ME 1110 – Engineering Practice 1

Engineering Drawing and Design - Lecture 16

Mechanical Elements
Screws, Fasteners, non-permanent Joints

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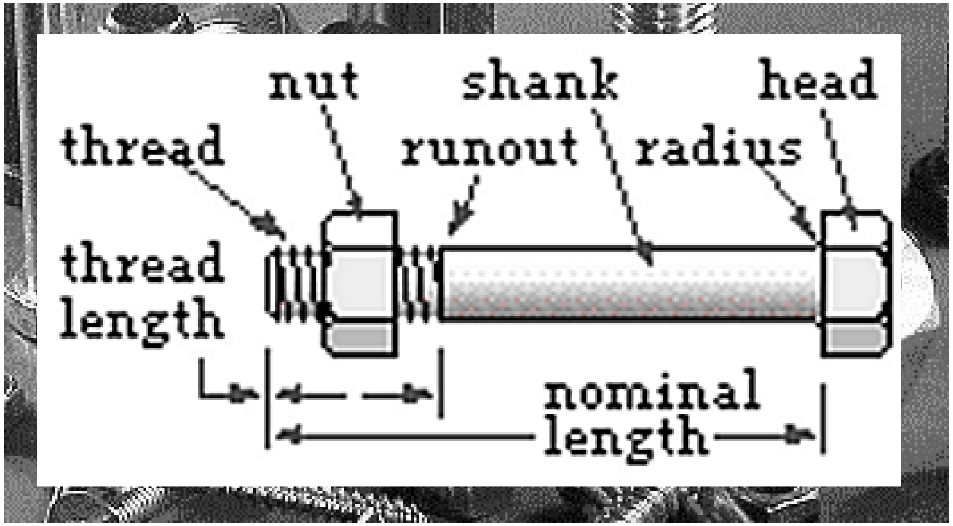
www.staff.city.ac.uk/~ra600/intro.htm

Design web

Introduction



The ***helical-thread screw*** was very important invention for application in:

- power transmission,
- angular to linear motion change,
- generation of large forces,
- non-permanent joints.

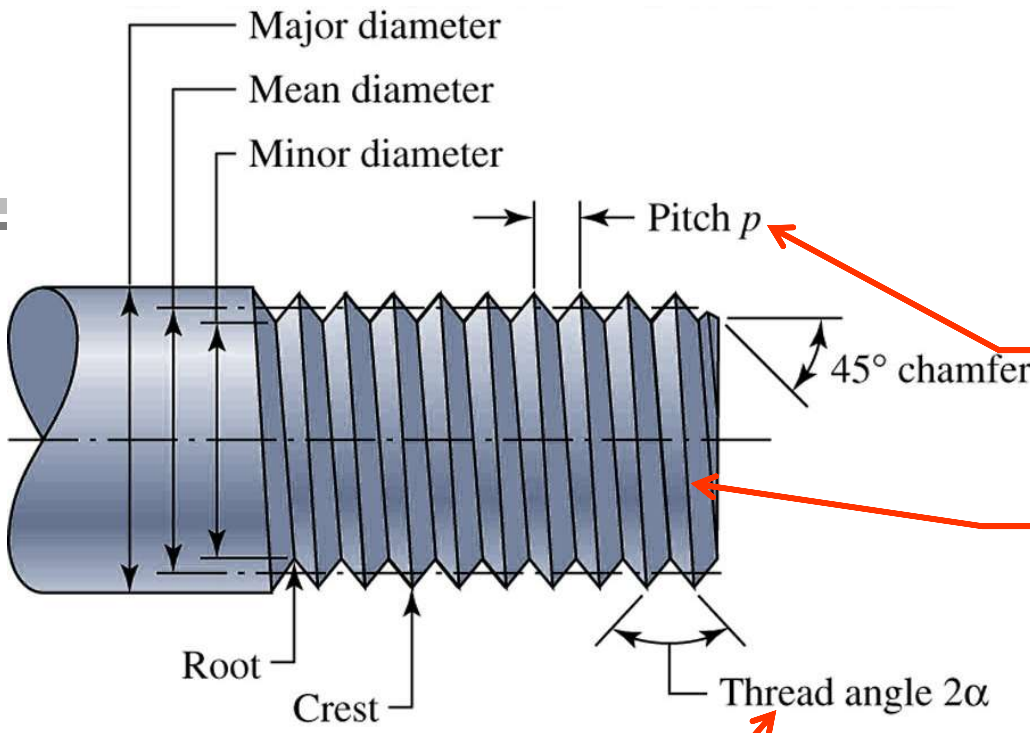
Fastening: the major target is to reduce number of joins. One of the most interesting subjects in engineering:

Example:
- Boeing 747 requires as many as 2.5 million fasteners. Some are very expensive.

Designer's ***aim is to select an adequate fastener*** (bolt, nut, cap, screw …) for an application in question:
- *the shape and the arrangement*
- *the size and other functional parameters*
- *to check if selected fastener can sustain required load*

Definitions and standards

Design web



Pitch

distance between adjacent thread forms measured parallel to the thread axis.

Orientation

Threads are usually right-handed (RH) unless otherwise required

Thread height (H)

For M and UN threads

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

Thread angle

60o for M and UN threads

Crest of the thread

May be flat or round

Major diameter (d, d_c)

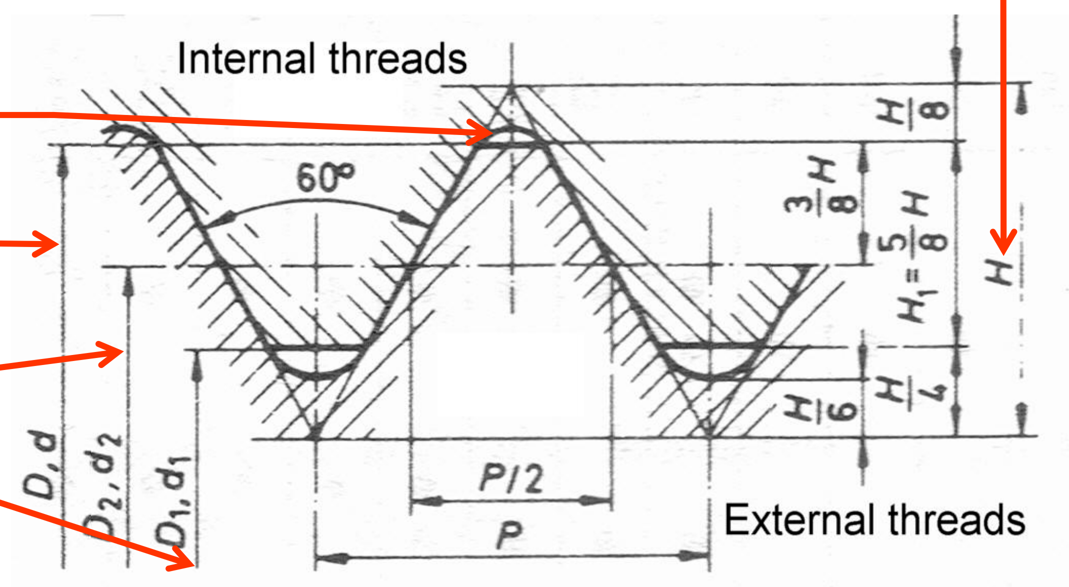
Largest diameter of a screw thread

Mean–Pitch diameter (d_2, d_p)

Mean diameter; teeth section is p/2 long

Minor diameter (d_1, d_r)

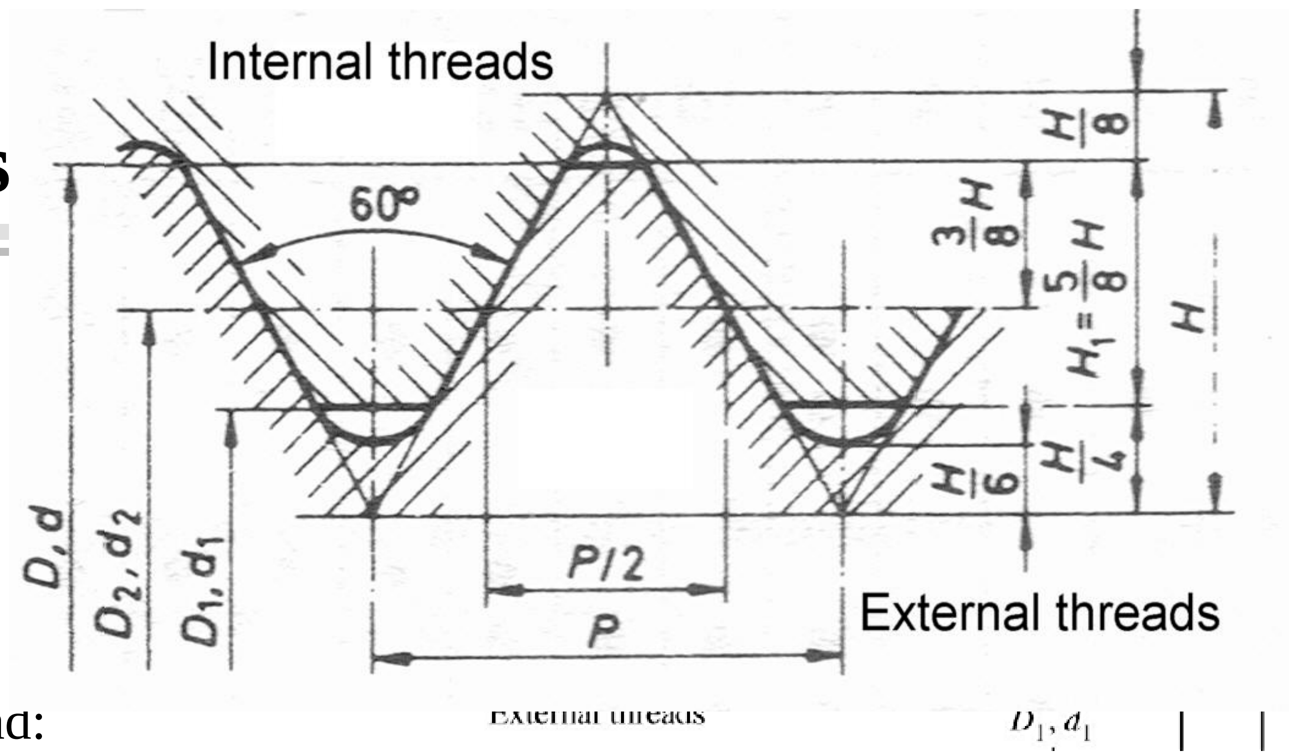
Smalest diameter of the thread



Screw Threads

Metric Threads:

- Thread angle = 60°
- Symmetric profiles
- Identified as M and MJ
- Coarse and fine pitch
- Specification of the thread:



M12 x 1.75

Pitch: coarse or fine

Nominal major diameter

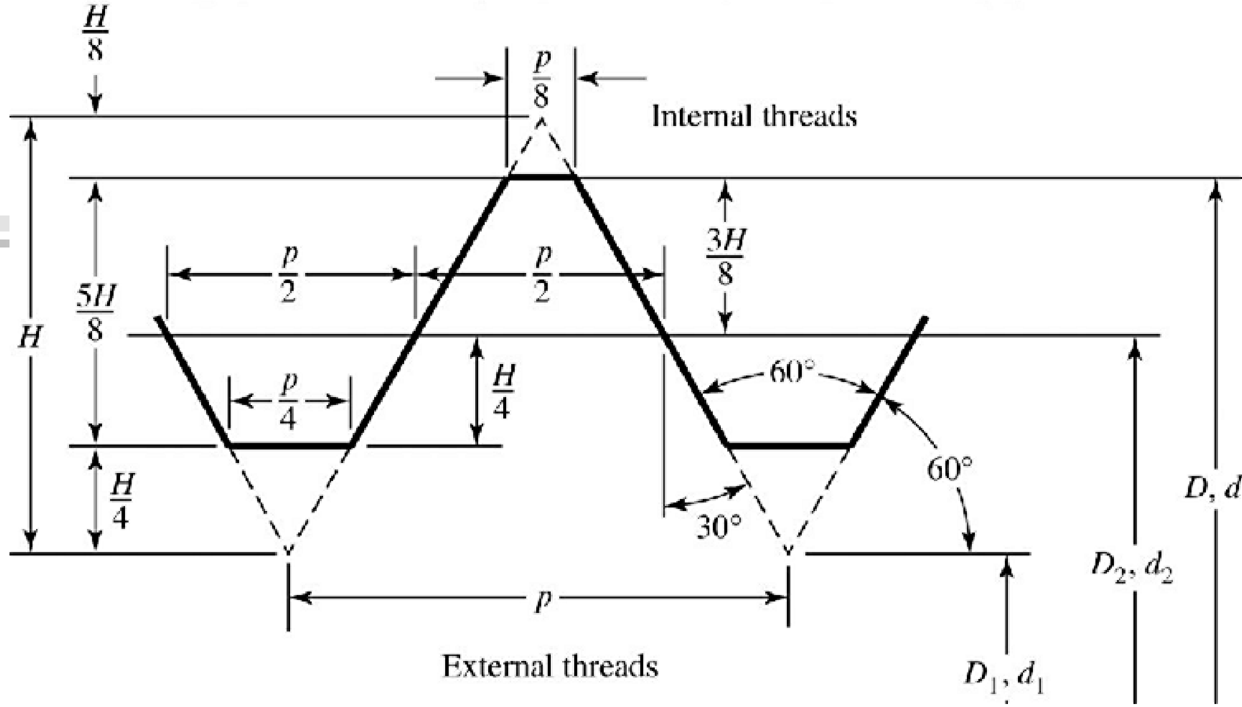
The metric thread designation

Metric threads

(all dimensions in mm)

Nominal Major Diameter d	Coarse-Pitch Series Pitch p	Coarse-Pitch Series Tensile-Stress Area A_t	Coarse-Pitch Series Minor-Diameter Area A_r	Fine-Pitch Series Pitch p	Fine-Pitch Series Tensile-Stress Area A_t	Fine-Pitch Series Minor-Diameter Area A_r
1.6	0.35	1.27	1.07			
2	0.40	2.07	1.79			
2.5	0.45	3.39	2.98			
3	0.5	5.03	4.47			
3.5	0.6	6.78	6.00			
4	0.7	8.78	7.75			
5	0.8	14.2	12.7			
6	1	20.1	17.9			
8	1.25	36.6	32.8	1	39.2	36.0
10	1.5	58.0	52.3	1.25	61.2	56.3
12	1.75	84.3	76.3	1.25	92.1	86.0
14	2	115	104	1.5	125	116
16	2	157	144	1.5	167	157
20	2.5	245	225	1.5	272	259
24	3	353	324	2	384	365
30	3.5	561	519	2	621	596
36	4	817	759	2	915	884
42	4.5	1120	1050	2	1260	1230
48	5	1470	1380	2	1670	1630
56	5.5	2030	1910	2	2300	2250
64	6	2680	2520	2	3030	2980
72	6	3460	3280	2	3860	3800
80	6	4340	4140	1.5	4850	4800
90	6	5590	5360	2	6100	6020
100	6	6990	6740	2	7560	7470
110				2	9180	9080

Screw Threads



Metric Threads:

- Thread angle = 60º
- Symmetric profiles
- Identified as M and MJ
- Coarse and fine pitch
- Specification of the thread:

M12 x 1.75

- *Pitch: coarse or fine*
- *Nominal major diameter*
- *The metric thread designation*

Unified threads:

(usually pipe threads)

Thread angle = 60º

- Symmetric profiles
- Serief UN and UNR
- Coarse (C) and fine (F) pitch
- Specification of the thread:

¼ in-20 UNRC

- ***Thread series: UNC, UNF, UNRC, UNRF***
- ***Threads per inch (coarse or fine)***
- ***Nominal major diameter***

Unified Screw Threads (dimensions in ")

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Size Designation	Nominal Major Diameter in	Coarse Series—UNC: Threads per Inch N	Coarse Series—UNC: Tensile-Stress Area A_t in^2	Coarse Series—UNC: Minor-Diameter Area A_r in^2	Fine Series—UNF: Threads per Inch N	Fine Series—UNF: Tensile-Stress Area A_t in^2	Fine Series—UNF: Minor-Diameter Area A_r in^2
0	0.0600				80	0.001 80	0.001 51
1	0.0730	64	0.002 63	0.002 18	72	0.002 78	0.002 37
2	0.0860	56	0.003 70	0.003 10	64	0.003 94	0.003 39
3	0.0990	48	0.004 87	0.004 06	56	0.005 23	0.004 51
4	0.1120	40	0.006 04	0.004 96	48	0.006 61	0.005 66
5	0.1250	40	0.007 96	0.006 72	44	0.008 80	0.007 16
6	0.1380	32	0.009 09	0.007 45	40	0.010 15	0.008 74
8	0.1640	32	0.014 0	0.011 96	36	0.014 74	0.012 85
10	0.1900	24	0.017 5	0.014 50	32	0.020 0	0.017 5
12	0.2160	24	0.024 2	0.020 6	28	0.025 8	0.022 6
$\frac{1}{4}$	0.2500	20	0.031 8	0.026 9	28	0.036 4	0.032 6
$\frac{5}{16}$	0.3125	18	0.052 4	0.045 4	24	0.058 0	0.052 4
$\frac{3}{8}$	0.3750	16	0.077 5	0.067 8	24	0.087 8	0.080 9
$\frac{7}{16}$	0.4375	14	0.106 3	0.093 3	20	0.118 7	0.109 0
$\frac{1}{2}$	0.5000	13	0.141 9	0.125 7	20	0.159 9	0.148 6
$\frac{9}{16}$	0.5625	12	0.182	0.162	18	0.203	0.189
$\frac{5}{8}$	0.6250	11	0.226	0.202	18	0.256	0.240
$\frac{3}{4}$	0.7500	10	0.334	0.302	16	0.373	0.351
$\frac{7}{8}$	0.8750	9	0.462	0.419	14	0.509	0.480
1	1.0000	8	0.606	0.551	12	0.663	0.625
$1\frac{1}{4}$	1.2500	7	0.969	0.890	12	1.073	1.024
$1\frac{1}{2}$	1.5000	6	1.405	1.294	12	1.581	1.521

Design web

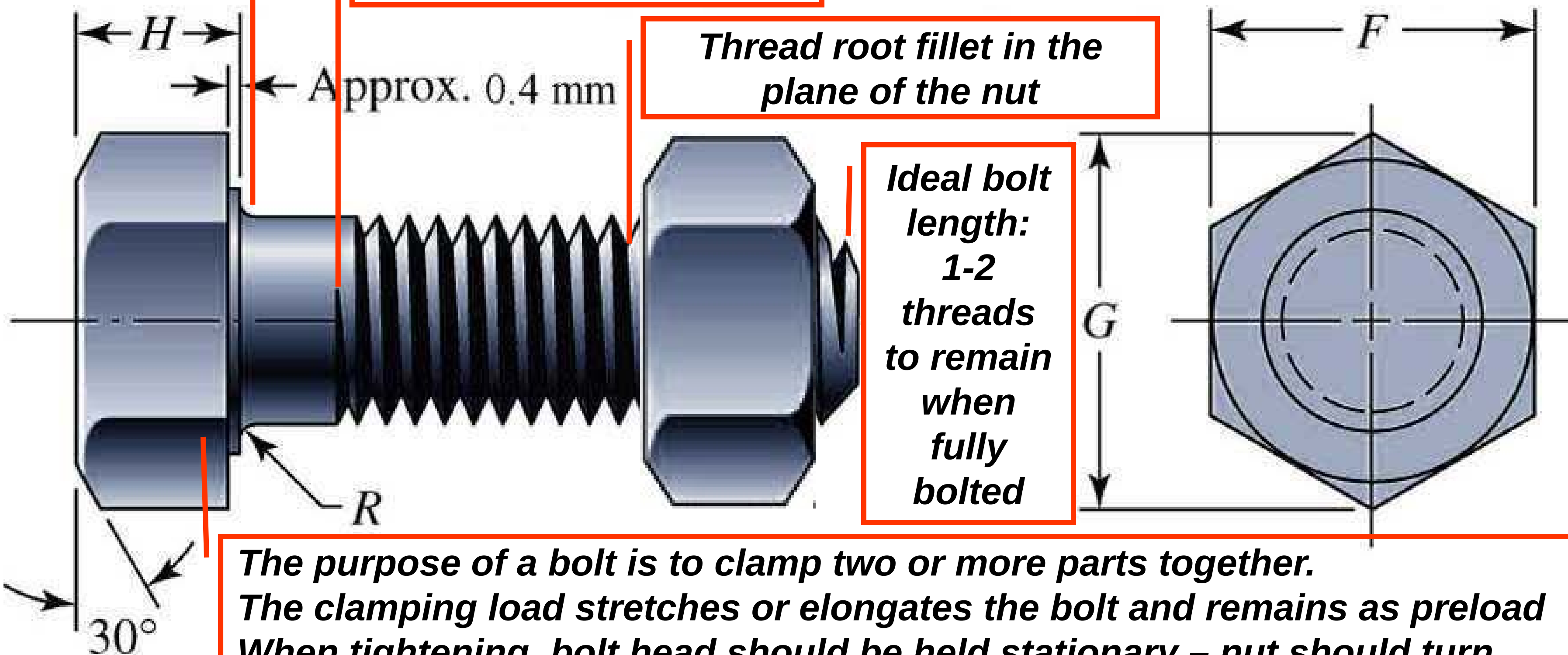
Threaded Fasteners

Fillet – stress concentration

Start of the thread

Thread root fillet in the plane of the nut

Ideal bolt length: 1-2 threads to remain when fully bolted



The purpose of a bolt is to clamp two or more parts together.
The clamping load stretches or elongates the bolt and remains as preload
When tightening, bolt head should be held stationary – nut should turn.

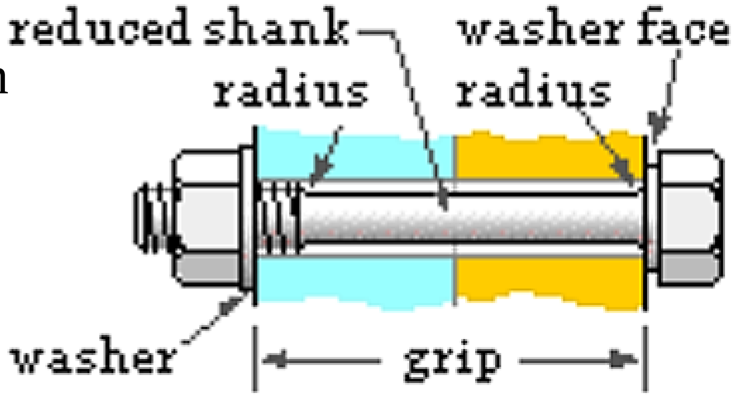
Hexagon head bolt

Properties of a threaded fastener

The ***shank*** diameter of a 'waisted' bolt is less than the thread diameter; allows a thread run out which reduces stress concentration.

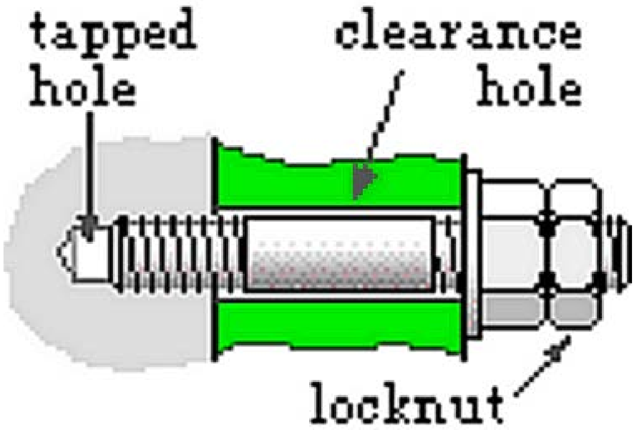
A ***Washer*** under the nut ensures uniformity of a contact.

A bolt's '***grip***' is the combined thickness of the fastened parts

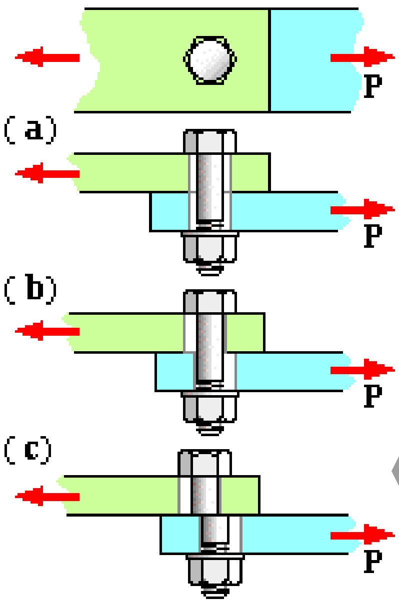


Bolt - has a nut which turns to tighten
Screw - turns itself in the threaded hole
Stud - has no head and is threaded on both sides

Clearance hole - 15-20% larger than a bolt/stud size
Taped hole - drilled smaller than the *minor* dia. extends deeper than the stud
Stud depth - 1.5 times the major diameter
Thread length - only a couple of threads longer than a bolt

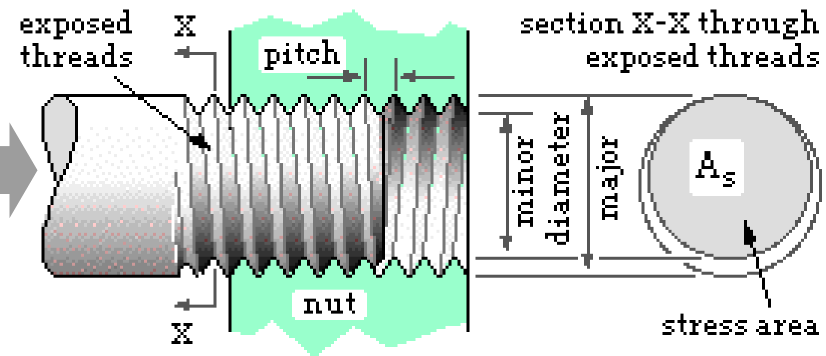


Load that a bolt can sustain



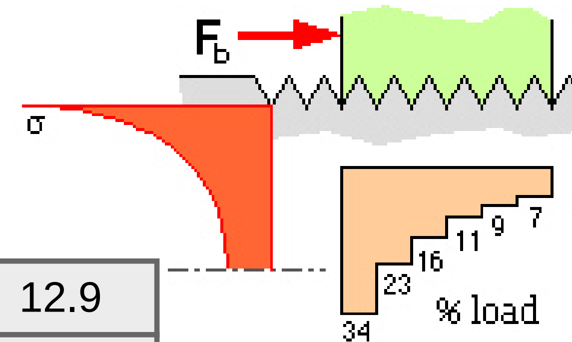
Tensile stress:

$$\sigma = F_b / A_t$$



Shear stress:

$$\tau = P / A_r$$



	class no.	4.6	5.8	8.8	9.8	10.9	12.9
St	Tensile [Mpa]	400	500	800	900	1000	1200
Sy	Yield [Mpa]	240	400	640	720	900	1080
Sp	Proof [Mpa]	225	380	590	650	830	970
	Elongation %	22	20	12	10	9	8

Strength table

Typical cap-screw heads

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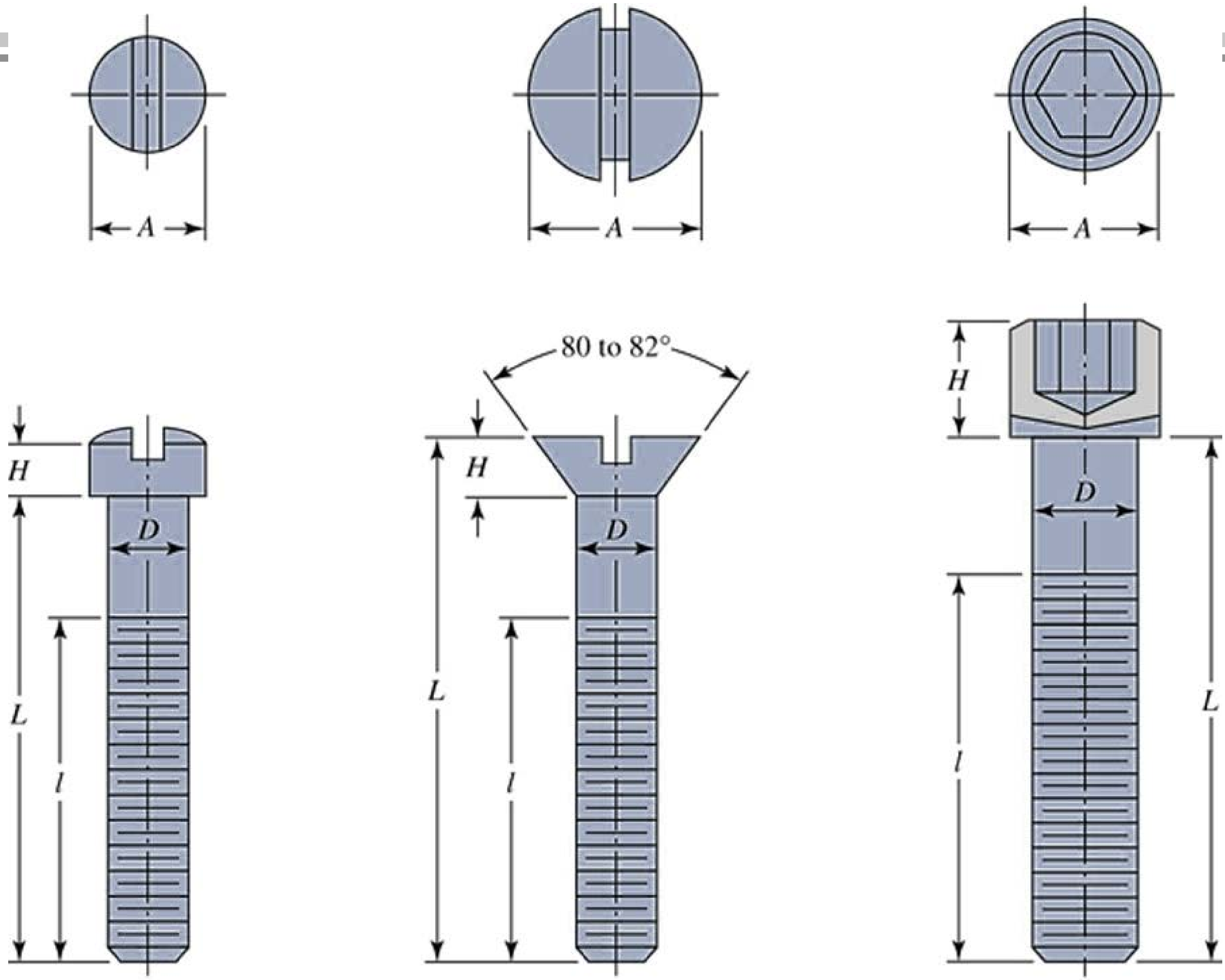
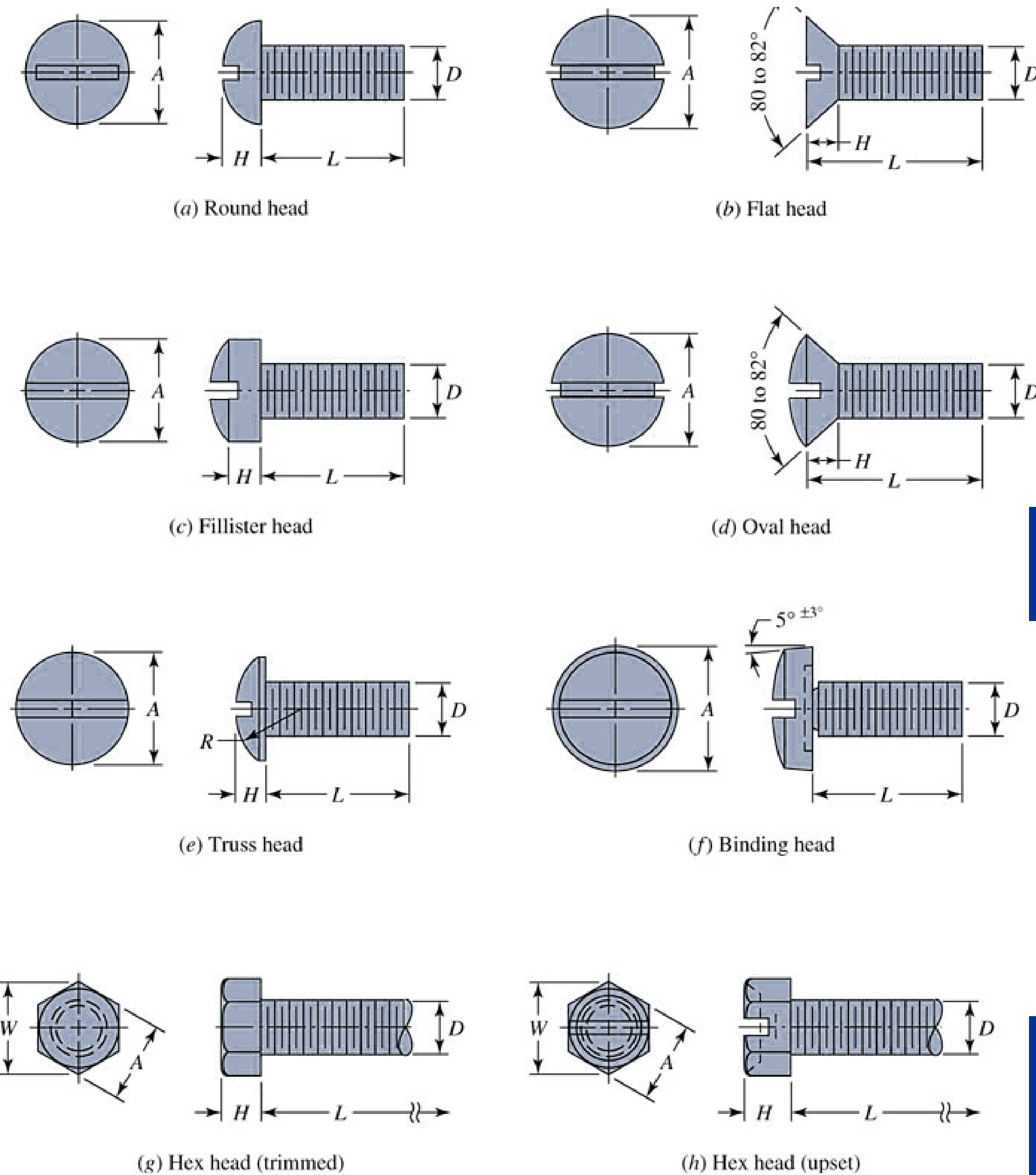


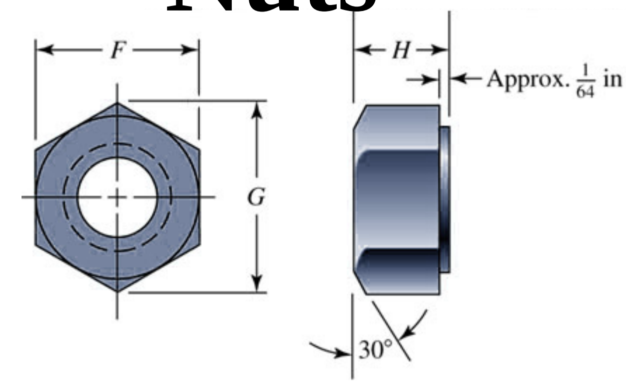
Fillister head **Flat head** **Hexagonal socket head**

Design web

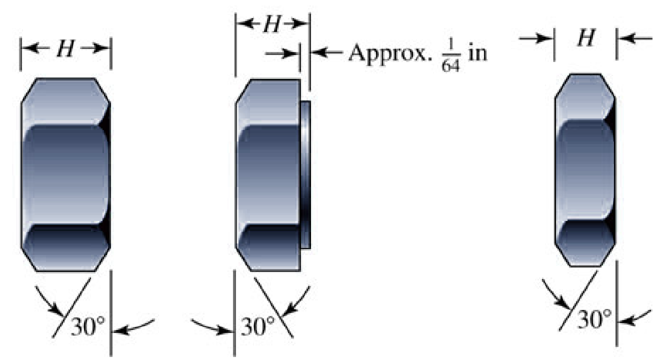
Other types of screw heads in use



Nuts

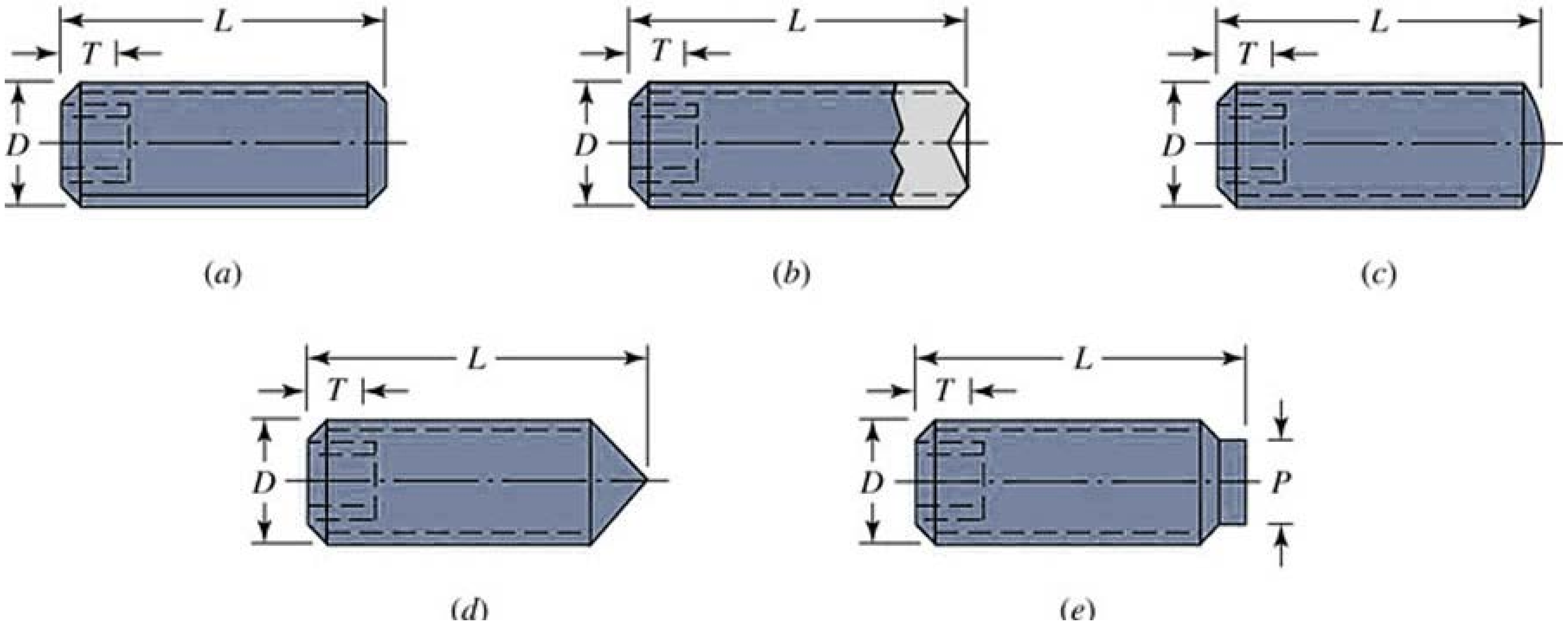


Hexagonal washer faced regular nut



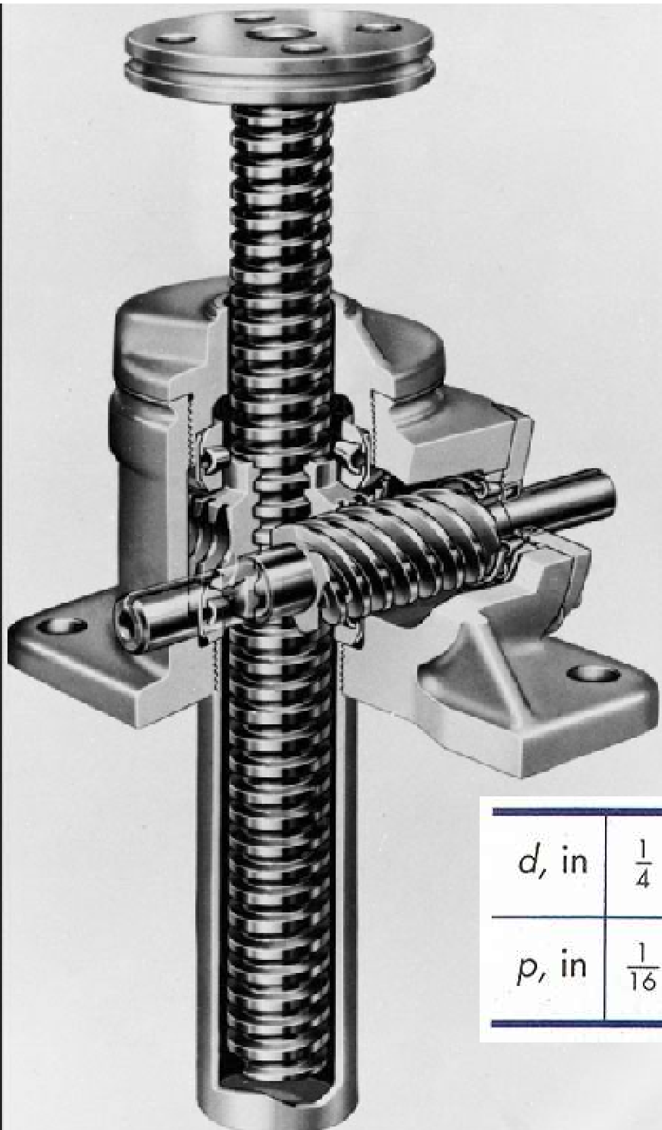
regular nut chamfered on both sides
jam nut with washer face
jam nut chamfered on both sides

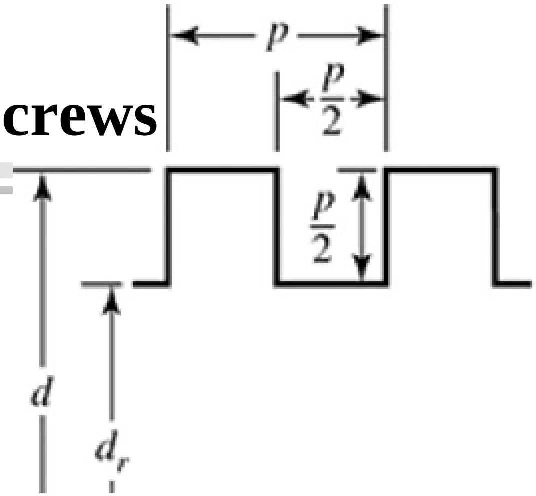
Setscrews

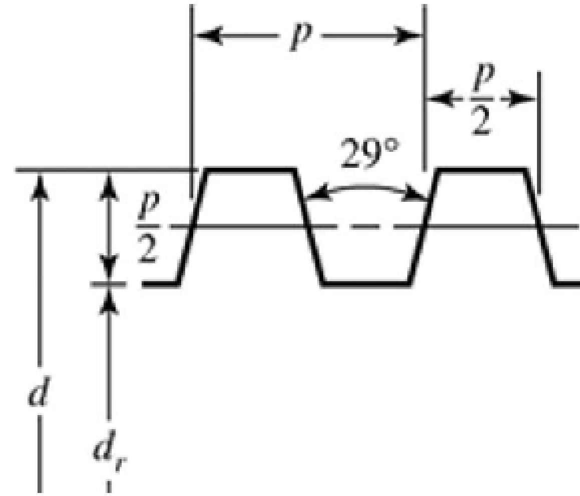


regular nut chamfered on both sides
jam nut with washer face
jam nut chamfered on both sides

Threads for power screws







Square and Acme threads:

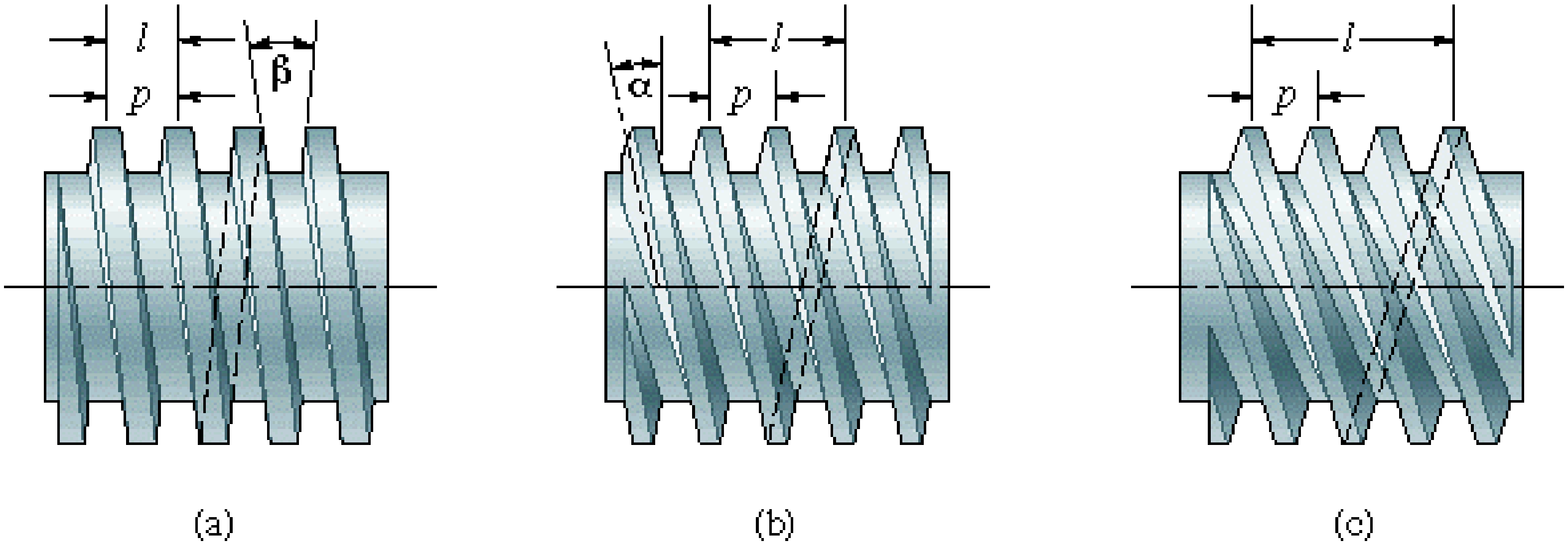
- Used for power transmission
- These have preferred sizes but also can vary
- Modifications to these threads are easy

Preferred Pitches for power threads:

d, in	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{2}$	3
p, in	$\frac{1}{16}$	$\frac{1}{14}$	$\frac{1}{12}$	$\frac{1}{10}$	$\frac{1}{8}$	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$

Design web

Multiple threaded screws



l=p

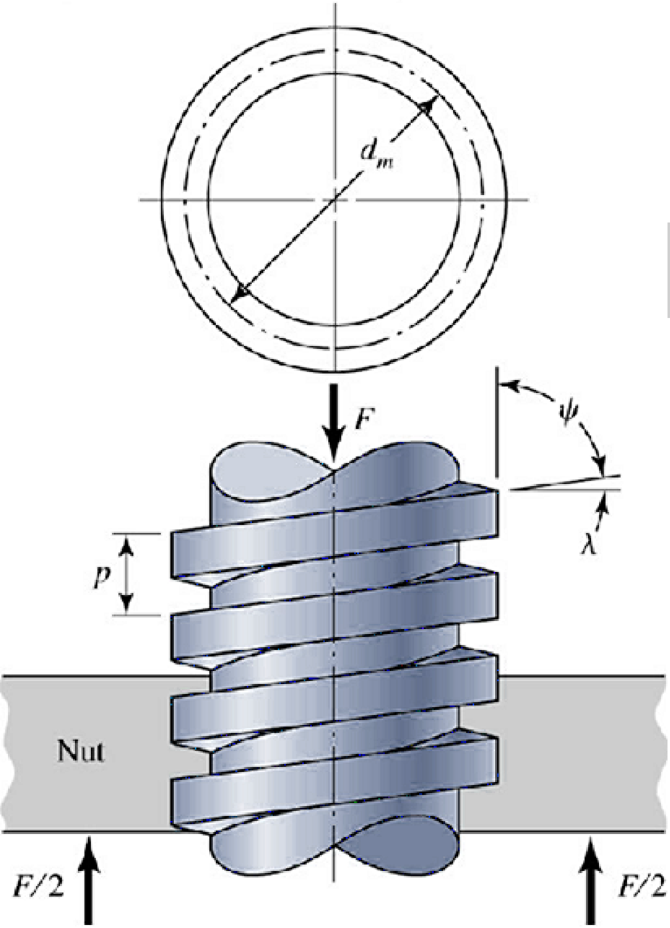
l=2p

l=3p

(a) Single, (b) double, (c) triple threaded screws.

Design web

Power screws



Rising the load

$$\sum F_x = P_R - N\sin\lambda - f\,N\cos\lambda$$

$$\sum F_y = F + f\,N\sin\lambda - N\cos\lambda$$

$$P_R = \frac{F(f\cos\lambda + \sin\lambda)}{\cos\lambda - f\sin\lambda} \qquad T_R = \frac{Fd_m}{2}\left(\frac{\pi f d_m + l}{\pi d_m - fl}\right)$$

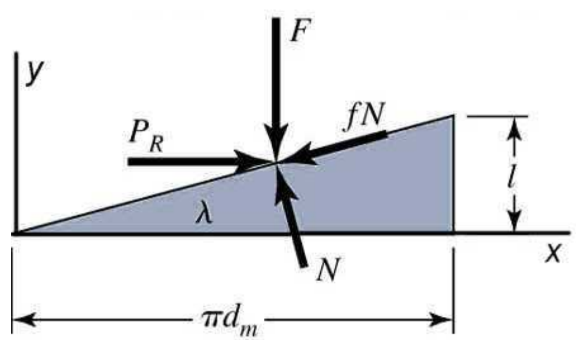
Lowering the load

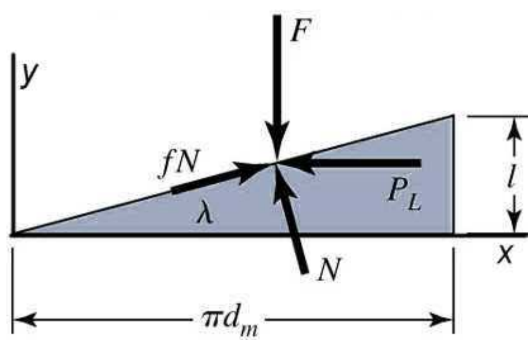
$$\sum F_x = -P_L - N\sin\lambda + f\,N\cos\lambda$$

$$\sum F_y = F - f\,N\sin\lambda - N\cos\lambda$$

$$P_L = \frac{F(f\cos\lambda - \sin\lambda)}{\cos\lambda + f\sin\lambda}$$

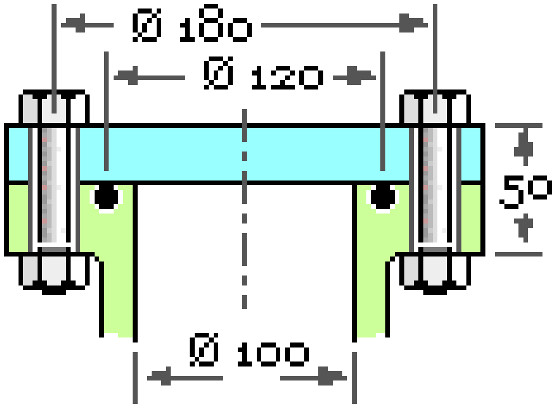
$$T_L = \frac{Fd_m}{2}\left(\frac{\pi f d_m - l}{\pi d_m + fl}\right)$$





Example

The cover of a pressurised cylinder is attached by a self-energising seal and 6 identical bolts M10x1.5 of class 8.8. The fluid pressure is essentially constant at 6 MPa. A safety factor of three is required. Check if the given bolt can sustain the pressure!



P=6MPa 6 class 8.8 M10x1.5

d_s=120 mm N_d=3

$S_t/\sigma=?$

SOLUTION:

Force on the cover caused by the pressure:

$$F_c = p \cdot A_s = p\frac{\pi d_s^2}{4} \qquad F_c = 6 \cdot 10^6 \frac{\pi \cdot 0.12^2}{4} = 67858N = 67.9kN$$

Force on the individual bolt

$$F_b = {F_c}/{6} = {67.9}/{6} \qquad F_b = 11.3kN$$

From tables: Tensile stress area $A_t = 58mm^2$ Proof strength $S_p = 590\,MPa$

Stress on each bolt:

$$\sigma = {F_b}/{A_t} = {11300}/{58} \qquad \sigma = 194MPa$$

$$\frac{S_p}{\sigma} = \frac{590}{194} = 3.04 \approx N_d$$

Selected number of bolts can sustain the load