UNIT III
TEMPORARY AND PERMANENT JOINTS
CHAPTER 1

Introduction

A screw thread is formed by cutting a continuous helical groove on a cylindrical surface. A screw made by cutting a single helical groove on the cylinder is known as single threaded (or single-start) screw and if a second thread is cut in the space between the grooves of the first, a double threaded (or double-start) screw is formed. Similarly, triple and quadruple (i.e. multiple-start) threads may be formed. The helical grooves may be cut either right hand or left hand.

A screwed joint is mainly composed of two elements i.e. a bolt and nut. The screwed joints are widely used where the machine parts are required to be readily connected or disconnected without damage to the machine or the fastening. This may be for the purpose of holding or adjustment in assembly or service inspection, repair, or replacement or it may be for the manufacturing or assembly reasons. The parts may be rigidly connected or provisions may be made for predetermined relative motion.

Advantages and Disadvantages of Screwed Joints

Following are the advantages and disadvantages of the screwed joints.

Advantages

1. Screwed joints are highly reliable in operation.
2. Screwed joints are convenient to assemble and disassemble.
3. A wide range of screwed joints may be adopted to various operating conditions.
4. Screws are relatively cheap to produce due to standardization and highly efficient manufacturing processes.

Disadvantages

The main disadvantage of the screwed joints is the stress concentration in the threaded portions which are vulnerable points under variable load conditions.

Important Terms Used in Screw Threads

The following terms used in screw threads, as shown in Fig. 1.1, are important from the subject point of view:

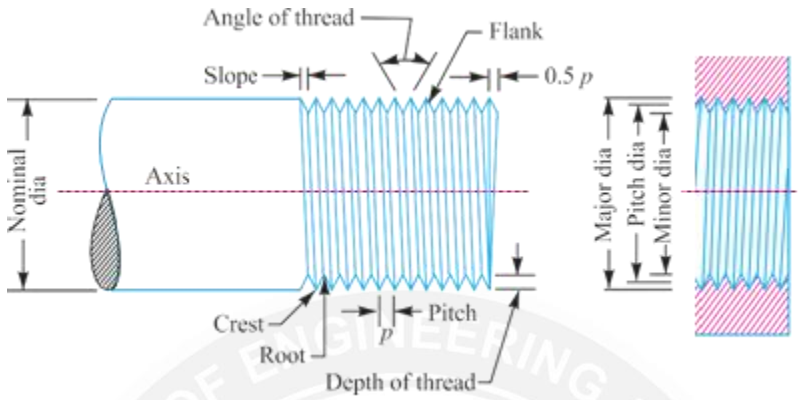

Fig 1.1 Terms used in screw threads.

[Source: "A Textbook of Machine Design by R.S. Khurmi J.K. Gupta, Page: 378]

1. Major diameter. It is the largest diameter of an external or internal screw thread. The screw is specified by this diameter. It is also known as outside or nominal diameter.

2. Minor diameter. It is the smallest diameter of an external or internal screw thread. It is also known as core or root diameter.

3. Pitch diameter. It is the diameter of an imaginary cylinder, on a cylindrical screw thread, the surface of which would pass through the thread at such points as to make equal the width of the thread and the width of the spaces between the threads. It is also called an effective diameter. In a nut and bolt assembly, it is the diameter at which the ridges on the bolt are in complete touch with the ridges of the corresponding nut.

4. Pitch. It is the distance from a point on one thread to the corresponding point on the next. This is measured in an axial direction between corresponding points in the same axial plane. Mathematically,

$$\text{Pitch} = \frac{1}{\text{No.of threads per unit length of screw}}$$

5. Lead. It is the distance between two corresponding points on the same helix. It may also be defined as the distance which a screw thread advances axially in one

rotation of the nut. Lead is equal to the pitch in case of single start threads, it is twice the pitch in double start, thrice the pitch in triple start and so on.

6. Crest. It is the top surface of the thread.

7. Root. It is the bottom surface created by the two adjacent flanks of the thread.

8. Depth of thread. It is the perpendicular distance between the crest and root.

9. Flank. It is the surface joining the crest and root.

10. Angle of thread. It is the angle included by the flanks of the thread.

11. Slope. It is half the pitch of the thread.

Forms of Screw Threads

The following are the various forms of screw threads.

1. British standard whitworth (B.S.W.) thread. This is a British standard thread profile and has coarse pitches. It is a symmetrical V-thread in which the angle between the flankes, measured in an axial plane, is 55°. These threads are found on bolts and screwed fastenings for special purposes. The various proportions of B.S.W. threads are shown in Fig. 1.2. The British standard threads with fine pitches (B.S.F.) are used where great strength at the root is required.

   These threads are also used for line adjustments and where the connected parts are subjected to increased vibrations as in aero and automobile work. The British standard pipe (B.S.P.) threads with fine pitches are used for steel and iron pipes and tubes carrying fluids. In external pipe threading, the threads are specified by the bore of the pipe.

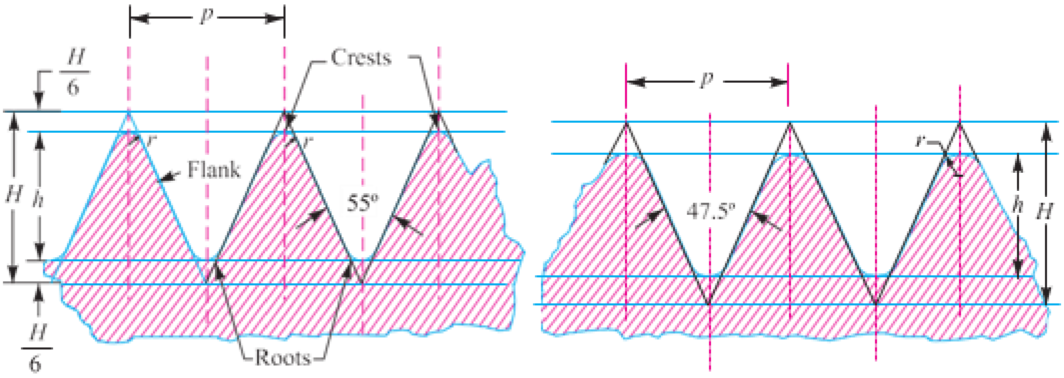

Fig 1.2 British standard whitworth (B.S.W) thread.

Fig 1.3 British association (B.A.) thread.

[Source: "A Textbook of Machine Design by R.S. Khurmi J.K. Gupta, Page: 379]

2. British association (B.A.) thread. This is a B.S.W. thread with fine pitches. The proportions of the B.A. thread are shown in Fig. 1.3. These threads are used for instruments and other precision works.

3. American national standard thread. The American national standard or U.S. or Seller's thread has flat crests and roots. The flat crest can withstand more rough usage than sharp V-threads. These threads are used for general purposes e.g. on bolts, nuts, screws and tapped holes. The various proportions are shown in Fig. 1.4.

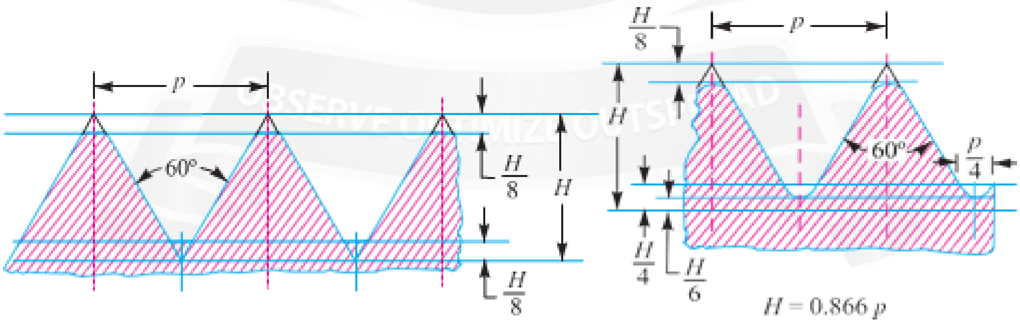

Fig 1.4 American national standard thread.

Fig 1.5 Unified standard thread.

[Source: "A Textbook of Machine Design by R.S. Khurmi J.K. Gupta, Page: 380]

4. Unified standard thread. The three countries i.e., Great Britain, Canada and United States came to an agreement for a common screw thread system with the

included angle of 60°, in order to facilitate the exchange of machinery. The thread has rounded crests and roots, as shown in Fig. 1.5.

5. Square thread. The square threads, because of their high efficiency, are widely used for transmission of power in either direction. Such type of threads is usually found on the feed mechanisms of machine tools, valves, spindles, screw jacks etc. The square threads are not so strong as V-threads but they offer less frictional resistance to motion than Whitworth threads. The pitch of the square thread is often taken twice that of a B.S.W. thread of the same diameter. The proportions of the thread are shown in Fig. 1.6.

6. Acme thread. It is a modification of square thread. It is much stronger than square thread and can be easily produced. These threads are frequently used on screw cutting lathes, brass valves, cocks and bench vices. When used in conjunction with a split nut, as on the lead screw of a lathe, the tapered sides of the thread facilitate ready engagement and disengagement of the halves of the nut when required. The various proportions are shown in Fig. 1.7.

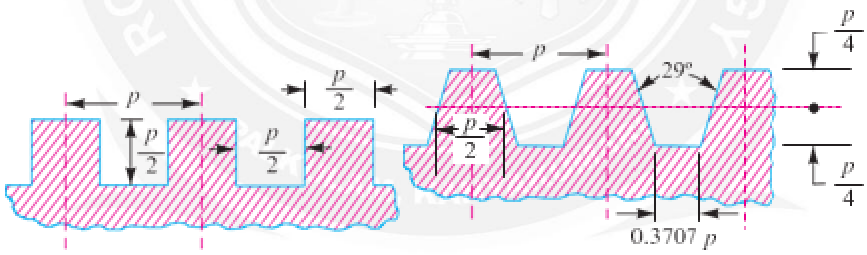

Fig 1.6 Square thread. Fig 1.7 Acme thread.

[Source: "A Textbook of Machine Design by R.S. Khurmi J.K. Gupta, Page: 380]

7. Knuckle thread. It is also a modification of square thread. It has rounded top and bottom. It can be cast or rolled easily and cannot economically be made on a machine. These threads are used for rough and ready work. They are usually found on railway carriage couplings, hydrants, necks of glass bottles and large moulded insulators used in electrical trade.

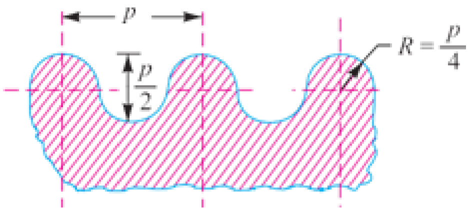

Fig 1.8 Knuckle thread.

[Source: "A Textbook of Machine Design by R.S. Khurmi J.K. Gupta, Page: 381]

8. Buttress thread. It is used for transmission of power in one direction only. The force is transmitted almost parallel to the axis. This thread unit the advantage of both square and V-threads. It has a low frictional resistance characteristics of the square thread and have the same strength as that of V-thread. The spindles of bench vices are usually provided with buttress thread. The various proportions of buttress thread are shown in Fig. 1.9.

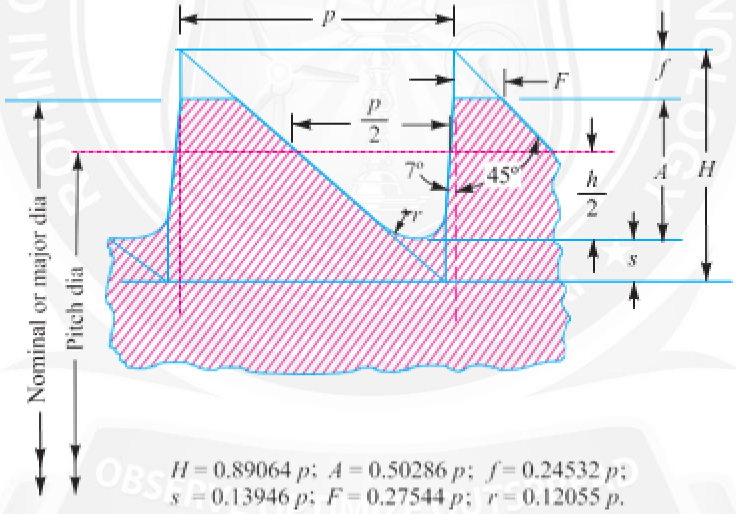

Fig 1.9 Buttress thread.

[Source: "A Textbook of Machine Design by R.S. Khurmi J.K. Gupta, Page: 381]

9.Metric thread. It is an Indian standard thread and is similar to B.S.W. threads. It has an included angle of 60° instead of 55°. The basic profile of the thread is shown in Fig. 1.10 and the design profile of the nut and bolt is shown in Fig. 1.11.

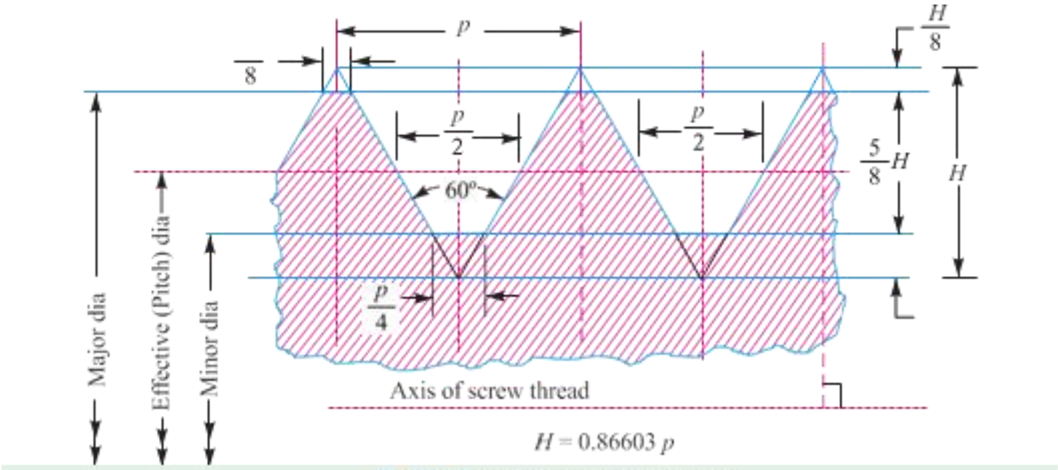

Fig. 11.10. Basic profile of the thread.

Fig 1.10 Basic profile of the thread.

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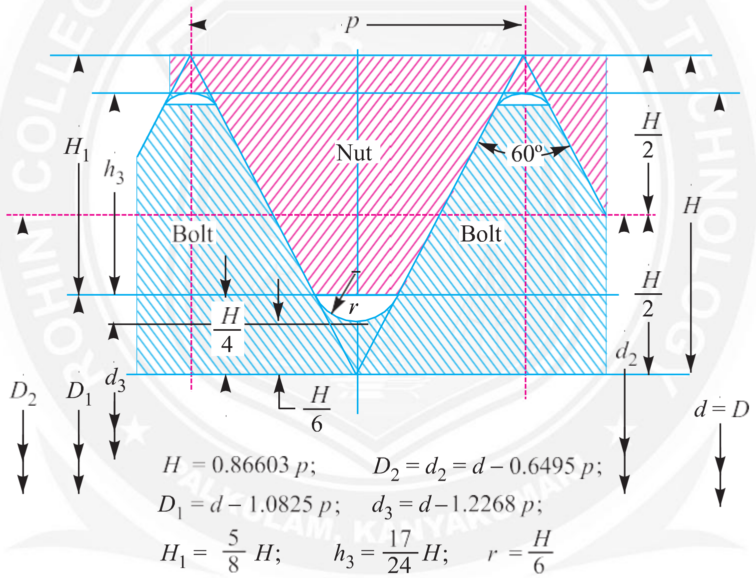

Fig 1.11 Design profile of the nut and bolt.

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Location of Screwed Joints

The choice of type of fastenings and its location are very important. The fastenings should be located in such a way so that they will be subjected to tensile and/or shear loads and bending of the fastening should be reduced to a minimum. The bending of the fastening due to misalignment, tightening up loads, or external loads are responsible for many failures. In order to relieve fastenings of bending stresses, the use of clearance spaces, spherical seat washers, or other devices may be used.

Common Types of Screw Fastenings

Following are the common types of screw fastenings:

1. Through bolts. A through bolt (or simply a bolt) is shown in Fig. 1.12 (a). It is a cylindrical bar with threads for the nut at one end and head at the other end. The cylindrical part of the bolt is known as shank. It is passed through drilled holes in the two parts to be fastened together and clamped them securely to each other as the nut is screwed on to the threaded end. The through bolts may or may not have a machined finish and are made with either hexagonal or square heads. A through bolt should pass easily in the holes, when put under tension by a load along its axis. If the load acts perpendicular to the axis, tending to slide one of the connected parts along the other end thus subjecting it to shear, the holes should be reamed so that the bolt shank fits snugly there in. The through bolts according to their usage may be known as machine bolts, carriage bolts, automobile bolts, eye bolts etc.

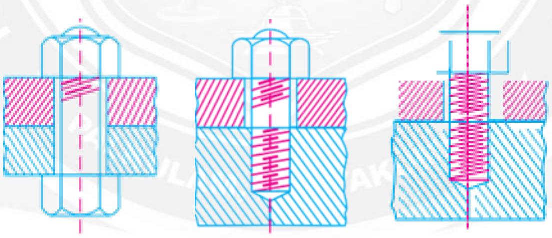

(a) Through bolt. (b) Tap bolt. (c) Stud.

Fig 1.12

[Source: "A Textbook of Machine Design by R.S. Khurmi J.K. Gupta, Page: 383]

2. Tap bolts. A tap bolt or screw differs from a bolt. It is screwed into a tapped hole of one of the parts to be fastened without the nut, as shown in Fig. 11.12 (b).

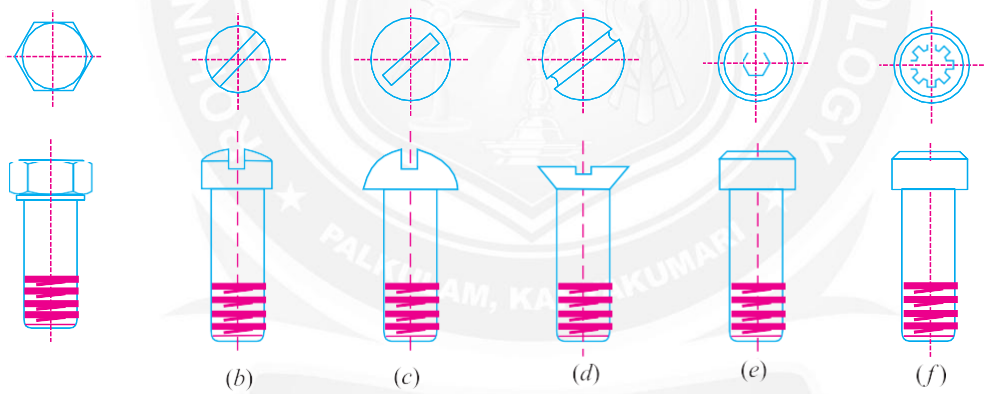
3. Studs. A stud is a round bar threaded at both ends. One end of the stud is screwed into a tapped hole of the parts to be fastened, while the other end receives a nut on it, as shown in Fig. 11.12 (c). Studs are chiefly used instead of tap bolts for securing various kinds of covers e.g. covers of engine and pump cylinders, valves, chests etc. This is due to the fact that when tap bolts are unscrewed or

replaced, they have a tendency to break the threads in the hole. This disadvantage is overcome by the use of studs.

4. Cap screws. The cap screws are similar to tap bolts except that they are of small size and a variety of shapes of heads are available as shown in Fig. 1.13.

5. Machine screws. These are similar to cap screws with the head slotted for a screw driver. These are generally used with a nut.

6. Set screws. The set screws are shown in Fig. 1.14. These are used to prevent relative motion between the two parts. A set screw is screwed through a threaded hole in one part so that its point (i.e. end of the screw) presses against the other part. This resists the relative motion between the two parts by means of friction between the point of the screw and one of the parts.



(a) Hexagonal head; (b) Fillister head; (c) Round head; (d) Flat head; (e) Hexagonal socket; (f) Fluted socket.

Fig 1.13 Types of cap screws.

[Source: "A Textbook of Machine Design by R.S. Khurmi J.K. Gupta, Page: 384]

They may be used instead of key to prevent relative motion between a hub and a shaft in light power transmission members. They may also be used in connection with a key, where they prevent relative axial motion of the shaft, key and hub assembly.

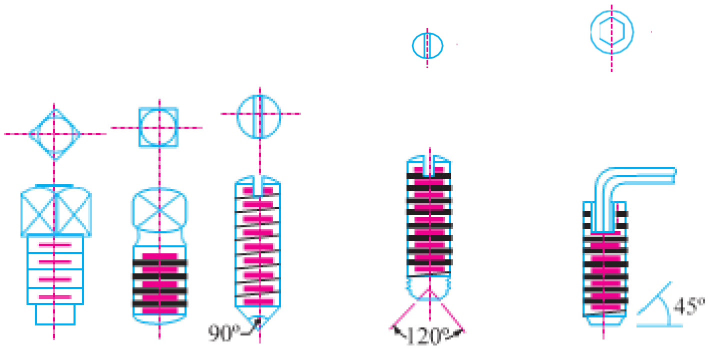


Fig 1.14 Set screws.

[Source: "A Textbook of Machine Design by R.S. Khurmi J.K. Gupta, Page: 384]

The diameter of the set screw (d) may be obtained from the following expression:

$$d = 0.125\ D + 8\ mm$$

where D is the diameter of the shaft (in mm) on which the set screw is pressed.

The tangential force (in newtons) at the surface of the shaft is given by

$$F = 6.6\ (d\ )^{2.3}$$

∴Torque transmitted by a set screw,

$$T = F \times \frac{D}{2}$$

and power transmitted (in watts), $P = \frac{2\pi NT}{60}$

where N is the speed in r.p.m.

Locking Devices

Ordinary thread fastenings, generally, remain tight under static loads, but many of these fastenings become loose under the action of variable loads or when machine is subjected to vibrations. The loosening of fastening is very dangerous and must be prevented. In order to prevent this, a large number of locking devices are available, some of which are discussed below:

1. Jam nut or lock nut. A most common locking device is a jam, lock or check nut. It has about one-half to two-third thickness of the standard nut. The thin

lock nut is first tightened down with ordinary force, and then the upper nut (i.e. thicker nut) is tightened down upon it, as shown in Fig. 1.15 (a). The upper nut is then held tightly while the lower one is slackened back against it.

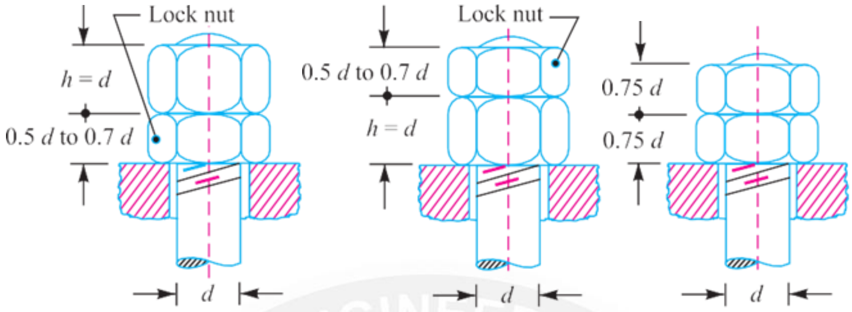


Fig 1.15 Jam nut or lock nut.

[Source: "A Textbook of Machine Design by R.S. Khurmi J.K. Gupta, Page: 385]

In slackening back, the lock nut, a thin spanner is required which is difficult to find in many shops. Therefore, to overcome this difficulty, a thin nut is placed on the top as shown in Fig. 1.15 (b). If the nuts are really tightened down as they should be, the upper nut carries a greater tensile load than the bottom one. Therefore, the top nut should be thicker one with a thin nut below it because it is desirable to put whole of the load on the thin nut. In order to overcome both the difficulties, both the nuts are made of the same thickness as shown in Fig. 1.15 (c).

2. Castle nut. It consists of a hexagonal portion with a cylindrical upper part which is slotted in line with the centre of each face, as shown in Fig. 1.16. The split pin passes through two slots in the nut and a hole in the bolt, so that a positive lock is obtained unless the pin shears. It is extensively used on jobs subjected to sudden shocks and considerable vibration such as in automobile industry.

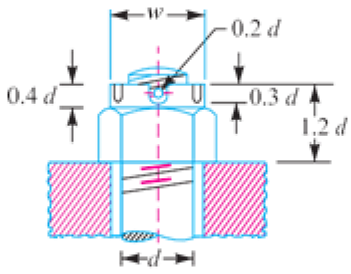


Fig 1.16 Castle nut.

[Source: "A Textbook of Machine Design by R.S. Khurmi J.K. Gupta, Page: 386]

3. Sawn nut. It has a slot sawed about half way through, as shown in Fig. 1.17. After the nut is screwed down, the small screw is tightened which produces more friction between the nut and the bolt. This prevents the loosening of nut.

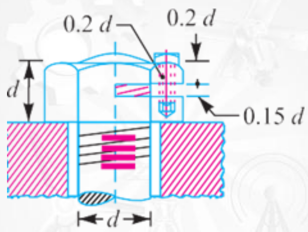


Fig 1.17 Sawn nut.

[Source: "A Textbook of Machine Design by R.S. Khurmi J.K. Gupta, Page: 386]

4. Penn, ring or grooved nut. It has an upper portion hexagonal and a lower part cylindrical as shown in Fig. 1.18. It is largely used where bolts pass through connected pieces reasonably near their edges such as in marine type connecting rod ends. The bottom portion is cylindrical and is recessed to receive the tip of the locking set screw. The bolt hole requires counter-boring to receive the cylindrical portion of the nut. In order to prevent bruising of the latter by the case hardened tip of the set screw, it is recessed.

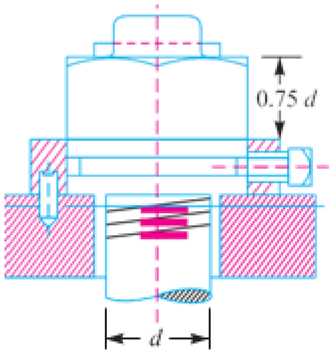


Fig 1.18 Penn, ring or grooved nut.

[Source: "A Textbook of Machine Design by R.S. Khurmi J.K. Gupta, Page: 386]

5. Locking with pin. The nuts may be locked by means of a taper pin or cotter pin passing through the middle of the nut as shown in Fig. 1.19 (a). But a split pin is often driven through the bolt above the nut, as shown in Fig. 1.19 (b).

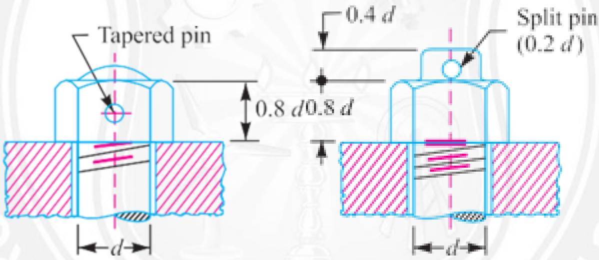


Fig 1.19 Locking with pin.

[Source: "A Textbook of Machine Design by R.S. Khurmi J.K. Gupta, Page: 386]

6. Locking with plate. A form of stop plate or locking plate is shown in Fig. 1.20. The nut can be adjusted and subsequently locked through angular intervals of 30° by using these plates.

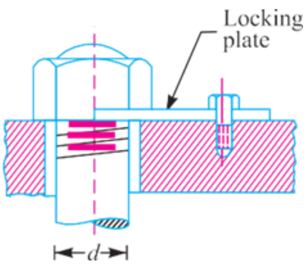


Fig 1.19 Locking with plate.

[Source: "A Textbook of Machine Design by R.S. Khurmi J.K. Gupta, Page: 386]

7. Spring lock washer. A spring lock washer is shown in Fig. 1.21. As the nut tightens the washer against the piece below, one edge of the washer is caused to dig itself into that piece, thus increasing the resistance so that the nut will not loosen so easily. There are many kinds of spring lock washers manufactured, some of which are fairly effective.

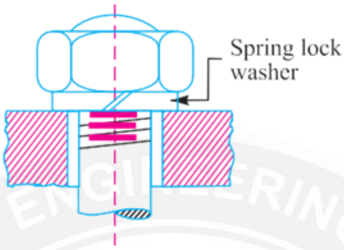


Fig 1.21 Locking with washer.

[Source: "A Textbook of Machine Design by R.S. Khurmi J.K. Gupta, Page: 386]

Washer

Washer, machine component that is used in conjunction with a screw fastener such as a bolt and nut and that usually serves either to keep the screw from loosening or to distribute the load from the nut or bolt head over a larger area. For load distribution, thin flat rings of soft steel are usual. They are specified by a nominal diameter d which is meant to be diameter of the bolt with which the washer is to be equal to 0.15d. the outside of the washer is twice the nominal diameter but the relationship between these two dimensions is not constant for all nominal sizes.

Stresses in Screwed Fastening due to Static Loading

The following stresses in screwed fastening due to static loading are important from the subject point of view:

1. Internal stresses due to screwing up forces,
2. Stresses due to external forces, and
3. Stress due to combination of stresses at (1) and (2).

Initial Stresses due to Screwing up Forces

The following stresses are induced in a bolt, screw or stud when it is screwed up tightly.

1. Tensile stress due to stretching of bolt. Since none of the above mentioned stresses are accurately determined, therefore bolts are designed on the basis of direct tensile stress with a large factor of safety in order to account for the indeterminate stresses. The initial tension in a bolt, based on experiments, may be found by the relation

$$P_i = 2840\ d\ N$$

where P_i = Initial tension in a bolt, and

d = Nominal diameter of bolt, in mm.

The above relation is used for making a joint fluid tight like steam engine cylinder cover joints etc. When the joint is not required as tight as fluid-tight joint, then the initial tension in a bolt may be reduced to half of the above value. In such cases

$$P_i = 1420\ d\ N$$

The small diameter bolts may fail during tightening, therefore bolts of smaller diameter (less than M 16 or M 18) are not permitted in making fluid tight joints. If the bolt is not initially stressed, then the maximum safe axial load which may be applied to it, is given by

P = Permissible stress × Cross-sectional area at bottom of the thread (i.e. stress area)

The stress area may be obtained from Table or it may be found by using the relation

$$\text{Stress area} = \frac{\pi}{4}\left(\frac{d_p + d_c}{2}\right)^2$$

where d_p = Pitch diameter, and

d_c = Core or minor diameter.

2. Torsional shear stress caused by the frictional resistance of the threads during its tightening. The torsional shear stress caused by the frictional resistance of the threads during its tightening may be obtained by using the torsion equation. We know that

$$\frac{T}{J} = \frac{\tau}{r}$$

$$\tau = \frac{T}{J} \times r$$

$$\tau = \frac{T}{\frac{\pi}{32(d_c)^4}} \times \frac{d_c}{2}$$

$$\tau = \frac{16T}{\pi(d_c)^3}$$

where τ = Torsional shear stress,

T = Torque applied, and

d_c = Minor or core diameter of the thread.

It has been shown during experiments that due to repeated unscrewing and tightening of the nut, there is a gradual scoring of the threads, which increases the torsional twisting moment (T).

3. Shear stress across the threads. The average thread shearing stress for the screw (τ_s) is obtained by using the relation:

$$\tau_s = \frac{P}{\pi d_c \times b \times n}$$

where b = Width of the thread section at the root.

The average thread shearing stress for the nut is

$$\tau_s = \frac{P}{\pi d \times b \times n}$$

where d = Major diameter.

4. Compression or crushing stress on threads. The compression or crushing stress between the threads (σ_c) may be obtained by using the relation:

$$\sigma_c = \frac{P}{\pi[d^2 - {d_c}^2]n}$$

where d = Major diameter,

d_c = Minor diameter, and

n = Number of threads in engagement.

5. Bending stress if the surfaces under the head or nut are not perfectly parallel to the bolt axis. When the outside surfaces of the parts to be connected are not parallel to each other, then the bolt will be subjected to bending action. The bending stress (σ_b) induced in the shank of the bolt is given by

$$\sigma_b = \frac{x.E}{2l}$$

where x = Difference in height between the extreme corners of the nut or head,

l = Length of the shank of the bolt, and

E = Young's modulus for the material of the bolt.

Problem 1.1

Two machine parts are fastened together tightly by means of a 24 mm tap bolt. If the load tending to separate these parts is neglected, find the stress that is set up in the bolt by the initial tightening.

Given Data:

d = 24 mm

From Table (coarse series), we find that the core diameter of the thread corresponding to M 24 is dc = 20.32 mm.

Let σ_t = Stress set up in the bolt.

We know that initial tension in the bolt,

$P = 2840\ d$

$P = 2840 \times 24$

$P = 68\ 160$ N

We also know that initial tension in the bolt (P),

$68160 = \frac{\pi}{4} (d_c)^2 \times \sigma_t$

$68160 = \frac{\pi}{4} (20.32)^2 \times \sigma_t$

$68160 = 324\ \sigma_t$

$\sigma_t = 68\ 160 / 324$

$\sigma_t = 210\ N/mm^2$

$\sigma_t = 210$ MPa