AKGEC/IAP/FM/02

AJAY KUMAR GARG ENGINEERING COLLEGE, GHAZIABAD

DEPARTMENT OF MECHANICAL ENGINEERING

SESSIONAL TEST-2 (SOLUTION)

Course : B. Tech.
Session: 2017-18
Subject: Machine Design-I
Max. Marks: 50

Semester: V
Section: ME1, ME2, ME3
Subject Code: NME-501
Time: 2 hours

Prepared By: Nirmal Garg

Section-A

Q1 What is notch sensitivity?

Ans Notch Sensitivity → Notch sensitivity is defined as the susceptibility of a material to succumb to the damaging effects of stress raising notches in fatigue loading. the notch sensitivity factor q is defined as

$$q = \frac{\text{Increase of actual stress over nominal stress}}{\text{Increase of theoretical stress over nominal stress}}$$

$$\boxed{q = \frac{K_f - 1}{K_t - 1}}$$

Q2 → What are the methods of reducing stress concentration?

Ans → Methods of reducing stress concentration.

1) Additional notches and holes in tension member.
2) Fillet radius, undercutting and notch for member in bending
3) Drilling additional holes for shaft with a keyway
4) In threaded joint by keeping shank dia up to core dia.

Q3 Describe types of riveted joint. Also explain the various failure modes of rivets.

Ans, types of riveted Joint

- Lap Joint
  - Single Row L.J.
  - Double Row L.J
  - Triple Row L.J
- Butt Joint
  - Single Strap
  - Double Strap
    - SRBJ
    - DRBJ
    - TRBJ

Modes of failure of rivets.

→ Shear failure of rivets.
→ Tearing failure of Plate
→ Crushing failure of Plate.

Q4, Given.

$$\frac{D_i}{D_o} = 0.8$$

$D_o = D$ & made of same material.

We know that

$$\frac{T_H}{T_S} = (1 - k^4)$$

$$T_S = \frac{T_H}{(1-k^4)} = \frac{T_H}{(1-0.8^4)}$$

$$T_S = 1.693\ T_H$$

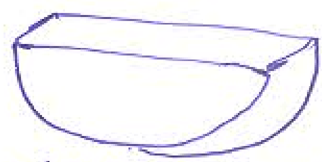
the torque transmitting capacity of ~~hollow~~ solid shaft is 1.693 times more than the ~~solid~~ hollow shaft.

Q5, Explain the function of key. Define woodruff key.

Ans, Function of key, Primary function of key is to transmit torque from shaft to hub and vice-versa.

the secondary function of key is to Prevent the relative rotational motion b/w shaft and hub.

woodruff key is a special type of key, in the form of an almost semicircular disk of uniform.



(woodruff key)

thickness. the keyway in the shaft of a semicircular with the same curvature as that of the key. ②

the key does not permit axial movement between the shaft and hub.

SECTION-B

Q6 A shaft is sub. to bending moment varying from -200 N-m to +500 N-m and a varying torque from +50N-m to +175 N-m. $K_f = 1.85$, $q = 0.95$, R = 95%, fos = 1.5, find the dia of shaft.

Q6 → Given,

$M_{min} = -200 \times 10^3$ N-mm , $M_{max} = 500 \times 10^3$ N-mm.

$T_{min} = 50 \times 10^3$ N-mm , $T_{max} = 175 \times 10^3$ N-mm.

material 30C8 , $K_f = 1.85$

$q = 0.95$, reliability 95%. , FoS = 1.5

$$M_m = \frac{M_{max} + M_{min}}{2} = 150 \times 10^3 \text{ N-mm}$$

$$M_v = \frac{M_{max} - M_{min}}{2} = 350 \times 10^3 \text{ N-mm.}$$

$$T_m = \frac{T_{max} + T_{min}}{2} = 112.5 \times 10^3 \text{ N-mm.}$$

$$T_v = \frac{T_{max} - T_{min}}{2} = 62.5 \times 10^3 \text{ N-mm.}$$

$$\sigma_m = \frac{32 M_m}{\pi d^3} = \frac{1527.88 \times 10^3}{d^3} \frac{N}{mm^2}$$

$$\sigma_v = \frac{32 M_v}{\pi d^3} = \frac{3565.07 \times 10^3}{d^3} \frac{N}{mm^2}$$

$$\tau_m = \frac{572.95 \times 10^3}{d^3} \frac{N}{mm^2}, \quad \tau_v = \frac{318.309 \times 10^3}{d^3} \frac{N}{mm^2}.$$

$$K_f = 1 + q(K_t - 1)$$
$$= 1 + 0.95(1.85 - 1) = 1.8075$$

for material 30C8 → $S_{yt} = 270$ MPa.
$S_{ut} = 490$ MPa.

$$\sigma_{ne} = \sigma_m + \frac{K_f \sigma_v \sigma_{yt}}{\sigma_e}$$

$\sigma_e^* = \frac{S_{ut}}{2} = 245 \text{ MPa}$

$\sigma_e = K_a K_b K_c K_d \sigma_e^*$

let $K_a = 0.75$

$K_b = 1, \quad K_c = 1, \quad K_d = 0.897$

$\sigma_e = 164.82 \text{ MPa}$

$$\sigma_{he} = \frac{1527.88 \times 10^3}{d^3} + \frac{1.8075 \times 3865.07 \times 10^3 \times 270}{d^3 \times 164.82}$$

$$\sigma_{he} = \frac{12083.69}{d^3} \times 10^3 \ \frac{N}{mm^2}$$

$$\tau_{se} = \tau_m + \frac{K_f \tau_v \tau_{yt}}{\tau_e}$$

$\tau_{yt} = 0.5 S_{yt} = 135 \text{ MPa}$

$\tau_e = 0.55 \sigma_e = 90.65 \text{ MPa}$

$$\tau_{se} = \frac{572.95 \times 10^3}{d^3} + 1.8075 \times \frac{318.309 \times 10^3 \times 135}{d^3 \times 90.65}$$

$$\tau_{se} = \frac{1429.77 \times 10^3}{d^3} \ \frac{N}{mm^2}$$

By MPST, $\sigma_{max} \le \frac{S_{yt}}{FOS}$

$$\frac{\sigma_{he}}{2} + \sqrt{\left(\frac{\sigma_{he}}{2}\right)^2 + \tau_{se}^2} \le \frac{S_{yt}}{FOS}$$

$$\frac{12250.55 \times 10^3}{d^3} \le \frac{270}{1.5}$$

$$\boxed{d \ge 40.83 \text{ mm}}$$

By MSST

$$\tau_{max} \le \frac{\tau_{yt}}{FOS}$$

$$\sqrt{\left(\frac{\sigma_{te}}{2}\right)^2 + \tau_{so}^2} \le \frac{S_{yt}}{FoS}$$

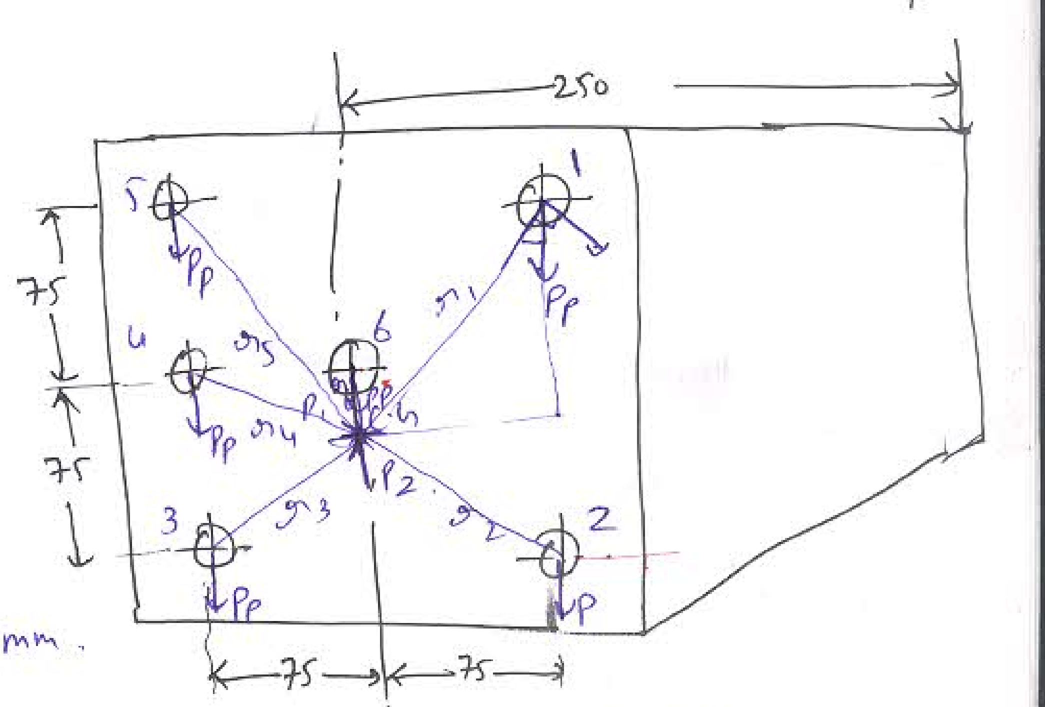
$$\frac{6208.7143 \times 10^3}{d^3} \le \frac{135}{1.5}$$

$$\boxed{d \geq 41.01 \text{ mm}}$$

take $\boxed{d = 42 \text{ mm}}$

Q7 → A bracket is riveted to a column by 6 rivets of equal size as show in fig. it carries a load of 100 KN at distance of 250 mm. If the max shear stress is 63 MPa. find the dia of rivet.

Q7 ⟹ Given.



$P = 100$ KN

$\tau_{per} = 63$ MPa.

1) Find the C.G of group of rivet

$$\bar{x} = \frac{75 + 150 + 75 + 150}{6}$$

$\bar{x} = 75$ mm

$\bar{y} = \frac{75 + 150 \times 2}{6} = 62.5$ mm.

2) Introduce two equal and opposite force on the C.G

$P_1 = P_2 = P$.

3) effect of P_1 $P_p = \frac{P}{6} = 16.66$ KN

4) effect of P_1 & P_2

$$P \times e = \frac{P_{s1}}{r_1} \left[r_1^2 + r_2^2 + r_3^2 + r_4^2 + r_5^2 + r_6^2 \right]$$

Since ① & ⑤ are far away from C.G and rivet 1 is near to the load so rivet 1 is critical.

$P_{s1} = 55.876$ KN

$$\sin(90 - \theta) = \frac{75}{115.244} = 0.6507.$$

$\cos\theta_1 = 0.6507$

$$R_1 = \sqrt{(P_p)^2 + (P_{s1})^2 + 2 P_p P_s \cos\theta_1}$$

$$= 67.905 \text{ KN} = R_{max}$$

for safe design.

$$\frac{R_{max}}{\frac{\pi}{4} d^2} \le C_{pcr}.$$

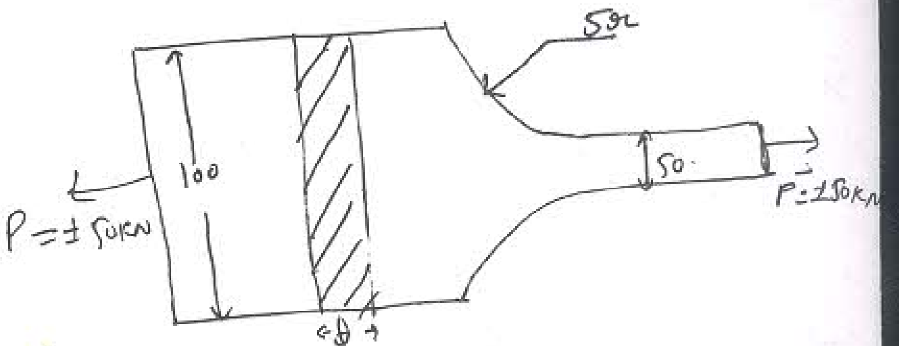
$$\frac{67.905 \times 10^3 \times 4}{\pi d^2} \le 63$$

$$d = 37.0476 \text{ mm}$$

Standard dia of rivet $\boxed{d = 38 \text{ mm}}$

Q8) A component machined from a plate made of steel 45C8 is shown in fig. R = 90%, FoS = 2, Ka = 0.85, Determine the plate thickness t for infinite life, q = 0.8.

S/P given,



$S_{ut} = 600$ MPa

FoS = 2, R = 90%

$q = 0.8$, $K_a = 0.85$, $t = ?$

$\sigma_e' = 0.5 S_{ut} = 300 \ N/mm^2$.

$K_b = 0.87$ (from data book)

Load factor $K_c = 0.8$

for the K_t $\frac{B}{b} = 2$, $\frac{r}{b} = 0.1$

$K_t = 2.26$

$K_f = 1 + q(K_t - 1) = 2.008$

$(\sigma_e)_{without\ notch} = K_a K_b K_c K_d \sigma_e'$

$= 159.199$ mm

$(\sigma_e)_{with\ notch} = \frac{159.199}{K_f} = 79.2823 \ \frac{N}{mm^2}$

$$\sigma_{max} = \frac{P}{b\,t} = \frac{50\times10^3}{50\times t} = \frac{10^3}{t}.$$

We will design for section having $b = 50$ mm since it is small in size.

for safe design $\sigma_{max} \le \frac{(\sigma t)_{\text{with notch}}}{FOS}.$

$$\frac{10^3}{t} \le \frac{79.2823}{2}$$

$$\boxed{t = 25.226 \text{ mm}}$$

Q9) A solid shaft to a bending moment of 3.48 KN-m and torsional moment of 11.5 KN-m the shaft is made of USC8 and FOS 6. Find the diameter of shaft.

9g) Given →

$M = 3.48$ KN-m

$T = 11.5$ KN-m.

material USC8 $\quad S_{yt} = 320$ MPa, $S_{ut} = 620$ MPa. (from data book)

FOS = 6, dia = ?

$$\sigma_{max} = \frac{16}{\pi d^3}\left[M + \sqrt{M^2+T^2}\right]$$

$$= \frac{78.784\times10^6}{d^3}$$

$$\tau_{max} = \frac{16}{\pi d^3}\sqrt{M^2+T^2} = \frac{61.162\times10^6}{d^3}$$

By using MPST $\quad \sigma_{max} \le \sigma_{per}.$

$$\frac{78.784\times10^6}{d^3} \le \frac{320}{6}.$$

$$d \ge 113.88 \text{ mm}$$

By using MSST $\quad \tau_{max} \le \tau_{per}.$

$$\frac{61.162\times10^3}{d^3} \le \frac{1}{6}\left(\frac{320}{2}\right)$$

$$d \ge 131.877 \text{ mm.}$$

Safe dia of shaft $\quad \boxed{d = 132 \text{ mm}}$

Q.10 Define the eff. of rivet Joint & Long. joint for a boiler shell for a steam pressure of 2.5 MPa and dia of 1.35 m and eff of 85%. $\sigma_t = 78$ MPa, $\tau = 62.5$ MPa, $\sigma_c = 135$ MPa.

Q.10 efficiency of riveted Joint → it is defined as the ratio of min. strength of shear str of rivet (P_s), (P_c) & P_t to the St. of solid Plate.

$$\eta_{R.J} = \frac{\min \text{ of } [P_t, P_c, P_s]}{P t \sigma_t}$$

Given → $P = 2.5$ MPa, $\eta_{RJ} = 85\%$

$D = 1.35$ m, $\sigma_t = 78$ MPa, $\tau = 62.5$ MPa, $\sigma_c = 135$ MPa.

1) thickness of Plate →

$$t = \frac{P D}{2 \sigma_t \eta_J} + 1\text{mm.}$$

$$t = 26.45 \text{ mm.}$$

Standard thickness $t = 28$ mm

2) Dia of rivet →

By unwin's formula. $d = 6\sqrt{t} = 31.749$ mm.

$d = 33$ mm

3) Pitch of rivets.

$$P = \frac{(n_1 + 1.875 n_2) \pi d^2 \tau}{4 t \sigma_t} + d.$$

Assuming Joint is triple rivet double strap Butt Joint with equal strap having Pitch in outer row double as the inner row and the rivets are arrange in zigzag fashion.

then $n_1 = 0$, $n_2 = 5$

$P = 262.464$ mm.

$P_{max} = K_1 t + 41$

$K_1 = 6$

$P_{max} = 209$

$P_{max} < P$

So, for safe we take $P_{max} = 209$ mm.

4) Transverse Pitch :-

$(P_t)_{out\ and\ inner\ row} = 0.2P + 1.15d = 78.6$ mm.

$(P_t)_{b/w\ inner\ row} = 0.165P + 0.67d = 55.9$ mm.

5) Thickness of strap :-

$t = 0.625 \left(\frac{P-d}{P-2d}\right) t = 20.439$ mm.

6) Margin :- $m = 1.5d = 49.5$ mm.

Section C

Ques Design a cast iron flange coupling for a mild steel shaft transmitting 90 kw at 250 rpm. the allowable shear stress is 40 MPa and angle of twist is not to be exceed 1° in a length of 20 diameters. the allowable shear stress in the coupling bolts in 30 MPa.

Q11. $P = 90\times10^3$ W , $N = 250$ rpm

$\tau_s = 40$ MPa

$\theta = 1° = \frac{\pi}{180} = 0.0175$ rad

$\tau_b = 30$ MPa

Find dia of Shaft :-

$T = \frac{P\times60}{2\pi N} = 3440\times10^3$ N-mm

$\tau_s = \frac{16T}{\pi D^3}$

$D = 76$ mm.

$\theta = \frac{TL}{GJ}$

$D = 78$ mm.

take $D = 80$ mm

Design for hub :-

$D_1 = 2d = 160$ mm

$L = 1.5d = 120$ mm.

$$T = \frac{\pi}{16}\left[\frac{D_1^4 - D^4}{D}\right] \tau_{max}$$

D_1 = outer Dia of hub $= 2D = 160$ mm

$\tau_{max} = 2.279$ MPa.

$\tau_{max} \leq \tau_{per}$.

Design for hub is safe.

Design for key :-

from data book dia of 80 mm.

$b = 22$ mm, $h = 14$ mm.

$l = L = 120$ mm.

$$T_{max} = \tau_{max}\, b \times l \times \frac{D}{2}$$

$\tau_{max} = 15.626$ MPa.

$\tau_{max} < \tau_{per}$ (40 MPa)

therefore design for key is safe.

Design for flange :-

$$T = \tau_{max} \frac{\pi D_1^2\, t}{2}$$

$t = 0.35D + 9 = 37$ mm.

$\tau_{max} = 2.3105$ MPa.

$\tau_{max} < \tau_{per}$ (14 MPa)

Design of flange is safe.

Design for bolt :-

No. of bolt $= 0.02D + 3 = 4.6$

take $i = 6$

dia of bolt $d = \frac{0.5D}{\sqrt{i}} = 17.88$

Considering Bolt dia ~~M20~~ M18

$$T = \frac{\tau_{max}\, \pi\, i\, d^2\, D_2}{8}$$

$D_2 = 3D = 240$ mm.

$$3437.74\times10^3 = \frac{\tau_{max}\, \pi \times 6 \times 18^2 \times 240}{8}$$

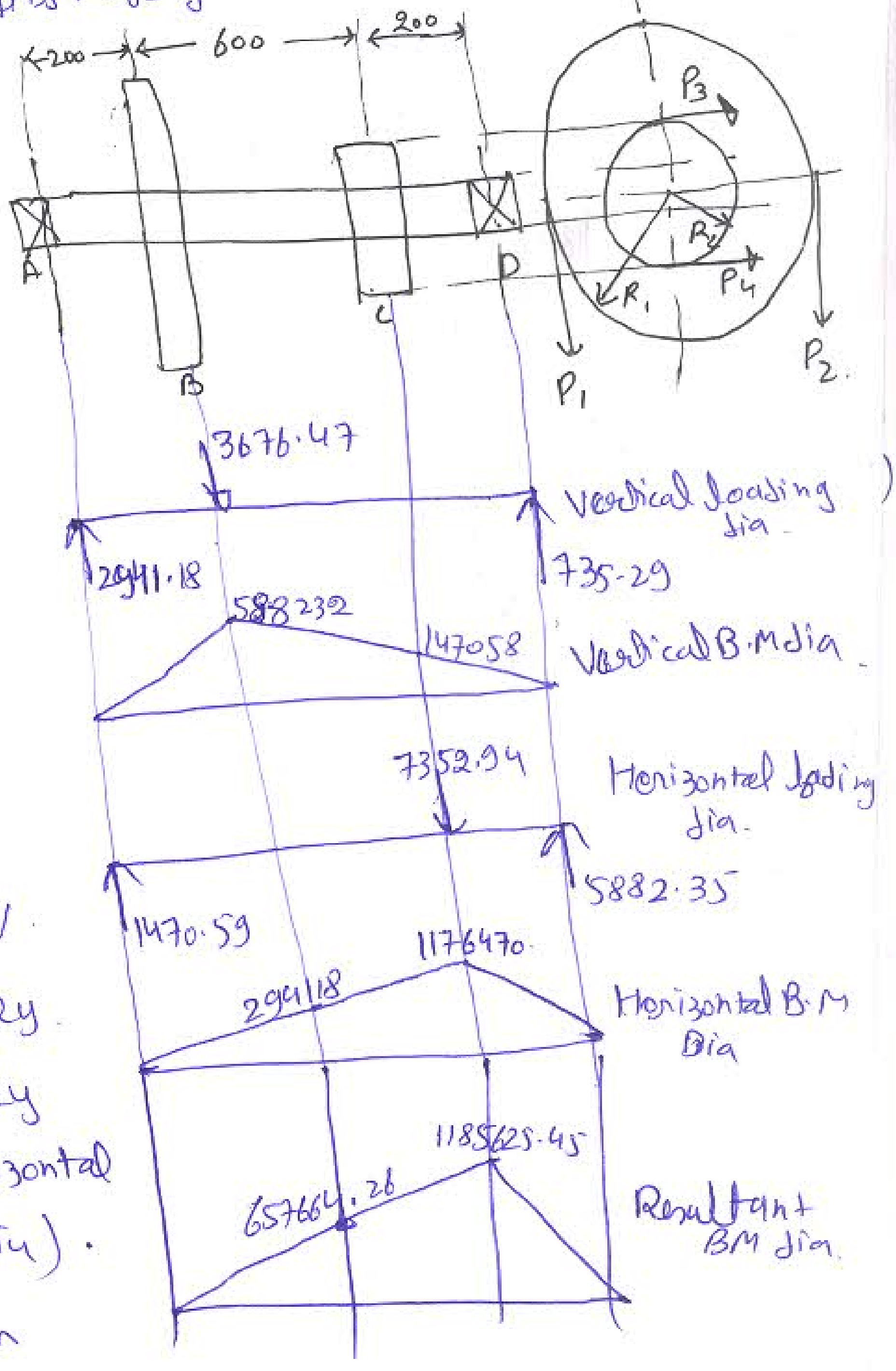
$\tau_{max} = 22.5$

$\tau_{max} < \tau_b$ (30 MPa).

therefore design of belt is safe.

Q12 the layout of shaft is show in fig. the maxi tension in belt on Pulley B is 2.5KN. the angle of wrap is 180°, μ = 0.24. the shaft is made of 30C8 and FoS = 3. Determine the

Q12 Shaft dia on Strength basis.



Given

$S_{ut} = 400$ MPa

FoS = 3

$T_1 = 2.5$ KN

$\mu = 0.24$, $\theta = 180°$

$\frac{T_1}{T_2} = e^{\mu\theta}$

$T_2 = 1176.47$ N

$T = (T_1 - T_2) R_1$

$= 330882.5$ N-m

$(T_3 - T_4) R_2 = T$

$\frac{T_3}{T_4} = e^{\mu\theta}$

$T_3 = 5000$ N, $T_4 = 2352.94$ N

Neglecting the weight of Pulley the downward force at Pulley B is $(T_1 + T_2)$ and force in horizontal plane at Pulley C is $(T_3 + T_4)$.

the force and B.M. dia in

horizontal and vertical planes are shown. the resultant BM is given by.

$$(M)_{at B} = 657664.26 \text{ N-mm}$$

$$(M)_{at C} = 1185625.45 \text{ N-mm} = M_{max}.$$

the B.M is max at C.

$$\tau_{max} = \frac{16}{\pi d^3}\sqrt{(M_{max})^2 + T_{max}^2}$$

dia of shaft

$$\tau_{max} \leq \tau_{per}.$$

$$\frac{16}{\pi d^3}\sqrt{(M_{max})^2 + (T_{max})^2} \leq \frac{0.5 S_{yt}}{FOS}.$$

$$\boxed{d = 45.47 \text{ mm}}$$