THREAD CUTTING & FORMING

Threading, Thread Cutting and Thread Rolling:
Machining Threads on External Diameters (shafts)

Tapping: Machining Threads on Internal Diameters (holes)

Size: Watch to 10” shafts

Straight Threads: Threads on cylindrical surfaces, ex. fasteners

Conical Threads: Threads on conical surfaces, ex. Pipe joints

Methods: Thread Rolling- small and standard parts, ductile materials
        Thread Cutting, Thread grinding.
Common thread applications: - fastening

Special thread applications: - to transmit motion
- to transmit power
- to measure
- to connect pipes
Standards:

Unified (American)- dim. in inches, pitch in Threads Per Inch (TPI)

ISO (Metric)- dim. in mm or inches, pitch in mm

Types:  
**UNC/NC:** Coarse Thread – Regular use not subjected to vibration

**UNF/NF:** Fine Thread – Automotive and Aircraft

**UNEF/NEF:** Extra Fine Thread – Thin structures, High TPI.

8Thread Series, 8UN, 8N: 8TPI, Dia 1-6”.

12Thread Series, 12UN, 12N: 12TPI, Dia 0.5-6”. Not widely used.

16Thread Series, 16UN, 16N: 16TPI, Dia 0.5-6”. Widely used for fine thread.

**ACME:** For power and motion transmission,

**Buttress Thread:**

**Square Thread:**

29deg worm Thread:

**Pipe thread**
Unified Thread:

FIGURE 30-1 Unified and American screw-thread form for internal and external threads.
ISO

Figure 30-2 Basic profile of metric general-purpose screw thread per ISO/R68-1969.

$D = \text{Major diameter of thread of nut}$
$d = \text{Major diameter of screw}$
$D_1 = \text{Minor diameter of thread of nut}$
$d_1 = \text{Minor diameter of screw}$
$D_2 = \text{Pitch diameter of thread of nut}$
$d_2 = \text{Pitch diameter of screw}$
$H = \text{Height of the complete theoretical thread profile}$
$H_1 = \text{Engagement}$
$P = \text{Pitch}$

$H = \frac{\sqrt{3}}{2} P$
Geometry: Form, Major Dia, Normal Dia, Minor Dia., Pitch Dia., Pitch, Root, Crest, Flank, Rounded or flat, Thread angle

Single thread = 1 × pitch
Double thread = 2 × pitch
Triple thread = 3 × pitch

FIGURE 30-3 Standard screw-thread nomenclature.
American Acme thread

Min. depth $D = 0.5 \times P$
Width $F = 0.3707 \times P$
Width $C = F - 0.0052$

Square thread

Depth $D = 0.5 \times P$
Width for screw $= 0.5 \times P$
$W$ for thread groove in nut $= 0.5 \times P$
plus 0.001 to 0.002” clearance

American Standard Pipe thread

Effective thread length $E$
Taper $= \frac{3}{4}$ in. per ft.

Pitch diam. at end of pipe $A = G - (0.05 + 1.1) P$

Buttress thread

Depth $D = 0.750 \times P$
Width of flat $= 0.125 \times P$
Flank angle $= 45^\circ$ in plane of axis

29 degree worm thread

Depth $D = 0.6866 \times P$
Depth $F = 0.355 \times P$
Depth $C = 0.310 \times P$

Angle $= 29^\circ$ in plane of axis

30-4 Special thread forms.
Thread Classes

ANSI: 3 classes, class 1, civil constructions
class 2, normal production
class 3, in tight fit requirements

ISO - external $\rightarrow$ e - large; g - small; h - no allowance
- internal $\rightarrow$ G - small; H - no allowance
- grades 3 $\rightarrow$ 9 (<6 fine, >6 coarse)

*there are two separate tolerances for crest and pitch
METHODS OF MANUFACTURING

1) THREAD CUTTING

MANUAL Tap and Die → usually for manual cutting of threads

*tap*: a bolt with flutes to provide cutting edges, turned by a handle

*sets of taps*: Taper tap (sufficient for through hole)
   Plug tap
   Bottoming tap (ISO 1,2 and 3)

→ before machining a hole has to be drilled to provide the necessary allowance for the threads

- *threads hole vs. tap size*
  
  (in general for M < 10 mm; $\varnothing_d \sim \varnothing_t \times 0.8$)
Figure 30-12 terminology for a plug tap with photographs of taper (t), plug (p), and bottoming (b) taps are used serially in threading holes.
Other types of taps:
Tapping machines may use chipless threading

FIGURE 30-13  *Left to right:* Spiral fluted tap; spiral point tap; spiral point tap cutting chips; fluteless bottoming tap and fluteless plug tap for cold-forming internal threads.  *Inset:* Cross section of fluteless forming tap.  *(Courtesy of TRW-Greenfield Tap & Die.)*
**Adjustable taps:**
- a drill press with a tapping attachment may be used
- during the tapping, the tap rotates slowly. When the spindle is raised, the tap is driven in opposite direction, and much faster
- these attachment – used on screw machines or on turret lathes.

**Collapsing tap** – cutting elements collapse inward automatically after the thread is completed.
Two types: * radial cutters ➔ small sizes
  * circular cutters ➔ large sizes

Solid adjustable and collapsible taps.
Common tapping problems:

-- taps overloading due to poor lubrication ➞ tap failure, wear

-- difficult to remove broken taps from holes

-- Tearing of threads when backing out

-- in soft materials taps stick to the work.

-- in hard materials (SS, Ti, Inco, Superalloys), back rake angle +3° to +5° and helical flutes.
External thread cutting—easier, size ≤ 1.5” dia.
die—Resembles a hardened nut with gullets and cutting edges.
- Eventually, it could be adjustable (Easy backing out, Wear compensation)
- Bevelled edges for starting/guiding.

Kept in a die stock with handle. Self-opening dies for fast return of the tool.

Thread chasing
- to reduce time and eliminate backtracking of the tool and to eliminate the damage of the thread as the tool is backed.

CHASERS—individual cutter dies mounted in holders
DIE HEADS—can have “chasers” mounted tangentially Radially or circularly

FIGURE 30-10 (a) Solid threading die; (b) solid-adjustable threading die; (c) threading-die stock for round die (die removed). (Courtesy of TRW-Greenfield Tap & Die.)
- Taps and dies can be used for the machine cutting of threads
- Because of the thread cutting operations, special devices to hold them during the machining are required (in order to avoid the injury of the threads).

The devices may do:
* reversing of the rotation
* splitting the cutter (mainly for dies)
THREAD CUTTING ON A LATHE

- used only for special threads or small production

Requirements:
- the tool has to be properly formed
- the tool moves longitudinally, proportionally to the revolution angle of the work.
- the lead-screw is used here and NOT the feed rod
- the shape of the tool, checked by a template

TWO types of feed are used.
* tool is fed straight
* tool is fed at an angle (the cutter is swiveled in the tool post)
  for both – cross feed is used.
FIGURE 30-6 Methods of checking the form and setting of the cutting tool for thread cutting by means of a template. (Courtesy of South Bend Lathe.)

FIGURE 30-7 Top view of two methods of feeding the tool into the work in cutting threads on a lathe: (a) radial feed, compound straight; (b) half thread angle feed, compound swiveled.
FIGURE 30-5 Cutting a screw thread on a lathe, showing the method of supporting the work and the relationship of the tool to the work. Inset shows face of threading dial.  (Courtesy of South Bend Lathe.)
- The pitch — accomplished by a train of gears

- The lead screw is spun at the required speed in order to produce any desired pitch of screw.
- The lead screw engages with the split nut, providing positive drive for the tool.
- This constant position relationship will be maintained between — the work piece spindle and the cutting tool through the lead screw

- For 2mm pitch, the tool travels by 2mm per revolution of the work
THREADING DIAL – attached to the carriage and is driven directly by the lead screw

Threading dial → divided in to 4 major divisions and 8 half divisions.

THE SPLIT NUT – in the apron → has to be engaged according the following rules regarding pitch of the thread

1-8 UNC (for even numbered threads) - at any line
0.5-13 UNC (for odd numbered thread) – any numbered line
2 – 45 UNC (for half threads) – any odd number
Special (for threads with ¼ ) – original starting point each time.
The thread – cutting procedure

- **Depth of cutting** – small 0.25 / 0.4 mm (0.010 in)

  Smallest – at the end of the cutting (to improve the quality to the thread)

- **The tool** : withdrawn using the cross – slide screw and returned by power, to the initial position

- **The change in depth of cut** is made by the compound rest
\( X_a \) Specifies the absolute \( X \) coordinate of the tool after axial infeed.

\( G32 \) Initiates the single-pass threading cycle.

\( Z_a \) Specifies the absolute \( Z \) coordinate of the tool after the threading pass.

\( F_n \) \( n \) specifies the feed rate

\( X_s, Z_s \) Specifies the absolute \( X \) and \( Z \) coordinates of the start point.

**FIGURE 30-9** Canned subroutines called G codes are used on CNC lathes to produce threads.
CUTTING SPEEDS – in correction with the lead of the thread.

- Tapered thread – pipe thread (NPT) – can be cut by setting the tailstock off – center
- The contemporary lathes – equipped with a gear box (NORTON) to be able to cut all screw pitches required → old lathes exchange gears installed between the lead screw and the spindle.

Ex: Lead screw = 5 rev/in → 5.08 mm lead thread to be cut = 2 mm
the ratio required: \( \frac{5.08}{2} = 2.54 \)

\[
\frac{b}{a} \times \frac{d}{c} = 2.54
\]

or: \( \frac{127}{100} \times \frac{80}{40} = 2.54 \)
THREAD MILLING (ON MILLING MACHINES)

- Requires expensive cutters, more complex settings; Despite all these, more productive than turning

- Better accuracy for large sizes: **productive** method

  Special milling machines are used for this scope in serial production

- Universal milling machines – for very singular parts

- Form cutters are used for different thread types → standardised

- More productive set of cutters → multiple form cutter
  (several rows of teeth)

- The cutter inclined according to the helix angle

- The work spins slowly and cutter moves parallel to the work axis.
FIGURE 30-16  Checking a large thread that was milled with a single-form cutter. The cutter can be seen behind the thread.  (Courtesy of Lees-Bradner Company.)
THREAD GRINDING

- Produce very accurate threads on hardened materials
- Three basic methods are used.

1. Center type grinding with axis feed: *(Work spins slower)*
   similar to cutting thread in the lathe.
   difference → a shaped grinding wheel is used instead of the point cutting tool.
   (even multiple shaped grinding wheel can be used).
   Speed – given by the RPM of the grinding.
   Several passes are necessary to complete the thread.

2. Centre type infeed thread grinding – similar to multiple form milling – a multiple ridged wheel as long as the length of the desired thread is used.
   Feed → inward radial to full thread depth → The blank is spun just more than a full revolution.
FIGURE 27-16  Plunge cut grinding of cylinder held between centers. Note that crush roll dressing is shown.
3. Centreless thread grinding – used for set straight screws. The blanks are hopper – fed to position A. The regulating wheel make them traverse the face. Threads of $\frac{1}{2}$” length, 60-70/min is possible.
THREAD ROLLING: Cold Forming Process

Materials: any material sufficiently plastic can be rolled.
(can with stand the forces of cold forming without disintegration)

Rollability → is the feature required from metal during the rolling process

- steel → not convenient to roll because it has the tendency to harden while worked on the surface. However, this tendency assures high hardness of the thread and can partly substitute for thermal hardening and then, grinding.
- Special qualities of steel have been developed for the purpose of rolling

- During thermal rolling, the metal on the cylindrical surface is cold-forged under considerable pressure by the rolling action of the dies

- The surface of the dies has the reverse profile form of the thread

- Rolling results in a plastic flow of the metal, so the blank for threading has about the pitch diameter (not the crest, as in cutting). This results in 16 – 25% saving in material
- Blank material has Narrow tolerances for rolling.

Only EXTERNAL THREADS can be ROLLED.
FIGURE 17-4  "Fiber" structure of a hot-formed (forged) transmission gear blank. (Courtesy of Bethlehem Steel Corporation.)

FIGURE 17-5  Schematic comparison of the grain flow characteristics in a machined thread (a) and a rolled thread (b). The rolling operation further deforms the axial structure produced by the previous wire- or rod-forming operations, while machining simply cuts through it.
USING OF FLAT DIES

- The blank is rolled between two dies (one is stationary), the second reciprocates.
- Grooves in the dies are inclined according to the helix angle of the thread.

**FIGURE 30-18** Combination thread rolling and knurling of wheel bolt at 70 per minute by flat die roll threading.
USING OF ROLLER – TYPE DIES

- Two or three dies can be used

- Adapted for automatic machines

- Some large sizes ~6”dia threads can be rolled

- Machines → High force For rolling the thread.

- Rolling is repeated several times in order to carry out the depth of thread.
ADVANTAGES OF ROLLING
- Improved strength,
- smooth surface,
- close accuracy,
- less material used,
- suitable for mass production.

DISADVANTAGES OF ROLLING
- Close blank tolerances
- Only external threads can be rolled
- Only soft materials < HRC 37 can be worked
- strain hardening while cold worked
Chipless Tapping

- A fluteless tap is used for Ø < ½” => cold formed in holes in ductile metals only

- The required forming torque is twice the cutting torque that is necessary to cut the section.

- They produce better accuracy than the fluted ones

- The diameter of the hole must be well controlled

- Lubricants (water soluble soaps) are essential

- Effective in blind holes
MACHINES

THREADING & TAPPING MACHINES
- Specially built automatic machines. They are equipped with automatic feeding of work pieces
- Multiple spindle threading machines

FIGURE 30-15  Two-spindle automatic threading machine.  
(Courtesy of Landis Machine Company.)
FIGURE 23-16 On the turret-type single-spindle automatic, the tools must take turns to make cuts.
SCREW MACHINES – used not only for threads
- Automatic screw machines is essentially a turret lathe
- Screw Machines exist because of standardised screw components are made in mass production
- Use only stock bar
- Can be fed automatically from magazines.
- Not only the screw components are made
- they can have not only multi-tool turrets but also multiple spindles

Single Spindle Automatic Screw Machine
Known as Brown & sharp
Fitted with cross slide and with a vertical turret.
Swiss Type Screw machines

Turning of small parts – ex: for watches
- Single point motions are controlled by cams.
- Extremely precise because the cutting tools are very close to collette \( \rightarrow \) very less distortion of the workpiece
Multiple spindle automatic screw machines

- Fully automatic – up to eight spindles
- Perform simultaneous cuts
- Perform non-cutting functions: tool withdrawal, index, blank bar feed at high speeds
- Very efficient production
Spindle arrangement for 6 spindle automatic. The shaded circle shows the position where the barstock is usually fed. The cutoff position is the one preceding the bar feed position.

FIGURE 23-18 The multiple spindle automatic makes all cuts simultaneously and then performs the noncutting functions (tool withdrawal, index, bar feed) at high speed.
All spindles on multiple-spindle automatic have the same tool path.

The six spindle automatic

Spindle arrangement for 6 spindle automatic. The shaded circle shows the position where the barstock is usually fed. The cutoff position is the one preceding the bar feed position.

FIGURE 23-18 The multiple spindle automatic makes all cuts simultaneously and then performs the noncutting functions (tool withdrawal, index, bar feed) at high speed.