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ME 1110 – Engineering Practice 1

Engineering Drawing and Design - Lecture 20

Revision Term 2

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

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To revise for 2nd test

- Test for MEA and EME students:
  - » 3rd April 2017 @ 9,00 – OTLT

- Review test examples on Moodle
- Revise lectures 11-18

- Test example

Let us REVISE

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Question 1

Indicate whether the following statements are **True** or **False** by **ticking** the appropriate selection box.

T	F	
	X	Engineering design process is an individual task performed to meet some requirement of humankind.
X		Mechanical design process is the use of scientific principles and technical information to define machine that will optimally perform a required function.
	X	General-purpose elements are components of the same machine which are different in the shape and geometry and carry out different tasks.
	X	The isolated system together with all forces and moments due to any external effects and the reactions with the main system is called equilibrium.
X		Strength is an inherent property of a material built into the part because of the use of a particular material and process.
	X	Stress is a state property of a body which is not a function of load, geometry, temperature and manufacturing processing.
	X	A static load is a force or moment with frequent change in magnitude, point of application and direction that acts on a member of a machine or mechanism
X		A static load can be axial tension, compression, a shear load, a bending load, a torsional load or any combination of these.
	X	If the time of application of load is shorter than three times its natural period, dynamic effects are neglected and the load can be considered static.
X		Factor of safety is ratio between loss of a function load and allowable load. strength and stress of a material.

X		Factor of safety is ratio between strength and stress of a material.
X		Thread pitch is a distance between adjacent thread forms measured parallel to the thread axis.
	X	Metric threads are usually pipe threads.
X		Both metric and unified threads can have coarse and fine pitch.
	X	A component that prevents relative motion between two bodies is called bearing.
	X	Ball bearings take more load then cylindrical bearings.
X		Rating life of a bearing, L_{10} is number of revolution or hours of operation that 90% of a group of identical bearings will achieve or exceed before the failure.
	X	An axle is a rotating element that carries torque and is supported by rotating bearings.
	X	The reason to use gears in speed reducers is because torque is easy to generate, while speed is not.
X		The fundamental premise of gearing is to maintain a constant relative rotation rate of gears.
X		Trusses are structures composed entirely of members that are loaded with forces in two points
X		The method of joints employs the summation of forces at a joint to calculate forces in members.
	X	A failure mode is any event that prevents a functional failure of a machine or a system.
X		Failure effects describe what happens when a failure mode occurs

Question 2

There are eleven (11) general considerations which should be taken into account during a mechanical design of a component or system. These are related to its most important design and manufacturing features. List at least five (5) of these and give their brief explanations.

Answer

1. **Type of load and stresses induced;**

   To design a machine part it is necessary to know the forces, which the part must sustain.

2. **Motion of the parts or kinematics of the machine;**

   Forces and their relations change during the motion of the part. The motion of the part may be:

   –Rectilinear motion
   –Curvilinear motion
   –Constant or variable velocity
   –Constant or variable acceleration

3. **Selection of materials;**

   Body of the component is the material. The designer should have thorough knowledge of the properties of the materials and their behaviour under working conditions.

   Important characteristics of materials are: *strength*, *stiffness/flexibility*, *durability*, *weight*, *resistance to heat*, *corrosion* and *wear*, *ability to cast*, *weld or hardened*, *machinability*, *electrical or magnetic properties* etc.

4. **Form and size of the parts;**

   The smallest practicable cross section may be used;
   Ensure that the stresses induced are reasonably safe.
   Easy to machine. Part or assembly should not involve undue stress concentrations.
   Small weight and minimum dimensions should be the criteria *(shape and material)*

5. **Production soundness;**

   The component should be designed such that its production requires the minimum expenditure of labour and time.

6. **Number to be manufactured;**

The number of components to be manufactured affects the design in a number of ways.

7. **Cost of construction;**

The cost of construction of a part is one of the most important considerations involved in design. The aim is to reduce the manufacturing costs in any circumstance.

8. **Safety;**

The shape and dimensions of the part should ensure safety of the personnel responsible for not only its manufacture but during its operation in a machine also.

9. **Workshop facilities;**

A design engineer should be familiar with the limitations of the available workshop. Here, the policy to manufacture or to by should be decided.

10. **Use of standard parts;**

The use of standard parts is closely related to cost.

The standard or stock *parts* should be used whenever possible:

gears, pulleys, bearings and *screws, bolts, nuts, pins*.

Variety (number and size) of such parts should be as few as possible.

11. **Conformance to standards and codes;**

Any part should confirm to the standards covering the shape, grade and type of material and safety codes where applicable.

Question 3

The design of the assembly in Figure a 'Transition fit', class H7 - k6, between the shaft and the crank housing. The transition fit ensures accurate location and stability under varying loads. Some form of mechanical assistance may be required to fit the crank to the shaft.

Using the BS4500A data sheet provided on the next page complete the table given below determining the max. and min. working limits for the diameter of the hole (bush) and shaft end diameter using:

- Class of fit: **H7 - k6**
- Basic size of **35** mm
- Basic size of **85** mm
- Basic size of your own choice

Also, fill in fields for a maximum and minimum clearance

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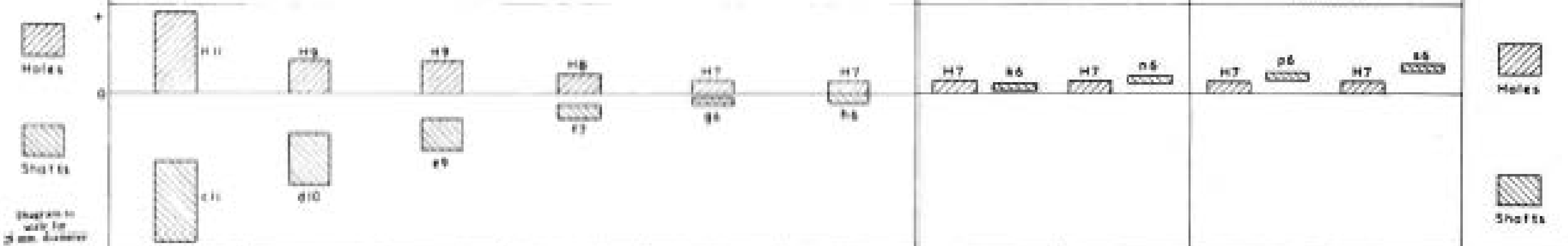
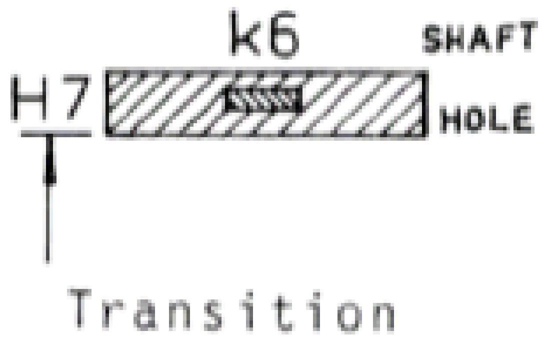
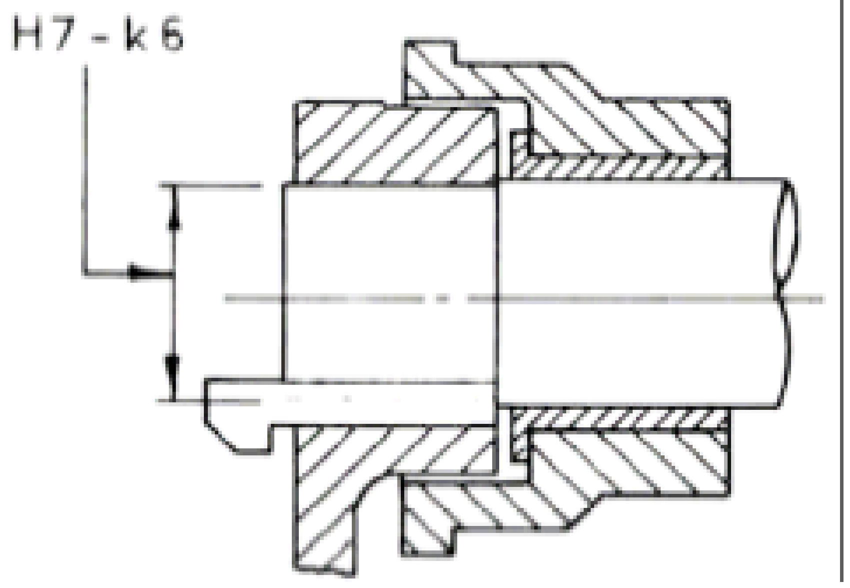


Nominal sizes		Clearance fits												Transition fits				Interference fits				Nominal sizes	
		Tolerance		Tolerance		Tolerance		Tolerance		Tolerance		Tolerance		Tolerance		Tolerance		Tolerance		Tolerance			
Over	To	H11	c11	H9	d10	H9	e9	H8	f7	H7	g6	H7	h6	H7	k6	H7	n6	H7	p6	H7	s6	Over	To
mm	mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	0.001 mm	mm	mm
—	3	+60 / 0	−60 / −120	+25 / 0	−20 / −60	+25 / 0	−14 / −39	+14 / 0	−6 / −16	+10 / 0	−2 / −8	+10 / 0	−6 / 0	+10 / 0	+6 / 0	+10 / 0	+10 / +4	+10 / 0	+12 / +6	+10 / 0	+20 / +14	—	3
3	6	+75 / 0	−70 / −145	+30 / 0	−30 / −78	+30 / 0	−20 / −50	+18 / 0	−10 / −22	+12 / 0	−4 / −12	+12 / 0	−8 / 0	+12 / 0	+9 / +1	+12 / 0	+16 / +8	+12 / 0	+20 / +12	+12 / 0	+27 / +19	3	6
6	10	+90 / 0	−80 / −170	+36 / 0	−40 / −98	+36 / 0	−25 / −61	+22 / 0	−13 / −28	+15 / 0	−5 / −14	+15 / 0	−9 / 0	+15 / 0	+10 / +1	+15 / 0	+19 / +10	+15 / 0	+24 / +15	+15 / 0	+32 / +23	6	10
10	18	+110 / 0	−95 / −205	+43 / 0	−50 / −120	+43 / 0	−32 / −75	+27 / 0	−16 / −34	+18 / 0	−6 / −17	+18 / 0	−11 / 0	+18 / 0	+12 / +1	+18 / 0	+23 / +12	+18 / 0	+29 / +18	+18 / 0	+39 / +28	10	18
18	30	+130 / 0	−110 / −240	+52 / 0	−65 / −149	+52 / 0	−40 / −92	+33 / 0	−20 / −41	+21 / 0	−7 / −20	+21 / 0	−13 / 0	+21 / 0	+15 / +2	+21 / 0	+28 / +15	+21 / 0	+35 / +22	+21 / 0	+48 / +35	18	30
30	40	+160 / 0	−120 / −280	+62 / 0	−80 / −180	+62 / 0	−50 / −112	+39 / 0	−25 / −50	+25 / 0	−9 / −25	+25 / 0	−16 / 0	+25 / 0	+18 / +2	+25 / 0	+33 / +17	+25 / 0	+42 / +26	+25 / 0	+59 / +43	30	40
40	50	+160 / 0	−130 / −290																			40	50
50	65	+190 / 0	−140 / −330	+74 / 0	−100 / −220	+74 / 0	−60 / −134	+46 / 0	−30 / −60	+30 / 0	−10 / −29	+30 / 0	−19 / 0	+30 / 0	+21 / +2	+30 / 0	+39 / +20	+30 / 0	+51 / +32	+30 / 0	+72 / +53	50	65
65	80	+190 / 0	−150 / −340																	+30 / 0	+78 / +59	65	80
80	100	+220 / 0	−170 / −390	+87 / 0	−120 / −260	+87 / 0	−72 / −159	+54 / 0	−36 / −71	+35 / 0	−12 / −34	+35 / 0	−22 / 0	+35 / 0	+25 / +3	+35 / 0	+45 / +23	+35 / 0	+59 / +37	+35 / 0	+93 / +71	80	100
100	120	+220 / 0	−180 / −400																	+35 / 0	+101 / +79	100	120
120	140	+250 / 0	−200 / −450	+100 / 0	−145 / −305	+100 / 0	−85 / −185	+63 / 0	−43 / −83	+40 / 0	−14 / −39	+40 / 0	−25 / 0	+40 / 0	+28 / +3	+40 / 0	+52 / +27	+40 / 0	+68 / +43	+40 / 0	+117 / +92	120	140
140	160	+250 / 0	−210 / −460																	+40 / 0	+125 / +100	140	160
160	180	+250 / 0	−230 / −480																	+40 / 0	+133 / +108	160	180
180	200	+290 / 0	−240 / −530	+115 / 0	−170 / −355	+115 / 0	−100 / −215	+72 / 0	−50 / −96	+46 / 0	−15 / −44	+46 / 0	−29 / 0	+46 / 0	+33 / +4	+46 / 0	+60 / +31	+46 / 0	+79 / +50	+46 / 0	+151 / +122	180	200
200	225	+290 / 0	−260 / −550																	+46 / 0	+159 / +130	200	225
225	250	+290 / 0	−280 / −570																	+46 / 0	+169 / +140	225	250
250	280	+320 / 0	−300 / −620	+130 / 0	−190 / −400	+130 / 0	−110 / −240	+81 / 0	−56 / −108	+52 / 0	−17 / −49	+52 / 0	−32 / 0	+52 / 0	+36 / +4	+52 / 0	+66 / +34	+52 / 0	+88 / +56	+52 / 0	+190 / +158	250	280
280	315	+320 / 0	−330 / −650																	+52 / 0	+202 / +170	280	315
315	355	+360 / 0	−360 / −720	+140 / 0	−210 / −440	+140 / 0	−125 / −265	+89 / 0	−62 / −119	+57 / 0	−18 / −54	+57 / 0	−36 / 0	+57 / 0	+40 / +4	+57 / 0	+73 / +37	+57 / 0	+98 / +62	+57 / 0	+226 / +190	315	355
355	400	+360 / 0	−400 / −760																	+57 / 0	+244 / +208	355	400
400	450	+400 / 0	−440 / −840	+155 / 0	−230 / −480	+155 / 0	−135 / −290	+97 / 0	−68 / −131	+63 / 0	−20 / −60	+63 / 0	−40 / 0	+63 / 0	+45 / +5	+63 / 0	+80 / +40	+63 / 0	+108 / +68	+63 / 0	+272 / +232	400	450
450	500	+400 / 0	−480 / −880																	+63 / 0	+292 / +252	450	500
		Slack fit		Loose fit		Easy fit		Normal fit		Close fit		Slide fit		Push fit		Drive fit		Press fit		Force fit			

Tolerance H7 (0·001 mm)	Tolerance k6 (0·001 mm)	Nominal sizes Over (mm)	Nominal sizes To (mm)
+10 0	+6 +0	—	3
+12 0	+9 +1	3	6
+15 0	+10 +1	6	10
+18 0	+12 +1	10	18
+21 0	+15 +2	18	30
+25 0	+18 +2	30	40
		40	50
+30 0	+21 +2	50	65
		65	80
+35 0	+25 +3	80	100
		100	120





Hole					Shaft					Clearance	
Basic size	Upper tol.	Lower tol.	Max. size	Min. size	Basic size	Upper tol.	Lower tol.	Max. size	Min. size	Min	Max
ϕ35	+0.025	0	35.025	35.0	ϕ35	+0.018	+0.002	35.018	35.002	-.018	+.023
ϕ85	+0.035	0	85.035	85.0	ϕ85	+0.025	+0.003	85.025	85.003	-.025	+.032
ϕ					ϕ						

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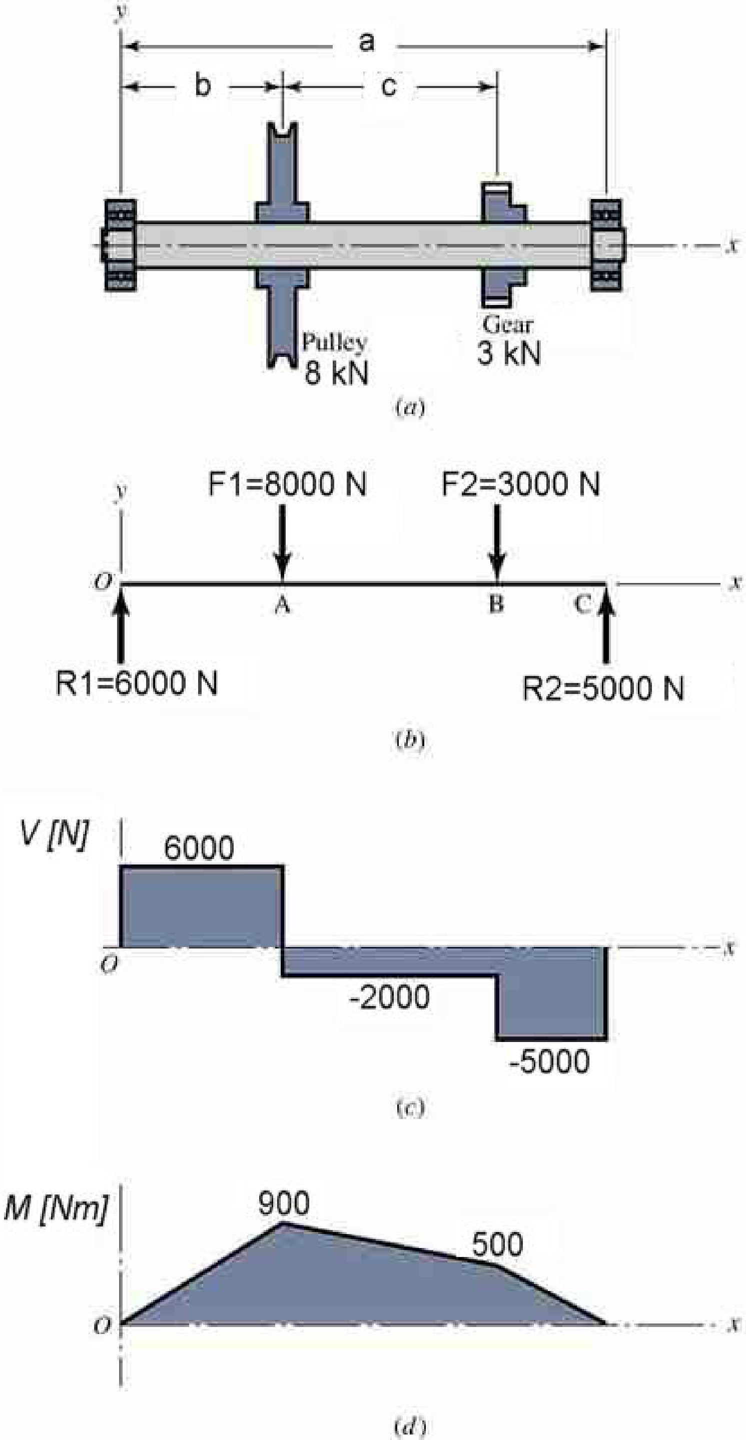
Example Shaft



Determine the diameter for the solid round shaft 450 mm long, as shown in Figure. The shaft is supported by self-aligning bearings at the ends. Mounted upon the shaft are a V-belt pulley, which contributes a radial load of F_1=8kN to the shaft, and a gear which contributes a radial load of F2=3kN. The two loads are in the same plane and have the same directions. The allowable bending stress (strength) is S=170 MPa. Assume factor of safety 1.5.

F1=8 kN; F2=3 kN

a=450 mm b=150 mm

c=200 mm

S=170 Mpa f=1.5

d=?

SOLUTION:

Assumptions

- the weight of the shaft is neglected
- the shaft is designed for the normal bending stress in the location of max. bending moment

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Shaft formulas

Bending stress

$$\sigma_z = \frac{M}{Z} = \frac{Mc}{I} = \frac{32M}{\pi d^3}$$

Torsional stress

$$\tau_{zy} = \frac{T}{S} = \frac{Tc}{J} = \frac{16T}{\pi d^3}$$

Minimum diameter
distortion energy theory

$$d = \sqrt[3]{\frac{32 f_s}{\pi S_y} \sqrt{M^2 + \frac{3}{4} T^2}}$$

$c = d/2$	- maximum span
$I = \pi d^4/64$	- second moment of area
$Z = c/I$	- section modulus
$J = \pi d^4/32$	- second polar moment of area
$S = c/J$	- polar section modulus
f_s	- factor of safety

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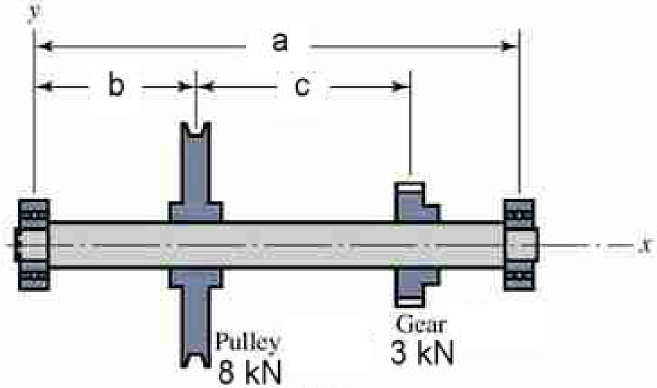
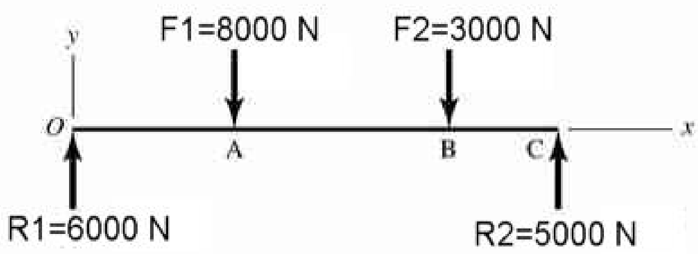
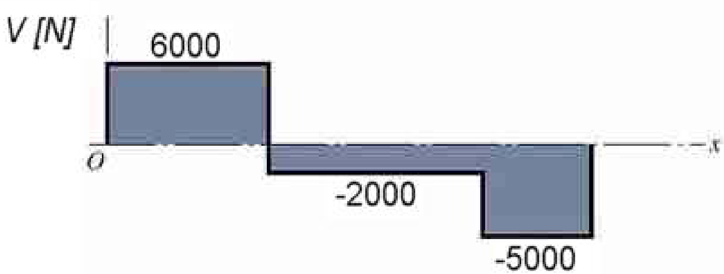
Solution



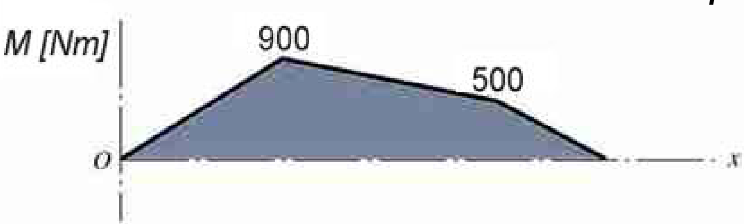
(a)



(b)



(c)



(d)

$$\sum M_c = -a\,R_1 + (a-b)\,F_1 + (a-b-c)\,F_2$$

$$R_1 = 6\,kN$$

$$R_2 = 5\,kN$$

$$M_{\max} = M_A = b \cdot R_1 = 900\ Nm$$

Second moment of area (moment of inertia)

Section modulus = --

max span

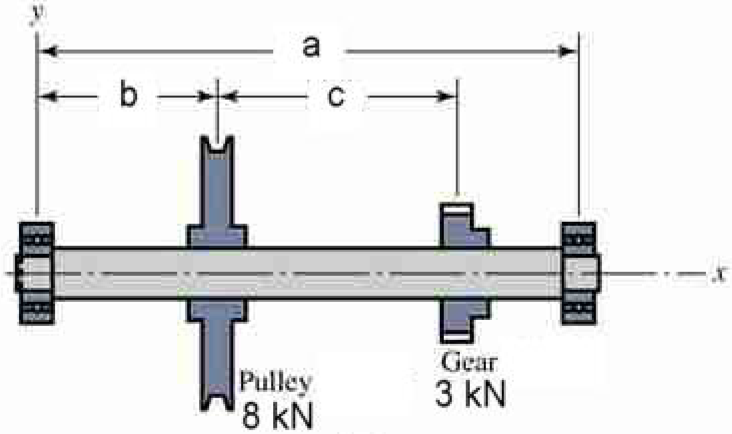
$$I = \frac{\pi d^4}{64} \qquad c = \frac{d}{2}$$

$$Z = \frac{I}{c} = \frac{\pi d^3}{32} \approx 0.1 d^3$$

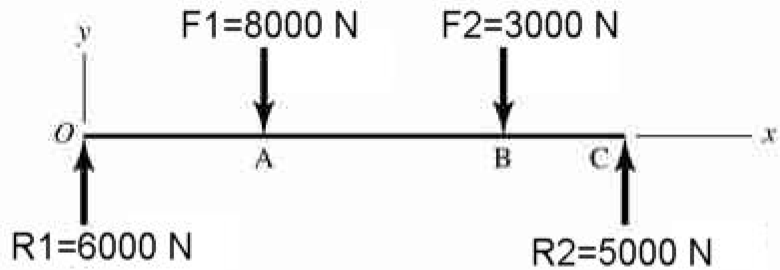
Stress = Strain = Bending moment / section modulus

$$f = S/\sigma \qquad S = f\sigma = f\frac{Mc}{I} = f\frac{M}{Z} = 1.5\frac{900}{0.1 \cdot d^3} = 170 \cdot 10^6$$

$$d = \sqrt[3]{\frac{1.5 \cdot 900}{170 \cdot 10^5}} = 0.01995\,m = 20\,mm$$



(a)



(b)

Example bearings

Select the bearings and determine their rating life for the driving mechanism shown in the Figure. The shaft is 450 mm long and supported by deep-groove bearing in point *O* and plane roller bearing in point *C*. Assume minimum shaft diameter to be 20 mm. Mounted upon the shaft are a V-belt pulley, which contributes a radial load of F_1=8kN to the shaft, and a gear which contributes a radial load of F_2=3kN. The two loads are in the same plane and have the same direction. Minimum required bearing life is 2000 h with 90% reliability. Shaft rotates constantly at n=1000 rpm.

F1=8 kN	a=450 mm	c=200 mm
F2=3 kN	b=150 mm	d=20 mm

$L_{10h}=(L_{10h})_O=(L_{10h})_C$=2000 h   n=1000 rpm

SOLUTION:

$$L_{10h}=\frac{10^6}{60n}\left(\frac{C}{P}\right)^a \Rightarrow C=P*\sqrt[a]{\frac{60n}{10^6}L_{10h}}$$

$$P_O=R_1=6000N \qquad P_C=R_2=5000N$$

$$C_0=6000*\sqrt[3]{\frac{60*1000}{10^6}2000}=29,595N$$

Selected from the catalogue for deep-groove ball bearings:
6404   20x72x19 mm C=30,700 N

$$C_0=5000*\sqrt[3.33]{\frac{60*1000}{10^6}2000}=21,025N$$

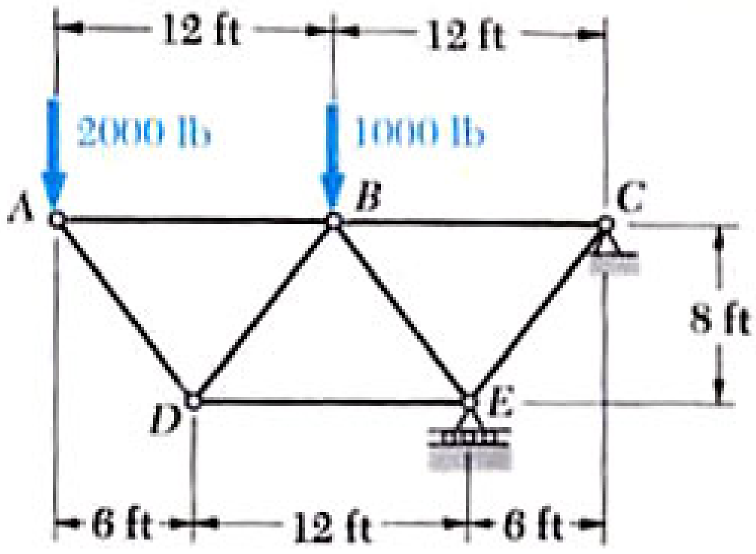
Selected from the catalogue for cylindrical roller bearings:
NU 204 20x47x14 mm   C=25,100 N

Method of Joints –Example

Using the method of joints,

a) Find is the truss determinate

b) the force in each member BD.



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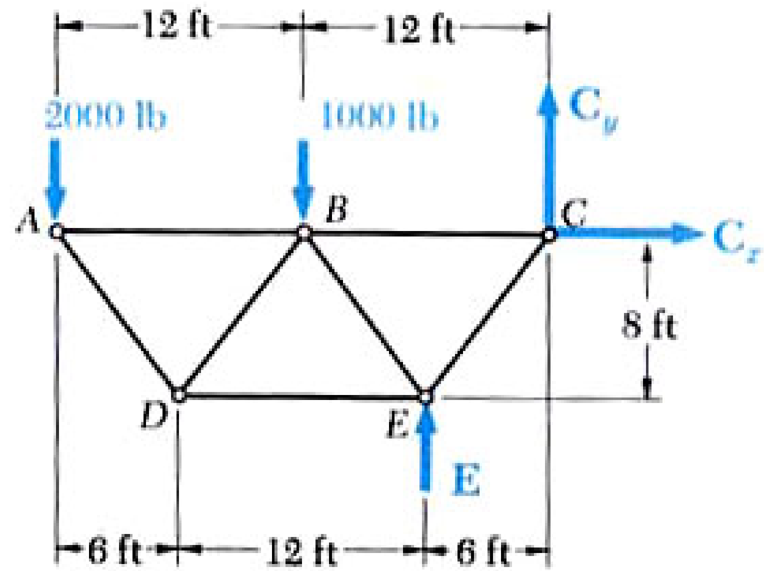
Method of Joints –Example

d=m+r-2·j = 0

Calculate restraint reactions



Draw the free body diagram of the truss and solve for the equations:

$$\sum F_x = 0: \qquad C_x = 0$$

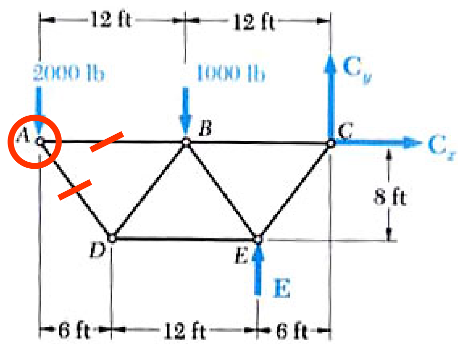
$$\sum F_y = 0: \qquad 2000\text{-}1000 + E + C_y = 0 \Rightarrow E + C_y = 3000 \text{ lb}$$

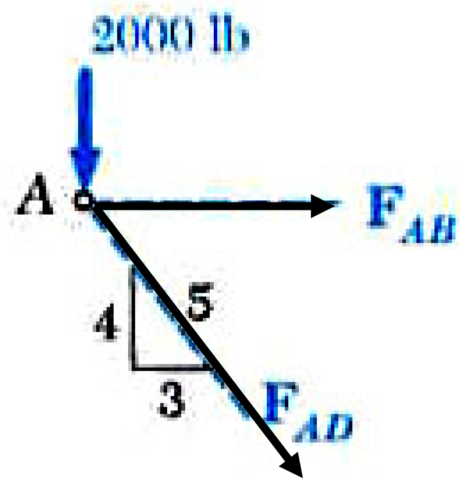
$$\sum M_C = 0: \qquad 2000(24 \text{ ft}) + 1000(12 \text{ ft}) - E(6 \text{ ft}) \Rightarrow E = 10000 \text{ lb}$$

$$C_y = 3000 - 10000 = -7000 \text{ lb}$$

Method of Joints –Example

Joint A





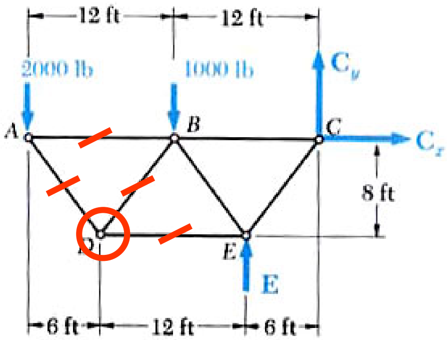
$$\sum F_y = 0 = -\frac{4}{5}F_{AD} - 2000\text{ lb}$$

$$F_{AD} = -2500\text{ lb} \Rightarrow \boxed{F_{AD} = 2500\text{ lb (C)}}$$

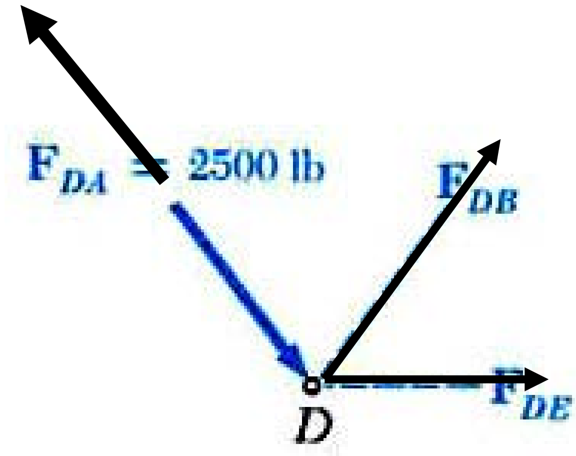
$$\sum F_x = 0 = \frac{3}{5}F_{AD} + F_{AB} = \frac{3}{5}(-2500\text{ lb}) + F_{AB}$$

$$F_{AB} = 1500\text{ lb} \Rightarrow \boxed{F_{AB} = 1500\text{ lb (T)}}$$

Method of Joints –Example



Joint D



$$\sum F_y = 0 = \frac{4}{5}F_{AD} + \frac{4}{5}F_{DB} = \frac{4}{5}(-2500) + \frac{4}{5}F_{DB}$$

$$F_{DB} = 2500\text{ lb} \Rightarrow \boxed{F_{DB} = 2500\text{ lb}(T)}$$

$$\sum F_x = 0 = -\frac{3}{5}F_{AD} + \frac{3}{5}F_{DB} + F_{DE} = \frac{-3}{5}(-2500) + \frac{3}{5}(2500) + F_{DE}$$

$$F_{DE} = -3000\text{ lb} \Rightarrow \boxed{F_{DE} = 3000\text{ lb}(C)}$$

Example screws

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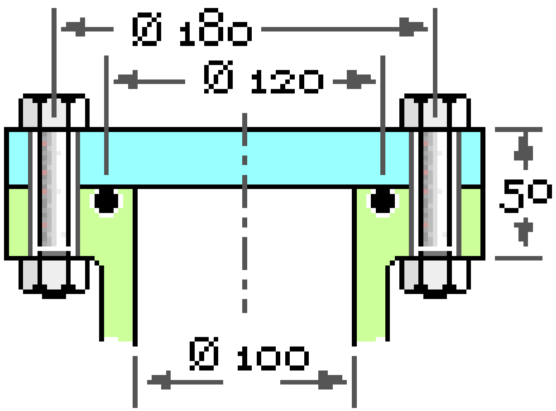
The cover of a pressurised cylinder is attached by a self-energising seal and 6 identical bolts M10x1.5 of class 8.8. The fluid pressure is essentially constant at 6 MPa. A safety factor of three is required. Check if the given bolt can sustain the pressure!



P=6MPa 6 class 8.8 M10x1.5

d_s=120 mm N_d=3

S_t / σ=?

SOLUTION:

Force on the cover caused by the pressure: $F_c = p \cdot A_s = p \frac{\pi d_s^2}{4}$ $F_c = 6 \cdot 10^6 \frac{\pi \cdot 0.12^2}{4} = 67858N = 67.9kN$

Force on the individual bolt $F_b = F_c / 6 = 67.9 / 6$ $F_b = 11.3kN$

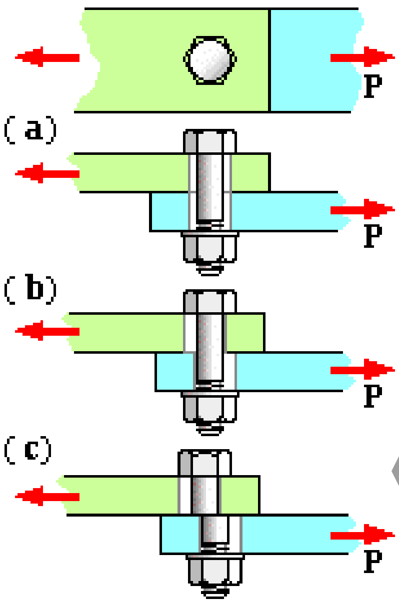
From tables: Tensile stress area $A_t = 58mm^2$ Proof strength $S_p = 590\,MPa$

Stress on each bolt: $\sigma = F_b / A_t = 11300 / 58$ $\sigma = 194MPa$

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

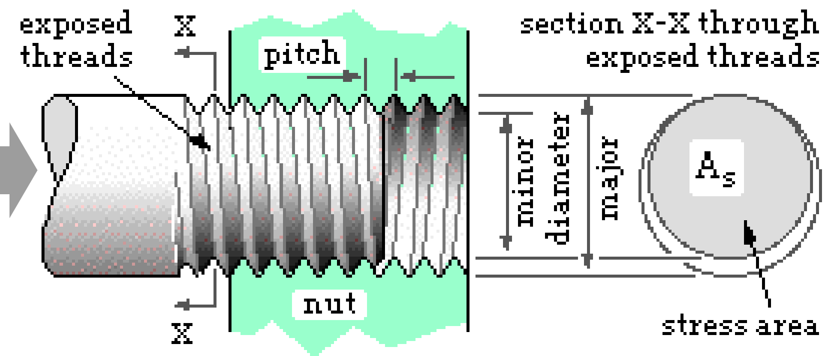
Selected number of bolts can sustain the load

Load that a bolt can sustain



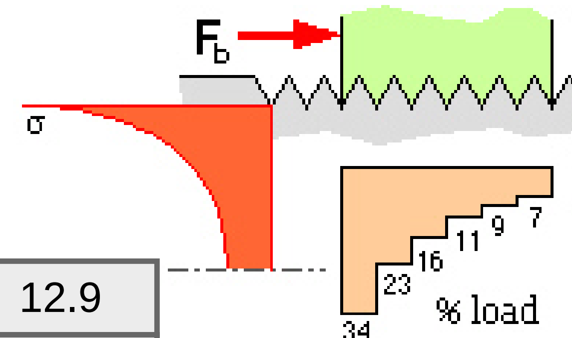
Tensile stress:

$$\sigma = {F_b}/{A_t}$$



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

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