Screw Fastenings

1. SCREW THREADS

2. BOLTS

3. STRESSES IN FASTNERS

1

Stresses in Screw Fasteners

Bolted Joints – Simple Analysis (Direct Loading)

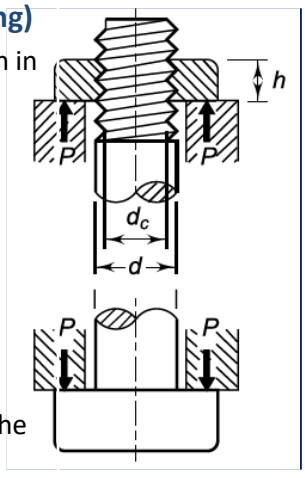
A bolted joint subjected to tensile force *P* is shown in Fig.

The cross-section at the core diameter d_c is the weakest section.

The maximum tensile stress in the bolt at this cross-section is given by,

$$\sigma_t = \frac{P}{(\frac{\pi}{4} d_c^2)} \qquad (1)$$

The height of the nut *h* can be determined by equating the strength of the bolt in tension with the strength in shear.



2

Stresses in Screw Fasteners

Bolted Joints – Simple Analysis (Direct Loading)

The procedure is based on the following assumptions:

(i) Each turn of the thread in contact with the nut supports an equal amount of load.

(ii) There is no stress concentration in the threads.

(iii) The yield strength in shear is equal to half of the yield strength in tension ($S_{sy} = 0.5S_{yt}$).

(iv) Failure occurs in the threads of the bolt and not in the threads of the nut.

Substituting, $\boldsymbol{\sigma_t = \frac{S_{yt}}{(FOS)}}$ in Equation (1)

Stresses in Screw Fasteners

Bolted Joints – Simple Analysis (Direct Loading)

The strength of the bolt in tension is given by,

$$\mathbf{P = \frac{\pi}{4} d_c^2 \frac{S_{yt}}{(fos)}} \qquad \text{(a)}$$

The threads of the bolt in contact with the nut are sheared at the core diameter d_c.

The shear area is equal to ($\pi d_c h$), where h is the height of the nut.

The strength of the bolt in shear is given by,

$$\mathbf{P = (\pi d_c h)\frac{S_{sy}}{(fos)}} \text{ or } \mathbf{P = (\pi d_c h)\frac{S_{yt}}{(2fos)}} \qquad \text{(b)}$$

Equating (a) and (b) , we get $h=0.5d_c$

Assuming ($d_c = 0.8d$), $h = 0.4d$

Stresses in Screw Fasteners

Bolted Joints – Simple Analysis (Direct Loading)

Therefore, for standard coarse threads,

the threads are equally strong in failure by shear and failure by tension, if the height of the nut is approximately 0.4 times of the nominal diameter of the bolt.

The height of the standard hexagonal nut is (0.8d).

Hence, the threads of the bolt in the standard nut will not fail by shear.

Rewriting the height of the standard nut, $h = 0.8d$ *(c)*

The design of the bolt consists of determination of correct size of the bolt.

The size of the bolt is given by the nominal diameter *d* and pitch *p*.

Stresses in Screw Fasteners

Bolted Joints – Simple Analysis (Direct Loading)

In design calculations, many times the core diameter d_c is determined.

Therefore, it is necessary to convert the core diameter d_c into the nominal diameter *d*.

This can be easily done when the tables like (1) and (2) are available.

Knowing the minor or core diameter, the corresponding designation of the thread can be obtained from these tables.

However, when the tables for threads are not available, some relationship between d_c and *d* has to be used.

The correct relationship for ISO metric screw threads is as follows,

$d_c = d - 1.22687p$ (d)

Stresses in Screw Fasteners

Bolted Joints – Simple Analysis (Direct Loading)

Since there are two unknowns on the right-hand side, it is not possible to find out the value of d by knowing the value of d_c. Therefore, the following approximate relationship can be used,

$d_c = 0.8d$ (e)

Preference should be given to use values given in Tables 1 and 2.

Table 1 Basic dimensions for ISO metric screw threads (coarse series)

Designation	Nominal or major dia d/D (mm)	Pitch (p) (mm)	Pitch diameter dp/ D_P (mm)	Minor diameter (mm)		Tensile stress area (mm^2)
				dc	Dc	
M 4	4	0.70	3.545	3.141	3.242	8.78
M 5	5	0.80	4.480	4.019	4.134	14.20
M 6	6	1.00	5.350	4.773	4.917	20.10

7

Stresses in Screw Fasteners

Table 1 Basic dimensions for ISO metric screw threads (coarse series)

Designation	Nominal or major dia d/D (mm)	Pitch (p) (mm)	Pitch diameter dp/ D_P (mm)	Minor diameter (mm)		Tensile stress area (mm^2)
				dc	Dc	
M 8	8	1.25	7.188	6.466	6.647	36.60
M 10	10	1.50	9.026	8.160	8.376	58.00
M 12	12	1.75	10.863	9.853	10.106	84.30
M 16	16	2.00	14.701	13.546	13.835	157
M 20	20	2.50	18.376	16.933	17.294	245
M 24	24	3.00	22.051	20.319	20.752	353
M 30	30	3.50	27.727	25.706	26.211	561
M 36	36	4.00	33.402	31.093	31.670	817
M 42	42	4.50	39.077	36.479	37.129	1120
M 48	48	5.00	44.752	41.866	42.587	1470
M 56	56	5.50	52.428	49.252	50.046	2030

8

Stresses in Screw Fasteners

Table 1 Basic dimensions for ISO metric screw threads (coarse series)

Designation	*Nominal or major dia d/D (mm)*	*Pitch (p) (mm)*	*Pitch diameter dp/ D_P (mm)*	*Minor diameter (mm)*		*Tensile stress area (mm^2)*
				dc	*Dc*	
M 64	64	6.00	60.103	56.639	57.505	2680
M 72	72	6.00	68.103	64.639	65.505	2680
M 80	80	6.00	76.103	72.639	73.505	4340
M 90	90	6.00	86.103	82.639	83.505	5590
M 100	100	6.00	96.103	92.639	93.505	7000

A screw thread of coarse series is designated by the letter 'M' followed by the value of the nominal diameter in mm. For example, M 12

9

Stresses in Screw Fasteners

Table 2 Basic dimensions for ISO metric screw threads (fine series)

Designation	*Nominal or major dia d/D (mm)*	*Pitch (p) (mm)*	*Pitch diameter dp/ D_P (mm)*	*Minor diameter (mm)*		*Tensile stress area (mm^2)*
				dc	*Dc*	
M 6 x 1	6	1.00	5.350	4.773	4.917	20.1
M 6 x 0.75	6	0.75	5.513	5.080	5.188	22.0
M 8 x 1.25	8	1.25	7.188	6.466	6.647	36.6
M 8 x 1	8	1.00	7.350	6.773	6.917	39.2
M 10 x 1.25	10	1.25	9.188	8.466	8.647	61.2
M 10 x 1	10	1.00	9.350	8.773	8.917	64.5
M 12 x 1.5	12	1.50	11.026	10.160	10.376	88.1
M 12 x 1.25	12	1.25	11.188	10.466	10.647	92.1
M 16 x 1.5	16	1.50	15.026	14.160	14.376	167.0
M 16 x 1	16	1.00	15.350	14.773	14.917	178.0
M 20 x 2	20	2.00	18.701	17.546	17.835	258.0

10

Stresses in Screw Fasteners

Table 2 Basic dimensions for ISO metric screw threads (fine series)

Designation	*Nominal or major dia d/D (mm)*	*Pitch (p) (mm)*	*Pitch diameter dp/ D_P (mm)*	*Minor diameter* dc (mm)	*Minor diameter* Dc (mm)	*Tensile stress area (mm^2)*
M 20 x 1.5	20	1.50	19.026	18.160	18.376	272.0
M 24 x 2	24	2.00	22.701	21.546	21.835	384.0
M 24 x 1.5	24	1.50	23.026	22.160	22.376	401.0
M 30 x 3	30	3.00	28.051	26.319	26.752	581.0
M 30 x 2	30	2.00	28.701	27.546	27.835	621.0
M 36 x 3	36	3.00	34.051	32.319	32.752	865.0
M 36 x 2	36	2.00	34.701	33.546	33.835	915.0
M 42 x 4	42	4.00	39.402	37.093	37.670	1150.0
M 42 x 3	42	3.00	40.051	38.319	38.752	1210.0
M 48 x 4	48	4.00	45.402	43.093	43.670	1540.0
M 48 x 3	48	3.00	46.051	44.319	44.752	1600.0

11

Stresses in Screw Fasteners

A screw thread of fine series is specified by the letter 'M', followed by the values of the nominal diameter and the pitch in mm and separated by the symbol 'X'. For example, M 12 X 1.25

MATERIALS AND MANUFACTURE

Lightly loaded small bolts, studs and nuts are made of free cutting steels.

High strength bolts often fail in fatigue.

They are made of plain carbon steels like 40C8 or 45C8 or alloy steels like 35Mn6Mo3, 40Cr4Mo2, 40Ni14 or 40Ni10Cr3Mo6. Stainless steel is used for threaded fastener where corrosion resistance is required.

The head of the bolt or screw is made by the upsetting process.

This is done on automatic forging machines, which give finished shape with practically no scrap. The head is cold formed for diameters up to 20 mm.

12

Stresses in Screw Fasteners

MATERIALS AND MANUFACTURE

For larger diameters, hot forming is employed.

There are two methods for making threads, viz., *thread cutting* and *thread rolling*.

Thread cutting is done on automatic machines called '*screw*' machines.

In the thread rolling method, threads are formed by rolling the bar stock between dies which depress part of the material to form the root of the thread and which force the remaining material up the top to form the crest of threads.

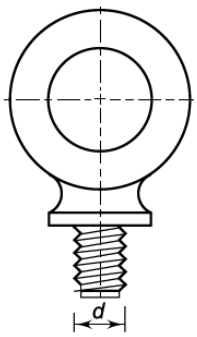
Therefore, the outside diameter of the thread is more than the bar stock on which it was rolled.

Thread rolling is a superior method of making threads.

Stresses in Screw Fasteners

Problem 1

An electric motor weighing 10 kN is lifted by means of an eye bolt as shown in Fig. The eye bolt is screwed into the frame of the motor. The eye bolt has coarse threads. It is made of plain carbon steel 30C8 (S_{yt} = 400 N/mm^2) and the factor of safety is 6. Determine the size of the bolt.



Stresses in Screw Fasteners

Problem 2

Two plates are fastened by means of two bolts as shown in Fig. The bolts are made of plain carbon steel 30C8 (S_{yt} = 400 N/mm^2) and the factor of safety is 5. Determine the size of the bolts if, P = 5 kN