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: /Series

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:

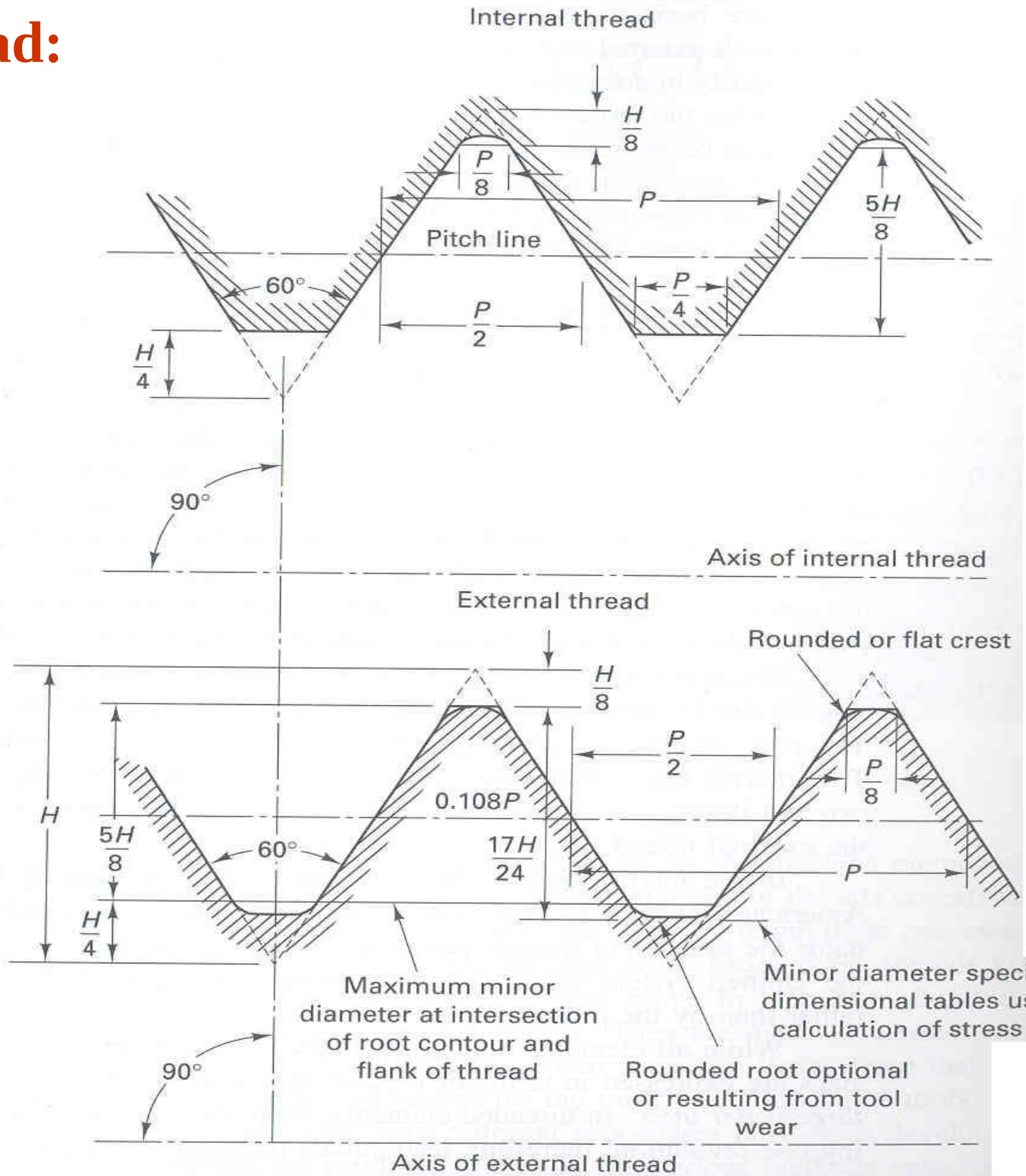
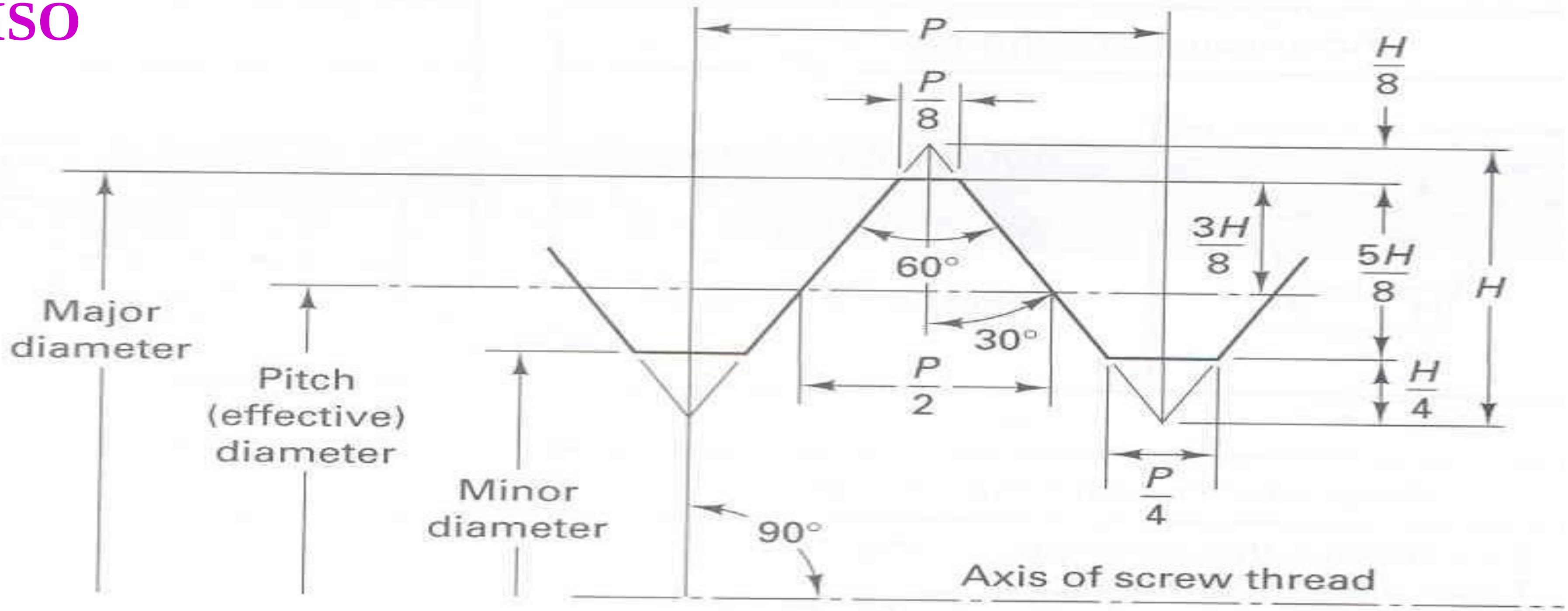


FIGURE 30-1 Unified and American screw-thread form for internal and external threads.

ISO



D = Major diameter of thread of nut
d = Major diameter of screw
} Normal diameter

D_1 = Minor diameter of thread of nut
d_1 = Minor diameter of screw
D_2 = Pitch diameter of thread of nut
d_2 = Pitch diameter of screw
H = Height of the complete theoretical thread profile
H_1 = Engagement
P = Pitch

$$H = \frac{\sqrt{3}}{2} P$$

FIGURE 30-2 Basic profile of metric general-purpose screw thread per 1S0/R68-1969.

Geometry: **Form, Major Dia, Normal Dia, Minor Dia., Pitch Dia., Pitch, Root, Crest, Flank, Rounded or flat, Thread angle**

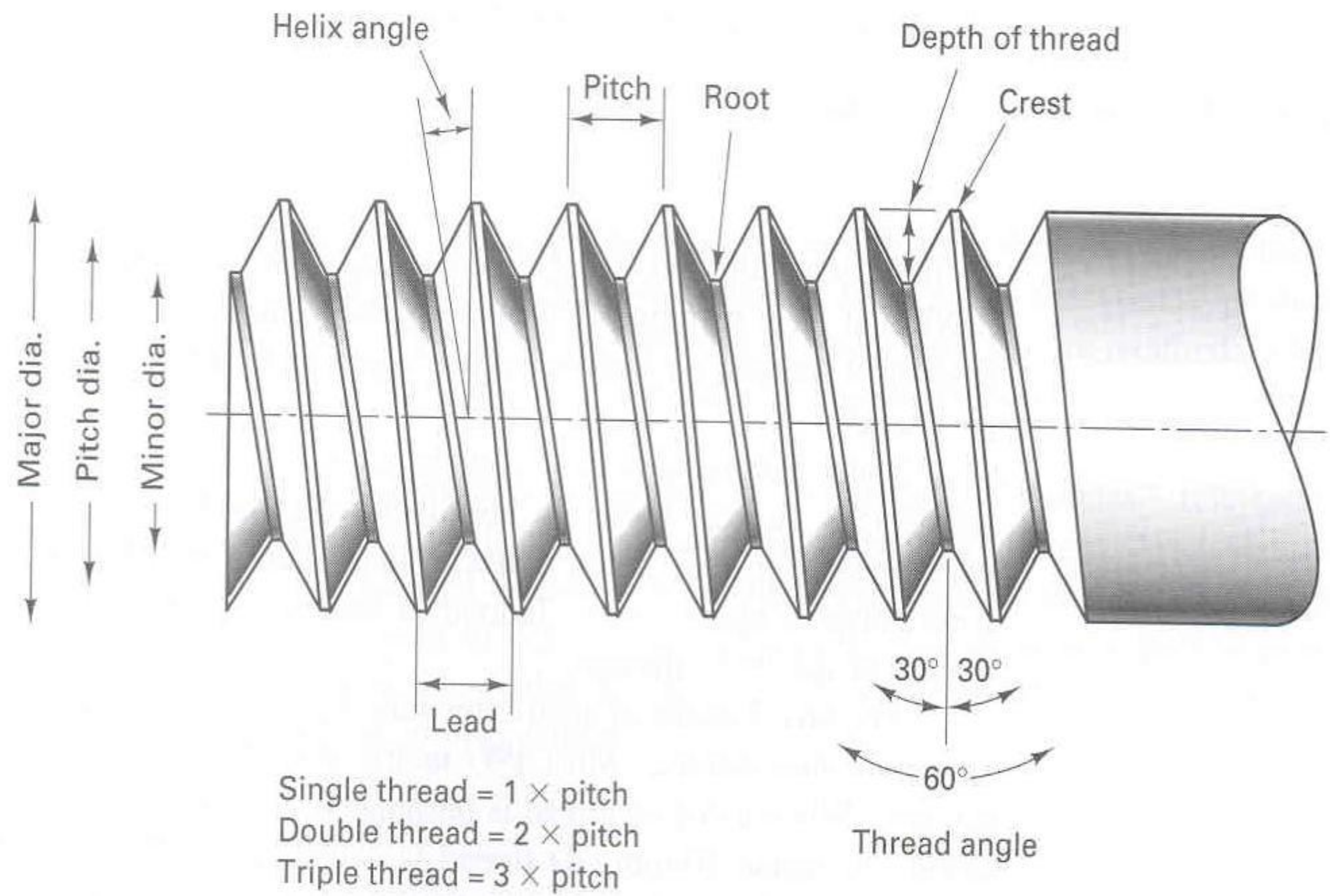
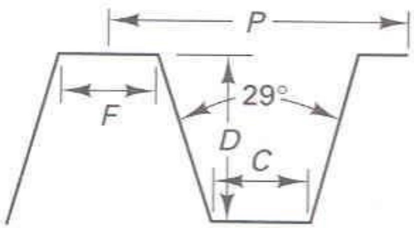


FIGURE 30-3 Standard screw-thread nomenclature.

American Acme thread

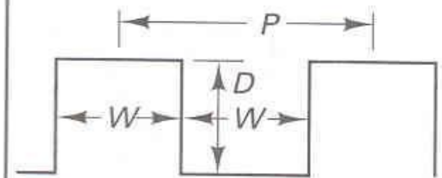


Min. depth $D = 0.5 \times P$

Width $F = 0.3707 \times P$

Width $C = F - 0.0052$

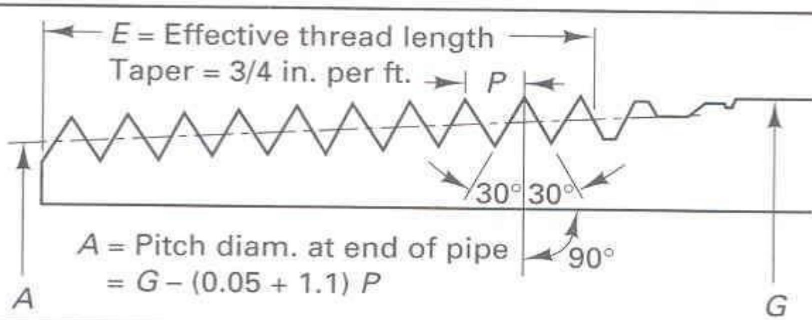
Square thread



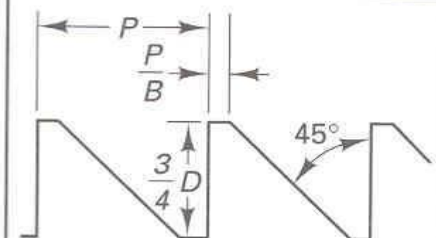
Depth $D = 0.5 \times P$
W for screw $= 0.5 \times P$

W for thread groove in nut $= 0.5 \times P$ plus 0.001 to 0.002″ clearance

American Standard Pipe thread



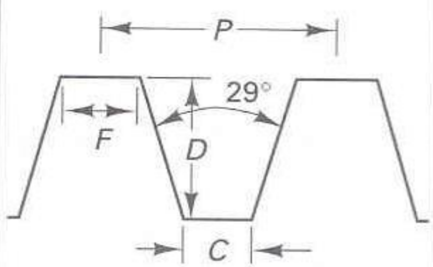
Buttress thread



Depth $D = 0.750 \times P$
Width of flat $= 0.125 \times P$

Flank angle = 45° 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° in plane of axis

FIGURE 30-4 Special thread forms.

Thread Classes

ANSI: 3 classes, **class 1, civil constructions**

class 2, normal production

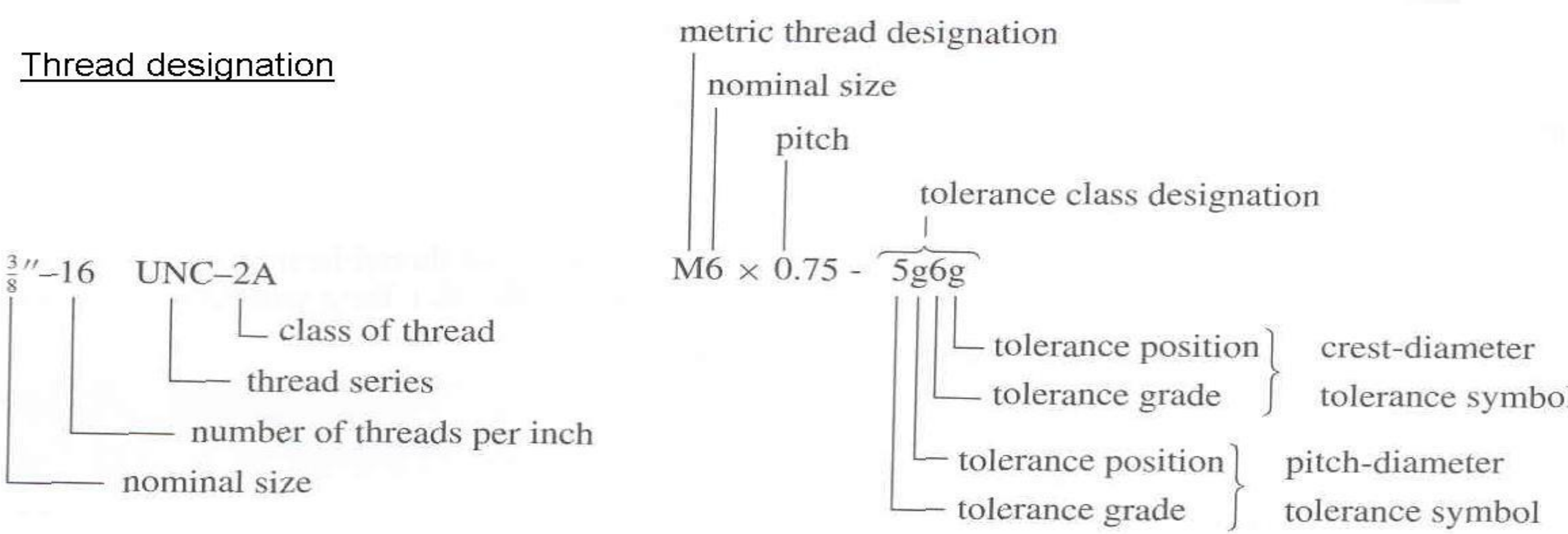
class 3, in tight fit requirements

ISO - *external* → e- large; g - small; h - no allowance

- *internal* → G- small; H- no allowance

- *grades* 3→ 9 **(<6 fine, >6 coarse)**

***there are two separate tolerances for crest and pitch**



METHODS OF MENUFACTURING

1) THREAD CUTTING

MANUAL Tap and Die → usually for manual cutting of threads

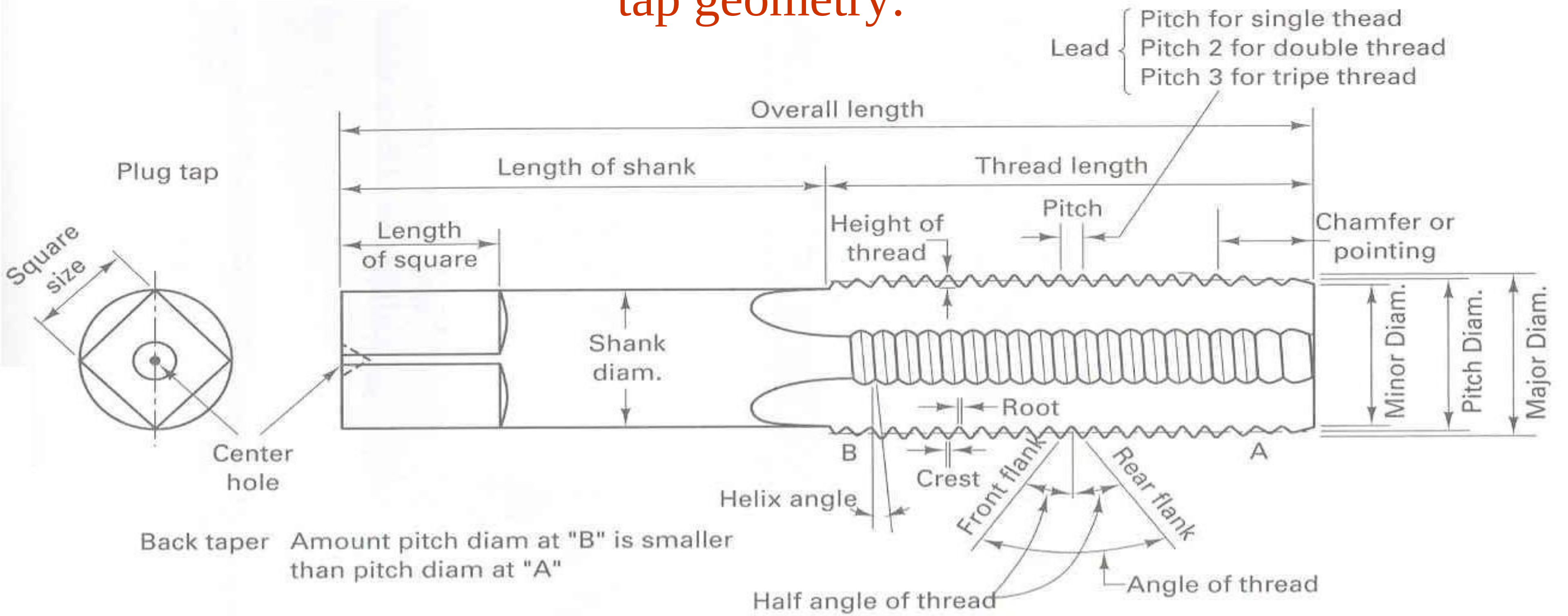
tap: a bolt with flutes to provide cutting edges, turned by a handle

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 t provide the necessary allowance for the threads

- **threads hole vs. tap size**
  (in general for M < 10 mm; $Ø_d \sim Ø_t * 0.8$)

tap geometry:



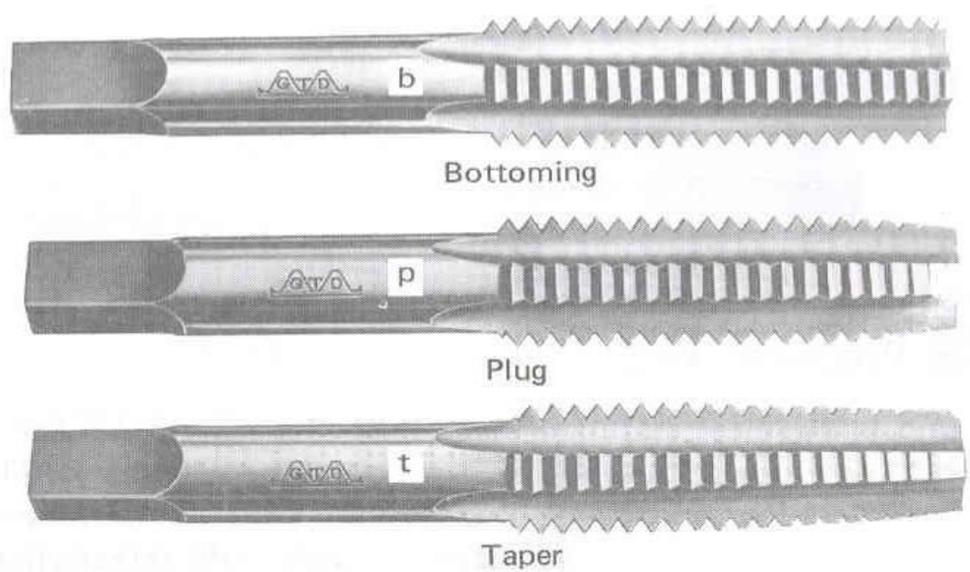


Figure 30-12 terminology for a plug tap with photographs of taper (t), plug (p), and bottoming (b) taps are used serially in threading holes.

Other types of taps:

Tapping machines may use chipless threading

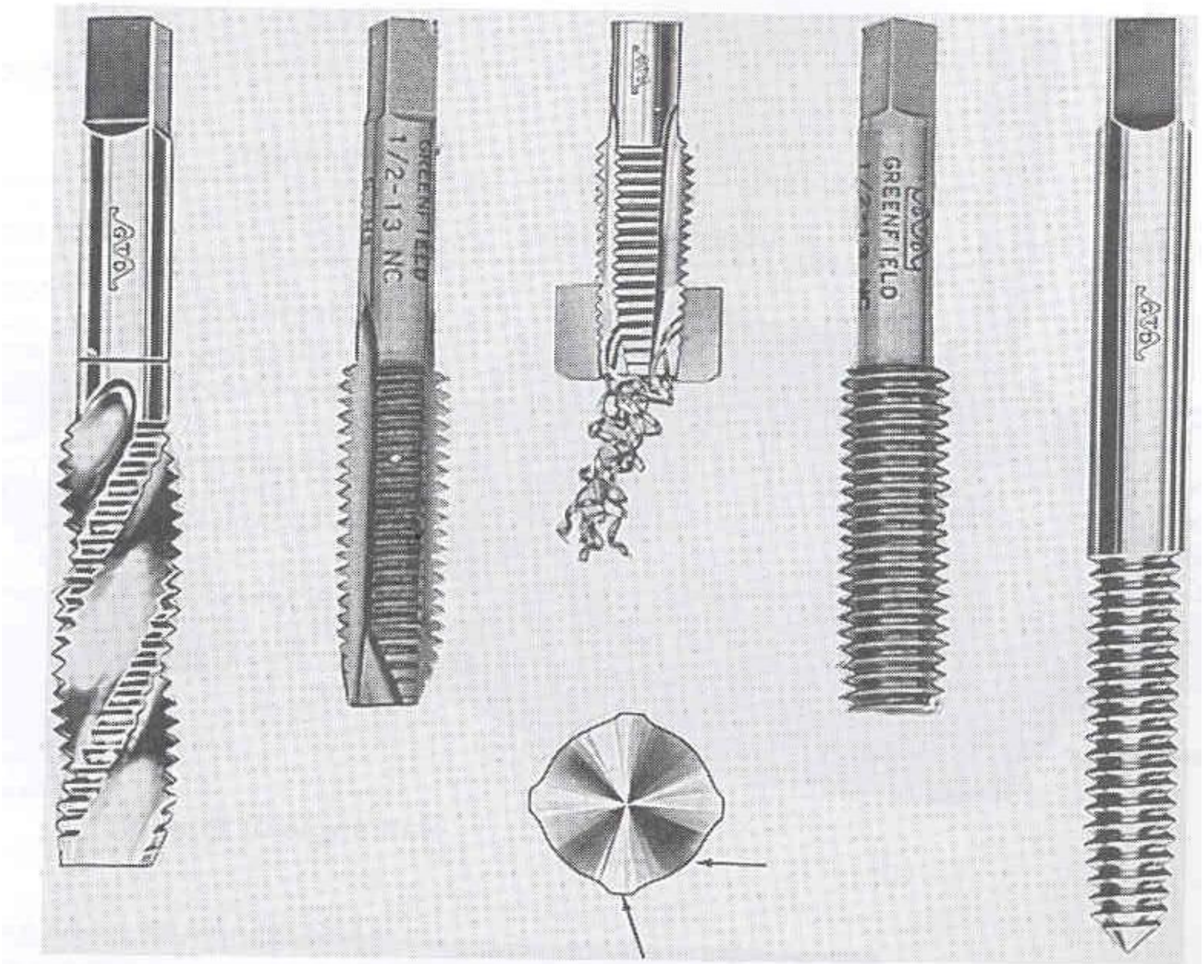


FIGURE 30-13 *Left to right:* Spiral fluted tap; spiral point tap; spiral point tap cutting chips; fluteless bottoming tap and fluteless plug tap for cold-forming internal threads. *Inset:* Cross section of fluteless forming tap. *(Courtesy of TRW-Greenfield Tap & Die.)*

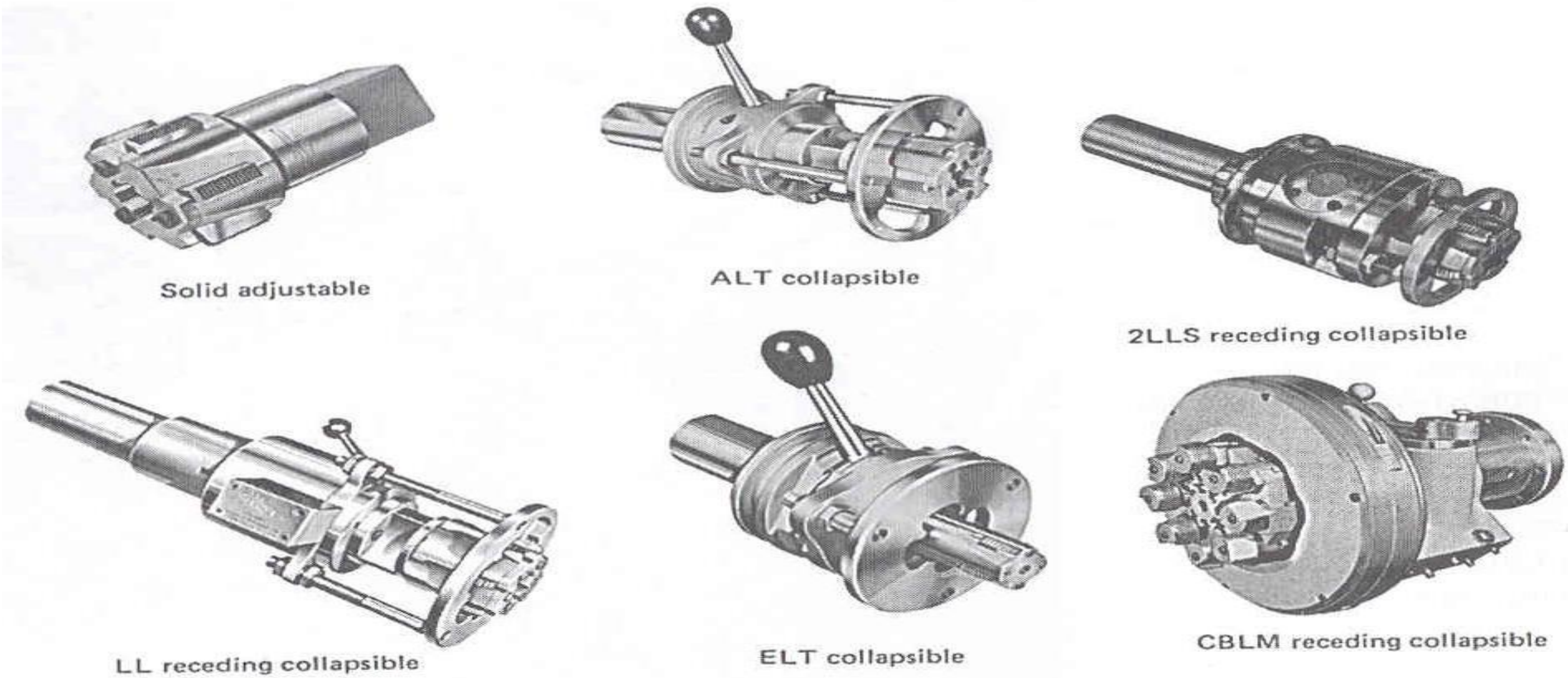
Adjustable taps:

- a drill press with a tapping attachment may be used
- during the taping, 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 $+3^0$ to $+5^0$ 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)
- **Beveled 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 <u>tangentially</u>
<u>Radially</u> or circularly

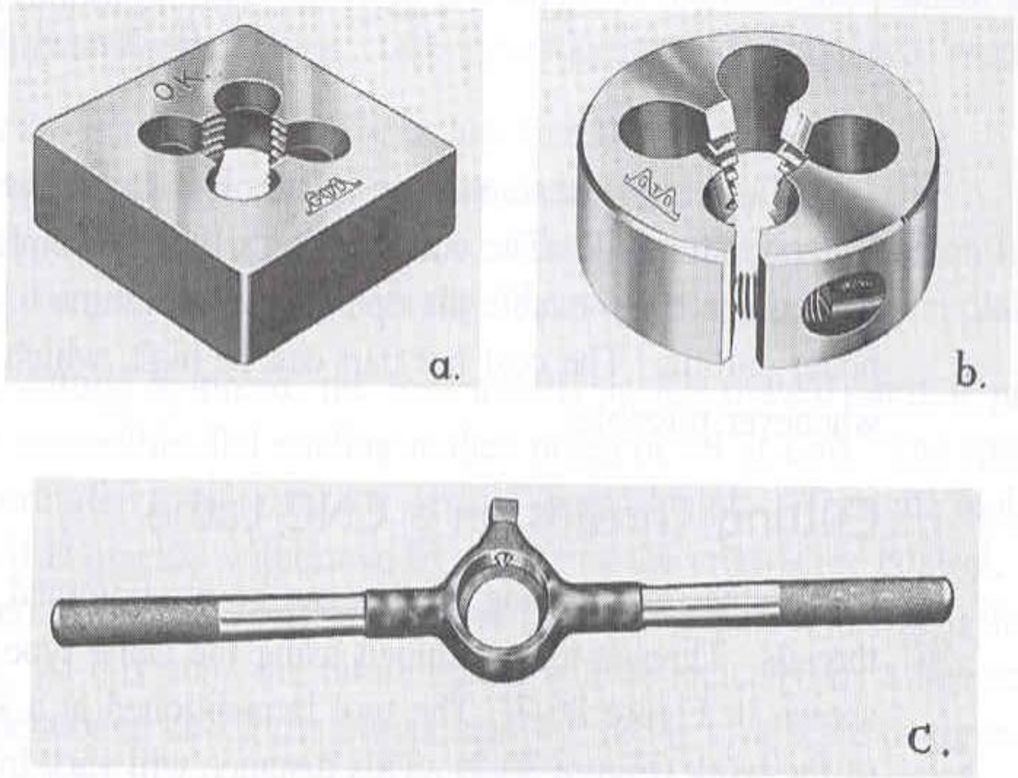
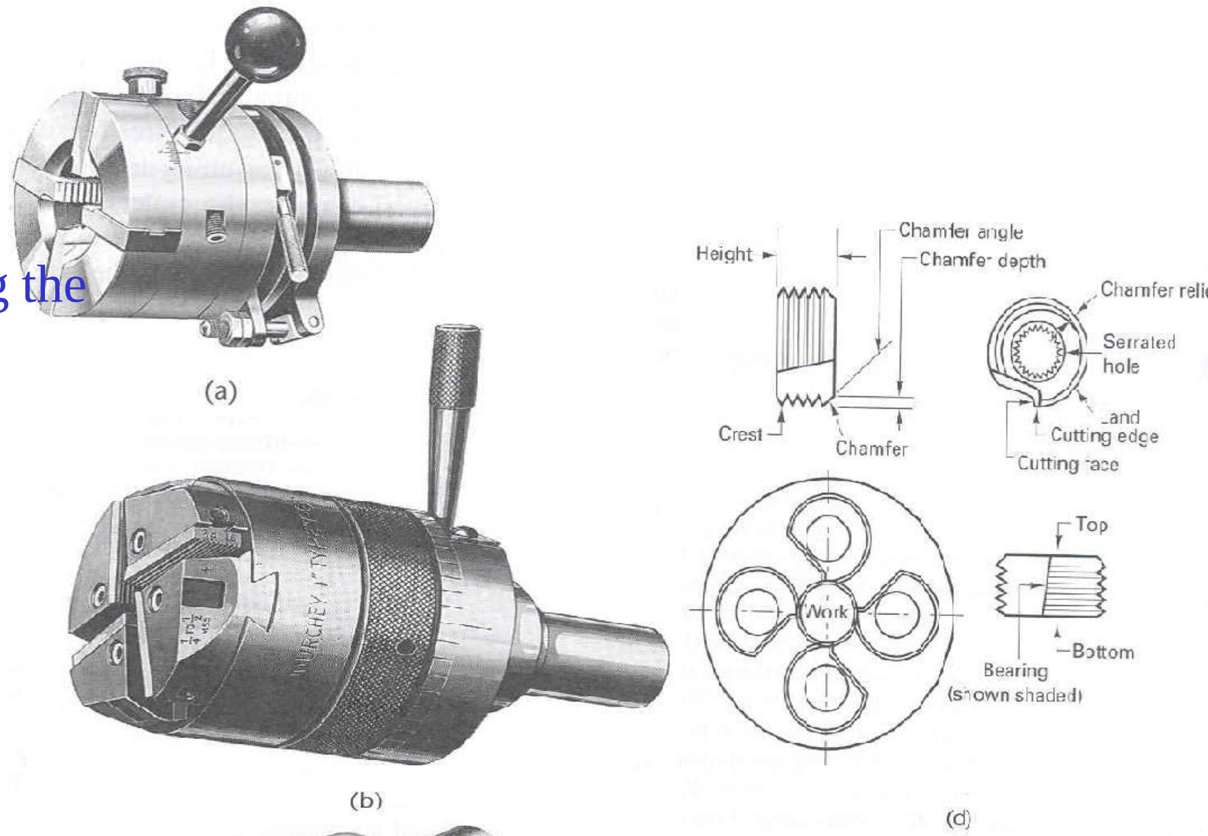


FIGURE 30-10 (a) Solid threading die; (b) solid-adjustable threading die; (c) threading-die stock for round die (die removed). *(Courtesy of TRW-Greenfield Tap & Die.)*

- 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)



Self- opening die heads, with
(a) radial cutter; (b) tangential cutters, and
(c) circular cutters. (d) terminology of circular chasers and their relation to the work.

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.

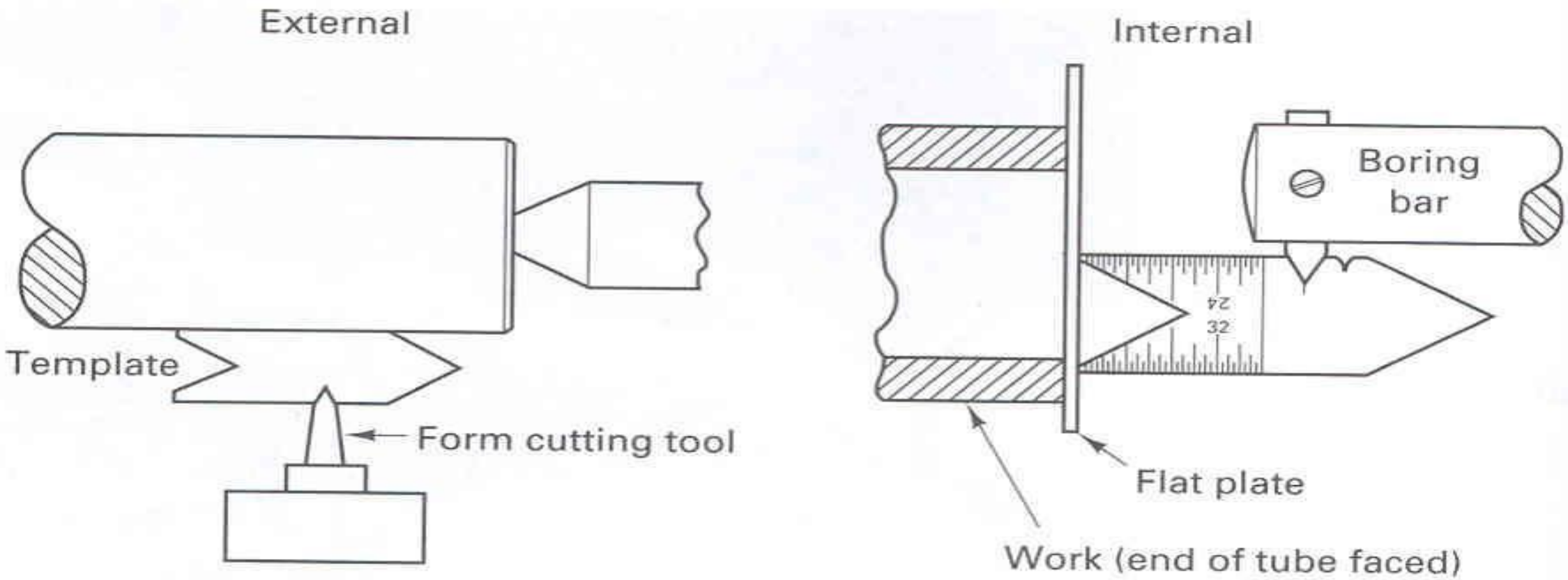


FIGURE 30-6 Methods of checking the form and setting of the cutting tool for thread cutting by means of a template. *(Courtesy of South Bend Lathe.)*

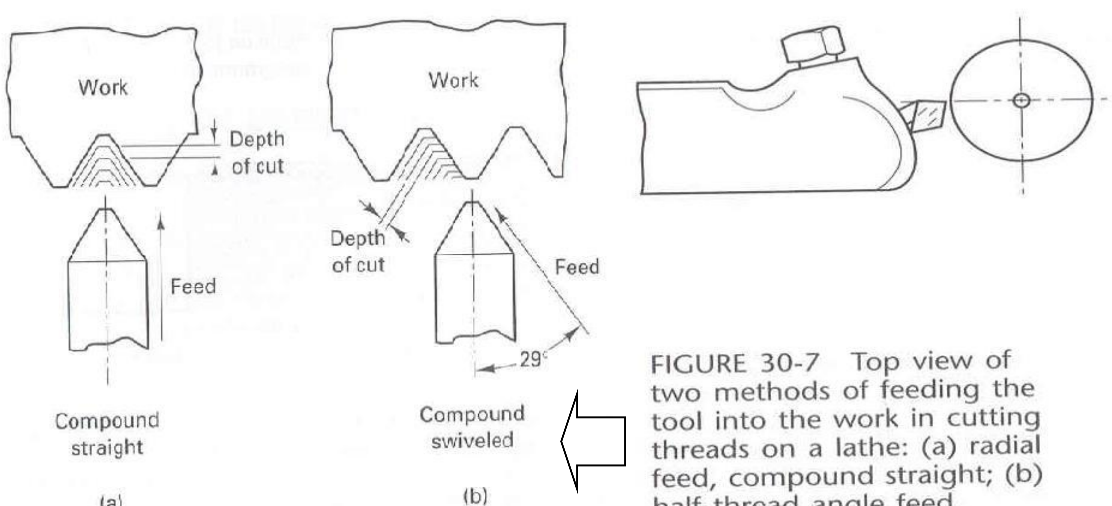
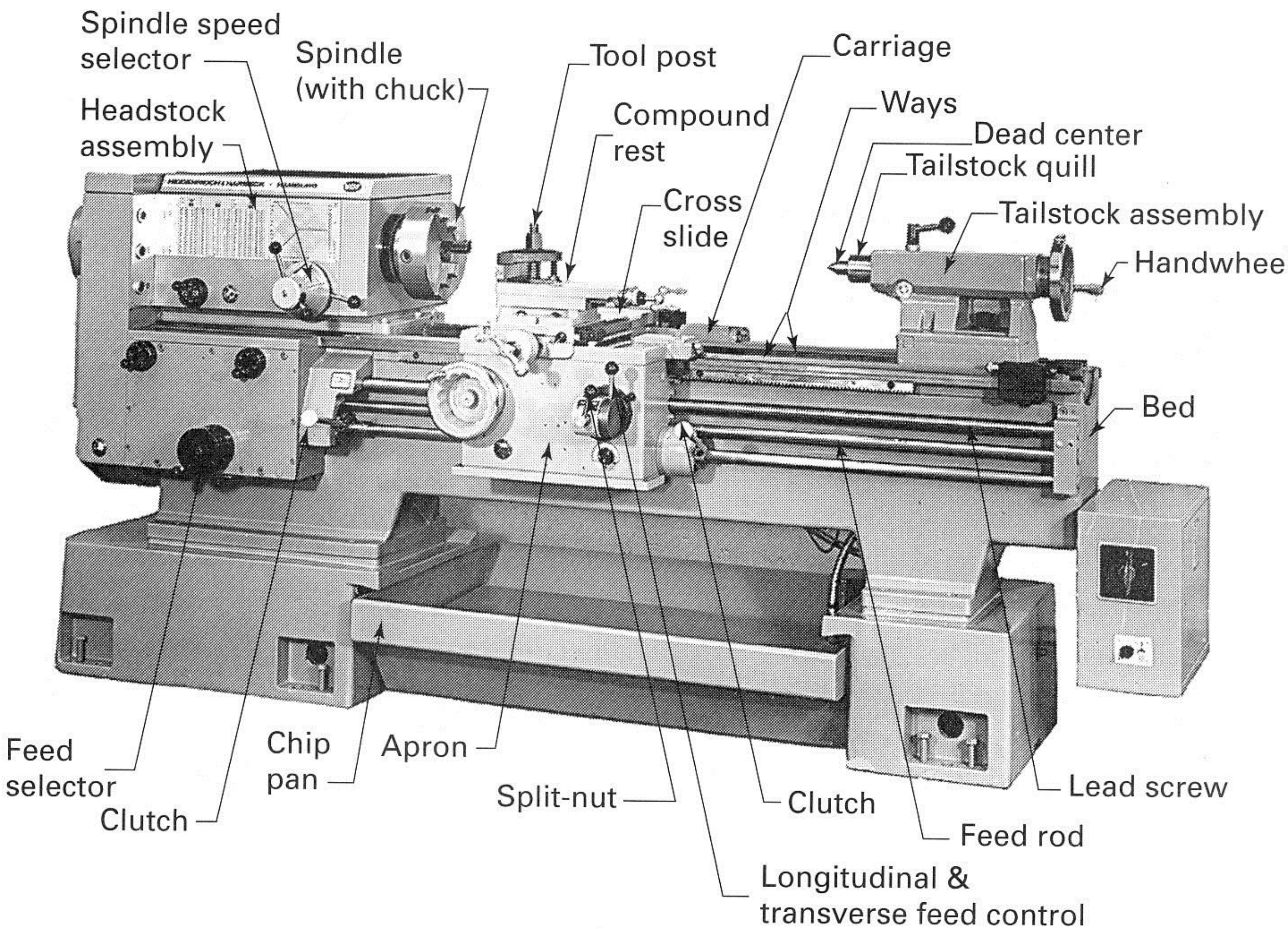


FIGURE 30-7 Top view of two methods of feeding the tool into the work in cutting threads on a lathe: (a) radial feed, compound straight; (b) half thread angle feed, compound swiveled.



engine
parts
enreich

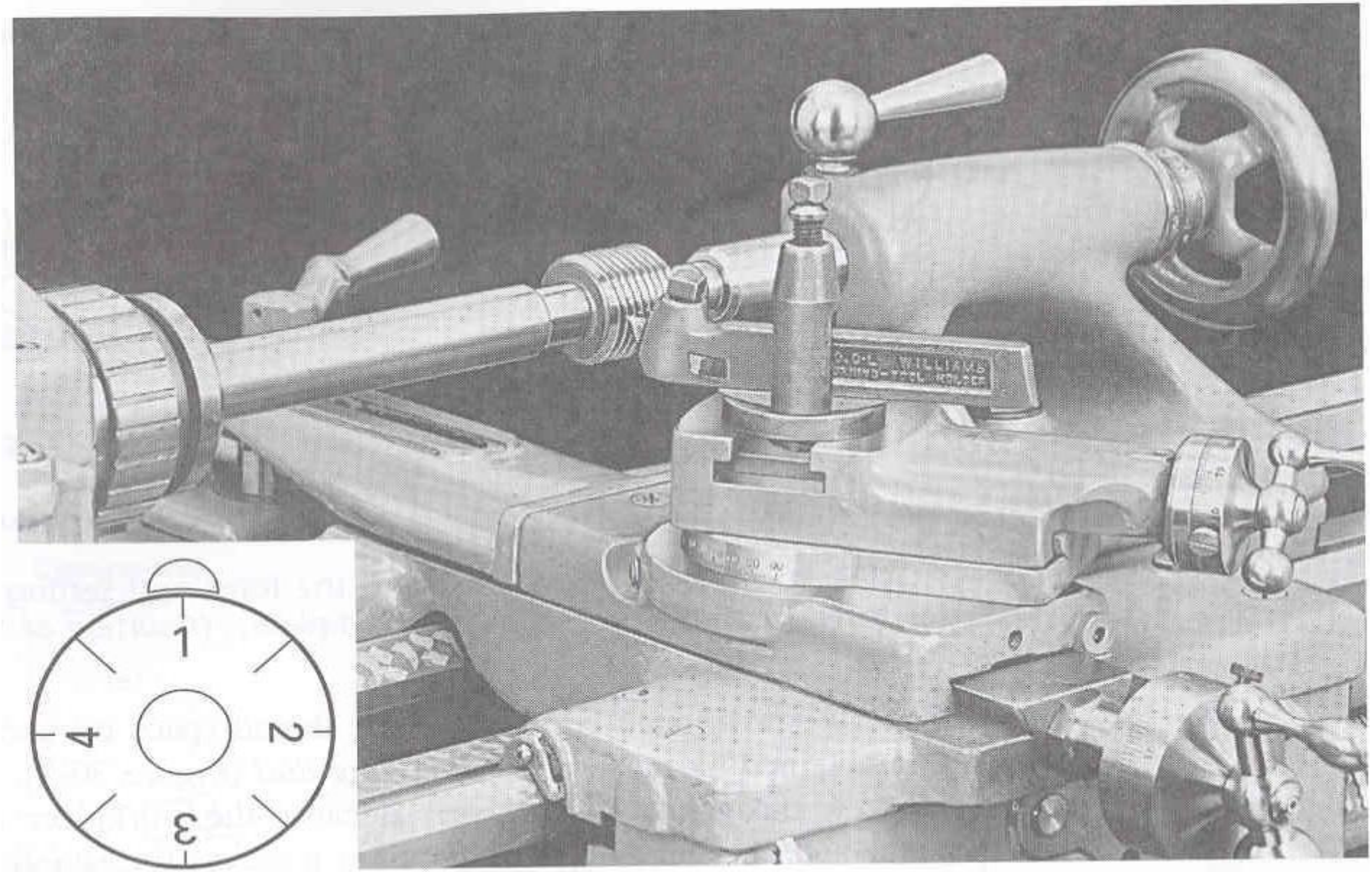


FIGURE 30-5 Cutting a screw thread on a lathe, showing the method of supporting the work and the relationship of the tool to the work. Inset shows face of threading dial. *(Courtesy of South Bend Lathe.)*

- 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.

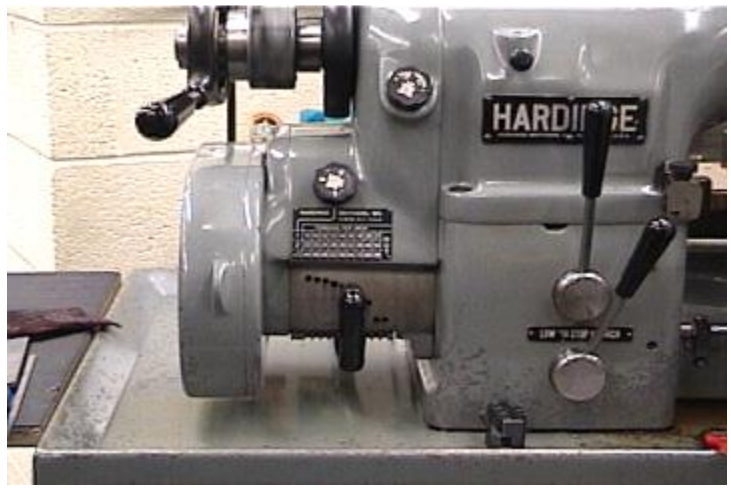
THE SPLIT NUT – in the apron → has to be engaged according the following rules regarding pitch of the thread

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.



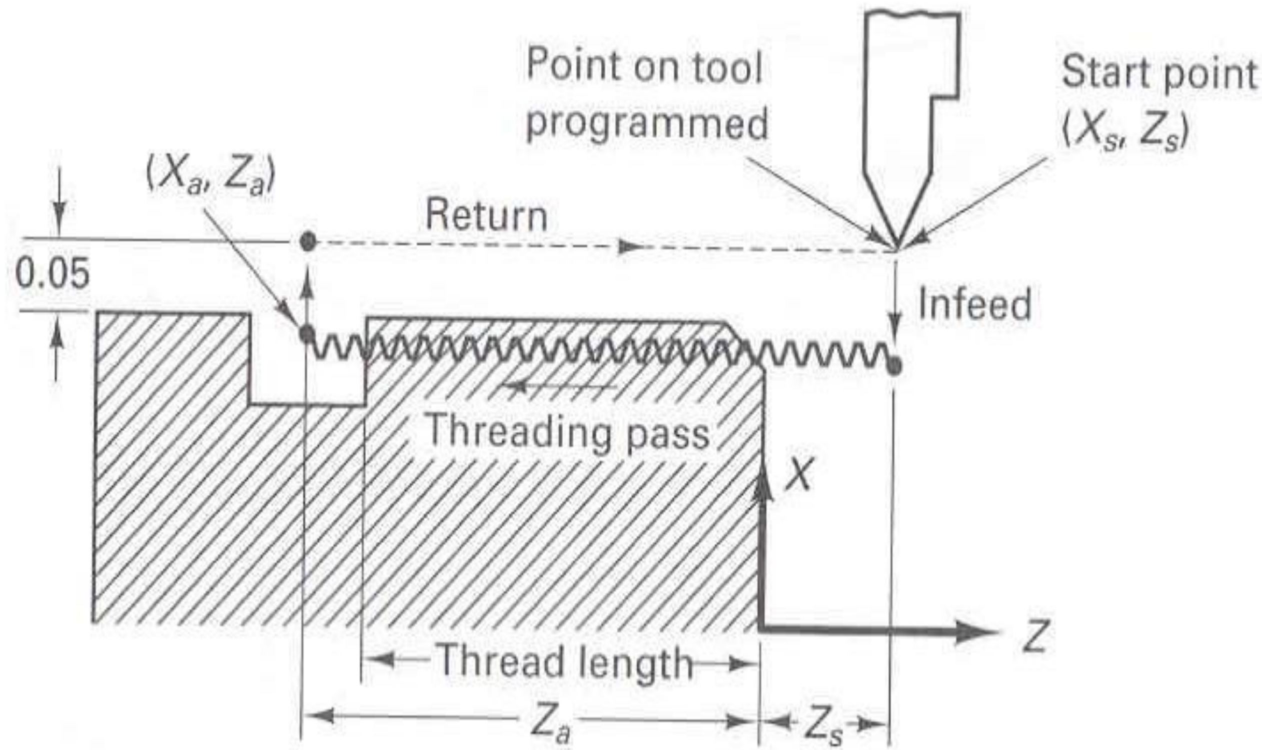
The thread – cutting procedure

- **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.
Fn	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

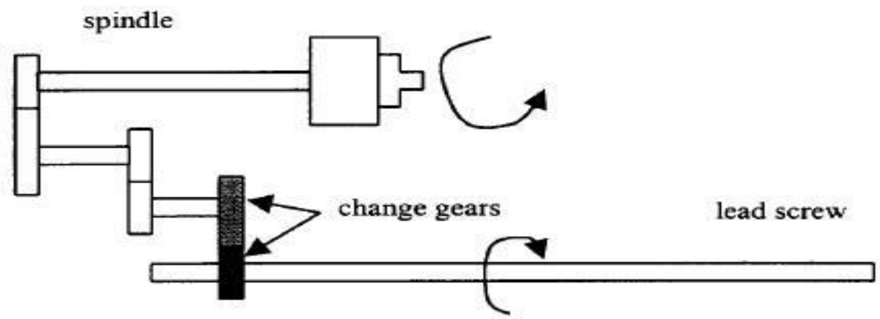
-The contemporary lathes – equipped with a gear box (NORTON) to be able to cut all screw pitches required → old lathes exchange gears installed between the lead screw and the spindle.

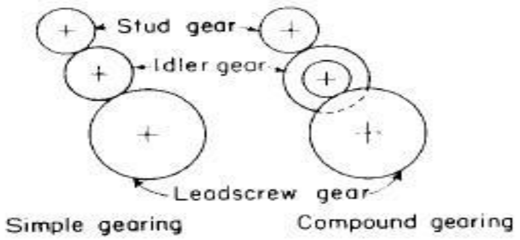
Ex: Lead screw = 5 rev/in → 5.08 mm lead

thread to be cut = 2 mm

the ratio required: 5.08 /2 = 2.54

$$\frac{b}{a} \times \frac{d}{c} = 2.54 \qquad \text{or: } \frac{127}{100} \times \frac{80}{40} = 2.54$$





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.

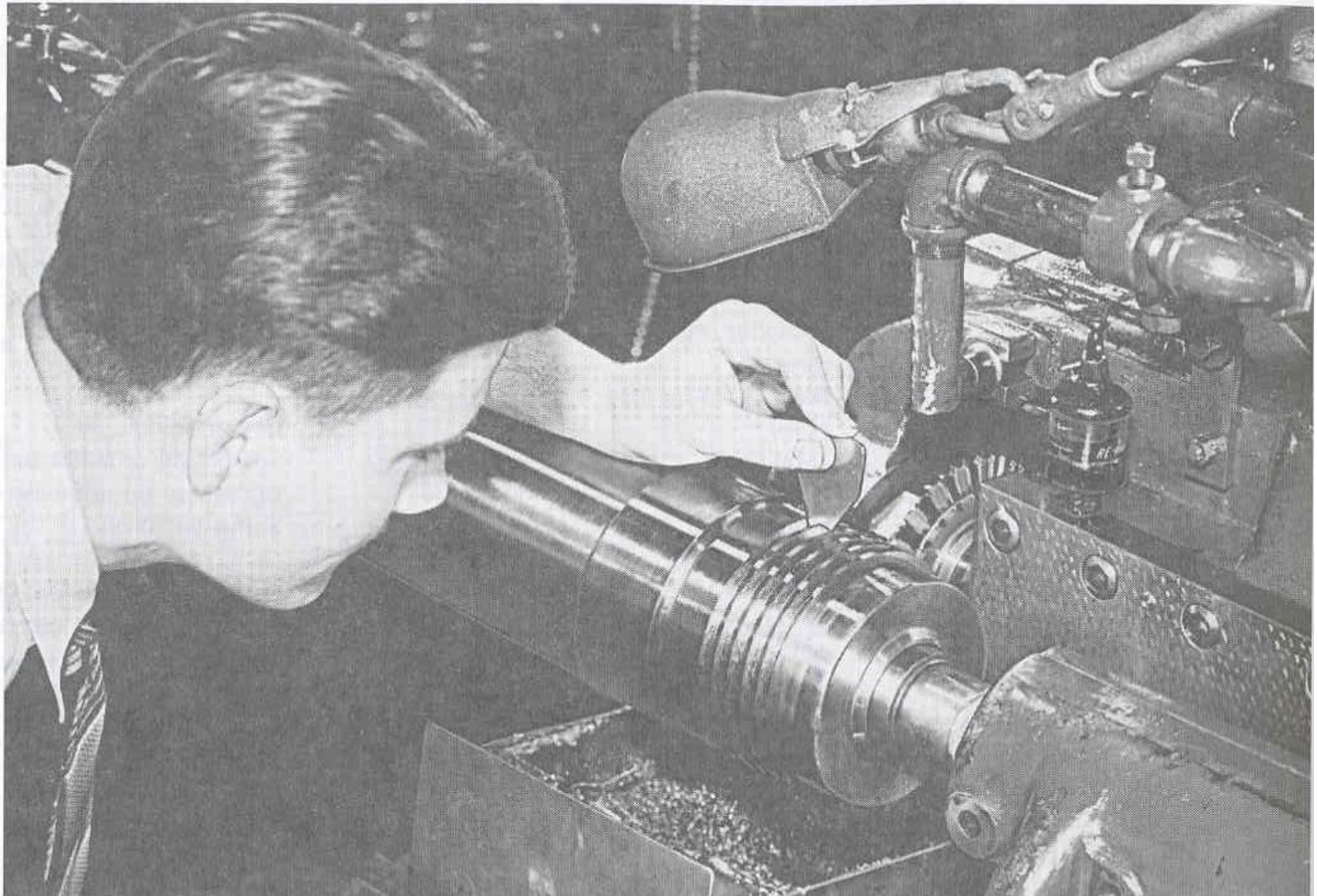


FIGURE 30-16 Checking a large thread that was milled with a single-form cutter. The cutter can be seen behind the thread. *(Courtesy of Lees-Bradner Company.)*

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.

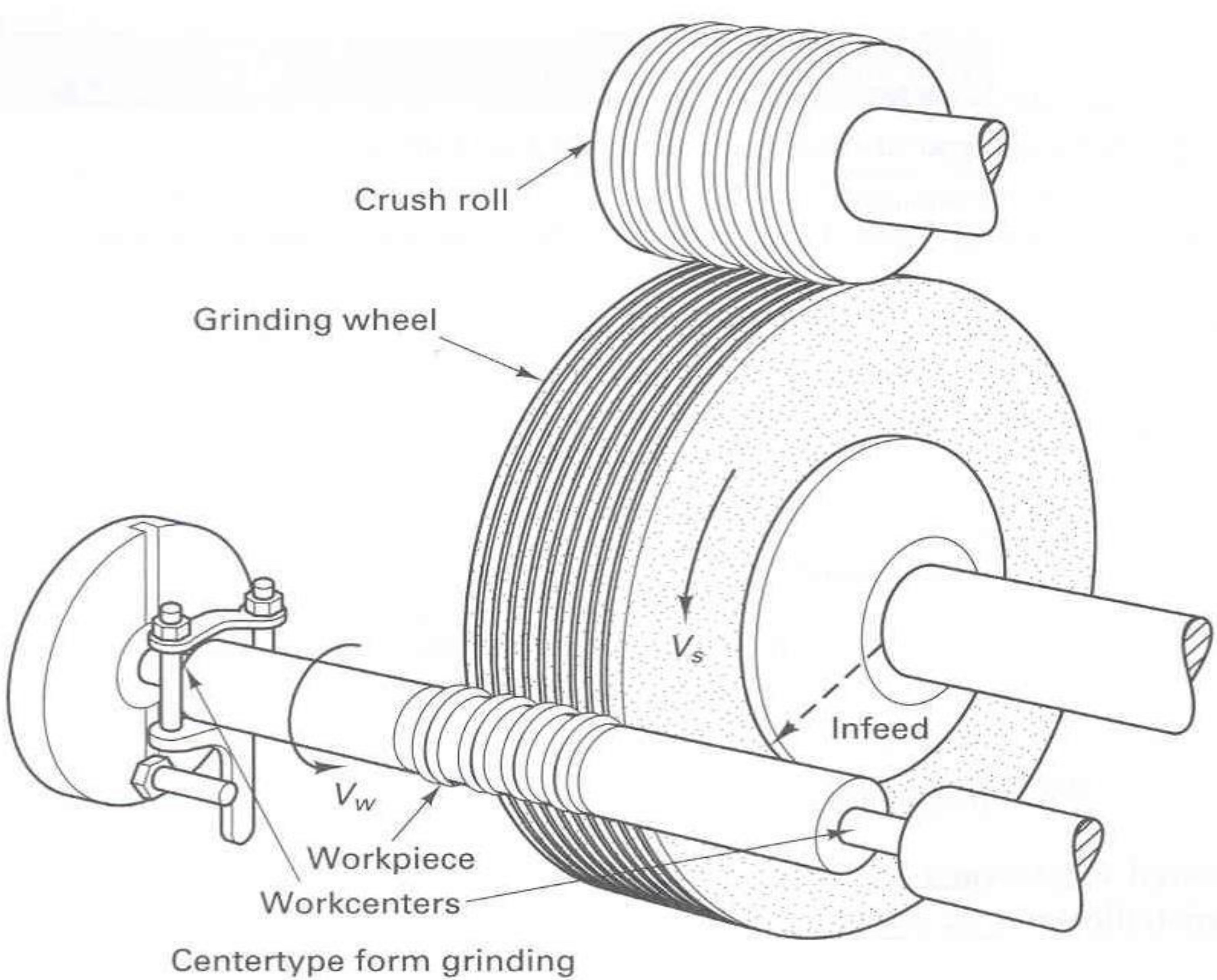


FIGURE 27-16 Plunge cut grinding of cylinder held between centers. Note that crush roll dressing is shown.

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 ½” length, 60-70/min is possible

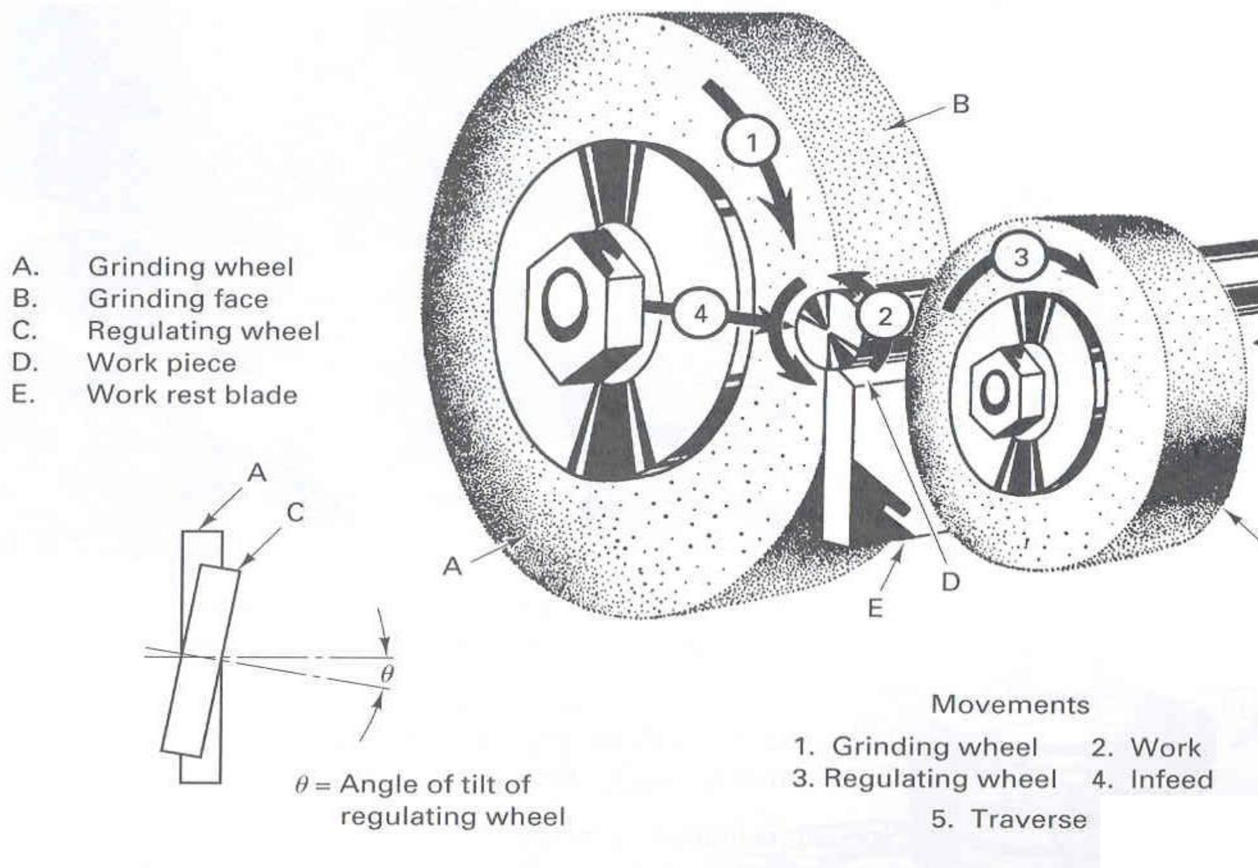


FIGURE 27-19 Centerless grinding showing the relationship between the grinding wheel, the regulating wheel, and the workpiece in centerless method. *(Courtesy of Carborundum Company.)*

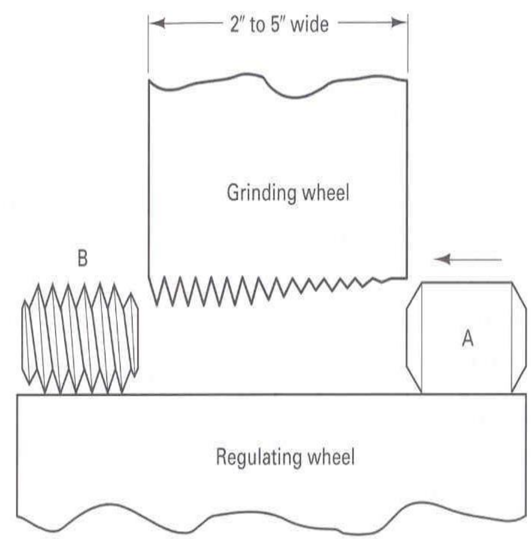


FIGURE 30-17 Principle of centerless thread grinding.

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

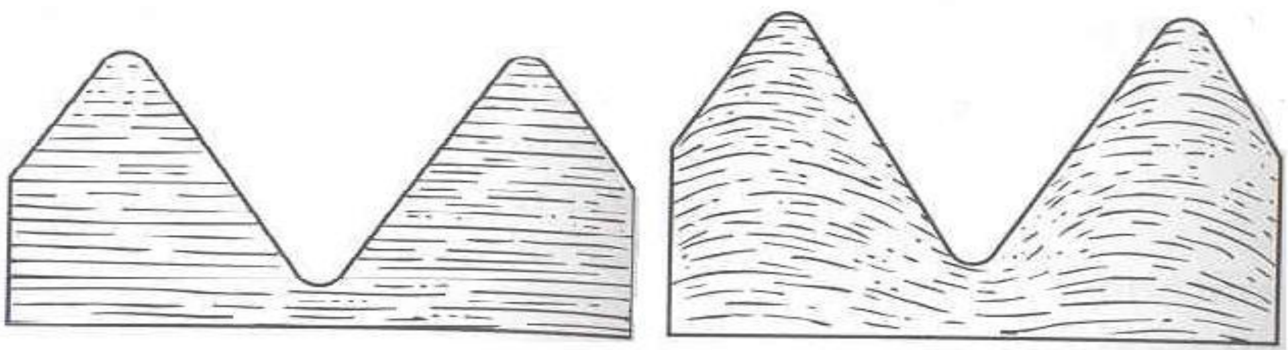
- **The surface of the dies has the reverse profile form of the thread**

- **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.)*



(a)

(b)

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.

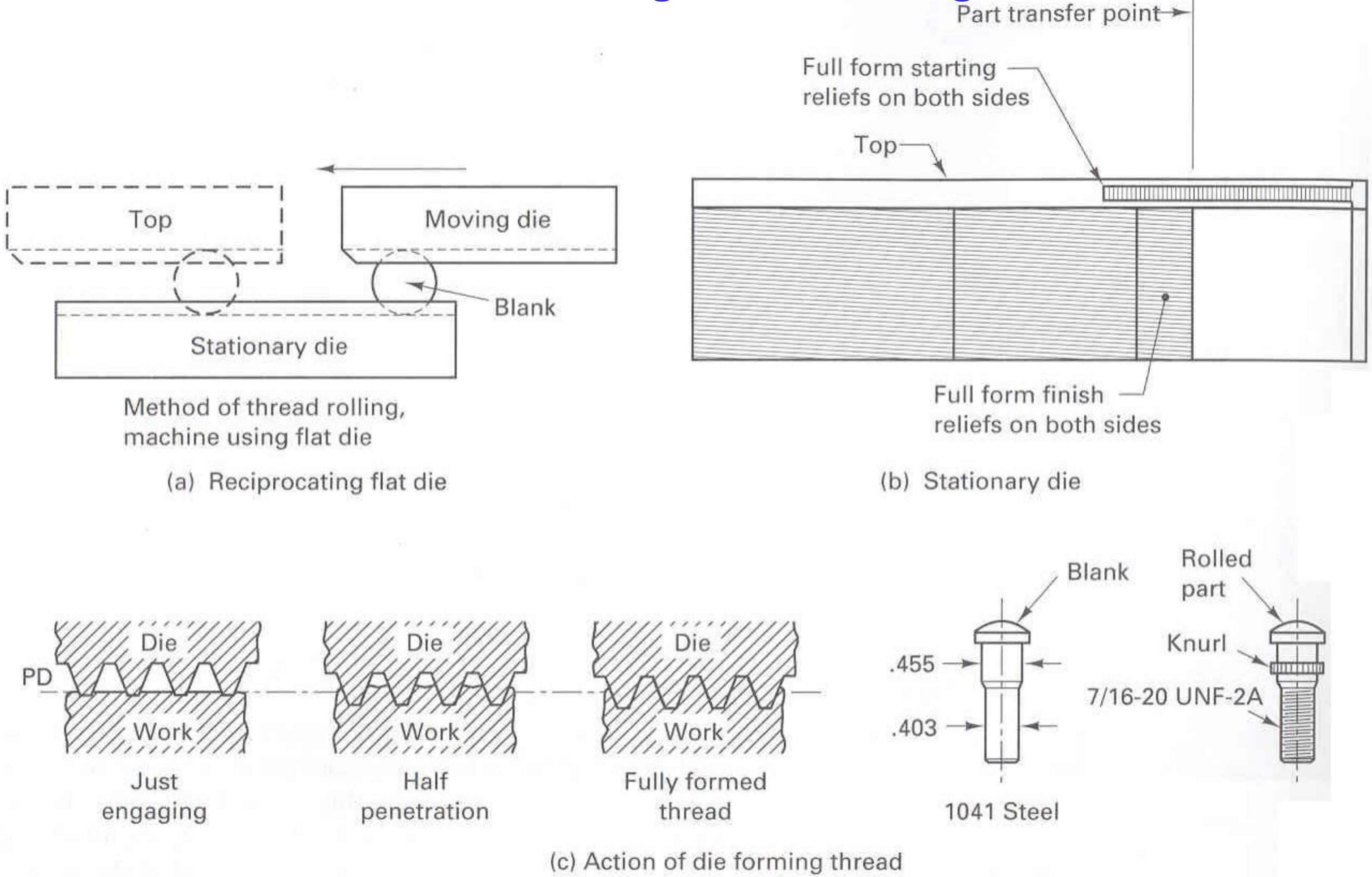


FIGURE 30-18 Combination thread rolling and knurling of wheel bolt at 70 per minute by flat die roll threading.

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.

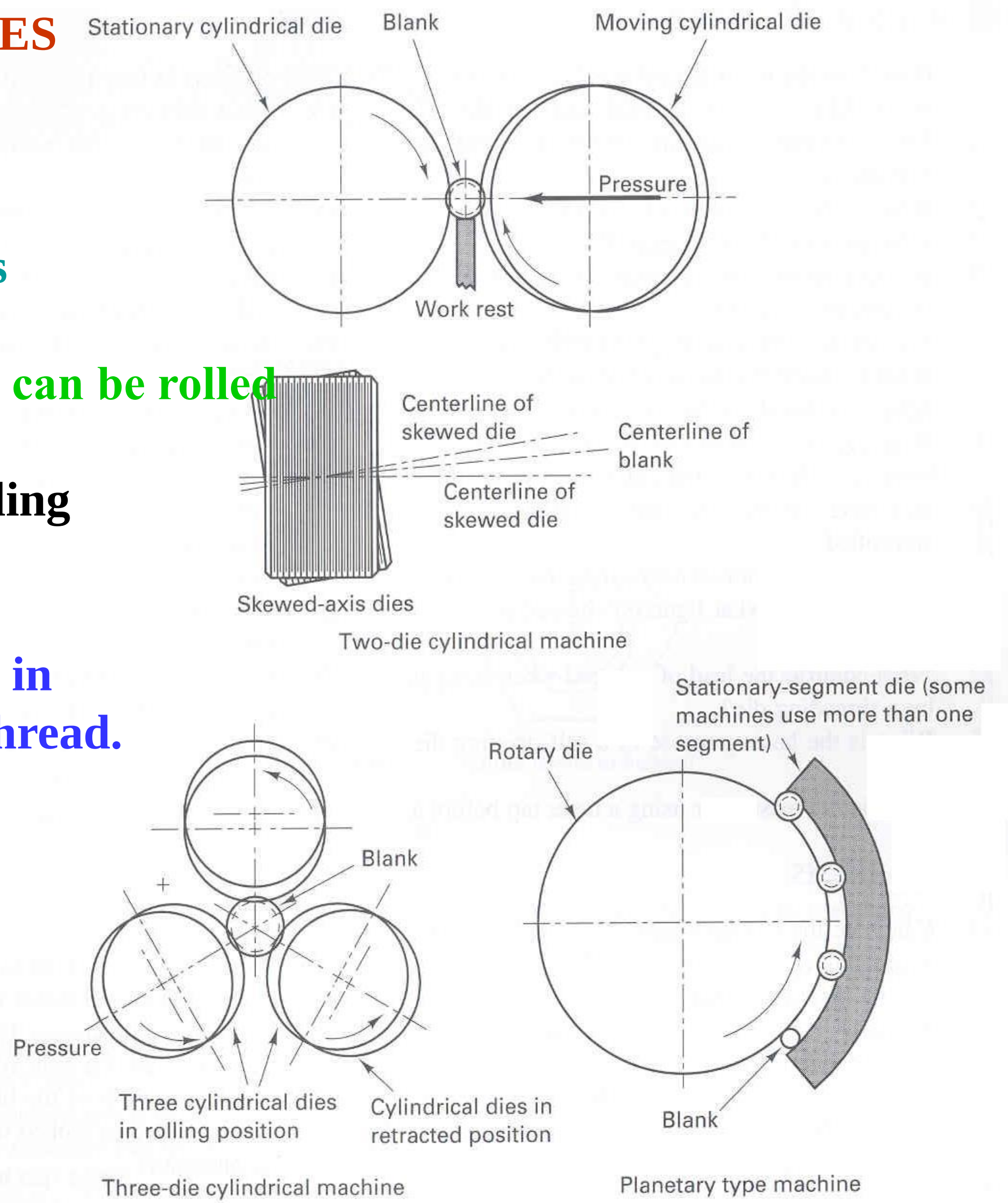


FIGURE 30-19 Methods for roll forming threads using cylindrical dies.

ADVANTAGES OF ROLLING

-Improved strength,

-smooth surface,

-close accuracy,

-less material used,

-suitable for mass production.

DISADVATAGES 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

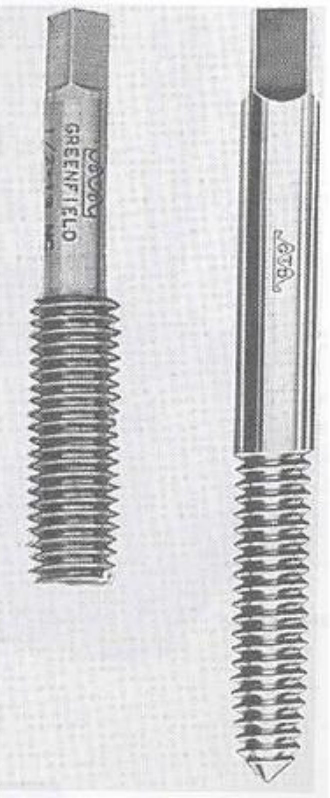
- The required forming torque is twice the cutting torque that is necessary to cut the section.

- 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

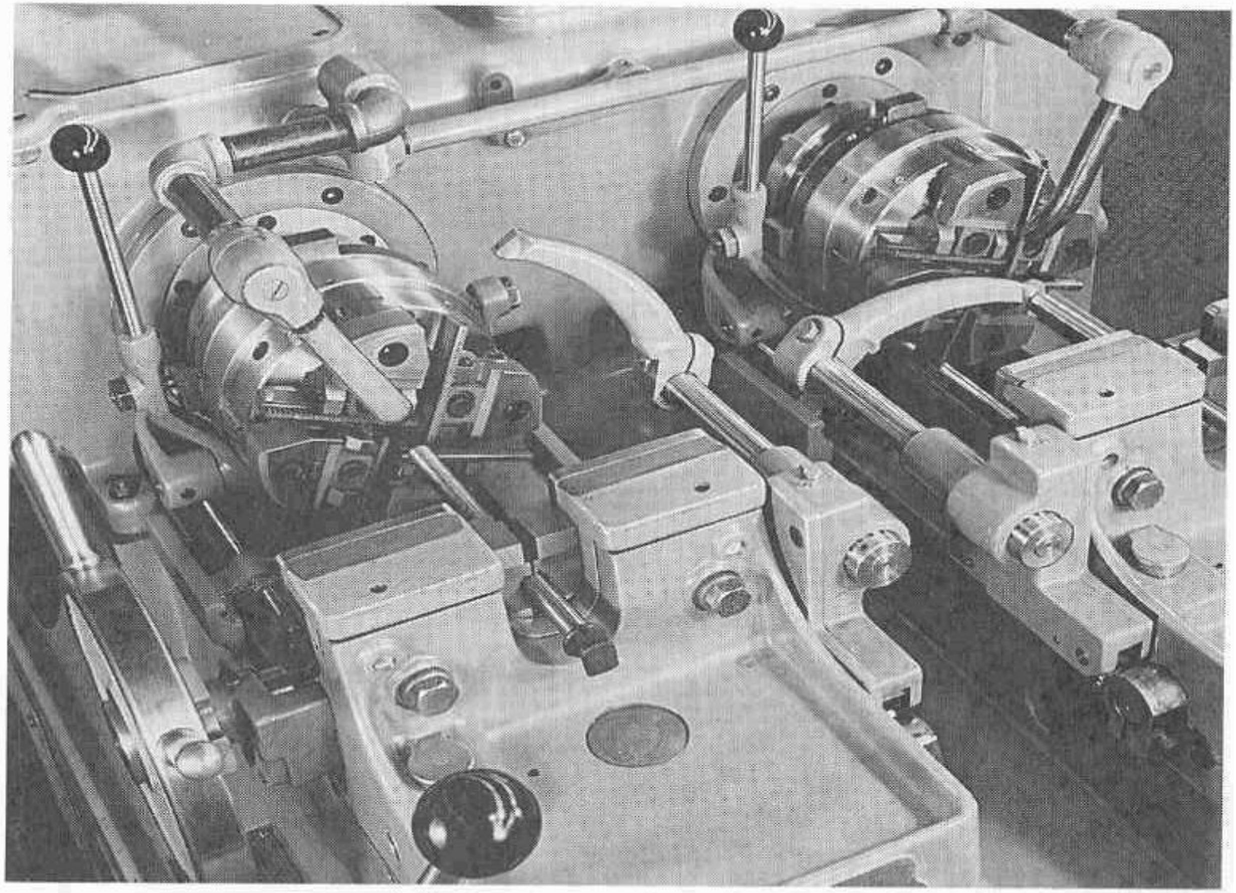


FIGURE 30-15 Two-spindle automatic threading machine. *(Courtesy of Landis Machine Company.)*

Threading machines for nuts (nut tapping machine)

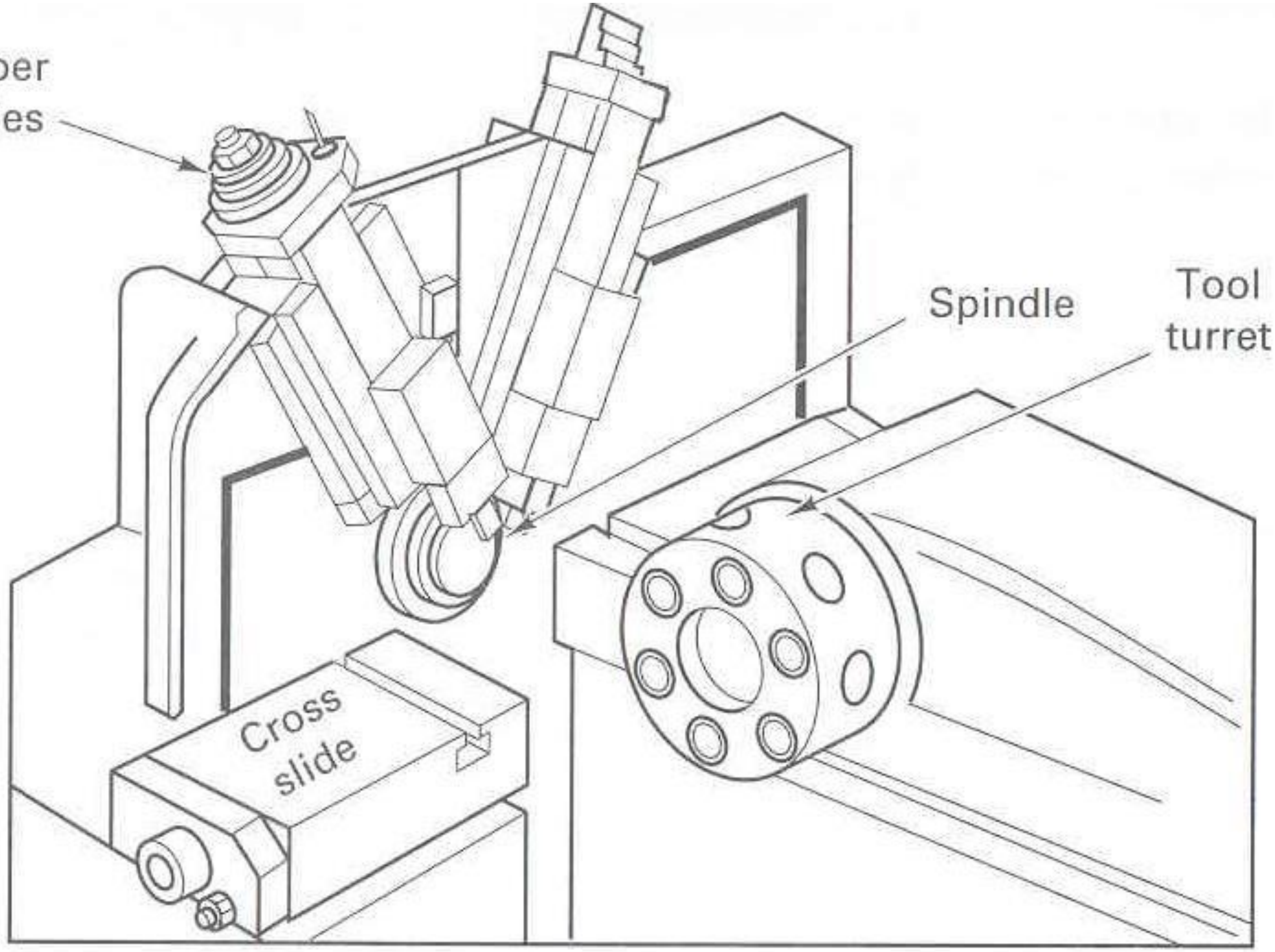


FIGURE 23-16 On the turret-type single-spindle automatic, the tools must take turns to make cuts.

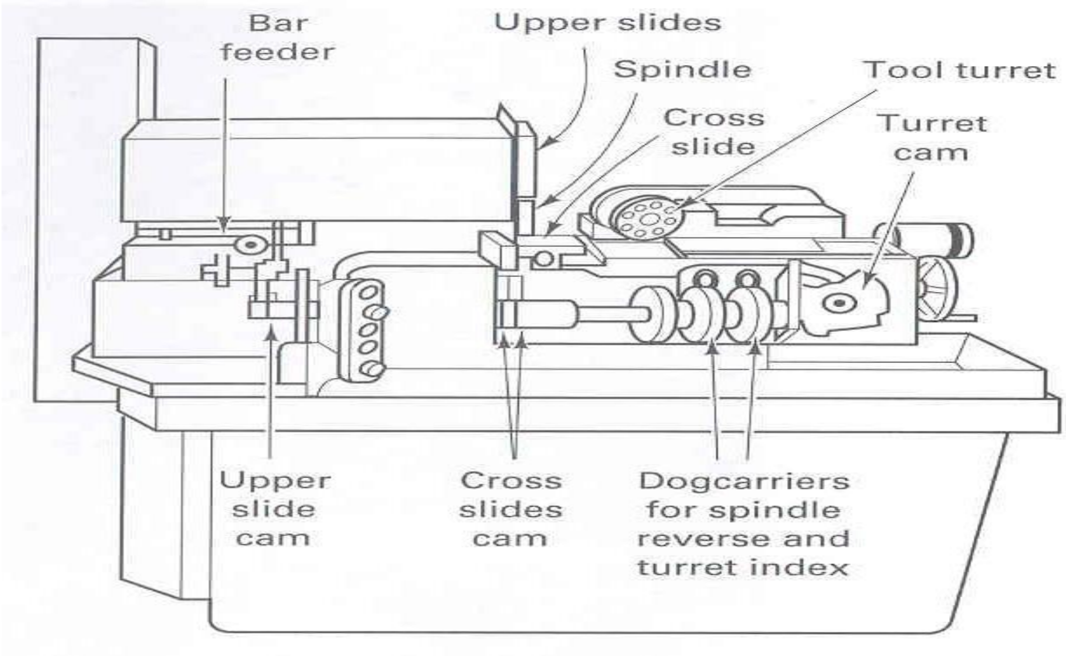
SCREW MACHINES –used not only for threads

- 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 **automatic**ally 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 → very less distortion of the workpiece

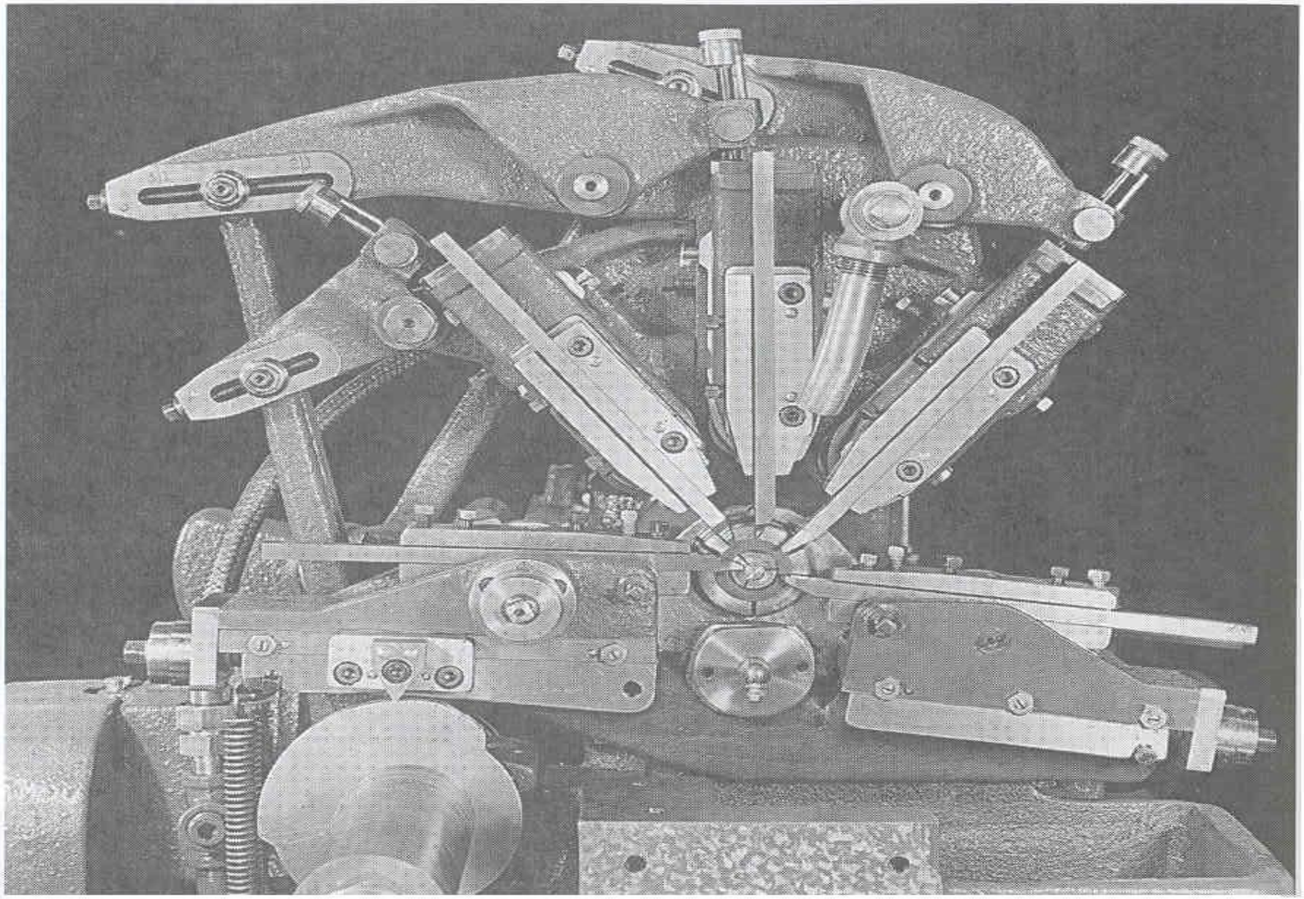
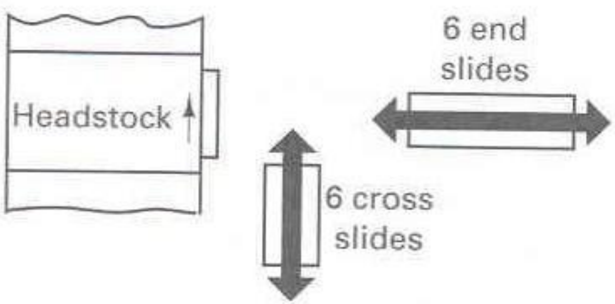


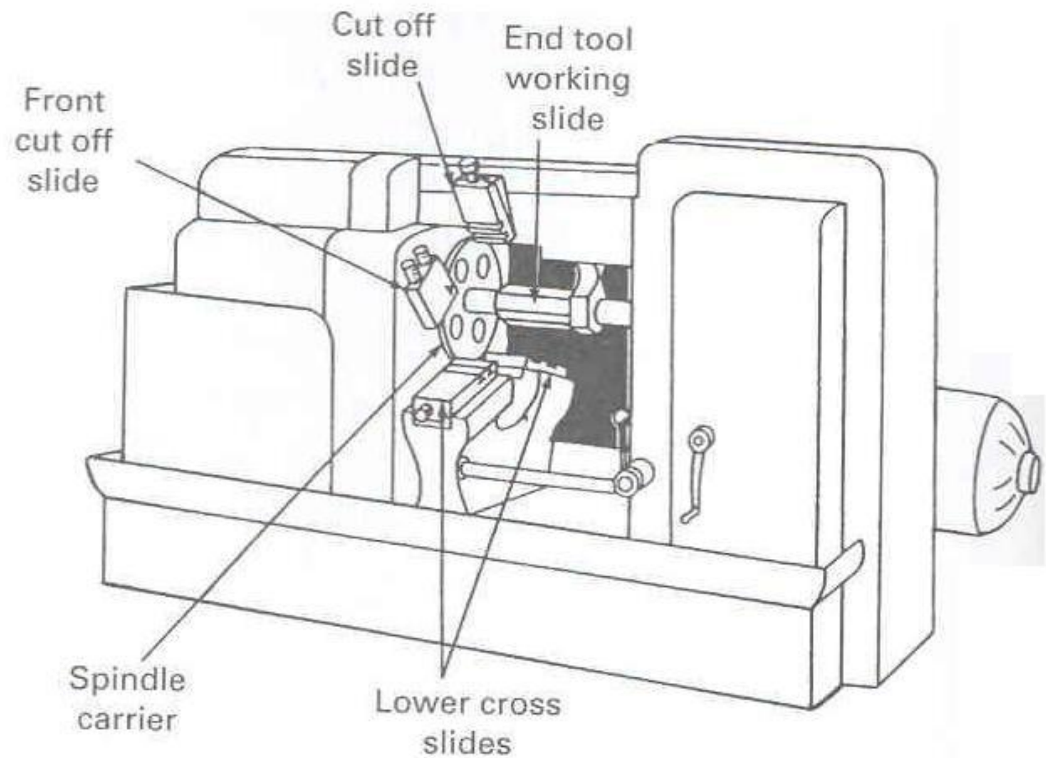
FIGURE 23-17 Close-up view of a Swiss-type screw machine, showing the tooling and radial tool sides, actuated by rocker arms. *(Courtesy of George Gorton Machine Corporation.)*

Multiple spindle automatic screw machines

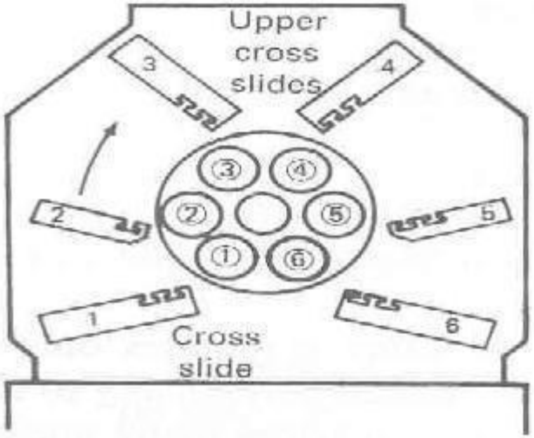
- Fully automatic – up to eight spindles
- Perform simultaneous cuts
- Perform non-cutting functions: tool withdrawal, index, blank bar feed at high speeds
- Very efficient production



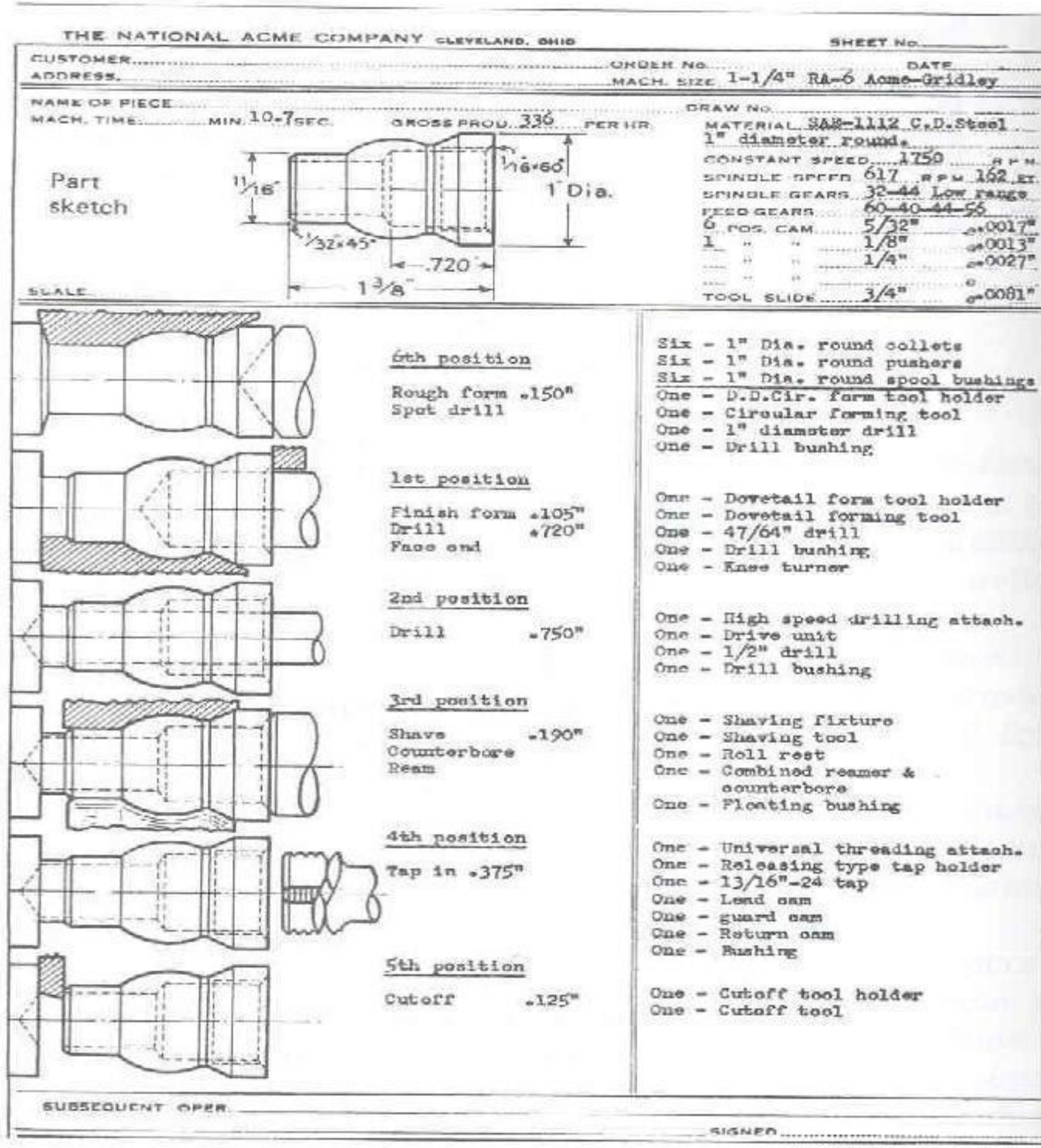
All spindles on multiple-spindle automatic have the same tool path



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.


THE NATIONAL ACME COMPANY CLEVELAND, OHIO SHEET No.

CUSTOMER ORDER No. DATE
ADDRESS MACH. SIZE 1-1/4" RA-6 Acme-Gridley

NAME OF PIECE DRAW No.
MACH. TIME MIN. 10.7 SEC. GROSS PROD. 336 PER HR.

Part sketch

MATERIAL SAE-1112 C.D. Steel 1" diameter round.
CONSTANT SPEED 1750 R.P.M.
SPINDLE SPEED 617 R.P.M. 162 SF.
SPINDLE GEARS 32-44 Low range
FEED GEARS 60-40-44-56
6 POS. CAM 5/32" .0017"
1 " " 1/8" .0013"
" " 1/4" .0027"
TOOL SLIDE 3/4" .0081"

SCALE

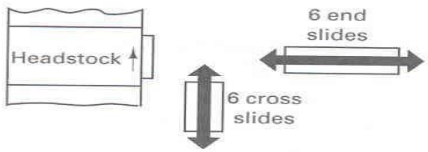
6th position	Rough form .150" Spot drill	Six - 1" Dia. round collets Six - 1" Dia. round pushers Six - 1" Dia. round spool bushings One - D.D.Cir. form tool holder One - Circular forming tool One - 1" diameter drill One - Drill bushing
1st position	Finish form .105" Drill .720" Face end	One - Dovetail form tool holder One - Dovetail forming tool One - 47/64" drill One - Drill bushing One - Knee turner
2nd position	Drill .750"	One - High speed drilling attach. One - Drive unit One - 1/2" drill One - Drill bushing
3rd position	Shave .190" Counterbore Ream	One - Shaving fixture One - Shaving tool One - Roll rest One - Combined reamer & counterbore One - Floating bushing
4th position	Tap in .375"	One - Universal threading attach. One - Releasing type tap holder One - 13/16"-24 tap One - Lead cam One - guard cam One - Return cam One - Bushing
5th position	Cutoff .125"	One - Cutoff tool holder One - Cutoff tool

SUBSEQUENT OPER.

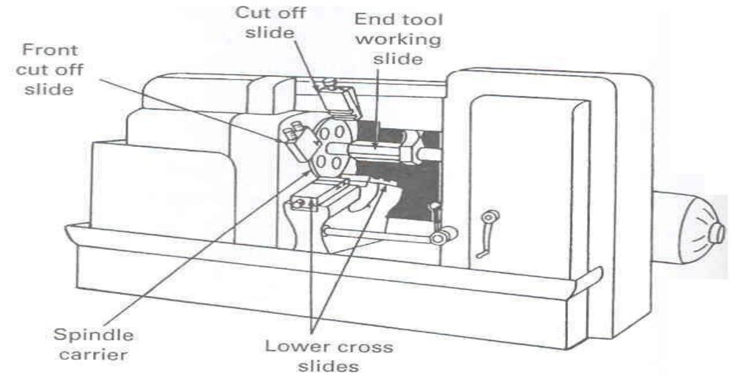
SIGNED

Tooling sheet for making a part on a six spindle.

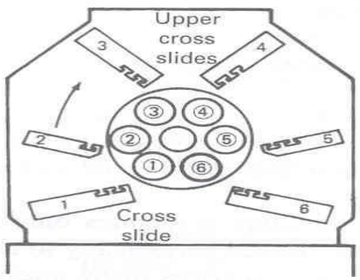
FIGURE 23-18 The multiple spindle automatic makes all cuts simultaneously and then performs the noncutting functions (tool withdrawal, index, bar feed) at high speed.



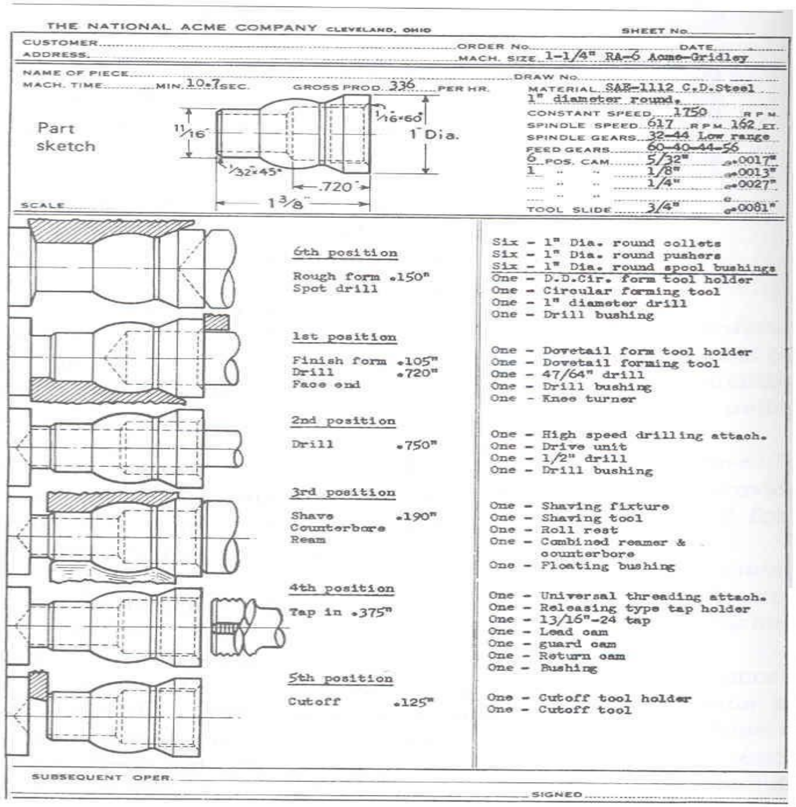
All spindles on multiple-spindle automatic have the same tool path



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.



Tooling sheet for making a part on a six-spindle.

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.