higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

MECHANICAL DRAWING AND DESIGN N5

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This marking guideline consists of 8 pages.

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QUESTION 1

Data:
$ds = 80\ mm;\quad N\ 133r/\min;\quad D = 80\ mm;\quad d = 70\ mm;\quad L = 55\ mm;\quad \tau = 81\ MPa;\quad n = 10$

1.1 Power transmitted by splines

$$w = t = \frac{\pi d}{2n} = \frac{\pi(0{,}07)}{2(10)} = 0{,}010\,996\ m = 11\ m$$

$$F = A \times \tau\ (nwL)\,\tau = (10)(0{,}011)(0{,}055)\left(81 \times 10^{6}\right) = 490{,}05\ kN$$

$$R_{mean} = \tfrac{1}{4}_{(D+d)} = \tfrac{1}{4}\left(80 + 70\right) = 37{,}5\ mm$$

$$T_{\max} = F \times R_{mean} = \left(49\ 0050\right)\left(0{,}0375\right) = 18\ 376{,}875\ Nm$$

$$T_{\max} = R_{mean}$$

$$P = \frac{2\pi NTmean}{60} = \frac{2\pi(133)(18\ 376{,}875)}{60} = 255{,}948\ kW$$ (9)

1.2 Force to slide hub axially $(\mu = 0{,}12)$

$$F_{\mu} = \mu \times F = (0{,}12)\left(490{,}05 \times 10^{3}\right) = 58{,}806\ kN$$ (2)

1.3 Angle of twist in degrees $(G = 89\ GPa)$

$$\theta = \frac{584 T_{\max} L}{G d^{4}} = \frac{584(18\ 376{,}875)(1)}{\left(83 \times 10^{9}\right)(0{,}08)^{4}} = 3{,}157°$$ (3)

[14]

QUESTION 2

2.1 Data:
$D = d = 450\ mm;\quad v = 18\ m/s;\quad o_t = 3{,}5\ MPa;\quad p = 16{,}5\ kW;\quad T_1 = 3T_2;\quad t = 8\ mm$

2.1.1 Speed of belt pulley in r/s

$$v = \pi\ (D + t)N$$
$$\therefore N = \frac{v}{\pi(D + t)} = \frac{18}{\pi(0{,}45 + 0{,}008)} = 12{,}509\,996 = 12{,}51\ r/s$$ (3)

2.1.2 Effective driving force of belt

$$P = (T_1 - T_2)v$$
$$\therefore T1 - T2 = \frac{P}{v} = \left(\frac{16{,}5 \times 10^3}{18}\right) 916{,}667\ N$$

(3)

2.1.3 Tension in tight and slack side

$$T_1 - T_2 = 916{,}667\ N\ but\ T_1 = 3T_2$$
$$\therefore T_2 = \tfrac{1}{2}(916{,}667) = 458{,}333\ N$$
$$\therefore T_1 = 3T_2 = 3(458{,}333) = 1\,375\ N$$

(4)

2.1.4 Width of belt

$$T_1 = w.t.o_t$$
$$\therefore w = \frac{T_1}{\sigma_t t} = \frac{(1\,375)}{(3{,}5 \times 10^6)(0{,}008)} = 0{,}049\,107\ m\ 50\ mm$$

(3)

2.2 Data: $d_s = 50\ mm;\ \mu = 0{,}04$

2.2.1 Reaction on each bearing

$$R_1 = R_2 = \tfrac{1}{2}(T_1 + T_2) = \tfrac{1}{2}(1\,375 + 458{,}333) = 916{,}667\ N$$

(2)

2.2.2 Work done to overcome friction

$$w_1 = \mu R_1 v = (0{,}04)(916{,}667)(18)\,660\ J/s\ per\ bearing$$
$$\therefore W_T = 2W_1 = 2(660)\,1\,320\ J/s$$

(3)
[18]

QUESTION 3

3.1 Data:

$d = 65\ mm;\ \ PCD = 250\ mm;\ \ N = 90\ r/\min;\ SF = 4; n = 4;\ \ T_{shaf\ t} = 440 \div 4 = 110\ MPa$

3.1.1 Size of bolts

$$T_{shaf\ t} = \frac{\pi}{16}(ds)^3{}_t = \frac{\pi}{16}(0{,}065)^3(110 \times 10^6) = 5\,931{,}474\ nm$$
$$T_{bolt\ s} = T_{shaft}\ n\frac{\pi}{8}(d_b)^2\ PCDt_b$$
$$\therefore d_b = \sqrt{\frac{8T_{shaf\ t}}{n\pi\ PCD_{tb}}} = \sqrt{\frac{8(5\,931{,}4474)}{4\pi\ (0{,}25)(110 \times 10^6)}} = 0{,}001\,718\ m$$
$$= 12\ mm\ (standard\ size)$$

(4)

3.1.2 Torsion in shaft due to coupling

$$T_{bolt} = n\frac{\pi}{8}(d_b)\,2\,PCD\,t_b = 4\left(\frac{\pi}{8}\right)(0{,}012)^2\,(0{,}25)\left(110\times10^6\right)$$
$$= 6\,220{,}354\ Nm \quad (3)$$

3.1.3 Power transmitted

$$T_{mean} = T_{bolts}$$
$$P = \frac{2\pi NT_{mean}}{60} = \frac{2\pi(90)(6\,220{,}354)}{60} = 58{,}625\ kW \quad (3)$$

3.2 Data: $d_s = 65\ mm;\ t = 0{,}168\,d; L = 1{,}4d; t\ 110\ MPa$

Size of the key

$$L = 1{,}4d = 1{,}4(65) = 91\ mm$$

$$t = 0{,}168\,d = 0{,}168(65) = 11\ mm$$

$$T_{shaf\ t} = \tfrac{1}{2}\,wLtd_s$$

$$\therefore w = \frac{2T_{shaft}}{Ltd_s} = \frac{2(6\,220{,}354)}{(0{,}091)(110\times10^6)(0{,}065)} = 0{,}019\,120\ m = 20\ mm$$

$$\therefore Key\ size = w\times t\times L = 20\times11\times91\ mm \quad (4)$$

[14]

QUESTION 4

Data: $D = 2{,}4m;\ \wp = 1{,}8\ MPa;\ \sigma_t = 87\ MPa;\ \tau\ 60\ MPa; \sigma_o = 108\ MPa; \eta_L = 75\%$

4.1 Boiler plate thickness

$$\sigma_t = \frac{\wp D}{2t\eta_L}$$
$$\therefore t = \frac{\wp D}{2\sigma_t\eta_L} = \frac{(1{,}8\times10^6)(2{,}4)}{2(87\times10^6)(0{,}75)} = 0{,}033\,103\ mm\ (standard\ size) \quad (4)$$

4.2 Rivet diameter

$$d = 6\sqrt{t} = 6\sqrt{35=}\ 35{,}496\ mm = 36\ mm\ (standard\ size) \quad (2)$$

4.3 Pitch of rivets

$$F_t = F_s \therefore (P-d)t\sigma_t \; n\frac{\pi}{4}(d)^2 t$$

$$\therefore (P-d) = \frac{n\pi(d)^2 t}{4t\sigma_t}$$

$$\therefore P = \frac{n\pi(d)^2 t}{4t\sigma_t} + d = \frac{2\pi(0{,}036)^2(60\times10^6)}{4(0{,}035)(87\times10^6)} + (0{,}036) = 0{,}076\,113\ m = 77\ mm$$

(4)
[10]

QUESTION 5

Data: $t_{cover} = 45\ mm;\ D = 350\ mm;\ \wp = 1{,}45\ MPa;\ t_{flange} = 45\ mm;\ n = 10;$
$\sigma_t\ (_{studs}) = 38\ MPa;\ t_{wall} = 30\ mm;\ A_o = 0{,}85\ A_n$

5.1 5.1.1 Diameter of studs

$$F = \frac{\pi}{4}D^2\wp = \frac{\pi}{4}(0{,}35)^2(1{,}45\times10^6) = 139{,}506\ kN$$

$$F = F_e = 0{,}85A_n\sigma_t = 0{,}85n\frac{\pi}{4}d^2\sigma_t$$

$$\therefore d = \sqrt{\frac{4F}{0{,}85n\pi\sigma_t}} = \sqrt{\frac{4(139{,}506\times10^3)}{0{,}85(10)\pi(38\times10^6)}} = 0{,}023\,45\ m = M24$$

(6)

5.1.2 Pitch of holes for studs

$$PCD = D + 2t\ d = 350 + 2(30) + 434\ mm$$

$$\therefore CP = \frac{\pi PCD}{\pi} = \frac{\pi(0{,}434)}{10} = 136{,}345\ mm$$

(3)

5.1.3 Outside diameter of cover

$$OD = PCD + 3d = 434 + 3(24) = 506\ mm$$

(1)

5.1.4 Steamtightness

$\wp = 1{,}45\ Mpa \therefore \wp > 1{,}125\ MPa \therefore 3d \le CP \ge 5d$

$3d = 3(24) = 72\ mm \quad 5d = 5(24) = 120\ mm$

CP = 136,345 *mm does not fall between 3d and 5d*

- *Cover is NOT steamtight.*

(2)

5.2 Data:

$L = 410\ mm; \quad B = 320\ mm; \quad d = M24; \quad \wp = 1{,}5\ MN/m^2$

$o_t = 30\ Mpa; \quad c = 35\ mm$

5.2.1 Total force on cover

$a = L + 2c - d = 410 + 2(35) - 24 = 456\ mm$

$b = B + 2c - d = 320 + 2(35) - 24 = 366\ mm$

$\therefore = F = ab\wp = (0{,}456)(0{,}366)(1{,}5 \times 10^6) = 250{,}344\ kN$ (4)

5.2.2 Number of bolts required to make cover steamtight

$F = F_e = 0{,}8n^{\pi}/4^{d2}o_t$

$$\therefore n = \frac{4F}{0{,}8\pi d^2 o_t} = \frac{4(250{,}344 \times 10^3)}{0{,}8\pi(0{,}024)^2(32 \times 10^6)} = 21{,}617 = 22\ bolts$$

Steamtightness - calculate pitch between bolts

Long side: $P_L = \frac{L + 20}{5}\ \frac{410 + 2(35)}{5} = 96\ mm$

Short side: $P_B = \frac{B + 20}{4}\ \frac{320 + 2(35)}{4} = 97{,}5\ mm$

$\wp = 1{,}5\ MPa \therefore \wp > 1{,}125\ MPa$

$\therefore 3d \le CP \ge 5d$

$3d = 3(24) = 72\ mm \qquad 5d = 5(24) = 120\ mm$

$\therefore YES, steam\ tight$ (4)

[20]

QUESTION 6

Data: $d = 50\ mm; \sigma_t = 130\ MPa; \tau = 80\ MPa;\ \sigma_o = 280\ MPa$

Solution:

6.1 Tensile load on rods away from joints

$$F_t = \pi/4\ d^2\sigma_t\ \pi/4(0{,}05)^2(130\times10^6) = 255{,}254\ kN$$ (2)

6.2 Tensile load on the rod end at the cotter hole

$$F_t = \left[\pi/4\ (d_1)^{2-} d_1 t\right]\sigma_t$$

$$but\ t = 0{,}3d = 0{,}3(0{,}05) = 0{,}015\ m\ and\ d_1 = 1{,}2d = 1{,}2(0{,}05) = 0{,}06\ m$$

$$\therefore F_t = \left[\pi/4\ (0{,}06)^2 - (0{,}06)(0{,}015)\right](130\times10^6) = 250{,}566\ kN$$ (3)

6.3 Tensile load on the socket at the cotter hole

$$F_t = \left[\pi/4\ \left[(D^2 - d_1{}^2) - (D-d)t\right]\sigma_t\right]$$

$$but\ D = 1{,}75d = 1{,}75(0{,}05) = 0{,}0875\ m\ \ and\ d_1 = 1{,}2d = 1{,}2(0{,}05)\ 0{,}06\ m$$

$$and\ t = 0{,}3d = 0{,}3(0{,}05) = 0{,}015\ m$$

$$\therefore F_t = \left[\pi/4\ \left[(0{,}0875)^2 - (0{,}06)^2\right] - (0{,}0875 - 0{,}06)(0{,}015)\right](130\times10^6) = 360{,}525\ kN$$ (3)

6.4 Shear load on the cotter

$$F_s = 2btt$$

$$but\ t = 0{,}3d = 0{,}3(0{,}05) = 0{,}015\ m\ and\ b = 1{,}3d = 1{,}3\ (0{,}05) = 0{,}065\ m$$

$$\therefore F_s = 2(0{,}065)(0{,}015)(80\times10^6) = 156\ kN$$ (2)

6.5 Crushing load between cotter and rod end

$$F_o = d_1 to_t = (0{,}06)(0{,}015)(280\ x\ 10^6) = 252\ kN$$ (2)

6.6 Crushing load between cotter and socket

$$F_o = \left[(D_1 - d_1)t\right]\sigma_o$$

$$but\ D = 2{,}42d = 2{,}42\ (0{,}05) = 0{,}121\ m\ and\ d_1 = 1{,}2d = 1{,}2(0{,}05) = 0{,}06\ m$$

$$and\ t = 0{,}3d = 0{,}3(0{,}05) = 0{,}015\ m$$

$$F_o = \left[(0{,}121 - 0{,}06)(0{,}015)\right](280\times10^6) = 256{,}2\ kN$$ (2)

6.7 Shear load on the collar of the rod end

$$F_s = \pi d t_2 t$$

$$but\ t_1 = 0{,}5d\ 0{,}5(0{,}05 = 0{,}025\ m)$$

$$\therefore F_s = \pi(0{,}05)(0{,}025)(80\times10^6) = 314{,}159\ kN$$ (2)

[16]

QUESTION 7

Data: $d = 60\ mm;\ \tau\ 78\ MPa; t_1 = 8\ mm$

Effective length

$L = \pi d = \pi(0{,}06) = 0{,}1885\ m$ (2)

Throat size

$t = 0{,}707 t_1 = 0{,}707(8) = 5{,}656\ mm$ (2)

Weld area

$A = Lt = (0{,}1885\ 2)\left(5{,}656 \times 10^{-3}\right) = 1{,}0662 \times 10^{-3}\ \ m^2$ (2)

Force

$F = A\tau = \left(1{,}066\ 2 \times 10^{-3}\right)\left(78 \times 10^{6}\right) = 83{,}16\ kN$ (2)

[8]

TOTAL: 100

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