For d = 36 mm; σ_t = 200 MPa

From table 2.2 for M36 bolt, $A_C = 817\ mm^2$

Safe tensile load, $P = \sigma_t A_C$

$= 200 \times 817$

$= 163400$ N

$= 163.4$ KN **Ans**

Problem 2.4 : An eye bolt carries a tensile load of 20 KN. Find the size of the bolt; if the tensile stress is not to exceed 100 MPa.

Solution : Given : P = 20 KN = 20×10^3 N; σ_t = 100 MPa = 100 N/mm²

$$\sigma_t = \frac{P}{\frac{\pi}{4} d_C^2}$$

$$\therefore \quad d_c = \sqrt{\frac{4 \times P}{\pi \times \sigma_t}}$$

$$= \sqrt{\frac{4 \times 20 \times 10^3}{\pi \times 100}}$$

$$= 15.9567 \text{ mm}$$

From table 2.2 (coarse series),

d_c = 16.933 mm

∴ Size of bolt = M 20 **Ans**

or d = 20 mm

Problem 2.5 : Two machine parts are fastened together tightly by means of a 22 mm t bolt. If the load tending to separate these parts are neglected, find the stress that set up in the bolt by initial tightening.

Solution : Given : d = 22 mm

From table 2.2 for M 22 bolt d_c = 18.933 mm

∴ Initial tension in the bolt

$P_1 = 2840 \times d$

$= 2840 \times 22 = 62480$ N

Also initial tension

$$P_1 = \frac{\pi}{4} d_c^2 \times \sigma_t$$

$$\therefore \quad 62480 = \frac{\pi}{4} d_c^2 \times \sigma_t$$

$$\therefore \quad \sigma_t = \frac{62480}{\frac{\pi}{4}(18.933)^2} = 222 \text{ MPa} \quad \textbf{Ans}$$

Problem 2.6 : Two machine parts are fastened together tightly by means of a 25 mm tap bolt. If the load tending to separate these parts are neglected, find the stress that is set up in the bolt by initial tightening. **(May 2012)**

Solution : Given : d = 25 mm

From the data book, table 9.8;

For M 25, $d_c = 21.319$

Initial tension $P_1 = 2840 \times d$

$= 2840 \times 25$

$= 71000$ N

Also we know that, initial tension

$$P_1 = \frac{\pi}{4} d_c^2 \times \sigma_t = \frac{\pi}{4}(21.319)^2 \times \sigma_t$$

$$\therefore \quad 71000 = \frac{\pi}{4}(21.319)^2 \sigma_t$$

$$\therefore \quad \sigma_t = \frac{71000}{\frac{\pi}{4}(21.319)^2} = 199 \text{ MPa} \quad \textbf{Ans}$$

Problem 2.7 : An eye bolt is to be used to lift a load of 70 KN. Calculate the nominal diameter of the bolt, if the tensile stress is not to exceed 100 MPa. Assume coarse thread.

Solution : Given : P = 70 KN, σ_t = 100 MP

We know that,

$$P = \frac{\pi}{4} d_c^2 \times \sigma_t$$

$$\therefore \quad 70 \times 10^3 = \frac{\pi}{4} d_c^2 \times 100$$

$$\therefore \quad d_c = \sqrt{\frac{4 \times 70 \times 10^3}{\pi \times 100}} = 29.85 \text{ mm}$$

From data book table 9.8 (coarse series) we find standard nearest core diameter (d_c) is 31.09 mm and corresponding nominal diameter with 4 mm pitch is

$d = 36$ mm **Ans**

OR $d = 1.2 d_c = 1.2 \times 29.85 = 35.82 \simeq 36$ mm i.e., M 36 bolt.

Problem 2.8 : Two shafts are connected by means of flange coupling to transmit torque of 25 N-m. The flanges of the coupling are fastened by four bolts of the same material at a radius of 30 mm. Find the size of the bolt if the allowable shear stress for the bolt material is 40 MPa.

Solution : $T = 25$ N-m $= 25 \times 10^3$ N-mm; $n = 4$; $R_P = 30$ mm;

$\tau = 40$ MPa $= 40$ N/mm^2

The shearing load carried by the flange coupling,

$$P_S = \frac{T}{R_P} = \frac{25 \times 10^3}{30} = 833.3 \text{ N}$$

Resisting load on bolts,

$$= \frac{\pi}{4} d_c^2 \times \tau \times n$$

$$= \frac{\pi}{4} d_c^2 \times 40 \times 4$$

$$\therefore \quad 833.3 = \frac{\pi}{4} d_c^2 \times 40 \times 4$$

$$\therefore \quad d_c = \sqrt{\frac{833.3 \times 4}{\pi \times 40 \times 4}} = 2.575 \text{ mm}$$

From table 9.8, for $d_c = 3.141$ mm the selected bolt is M 4.

Problem 2.9 : A bolt in a steel structure is subjected to a tensile load of 9 KN. The initial tightening load on the bolt is 5 KN. Determine the size of the bolt taking allowable stress for the bolt material to be 80 MPa and K = 0.05. **(Dec. 2012)**

Solution : Given : $P_2 = 9$ KN = 9000 N; $P_1 = 5$ KN = 5000 N;

$\sigma = 80$ MPa = 80 N/mm²

The resultant axial load

$$P = P_1 + KP_2$$

$$= 5000 + 0.05 \times 9000 = 5450 \text{ N}$$

Since $P_2 > P_1$ Take final load on bolt as P_2

$$\therefore \quad P_2 = 9000 \text{ N}$$

$$\therefore \quad \sigma = \frac{P_2}{\frac{\pi}{4} d_c^2}$$

$$\therefore \quad d_c = \sqrt{\frac{P_2 \times 4}{\pi \times \sigma}} = \sqrt{\frac{9000 \times 4}{\pi \times 80}} = 11.968 \text{ mm}$$

From table 9.8 for core diameter (d_c) = 11.968 mm, the selected bolt is M 14 × 1.5 and corresponding d_c = 12.1596 mm.

Problem 2.10 : The cylinder head of a steam engine is subjected to a steam pressure of 0.7 N/mm². It is held in position by means of 12 bolts. A soft copper gasket is used to make the joint leak proof. The effective diameter of cylinder is 300 mm. Find the size of the bolts so that the stress in the bolts is not to exceed 100 MPa.

Solution : Given : P = 0.7 N/mm²; n = 12; D = 300 mm;

σ_t = 100 MPa = 100 N/mm²

$$\text{The external load on 12 bolts} = \frac{\pi}{4} D^2 \times P$$

$$= \frac{\pi}{4} \times (300)^2 \times 0.7$$

$$= 49480 \text{ N}$$

$$\text{External load/bolt} \quad P_2 = \frac{49480}{12}$$

$$= 4123 \text{ N}$$

$\therefore$ Initial tension due to tightening

$$P_1 = 2840 \, d$$

From table 2.1 for soft copper gasket with long through bolts K = 0.5

$$\therefore \quad P = P_1 + KP_2$$

$$= 2840 \times d + 0.5 \times 4123$$

$$= [(2840 \times d) + 2061.5] \text{ N}$$

$$\text{But,} \quad P = \frac{\pi}{4}(d_c)^2 \times \sigma_t$$

$$= \frac{\pi}{4}(0.84d)^2 \times 100 \quad (\text{taking } d_c = 0.84d)$$

$$= 55.4\, d^2$$

$$\therefore \quad 55.4d^2 = (2840 \times d) + 2061.5$$

$$55.4d^2 - 2840d - 2061.5 = 0$$

$$d^2 - 51.3d - 37.2 = 0$$

$$\therefore \quad d = \frac{51.3 \pm \sqrt{(51.3)^2 - 4 \times 1 \times (-37.2)}}{2 \times 1}$$

$$= \frac{51.3 \pm 52.7}{2} = 52 \text{ mm} \quad (\text{Taking } +\text{ve sign})$$

$\therefore$ bolt size is M 52 **Ans**

Problem 2.11 : The cylinder head of a steam engine is subjected to a steam pressure of 0.8 N/mm². It is held in position by means of 12 bolts. A soft copper gasket is used to make the joint leak-proof. The effective diameter of cylinder is 350 mm. Find the size of the bolts so that the stress in the bolts is not to exceed 100 MPa.

Solution : Given : $p = 0.8$ N/mm²; $n = 12$; $D = 350$ mm;

$$\sigma_t = 100 \text{ MPa} = 100 \text{ N/mm}^2$$

External load on 12 bolt $= \frac{\pi}{4} D^2 \times p = \frac{\pi}{4} \times 350^2 \times 0.8 = 76969$ N

External load/bolt $P_2 = \frac{76969}{12} = 6414$ N

Initial tension due to tightening

$$P_1 = 2840\, d$$

Problem 2.13 : A steam engine cylinder has an effective diameter of 350 mm and maximum steam pressure acting on the cylinder cover is 1.25 N/mm². Calculate the number and size of studs required to fix the cylinder cover. Assume the permissible stress in studs is 33 MPa. **(May 2013)**

Solution : Given : $D = 350$ mm; $p = 1.25$ N/mm²;

$$\sigma_t = 33 \text{ MPa} = 33 \text{ N/mm}^2$$

Upward force acting on cylinder cover

$$P = \frac{\pi}{4} D^2 \times p = \frac{\pi}{4} 350^2 \times 1.25 = 120265 \text{ N} \quad \ldots (1)$$

Assuming diameter of studs $d = 22$ mm

From table (course series) at $d = 22$ mm, $d_c = 18.933$ mm

Resisting force offered by n studs

$$P = \frac{\pi}{4} d_c^2 \times \sigma_t \times n = \frac{\pi}{4}(18.933)^2 \times 33 \times n = 9290.5 \text{ n} \quad \ldots (2)$$

Equating (1) and (2)

$$\therefore \quad 120265 = 9290.5 \text{ n}$$

$$n = \frac{120265}{9290.5}$$

$$\therefore \quad n = 12.9 \text{ say } 13 \text{ Nos.}$$ **Ans**

Taking diameter of stud hole $d_1 = 23$ mm and

Assuming $t = 10$ mm

$$\therefore \quad D_P = D + 2t + 3d_1$$

$$= 350 + 2 \times 10 + 3 \times 23 = 439 \text{ mm}$$

$\therefore$ Circumferential pitch of the studs

$$= \frac{\pi D_P}{n} = \frac{\pi \times 439}{13} = 106 \text{ mm}$$

For leak proof joint,

$20\sqrt{d_1}$ < circumferential pitch of the studs < $30\sqrt{d_1}$.

$$\therefore \quad 20\sqrt{d_1} = 20\sqrt{23} = 95.91 \text{ mm}$$

$$30\sqrt{d_1} = 30\sqrt{23} = 143.8 \text{ mm}$$

Since $20\sqrt{d_1} < 106 < 30\sqrt{d_1}$.

Therefore the chosen diameter of stud $d = 22$ mm is satisfactory. **Ans**

Problem 2.16 : An engine cylinder is 300 mm in diameter and the steam pressure is 0.7 N/mm². If the cylinder head is held by 12 studs. Find the size. Assume safe tensilė stress as 28 MPa.

Solution : Given : D = 300 mm; P = 0.7 N/mm²; n = 12;

σ_t = 20 MPa = 20 N/mm²

Upward force on cylinder cover

$$P = \frac{\pi}{4} D^2 p$$

$$= \frac{\pi}{4}(300)^2 \times 0.7 = 49480 \text{ N}$$

Taking diameter of the stud hole d_1 = 25 mm

Assuming t = 10 mm

$$D_P = D + 2t + 3d_1$$

$$= 300 + 2\times10 + 3\times25$$

$$= 395 \text{ mm}$$

Circumferential pitch of the bolts

$$= \frac{\pi D_P}{n}$$

$$= \frac{\pi \times 395}{12} = 103.41 \text{ mm}$$

For leak proof joint, the circumferential pitch of the studs should be betwe $20\sqrt{d_1}$ to $30\sqrt{d_1}$.

∴ Minimum circumferential pitch of the studs

$$= 20\sqrt{d_1} = 20\sqrt{25} = 100 \text{ mm}$$

Maximum circumferential pitch of the studs

$$= 30\sqrt{d_1} = 30\sqrt{25} = 150 \text{ mm}$$

Since 100 < 103.41 < 150 mm

Therefore, the size of the stud, d = 24 mm is satisfactory. **Ans**

Problem 2.17 : A steam engine cylinder of 400 mm diameter is supplied with steam pressure at 1.25 N/mm². The cylinder cover is fastened by means of 12 studs of M 20. The joint is made leak proof by using suitable gasket. Find the stress produced in the studs. Assume K = 0.5. **(May 2012)**

Solution : Given : D = 400 mm; p = 1.25 N/mm²; n = 12; d = 20 mm;

The external load on 12 bolts $= \frac{\pi}{4} D^2 \times p = \frac{\pi}{4} 400^2 \times 1.25 = 157079$ N

External load/bolt $\quad P_2 = \frac{157079}{12} = 13090$ N

∴ Initial tension due to tightening;

$$P_1 = 2840 \times d = 2840 \times 20 = 56800 \text{ N}$$

$$\therefore \quad P = P_1 + P_2 \times K$$

$$= 56800 + 13090 \times 0.5$$

$$= 63345 \text{ N} \quad \ldots (1)$$

From the table 2.2 For M 20 bolt (coarse series)

$$d_c = 16.933 \text{ mm}$$

Resisting force/bolts $\quad P = \frac{\pi}{4} d_c^2 \times \sigma_t = \frac{\pi}{4}(16.933)^2 \times \sigma_t = 225.19\,\sigma_t \quad \ldots (2)$

Equating (1) and (2)

$$\therefore \quad 63345 = 225.19 \times \sigma_t$$

$$\therefore \quad \sigma_t = \frac{63345}{225.19} = 281.29 \text{ N/mm}^2 \quad \textbf{Ans}$$

Problem 2.18 : The cylinder head of a steam engine subjected to a steam pressure of 1.25 N/mm². It is held in position by means of 14 studs. Find the size of the studs. Assume soft copper gasket for leak proof joint. The effective dia of the cylinder is 400 mm. The ultimate stress in the studs as 300 MPa. Assume factor of safety as 5. **(Dec. 2013)**

Solution : Given : p = 1.25 N/mm²; n = 14; D = 400 mm;

σ_{ut} = 300 MPa; F.O.S. = 5

Working stress $\quad \sigma_t = \frac{\sigma_{ut}}{FOS} = \frac{300}{5} = 60 \text{ MPa} = 60 \text{ N/mm}^2$

For soft copper gasket K = 0.5

The external load on 14 bolts

$$= \frac{\pi}{4} D^2 \times p = \frac{\pi}{4} \times 400^2 \times 1.25 = 157079 \text{ N}$$

External load/bolt $P_2 = \frac{157079}{14} = 11220$ N

Initial tension in bolt due to tightening

$$P_1 = 2840\, d$$

$$\therefore \quad P = P_1 + P_2.K$$

$$= 2840d + 0.5 \times 11220$$

$$= 2840d + 5610 \quad \ldots (1)$$

Resisting force/bolt $P = \frac{\pi}{4}(d_c)^2 \sigma_t$

$$= \frac{\pi}{4}(0.84\, d)^2 \times 60 \quad [\text{Taking } d_c = 0.84\, d]$$

$$= 33.25\, d^2 \quad \ldots (2)$$

Equating (1) and (2)

$$33.25\, d^2 = 2840\, d + 5610$$

$$d^2 - 85.41\, d - 168.72 = 0$$

b = -85.41

c = -168.72

$$\therefore \quad d = \frac{-(-85.41) \pm \sqrt{(-85.41)^2 - 4 \times 1 \times (-168.72)}}{2 \times 1}$$

$$= \frac{85.41 \pm \sqrt{(-85.41)^2 + 4 \times 168.72}}{2}$$

$$= 87.31 \text{ mm}$$

Therefore the size of bolt d = 90 mm i.e., M 90. **Ans**

Problem 2.19 : The head of a steam engine cylinder 600 mm diameter is subjected to a steam pressure of 1.3 N/mm². The head is held in leak proof by 16 bolts of M 39. A hard copper gasket is used to make the joint leak proof. Determine the probable stress in the bolt.

Solution : Given : D = 600 mm; p = 1.3 N/mm²; n = 16; d = 39 mm;

For hard copper gasket K = 0.25

Initial tension in the bolt due to tightening

$$P_1 = 2840 \times d = 2840 \times 39 = 110760 \text{ N}$$

Upward force acting on each bolt of a cylinder head

$$P_2 = \frac{\pi D^2 \times p}{4 \times n} = \frac{\pi \times 600^2 \times 1.3}{4 \times 16} = 23000 \text{ N}$$

$$\therefore \quad P = P_1 + P_2 \times K$$

$$= 110760 + 23000 \times 0.25 = 116520 \text{ N}$$

From table 2.2 the stress area for M 39 bolt a_c = 976 mm

Stress in the bolt

$$\sigma_t = \frac{P}{a_c} = \frac{116520}{976} = 119.3 \text{ N/mm}^2 \quad \textbf{Ans}$$

Problem 2.20 : The bore of a hydraulic cylinder is 300 mm and the maximum pressure to which the cylinder is subjected to is 1.4 N/mm². Calculate the number of bolts required to fasten the cover to the cylinder. The permissible stress in the bolts is 40 N/mm². The pitch circle dia of bolt is 400 mm and the pitch of the bolt is $20\sqrt{d}$ where d is core dia of bolt in mm. Take nominal dia = 1.2 d. **(Nov. 2011)**

Solution : Given : D = 300 mm; p = 1.4 N/mm²; σ_t = 40 N/mm²;

D_p = 400 mm; pitch of bolt = $20\sqrt{d_c}$; nominal dia d = $1.2d_c$

$$\therefore \quad d_c = \frac{1}{1.2} d = 0.84d$$

$$\text{Pitch of bolts} = \frac{\pi D_P}{n}$$

$$\text{No. of bolts } n = \frac{\pi D_P}{\text{pitch}} = \frac{\pi \times 400}{20\sqrt{d_c}} = \frac{62.83}{\sqrt{d_c}}$$

Upward force on cylinder cover = Resistance force offered by bolts

$$\frac{\pi}{4} D^2 \times p = \frac{\pi}{4} d_c^2 \times \sigma_t \times n$$

$$\frac{\pi}{4} \times 300^2 \times 1.4 = \frac{\pi}{4} \times (0.84d)^2 \times 40 \times \frac{62.83}{(0.84d)^{1/2}}$$