

Module

7

Screw threads and Gear Manufacturing Methods

Lesson

31

Production of screw threads by Machining, Rolling and Grinding

Instructional objectives

At the end of this lesson, the students will be able to;

- (i) Identify the general applications of various objects having screw threads
- (ii) Classify the different types of screw threads
- (iii) State the possible methods of producing screw threads and their characteristics.
- (iv) Visualise and describe various methods of producing screw threads by;
 - (a) Machining
 - (b) Rolling
 - (c) Grinding

(i) General Applications Of Screw Threads

The general applications of various objects having screw threads are :

- **fastening** : screws, nut-bolts and studs having screw threads are used for temporarily fixing one part on to another part
- **joining** : e.g., co-axial joining of rods, tubes etc. by external and internal screw threads at their ends or separate adapters
- **clamping** : strongly holding an object by a threaded rod, e.g., in c-clamps, vices, tailstock on lathe bed etc.
- **controlled linear movement** : e.g., travel of slides (tailstock barrel, compound slide, cross slide etc.) and work tables in milling machine, shaping machine, cnc machine tools and so on.
- **transmission of motion and power** : e.g., lead screws of machine tools
- **converting rotary motion to translation** : rotation of the screw causing linear travel of the nut, which have wide use in machine tool kinematic systems
- **position control in instruments** : e.g., screws enabling precision movement of the work table in microscopes etc.
- **precision measurement of length** : e.g., the threaded spindle of micrometers and so on.
- **acting as worm** for obtaining slow rotation of gear or worm wheel
- **exerting heavy force** : e.g., mechanical presses
- **conveying and squeezing materials** : e.g., in screw conveyor, injection moulding machine, screw pump etc.
- **controlled automatic feeding** in mass production assembly etc.

(ii) Classification Of Screw Threads

Screw threads having various applications can be classified as follows

:

- **According to location**
 - external screw thread (on bolts etc.)

- internal screw thread (in nuts etc.)
- **According to configuration**
 - straight (helical) – most common, e.g., bolts, studs etc.
 - taper (helical), e.g., in drill chuck
 - radial (scroll) as in self centering chuck
- **According to the direction of the helix**
 - right hand (common)
 - left hand (occasionally)
- **According to form**
 - vee thread (60° or 55° angle) – most common
 - acme thread (29°)
 - square thread (generally in power screws)
 - buttress thread (45°)
 - worm thread ($29^\circ \sim 40^\circ$)
 - semicircular (groove section) thread being used in recirculating type bolts, screws.
- **According to standard**
 - BSW (British Standard Whitworth); thread – size is designated by TPI (threads per inch)
 - metric thread; thread size is specified by pitch or lead (in mm)
- **According to number of start**
 - single start – most common
 - multi-start (2 to 4)
- **According to spacing of threads**
 - TPI (no. of threads per inch), e.g. 12 TPI
 - pitch (or lead) – distance between two successive threads (or length of travel of the nut for one rotation of the screw), in mm
- **According to compactness or fineness of threads**
 - general threads (with usually wide thread spacing), pipe threads (more denser desired)
 - fine threads (generally for leak proof)
- **According to segmentation**
 - full threads (common)
 - half turns as in half nuts
 - sector thread – e.g., in the jaws of lathe chucks.

(iii) Production Of Screw Threads – Possible Methods And Their Characteristics.

The various methods, which are more or less widely employed for producing screw threads are :

- **Casting**
characteristics;
 - only a few threads over short length
 - less accuracy and poor finish
 - example – threads at the mouth of glass bottles, spun cast iron pipes etc.

- **Forming (Rolling)**
characteristics;
 - blanks of strong ductile metals like steels are rolled between threaded dies
 - large threads are hot rolled followed by finishing and smaller threads are straight cold rolled to desired finish
 - cold rolling attributes more strength and toughness to the threaded parts
 - widely used for mass production of fasteners like bolts, screws etc.
- **Removal process (Machining)**
 - accomplished by various cutting tools in different machine tools like lathes, milling machines, drilling machines (with tapping attachment) etc.
 - widely used for high accuracy and finish
 - employed for wide ranges of threads and volume of production; from piece to mass production.
- **Semifinishing and finishing (Grinding)**
characteristics :
 - usually done for finishing (accuracy and surface) after performing by machining or hot rolling but are often employed for direct threading on rods
 - precision threads on hard or surface hardened components are finished or directly produced by grinding only
 - employed for wide ranges of type and size of threads and volume of production
- **Precision forming to near – net – shape**
characteristics :
 - no machining is required, slight grinding is often done, if needed for high accuracy and finish
 - application – investment casting for job order or batch production
– injection moulding (polymer) for batch or mass production
- **Non conventional process (EDM, ECM etc)**
characteristics :
 - when conventional methods are not feasible
 - high precision and micro threads are needed
 - material is as such difficult – to – process

(iv) Processes, Machines And Tools Used For Producing Screw Threads By;

- (a) Machining
- (b) Rolling
- (c) Grinding

(a) Production of screw threads by machining

Machining is basically a removal process where jobs of desired size and shape are produced by gradually removing the excess material in the form of chips with the help of sharp cutting edges or tools. Screw threads can be produced by such removal process both manually using taps and dies as well as in machine tools of different types and degree of automation. In respect of process, machine and tool, machining of screw threads are done by several ways :

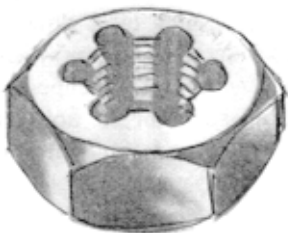
□ Thread cutting by hand operated tools

Usually small threads in few pieces of relatively soft ductile materials, if required, are made manually in fitting, repair or maintenance shops.

• External screw threads

Machine screws, bolts or studs are made by different types of dies which look and apparently behave like nuts but made of hardened tool steel and having sharp internal cutting edges. Fig. 7.1.1 shows the hand operated dies of common use, which are coaxially rotated around the premachined rod like blank with the help of handle or die stock.

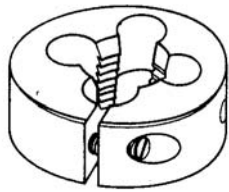
- △ **Solid or button die** : used for making threads of usually small pitch and diameter in one pass.
- △ **Spring die** : the die ring is provided with a slit, the width of which is adjustable by a screw to enable elastically slight reduction in the bore and thus cut the thread in number of passes with lesser force on hands.
- △ **Split die** : the die is made in two pieces, one fixed and one movable (adjustable) within the cavity of the handle or wrench to enable cut relatively larger threads or fine threads on harder blanks easily in number of passes, the die pieces can be replaced by another pair for cutting different threads within small range of variation in size and pitch.
- △ **Pipe die** : pipe threads of large diameter but smaller pitch are cut by manually rotating the large wrench (stock) in which the die is fitted through a guide bush as shown in Fig. 7.1.1.



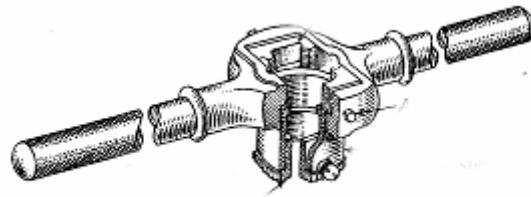
(a) solid die



(c) split die



(b) spring die



(d) pipe die

Fig. 7.1.1 Different types of thread cutting dies.

- **Internal screw threads :**

Internal screw threads of usually small size are cut manually, if needed, in plates, blocks, machine parts etc. by using taps which look and behave like a screw but made of tool steel or HSS and have sharp cutting edges produced by axial grooving over the threads as shown in **Fig. 7.1.2**. Three taps namely, taper tap, plug tap and bottoming tap are used consecutively after drilling a tap size hole through which the taps are axially pushed helically with the help of a handle or wrench.



(a) Taper tap



(b) Second tap



(c) Plug tap

Fig. 7.1.2 Hand operated taps for cutting internal threads.

Threads are often tapped by manually rotating and feeding the taps through the drilled hole in the blank held in lathe spindle as shown in **Fig. 7.1.3**.

The quality of such external and internal threads will depend upon the perfection of the taps or dies and skill of the operator.

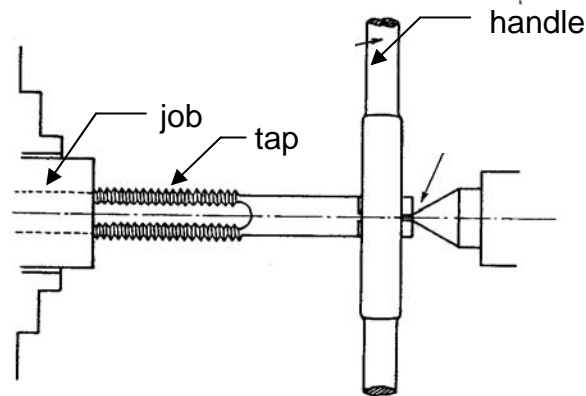


Fig. 7.1.3 Hand operated tapping in centre lathe.

□ **Machining screw threads in machine tools**

Threads of fasteners in large quantity and precision threads in batches or lots are produced in different machine tools mainly lathes, by various cutting tools made of HSS or often cemented carbide tools.

* **Machining screw threads in lathes**

Screw threads in wide ranges of size, form, precision and volume are produced in lathes ranging from centre lathes to single spindle automats. Threads are also produced in special purpose lathes and CNC lathes including turning centres.

• **In centre lathes**

○ **External threads :**

External threads are produced in centre lathes by various methods :

△ **Single point and multipoint chasing**, as schematically shown in **Fig. 7.1.4** This process is slow but can provide high quality. Multipoint chasing gives more productivity but at the cost of quality to some extent

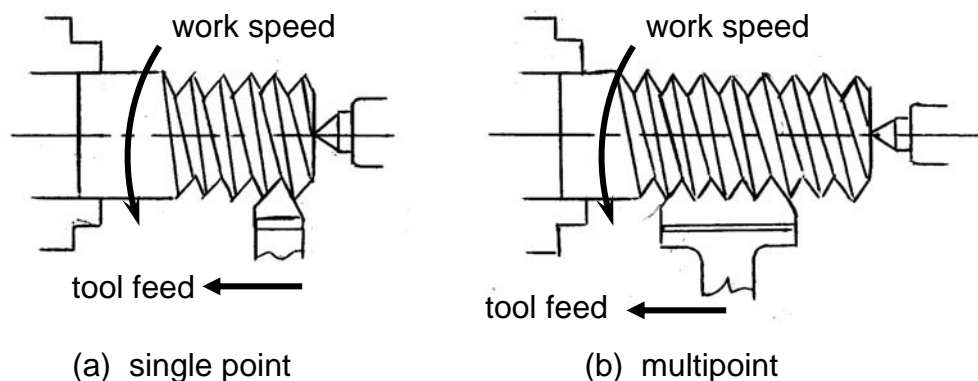


Fig. 7.1.4 External threading in lathe by chasing.

△ **Thread milling:**

This process gives quite fast production by using suitable thread milling cutters in centre lathes as indicated in **Fig. 7.1.5**. The milling attachment is mounted on the saddle of the lathe. Thread milling is of two types;

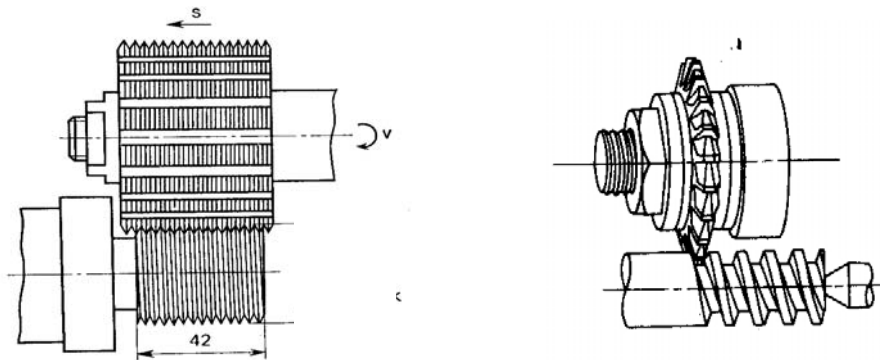


Fig. 7.1.5 Thread milling by attachment in centre lathes.

○ **Long thread milling**

Long and large diameter screws like machine lead screws are reasonably accurately made by using a large disc type form milling cutter as shown in **Fig. 7.1.5**.

○ **Short thread milling**

Threads of shorter length and fine pitch are machined at high production rate by using a HSS milling cutter having a number of annular threads with axial grooves cut on it for generating cutting edges. Each job requires only around 1.25 revolution of the blank and very short axial (1.25 pitch) and radial (1.5 pitch) travel of the rotating tool

△ **Rotating tool**

Often it becomes necessary to machine large threads on one or very few pieces of heavy blanks of irregular size and shape like heavy casting or forging of odd size and shape. In such cases, the blank is mounted on face plate in a centre lathe with proper alignment. The deep and wide threads are produced by intermittent cutting action by a rotating tool. A separate attachment carrying the rotating tool is mounted on the saddle and fed as usual by the leadscrew of the centre lathe. **Fig. 7.1.6** shows schematically the principles of threading by rotary tools. The tool is rotated fast but the blank much slowly. This intermittent cut enables more effective lubrication and cooling of the tool.

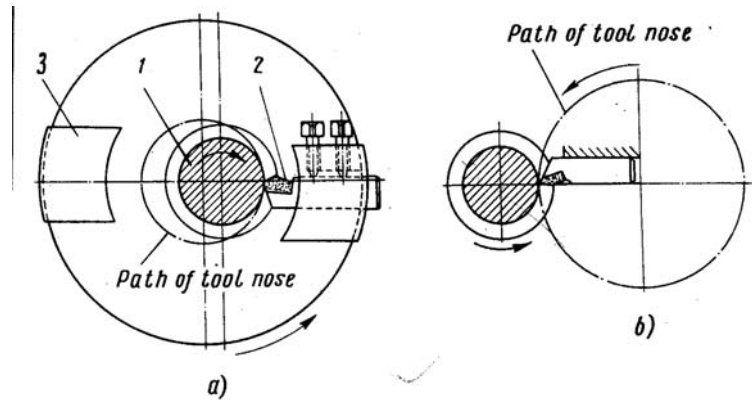


Fig. 7.1.6 Thread cutting in centre lathe by rotating tools.

Internal threads :

Internal threads are produced in centre lathes at slow rate by using;

- △ Single point tool
- △ Machine taps
- △ Internal thread milling

△ Internal threading by single point chasing

Internal threads in parts of wide ranges of diameter and pitch are accurately done in centre lathes by single point tool, as in boring, as shown in **Fig. 7.1.7 (a)**. Multipoint flat chaser is often used for faster production.

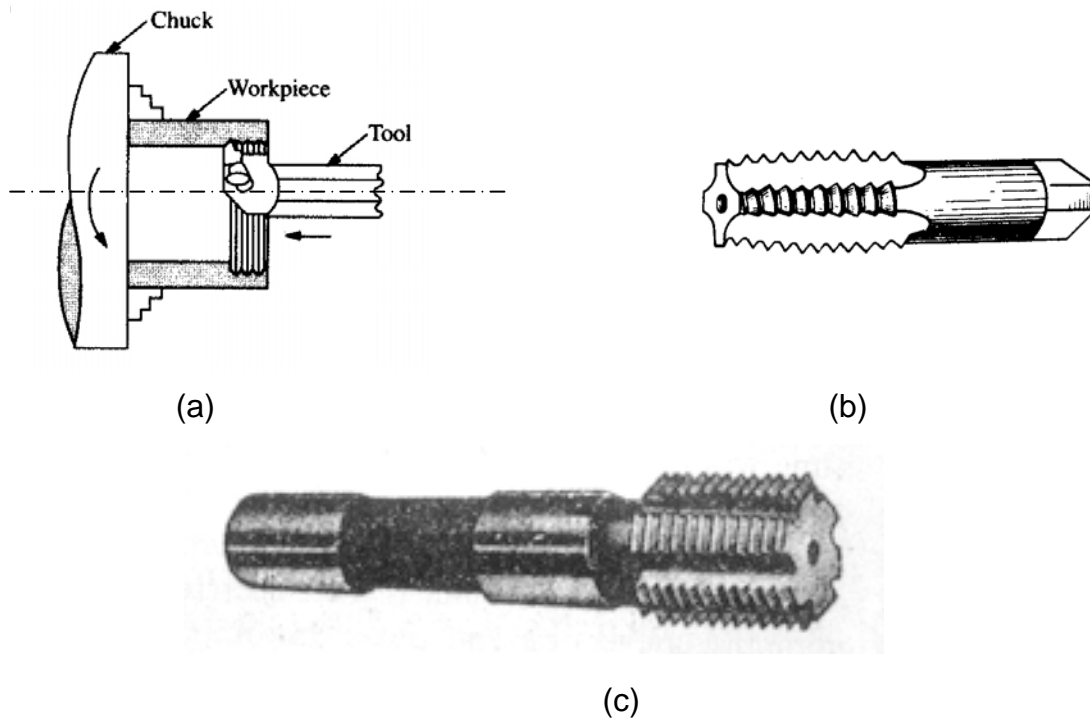


Fig. 7.1.7 (a) single point tool , (b) solid tap and (c) milling cutter for internal threading in centre lathe.

△ **Internal threading by taps**

Internal threads of small length and diameter are cut in drilled holes by different types of taps;

- △ Straight solid tap (**Fig. 7.1.7 (b)**) – used for small jobs
- △ Taps with adjustable blades – usually for large diameter jobs
- △ Taper or nut taps – used for cutting threads in nuts.

△ **Internal thread milling cutter**

Such solid cutter, shown in **Fig. 7.1.7 (c)** produces internal threads very rapidly, as in external short thread milling, in lathes or special purpose thread milling machine.

○ **Machining threads in semiautomatic lathes**

Both external and internal threads are cut, for batch or small lot production, in capstan and turret lathes using different types of thread cutting tools;

△ External threads in capstan lathe by self opening die and single or multipoint chaser in turret lathe

△ Internal threads of varying size by collapsible tap.

The self opening die, typically shown in **Fig. 7.1.8 (a)**, is mounted in the turret and moved forward towards the rotating blank. At the end point, when the turret slows down and is about to stop or reverse, the front position of the die gets pulled and open automatically to enable free return of the die without stopping the job – rotation. The thread chasers may be flat or circular type as shown.

In a collapsible tap, shown in **Fig. 7.1.8 (b)**, the radially raised blades collapse (move radially inward) and the tap returns (along with the turret or saddle) freely from the threaded hole after completing the internal thread in one stroke.

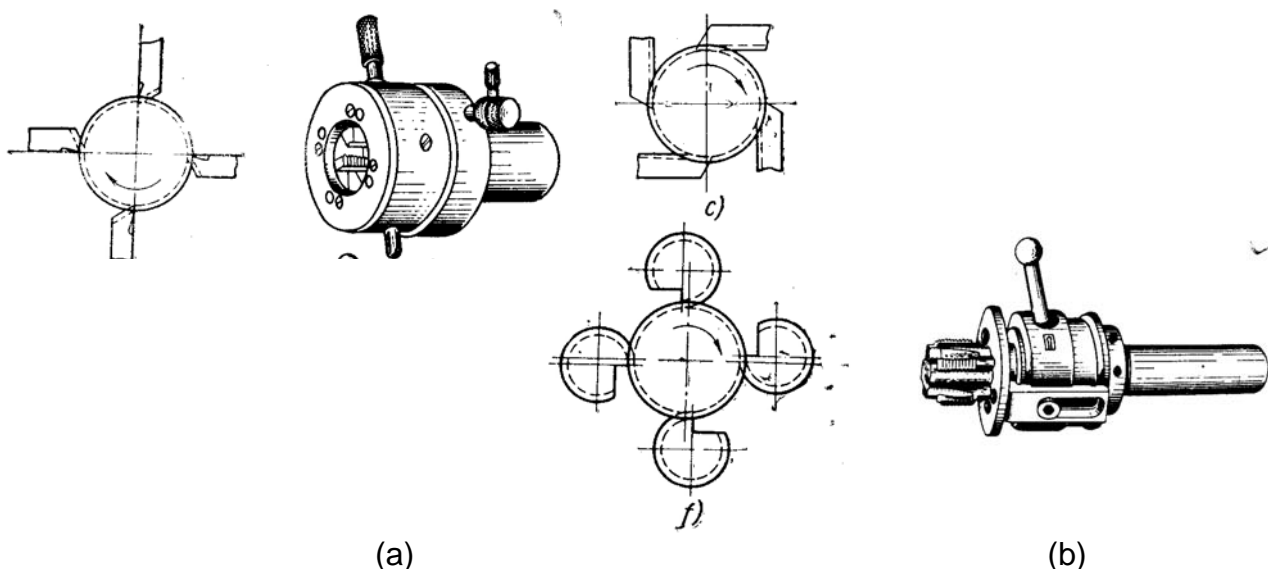


Fig. 7.1.8 Cutting (a) external and (b) internal threads in capstan and turret lathes.

* **Machining threads in automatic lathes**

Small external threads for mass production of fasteners are produced by machining in single spindle automatic lathes or similar but special purpose (threading) lathes using solid die. The die is mounted on the coaxially moving turret or sliding attachment in turret lathes and SPM respectively.

In turret lathe, the solid die is returned by reversing the job rotation, and in the special purpose machine, the die is freely returned by rotating the die slightly faster than the job and in the same direction.

* **Machining screw threads in drilling machine**

Drilling machines are used basically for originating cylindrical holes but are also used, if needed, for enlarging drilled holes by larger drills, counterboring, countersinking etc. Internal threads of relatively smaller diameter, length and pitch are also often produced in drilling machines by using tapping attachment with its taper shank fitted axially in the spindle bore. **Fig. 7.1.9** typically shows one such tapping attachment.



Fig. 7.1.9 Tapping attachment for machining internal threads in drilling machines.

The tapping attachment is pushed slowly inside the drilled hole at low speed for cutting threads and at the end of this stroke, it is withdrawn slowly by rotating in reversed direction. Just at the point of start of return, the lower part of the attachments momentarily gets delinked from the upper part and is then up and rotated respectively by the spring and the clutch as shown in **Fig. 7.1.9** to move at per with the upper part fitted into the spindle. This is necessary for the safe return of the tap without damaging the through or blind hole. Threading of small identical components like nuts for its mass production is also possible and done in general purpose drilling machines by using special attachment as shown in **Fig. 7.1.10**. The taper tap is connected with a bent rod which is made to rotate at high speed along with the spindle

causing rotation of the tap at the same speed. The blanks are automatically pushed intermittently under the tap and after threading the tap returns but along with the threaded nut. Finally the accumulated nuts are thrown out from the rod by centrifugal force to come out from the hopper as shown.

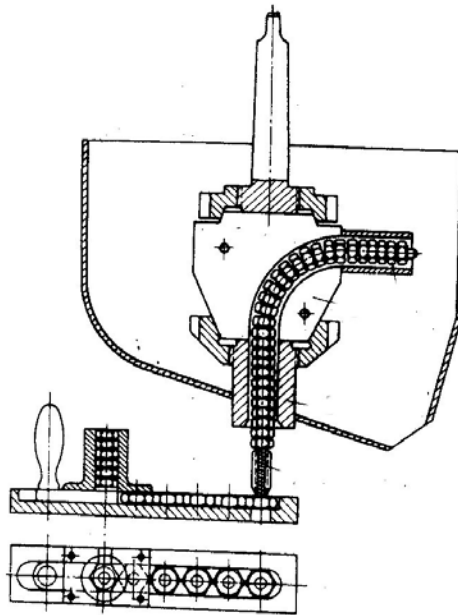


Fig. 7.1.10 Threading of nuts in drilling machine by special tapping attachment.

(b) Production of screw threads by thread rolling

In production of screw threads, compared to machining thread rolling,

- is generally cold working process
- provides higher strength to the threads
- does not cause any material loss
- does not require that high accuracy and finish of the blank
- requires simpler machines and tools
- applicable for threads of smaller diameter, shorter length and finer pitch
- enables much faster production of small products like screws, bolts, studs etc.
- cannot provide that high accuracy
- is applicable for relatively softer metals
- is used mostly for making external screw threads
- needs separate dies for different threads

Thread rolling is accomplished by shifting work material by plastic deformation, instead of cutting or separation, with the help of a pair of dies having same threads desired..

Different types of dies and methods are used for thread rolling which include,

- Thread rolling between two flat dies
- Thread rolling between a pair of circular dies
- Thread rolling by sector dies

- **Rolling of external screw threads by flat dies**

The basic principle is schematically shown in **Fig. 7.1.11**. Flat dies; one fixed and the other moving parallelly, are used in three configurations :

- △ **Horizontal** : most convenient and common
- △ **Vertical** : occupies less space and facilitates cleaning and lubrication under gravity
- △ **Inclined** : derives benefit of both horizontal and vertical features

All the flat dies are made of hardened cold die steel and provided with linear parallel threads like grooves of geometry as that of the desired thread.

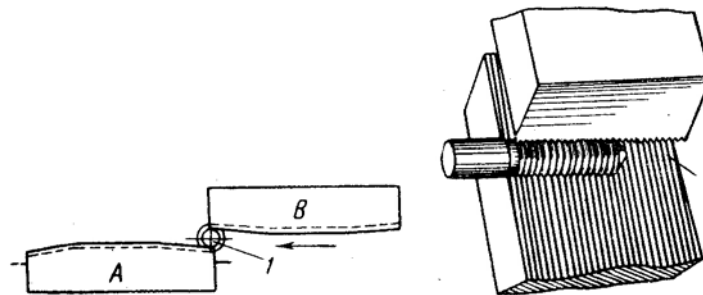


Fig. 7.1.11 Principle of thread rolling by flat dies.

- **Thread rolling by circular dies**

Circular die sets occupy less space and are simpler in design, construction, operation and maintenance. The different types of thread rolling circular dies of common use and their working methods are :

- △ **Circular dies with plunge (radial) feed :**

The two identical circular dies with parallel axis are rotated in the same direction and speed as indicated in **Fig. 7.1.12**. One stays fixed in a position the other is moved radially desirably depending upon the thread depth

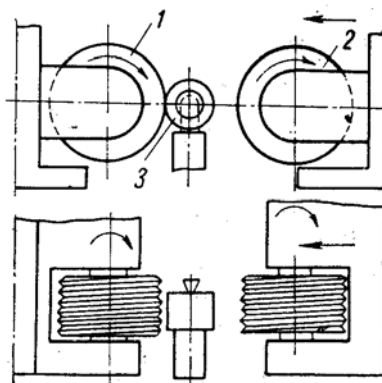


Fig. 7.1.12 Principle of thread rolling by circular die with plunge feed

△ **Circular die with inherent radial feed :**

Here the forced penetration of the threads in the blank is accomplished not by radial shifting of one of the dies but gradual projection of the thread in archemedian spiral over an angle on one of the dies as indicated in **Fig. 7.1.13**. This makes the system simpler by eliminating a linear motion.

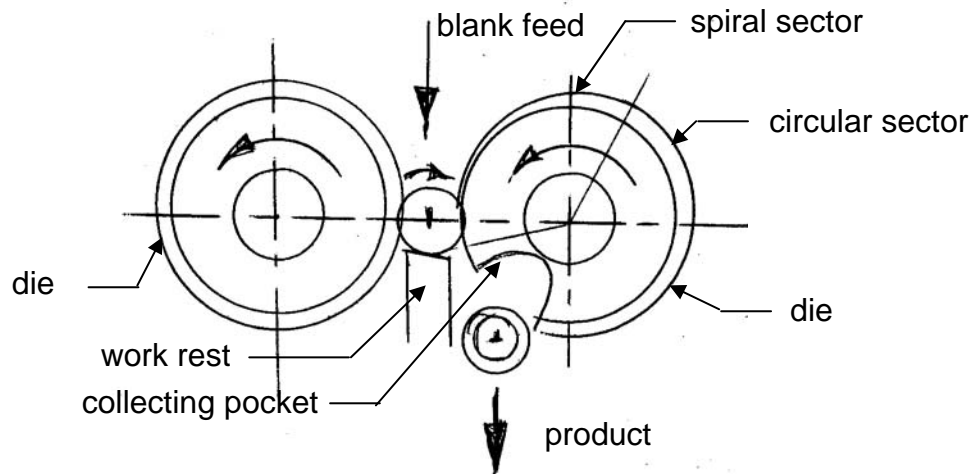


Fig. 7.1.13 Thread rolling by spiral feed circular die.

△ **Thread rolling in the annular space between two dies ;**

In this simpler system and process the outer die remains fixed and the inner one rotates as shown in **Fig. 7.1.14**. Because of simple construction and motions, this method is more productive but limited to smaller jobs.

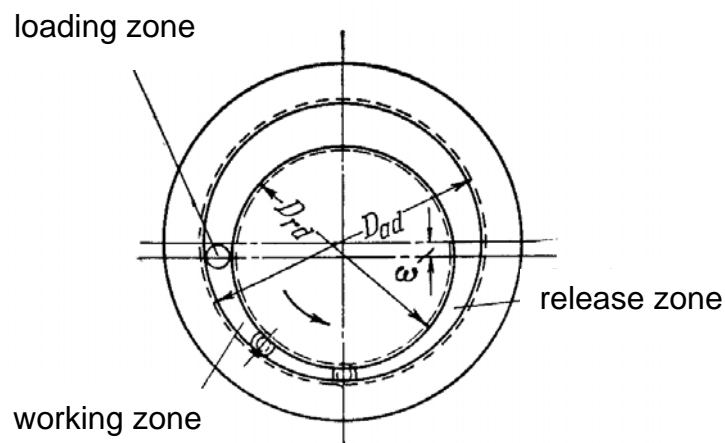


Fig. 7.1.14 Thread rolling in the annular space between two circular dies.

△ **Thread rolling by circular die sector**

This method, schematically shown in **Fig. 7.1.15**, is the simplest and fastest way of thread rolling enabling easy auto-feed of the blanks.

Fine internal threads on large diameter and unhard metals may also be done, if needed, by using a screw like threaded tool which will be rotated and pressed parallelly against the inner cylindrical wall of the product.

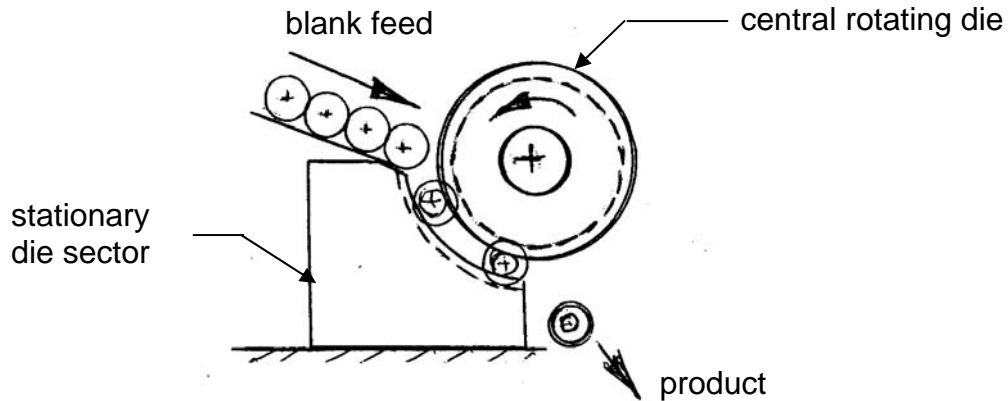


Fig. 7.1.15 Thread rolling by sector circular die

(c) Finishing and production of screw threads by grinding

In production of screw threads, grinding is employed for two purposes;

- Finishing the threads after machining or even rolling when
 - High dimensional and form accuracy as well as surface finish are required, e.g., screw threads of precision machines and measuring instruments
 - The threaded parts are essentially hardened and cannot be machined or rolled further, e.g., leadscrews of machine tools, press – screws etc.
- Directly originating (cutting) and simultaneously finishing threads in any hard or soft preformed blanks. This is employed generally for finer threads of small pitch on large and rigid blanks

However screw threads are ground in several methods which include;

- △ **External and internal thread grinding** by single ribbed formed grinding wheel as schematically shown in **Fig. 7.1.16 (a)**. Such grinding is usually done in cylindrical grinding machine but is also occasionally done in rigid centre lathes by mounting a grinding attachment like thread milling attachment, on the lathe's saddle.
- △ **Multi-ribbed wheels** save grinding time by reducing the length of travel of the wheel but raises wheel cost. **Fig. 7.1.16 (b)** shows such thread grinding with both fully covered and alternate ribbing.

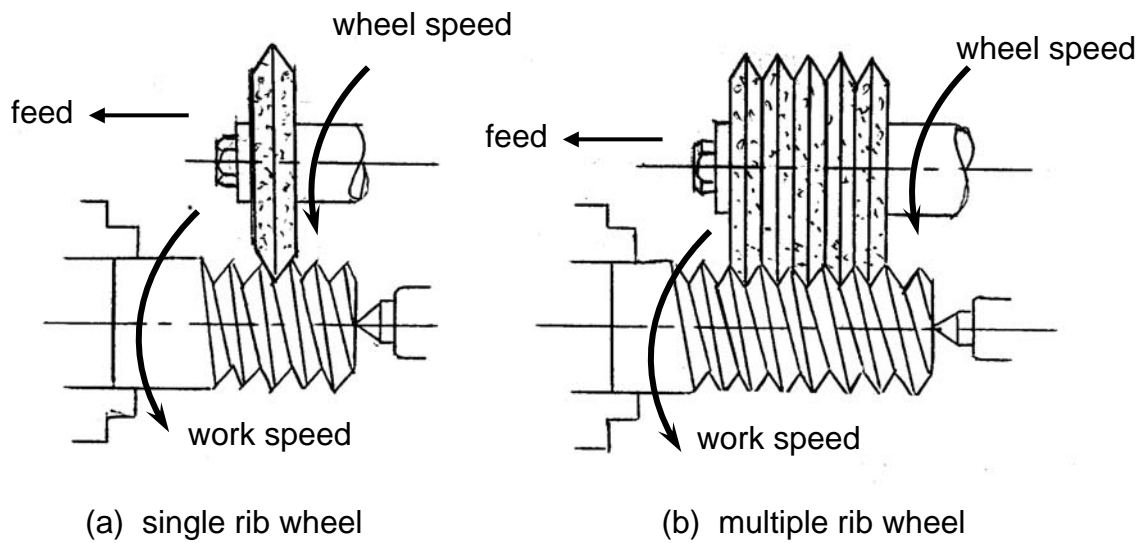


Fig. 7.1.16 Grinding of external screw threads.

△ **External threads by centreless grinding**

Like centreless grinding of short and long rods by plunge feed and through feed respectively, centreless thread grinding is also done by ribbed grinding wheel using respectively parallel and desirably inclined plain guide wheels. Centreless grinding, if feasible, is more productive but at the cost of accuracy to some extent.