Cutting Tool Geometries

Training Objectives

After watching the program and reviewing this printed material, the viewer will gain knowledge and understanding of the shapes, angles, and other geometric aspects of single-point and multi-point cutting tools.

- the geometry of turning insert tools are explained
- the geometric aspects of multi-point milling cutters are detailed
- the mechanics of chip generation in respect to tool geometry is shown
- face milling cutter geometry is discussed

Cutting Tool Geometry

Cutting tools for metalcutting have many shapes, each of which are described by their angles or geometries. Every one of these tool shapes have a specific purpose in metalcutting. The primary machining goal is to achieve the most efficient separation of chips from the workpiece. For this reason, the selection of the right cutting tool geometry is critical. Other chip formation influences include:

- the workpiece material
- the cutting tool material
- the power and speed of the machine
- various process conditions, such as heat and vibration

Turning & Single-Point Cutting Tools

Nearly all turning processes use single point cutting tools, this is, tools that cut with only a single edge in contact with the work. Most turning is done with coated indexable carbide inserts, but the tool material may also be high-speed steel, brazed carbide, ceramic, cubic boron nitride, or polycrystalline diamond. 75 percent of turning operations use just a few basic tool geometries. When turning with inserts, much of the geometry is built into the tool holder itself rather than the actual insert. However, let's first focus on the inserts. The geometry of an insert includes:

- the insert's basic shape
- its relief or clearance angle
- the insert type
- the insert's inscribed circle or "IC" size
- the insert's nose radius
- the insert's chip breaker design

In turning, insert shape selection is based on the trade-off between strength and versatility. For example, larger point angles are stronger, such as round inserts for contouring and square inserts for roughing and finishing. The smaller angles (35^o and 55^o) are the most versatile for intricate work.

Turning inserts may be molded or ground to their working shape. The molded types are more economical and have wide application. Ground inserts are needed for maximum accuracy and to produce well defined or sharp contours.

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Several angles are important when introducing the cutting tool's edge into a rotating workpiece. These angles include:

- the angle of inclination
- rake angle
- effective rake angle
- lead or entry angle
- tool nose radius

The angle of inclination when viewed from the side or front is the angle of the insert seat or pocket in the toolholder, from front to back. This inclination can be either positive, negative, or neutral.

The cutting tool's rake angle is the angle between the cutting edge and the cut itself. It may also be positive, negative, or neutral.

The effective rake angle is the combination of the tool holder's angle of inclination and the rake built into the insert.

The lead or entry angle is the angle between the direction of the cutting tool feed and the cutting edge.

The tool nose radius is the angle formed by the point of the tool. This radius may be large for strength, or sharp for fine radius turning.

Since a sharp edge is weak and fractures easily, an insert's cutting edge is prepared with particular shapes to strengthen it. Those shapes include a honed radius, a chamfer, a land, or a combination of the three.

Insert size is designated by the largest circle which can be inscribed within the perimeter of the insert, called the inscribed circle. Insert size is directly connected to the toolholder size.

Insert type toolholders for turning consist of a shank, head, insert pocket, and clamping hardware. Toolholders are either right or left handed, or neutral. The size and type of the toolholder are determined by:

- the turning operation
- the feed direction
- the size of cuts
- machine tool design
- the need for accessibility
- the shape of workpiece

In turning, chipbreaking is critical to efficient work processing and good finishing qualities. Proper chipbreaking results from balancing the depth of the cut and the geometry of the tool. Many inserts have chipbreaker grooves molded into them. The four basic chip styles generated in turning are:

- small "sixes" and "nines" chips
- helical or spiral chips
- long, stringy chips

- corrugated chips

The first type, shaped like the numerals "6" or "9", represents the ideal chip. The other types indicate the need for speed and feed adjustments, or selection of a different chipbreaker design.

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Milling & Multi-Point Cutting Tools

Multi-point cutting tools are those that have two or more chip producing edges on a common body. Tool rotation then achieves the cut. Multi-point cutting tools include milling cutters, end mills, drills, reamers, and taps.

In face milling operations each insert cutter alternately enters and exits the workpiece and generates a short discontinuous chip. Most milling with insert cutters is done using the climb milling mode. This means that the insert cutting edge is biting into the work and creating the thickest part of the chip first and thinning the chip towards the exit point. This is the reverse of the conventional milling mode.

Not all face mills are used for large, flat machining. Smaller diameter face mills are used to ramp into a surface, plunge to a depth, and interpolate outwards to mill a pocket. The major variables in face mill body design that will influence tool selection are:

- the cutter's diameter
- the left- or right-handedness of the cut
- cutter geometries, including the rake and lead angles
- insert pocket design
- the milling cutter pitch
- cutter's mounting method to the machine

Most face mills are designed with fixed position insert pockets. Others are "modular" in that they accept a variety of insert cartridges that can hold inserts of different designs, and seat them at different angles. This expands the machining range of a single cutter body.

The pitch of a milling cutter refers to the number of inserts it holds in relation to its diameter. The coarser the pitch (fewer cutting inserts), the larger the chip gullet, which provides room for the chip as the cutter passes through a workpiece. Milling cutters may have coarse, fine, or extra-fine pitches.

Milling inserts are available in many grades and shapes. Each has its unique corner geometry.

To maintain close tolerances, maximize tool life, and obtain good finishes, careful and precise mounting of the insert is necessary. Additionally, the mounting of the milling tool to the machine is of high importance. Milling cutters less than 3 inches in diameter are of the integral-shank or one piece type. Those between 3 and 8 inches mount into an adapter which is fitted to the machine spindle. The larger ones, 8 inches and up, mount directly on the machine's spindle.

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Review Questions

1. Most turning uses tools that are:
   a. modular
   b. single-pointed
   c. multi-pointed
   d. ceramic

2. Maximum accuracy is obtained with inserts that are:
   a. molded
   b. ground
   c. coated
   d. made of polycrystalline diamond

3. The ideal chip shape or form in turning is:
   a. discontinuous, corrugated
   b. continuous, stringy
   c. discontinuous, "6's" and "9's"
   d. continuous, spirals

4. Smaller face mills are used to machine:
   a. large holes
   b. sharp shoulders
   c. pockets
   d. chamfered edges

5. A "modular" face mill is one that:
   a. has a variable pitch
   b. has fixed insert pockets
   c. accepts insert cartridges
   d. is either left- or right-handed

6. A multi-point cutter "pitch" refers to:
   a. the angle of cut in relation to the insert rake angle
   b. the number of inserts in relation to the insert rake angle
   c. the number of inserts in relation to rotational speed
   d. the number of inserts in relation to diameter

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Answer Key

1. b
2. b
3. c
4. c
5. c
6. d