Threading Basics

Training Objectives

After watching the video and reviewing this printed material, the viewer will gain knowledge and understanding of the design and use of various thread types and how they are produced.

- the types and terminology of threads are detailed
- the various forms of tooling used to produce threads are shown
- details of thread producing machinery are provided
- both internal and external threading are covered

The Helical Thread

The helical screw form has two basic functions in manufacturing. One is to transmit power and motion, as with a lead screw that moves a machine table. The second is in the assembly of objects using bolts, screws, nuts and other "threaded" fasteners. Most industrial thread making is performed in fastener manufacturing. The two fundamental types of threads are the external thread and the internal thread. Most threads are right-handed, meaning they are advanced or tightened by turning the thread in a clockwise direction. Special applications such as gas line connections have left-handed threads.

Standard and metric threads are defined by common dimensions:

- the major diameter, which is the outside thread crest diameter on external threads, and the base or root diameter on internal threads
- the minimum or minor diameter, which is the screw diameter at the base of an external thread, and the thread crest diameter of an internal thread
- the thread pitch, which is the distance between two adjacent thread crests
- the thread pitch diameter, which is an imaginary diameter measured through the threads where the width of the groove and thread are equal

This last dimension, the thread pitch diameter, is the most important as it is a reference from which all other thread measurements originate.

Most thread angles are 60°, however threads used to transmit power or torque approach a square configuration for maximum strength. Screw lead is the distance a fastener travels in one revolution and varies with the fastener's job. Most fasteners are single lead, meaning one fastener revolution advances the fastener one thread pitch. Depending on the application, two, three, or four screw lead threads can be used to speed up assembly. The trade-off is that the greater the number of screw leads, the less holding power because the threads have a steeper pitch.

There are several thread types, but the broadest categories are coarse and fine. This refers to the number of threads per inch. Fine threads have more threads per inch, and have more holding power. Fine threads are also more resistant to vibration. Coarse threads resist stripping and lend themselves to automatic assembly.

External threads can be produced manually using tap and die sets. Fixed or adjustable dies and taps are mounted in hand operated holding collets and applied to the work, which is usually held fixed in a vise.
In manufacturing, external threads are produced in several ways. "Thread turning" is a lathe operation in which the cutting tool moves along the axis of a rotating workpiece, cutting a helix. By changing rotation speed and longitudinal feed, a wide variety of thread sizes, shapes, and pitch can be created.

"Chasing" involves forcing a piece of round stock into a set of rotating dies called chasers. Chasing can be done manually or automatically.

"Thread milling" is a method of producing larger diameter internal and external threads. To perform thread milling, a machine with three-axis control capable of helical interpolation is required. Thread milling combines three motions:

- the rotation of the cutting tool with the thread profile shape about its own axis
- the orbiting motion around the workpiece
- the longitudinal motion of the tool

Threads on very hard materials may be ground. This is a very costly method requiring specialized equipment.

The most common high-volume method of thread production is "cold forming" or "thread rolling". In this method, threads are forced under high pressure into a blank by dies having the desired thread form. Most thread rolling is done at room temperature, but harder material receives some amount of pre-heat. Two thread rolling techniques are used:

- flat plate thread rolling, in which blanks are fed between plates that move relative to each to form the major and minor diameter of the thread
- radial or cylindrical thread rolling, where threads are produced by the infeeding motion of circular dies

It is possible to thread roll an internal thread, but most are cut with a tap having a progression of sharp thread cutting sections surrounding its exterior. This tap is driven into a previously drilled hole to cut a thread shape in the hole's wall as the tap moves axially. The main difference among taps is the amount of chamfer at the cutting edge. More chamfer results in a gradual cutting action. Less chamfer provides more cutting power. The three commonly used tap forms are:

- the taper tap, which has the most chamfer and does the least cutting; used as a starting tap
- the plug tap, which is a general purpose tap
- the bottoming tap, which has the least chamfer and is often used for as a finishing tap

Taps will have two, three, or four flutes which facilitate lubrication and help remove chips and cuttings. Flutes may be straight or spiral. Spiral flutes are especially useful in lifting chips out of blind holes. Most taps are made of high speed steel, and sometimes carbide or carbon steel. Taps are designed chiefly to cut steel, but special taps are available for working with aluminum, cast iron and other materials.
High volume tapping is accomplished using dedicated tapping machines, lathes, machining centers, and numerically controlled or "NC" drill and tap centers. These drill and tap centers are similar to, but smaller than, regular machining centers. They can be programmed to perform holemaking and tapping to produce a variety of threaded parts in high quantities. Some machines have multi-spindles and gangs of ten or more taps.

Cutting fluid delivery is important in all thread cutting operations, both internal and external. Cutting fluids maintain lubricity between the cutting or forming tools and the workpiece, cool the work area, and flush away chips. An exception to this rule are cast iron parts which are usually cut dry.
Threading Basics

Review Questions

1. Most industrial thread making is performed for:
   a. machine applications
   b. to transmit power and motion
   c. gas and piping use
   d. fastener manufacturing

2. The dimension from which all other thread dimensions originate is its:
   a. the major diameter
   b. the minimum or minor diameter
   c. the thread pitch dimension
   d. the thread pitch diameter

3. "Thread Milling" is a process for producing:
   a. very small-diameter threaded holes
   b. larger diameter threaded holes
   c. irregular diameter threaded holes
   d. deep-threaded holes

4. The most common high-volume method of thread production is:
   a. thread turning
   b. thread chasing
   c. thread grinding
   d. thread rolling

5. The principal difference among taps is:
   a. hardness of tap
   b. thread pitch
   c. amount of chamfer
   d. number of flutes

6. Cutting fluids for thread making are needed except for when working with:
   a. tool steel
   b. aluminum
   c. cast iron
   d. carbon steel
Answer Key

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

Threading Glossary

acme thread
A screw thread having a 29 degree included angle. Used largely for feed and adjusting screws on machine tools.

addendum
The addendum of an external thread is the radial distance between the major and pitch cylinders or cones, respectively. The addendum of an internal thread is the radial distance between the minor and pitch cylinders or cones, respectively. This term applies to those threads having a recognized pitch diameter or pitch cone. The addendum can also be defined as the height by which a tooth projects beyond a pitch cylinder, plane, or cone.

allowance
An intentional clearance between internal or external thread and the design form of the thread when the thread form is on its maximum metal condition. Not all classes of fit have an allowance. For metric threads the allowance is called the fundamental deviation.

axis
The line, real or imaginary, passing through the center of an object about which it could rotate; a point of reference.

axis of thread
The axis of a thread is coincident with the axis of its pitch cylinder or cone.

back taper
A slight decrease in diameter from point to back in the body of the drill. Back taper can also be defined as a light decrease in diameter, from front to back in the flute length of reamers, or as a gradual decrease in the diameter of the thread form on a tap from the chamfered end of the land towards the back which creates a slight radial relief in the threads.

basic form of thread
The permanent reference profile, from which the design forms for both external and internal threads are developed.

basic thread profile
This is the theoretical profile of external and internal threads with no manufacturing tolerance applied.

blunt start (blunt end) thread
“Blunt start” ("blunt end") designates the removal of the incomplete thread at the end of the thread. This is a feature of threaded parts that are repeatedly assembled by hand, such as hose couplings and thread plug gages, to prevent cutting of hands and crossing of threads, and which was formerly known as a Higbee cut.
**center gage**
A small, flat gage having 60 degree angles that is used for grinding and setting the thread cutting tools in a lathe. It may also be used to check the pitch of threads and the points of center.

**chamfer**
The tapering of the threads at the front end of each land of a tap by cutting away and relieving the crest of the first few teeth to distribute the cutting action over several teeth. Taper taps are chamfered 7-10 multiples of the thread pitch from the tap point. Plug taps are chamfered 3-5 times the pitch. Bottoming taps are chamfered 1-2 times the pitch. Specification of chamfer lengths in multiples of pitch avoids variations in the counting of threads on various tap lands.

**chasing threads**
Cutting threads in a lathe or screw machine.

**classes of threads**
Threads of a given type are distinguished from each other by the amounts of tolerance or tolerance and allowance specified. Various combinations of these tolerances and allowances have been set in tables to form a set of standard classes.

**complete thread**
The complete (full form) thread is that cross section of a threaded length having full form at crest and root. (See effective thread, length of complete thread.) Note: Formerly in pipe thread terminology this was referred to as “the perfect thread” but that term is no longer considered desirable.

**crest**
The surface of the thread that joins the flanks of the thread and is farthest from the cylinder or cone from which the thread projects. The crest of an external thread is at its major diameter while the crest of an internal thread is at its minor diameter.

**crest truncation**
The crest truncation of a thread is the radial distance between the sharp crest (crest apex) and the cylinder or cone that would bound the crest.

**cumulative pitch**
The distance measured parallel to the axis of the thread between corresponding points on any two threads whether or not they are in the same axial plane.

**dedendum (thread)**
The dedendum of an external thread is the radial distance between the pitch and minor cylinders or cones, respectively. The dedendum of an internal thread is the radial distance between the major and pitch cylinders or cones, respectively. (This term applies to those threads having a recognized PD or pitch cone.)
### Threading Basics

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>depth of thread engagement</td>
<td>The depth (or height) of thread engagement between two coaxially assembled mating threads is the radial distance by which their thread forms overlap each other.</td>
</tr>
<tr>
<td>design form of thread</td>
<td>The design form of an internal or external thread is the thread form in its maximum metal condition. It is the same as the basic thread profile except that the thread roots are rounded. If either the internal or external thread form exceeds the design form of the thread profile, a potential interference exists.</td>
</tr>
<tr>
<td>design thread form</td>
<td>The design thread form is the maximum material form permitted for the external or internal thread. In practice, unless otherwise specified, the form of root is an indeterminate contour not encroaching on the maximum material form of the mating thread when assembled.</td>
</tr>
<tr>
<td>die (threading)</td>
<td>A tool used to cut external threads.</td>
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<tr>
<td>die stock</td>
<td>The frame and two handles (bars) which hold the dies (chasers) used for cutting (chasing) external screw threads.</td>
</tr>
<tr>
<td>die threading</td>
<td>A process for producing external threads, usually on small diameter rod, wire, pipe or tubing, using a one-piece or two-piece die with integral cutting edges. Die threading is the counterpart of tapping.</td>
</tr>
<tr>
<td>effective diameter</td>
<td>This is the diameter of an imaginary cylinder coaxial with the thread, which has equal metal and space widths. It is often referred to as pitch diameter. Sometimes referred to as the simple effective diameter to differentiate from the virtual effective diameter.</td>
</tr>
<tr>
<td>effective thread</td>
<td>The effective (or useful) thread includes the complete thread, and those portions of the incomplete thread which are fully formed at the root but not at the crest (in taper pipe threads this includes the so-called black crest threads), thus excluding the vanish thread.</td>
</tr>
<tr>
<td>external thread</td>
<td>A thread on a cylindrical or conical external surface.</td>
</tr>
<tr>
<td>feather edge</td>
<td>Same as feather burr except that feather edge can also refer to the ends of a lead-in or lead-out thread, which is a very thin machined ridge. Sometimes called a wire edge or whisker-type burr.</td>
</tr>
<tr>
<td>first full thread</td>
<td>The first full thread on the cutting edge back of the chamfer. It is at this point that rake, hook, and thread elements are measured.</td>
</tr>
</tbody>
</table>
fishtail
A common name for the center gage. It is used to set thread cutting tools and has scales on it for determining the number of threads per inch.

flank
The flank (or side) of a thread is either surface connecting the crest with the root. The flank-surface intersection with an axial plane is theoretically a straight line.

flank angle
The flank angles are the angles between the individual flanks and the perpendicular to the axis of the thread, measured in an axial plane. A flank angle of a symmetrical thread is commonly termed the half angle of thread.

flank-leading
1. The flank of a thread facing toward the chamfered end of a threading tool. 2. The leading flank of a thread is the one which, when the thread is about to be assembled with a mating thread, faces the mating thread.

flank-trailing
The trailing flank of a thread is the one that is opposite to the leading flank.

flutes (tap)
The longitudinal channels formed in a tap to create cutting edges on the thread profile and to provide chip spaces and cutting fluid passages. On a parallel or straight thread tap they may be straight, angular, or helical; on a taper thread tap they may be straight, angular, or spiral.

following flank
The following (trailing) flank of a thread is the one that is opposite to the leading flank.

form diameter
The diameter at the point nearest the root from which the flank is required to be straight.

form of thread
The form of a thread is its profile in an axial plane for a length of one pitch of the complete thread.

front taper
A gradual increase in the diameter of the thread form on a tap from the leading end of the tool toward the back.
Threading Basics

**functional (virtual) diameter**

The functional diameter (virtual condition per ANSI Y14.5M) of an external or internal thread is the pitch diameter of the enveloping thread of perfect pitch, lead, and flank angles, having full depth of engagement but clear at crests and roots and of a specified length engagement. It may be derived by adding to the pitch diameter in the case of an external thread, or subtracting from the pitch diameter in the case of an internal thread, the cumulative effects of deviations from specified profile, including variations in lead (uniformity of helix) and flank angle over a specified length of engagement. The effects of taper, out-of-roundness, and surface defects may be positive or negative on either external or internal threads. A perfect internal or external GO-thread gage having a pitch diameter equal to that of the specified material limit and having clearance at crest and root is the enveloping thread corresponding to that limit.

**fundamental deviation**

An intentional clearance between internal or external thread and the design form of the thread when the thread form is on its maximum metal condition. For metric threads the fundamental deviations are designated by letters—capitals for internal threads and small letters for external threads. Some tolerance classes have a fundamental deviation of zero. For imperial threads the fundamental deviation is called the allowance.

**fundamental triangle height**

The fundamental triangle height is normally designated with the letter H. This is the height of the thread when the profile is extended to a sharp vee form. For 60 degree thread forms such as metric and Unified thread series, H equals 0.866025 times the thread pitch.

**gage, screw pitch**

A gage consisting of a group of thin blades, used for checking the number of screw threads per unit of distance—usually per inch—on a screw, bolt, nut, pipe, or fitting.

**half nut**

A lever-operated mechanism that resembles a split nut that can be closed on the lead screw of a lathe when threads are being cut.

**height of fundamental triangle**

The height of the fundamental triangle of a thread, that is, the height of a sharp-V thread, is the distance, measured radially, between the sharp major and minor cylinders or cones, respectively.

**height of thread**

The height (or depth) of thread is the distance, measured radially between the major and minor cylinders or cones, respectively.
### Threading Basics

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<td>helix</td>
<td>A path formed as a point advances uniformly around a cylinder, as the thread on a screw or the flutes on a drill.</td>
</tr>
<tr>
<td>helix angle (threading)</td>
<td>On a straight thread, the helix angle is the angle made by the helix of the thread and its relation to the thread axis. On a taper thread, the helix angle at a given axial position is the angle made by the conical spiral of the thread with the axis of the thread. The helix angle is the complement of the lead angle.</td>
</tr>
<tr>
<td>included angle</td>
<td>The included angle of a thread (or angle of thread) is the angle between the flanks of the thread measured in an axial plane.</td>
</tr>
<tr>
<td>incomplete thread</td>
<td>A threaded profile having either crests or roots, or both crests and roots not fully formed, resulting from their intersection with the cylindrical or end surface of the work or the vanish cone. It may occur at either end of the thread.</td>
</tr>
<tr>
<td>internal thread</td>
<td>A thread on a cylindrical or conical internal surface.</td>
</tr>
<tr>
<td>interpolation</td>
<td>A function of control enabling data points to be generated between specific coordinate positions to allow simultaneous movement of two or more axes of motion in a defined geometric pattern. For example, in NC, curved sections can be approximated by a series of straight lines or parabolic segments. Also known as linear interpolation.</td>
</tr>
<tr>
<td>interrupted thread tap</td>
<td>A tap having an odd number of lands with alternate teeth in the thread helix removed. In some cases, alternate teeth are removed only for a portion of the thread length.</td>
</tr>
<tr>
<td>land (tap)</td>
<td>One of the threaded sections between the flutes of a tap.</td>
</tr>
<tr>
<td>lead</td>
<td>The distance a thread will advance along its axis in one complete revolution.</td>
</tr>
<tr>
<td>left-hand thread</td>
<td>A screw thread that is screwed in by rotating counterclockwise.</td>
</tr>
<tr>
<td>length of engagement</td>
<td>The axial distance over which an external thread is in contact with an internal thread.</td>
</tr>
<tr>
<td>major diameter</td>
<td>This is the diameter of an imaginary cylinder parallel with the crests of the thread; in other words, it is the distance from crest to crest for an external thread, or root to root for an internal thread.</td>
</tr>
</tbody>
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<td>minor diameter</td>
<td>The smallest diameter of a screw thread. Also known as the &quot;root diameter.&quot;</td>
</tr>
<tr>
<td>multiple-thread screw</td>
<td>A screw made of two or more threads to provide an increased lead with a specified pitch.</td>
</tr>
<tr>
<td>nominal diameter</td>
<td>The diameter equal to the external diameter of the threads.</td>
</tr>
<tr>
<td>overtapping</td>
<td>Tapping of a thread following a plating operation so that the thread tolerances comply within specification, allowing the internal and external threads to assemble. It is normal practice to overtap the internal rather than the external thread.</td>
</tr>
<tr>
<td>pitch</td>
<td>The distance from any point on a thread to the corresponding point on the adjacent thread, measured parallel to the axis. Also applied to spur gears. See diametral pitch.</td>
</tr>
<tr>
<td>pitch diameter</td>
<td>The diameter of a thread at an imaginary point where the width of the groove and the width of the thread are equal.</td>
</tr>
<tr>
<td>pitch line</td>
<td>An imaginary line which passes through threads at such points that the length of the part of the line between adjacent threads is equal to the length of the line within a thread.</td>
</tr>
<tr>
<td>right-hand thread</td>
<td>A screw thread that is screwed in by rotating clockwise. The majority of screw threads are right handed.</td>
</tr>
<tr>
<td>rolled thread</td>
<td>A thread formed by plastically deforming a blank rather than by cutting. Increases both fatigue strength and thread shear strength.</td>
</tr>
<tr>
<td>screw</td>
<td>Threaded fastener with the thread running up to the head of the fastener; has no plain shank.</td>
</tr>
<tr>
<td>screw thread</td>
<td>A ridge of constant section which is manufactured so that a helix is developed on the internal or external surface of a cylinder.</td>
</tr>
<tr>
<td>square threads</td>
<td>A thread having a depth, width, and space between threads that are equal. It is used on heavy jack screws, vise screws, and other similar items.</td>
</tr>
<tr>
<td>stress area (fasteners)</td>
<td>The effective cross sectional area of a thread when subjected to a tensile force. It is based upon a diameter which is the mean of the pitch (or effective) and the minor (or root) diameters of the thread.</td>
</tr>
</tbody>
</table>
Threading Basics

**symmetrical thread**  
A symmetrical thread is one which has both flanks of the thread profile inclined are the same angle.

**tap**  
A tool used to cut threads on the inside of a round hole.

**tapping**  
The process of cutting screw threads in a round hole with a tap (an internal thread cutting tool).

**thread**  
a helical projection of uniform section on the internal or external surface of cylinder or cone. Also, the operation of cutting a screw thread.

**thread angle**  
The angle formed by the two sides of the thread (or their projections) with each other.

**thread axis**  
a line running lengthwise through the center of the screw.

**thread crest**  
The top part of the thread. For external threads, the crest is the region of the thread which is on its outer surface; for internal threads it is the region which forms the inner diameter.

**thread crest**  
The top surface joining the two sides of a thread.

**thread depth**  
The distance between the crest and the root of a thread.

**thread flank**  
The thread flanks join the thread roots to the crest.

**thread height**  
This is the distance between the minor and major diameters of the thread measured radially.

**thread length**  
Length of the portion of the fastener with threads.

**thread pitch**  
The distance from a point on one screw thread to a corresponding point on the next thread.

**thread pitch diameter**  
The diameter of a screw thread measured from the thread pitch line on one side to the thread pitch line on the opposite side.

**thread root**  
The thread root is the bottom of the thread. On external threads the roots are usually rounded so that fatigue performance is improved.

**thread root**  
The bottom surface joining the sides of two adjacent threads.

**thread runout**  
The portion at the end of a threaded shank which is not cut or rolled to full depth, but which provides a transition between full depth threads and the fastener shank or head.
### Threading Basics

**tolerance class**
A combination of tolerance grade and a fundamental deviation which is given to an internal or external thread. A tolerance class for an internal thread when combined with the tolerance class for an external thread gives the class of fit for the mating threads.

**tolerance grade**
The difference between maximum and minimum metal conditions for a tolerance applied to a screw thread. For metric threads the tolerance grade is given a number.

**virtual effective diameter**
The effective diameter of a thread, but allowing for errors in pitch and flank angles.