking.

titanium carbide TiC. A material used to make carbide cutting tools that offers improved chemical stability and crater resistance.

tungsten carbide The original carbide tool material. Tungsten carbide offers excellent hardness. However, it is somewhat expensive and tends to crater when machining steel.

wear land The flattened section that forms on the flank of the tool behind the cutting edge due to abrasive wear with the workpiece.

work harden To increase the hardness of a workpiece exterior due to temperature and pressure at the point of contact.