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:

$t = 10\ \text{mm};\ n = 2;\ p = 60\ \text{mm};\ \sigma_t = \frac{420}{4}\ \text{MPa} = 105\ \text{MPa};\ \tau = \frac{300}{4}\ \text{MPa} = 75\ \text{MPa}$

$\sigma_c = \frac{600}{4}\ \text{MPa} = 150\ \text{MPa}$

Solution:

1.1 The efficiency of the joint:

$F_t = (p - d)t\sigma_t = (60 - d)(10)(105) = 63\,000 - 1\,050d$✓

$F_s = \frac{\pi}{4}d^2\,\tau_R n = \frac{\pi}{4}d^2(75)(2) = \frac{75}{2}\pi d^2$✓

$F_t = F_s$

$63\,000 - 1\,050d = \frac{75}{2}\pi d^2$✓

$\frac{75}{2}\pi d^2 + 1\,050d - 63\,000 = 0$✓

$$d = \frac{-1\,050 \pm \sqrt{1\,050^2 - 4\left(\frac{75}{2}\pi\right)(-63\,000)}}{2\left(\frac{75}{2}\pi\right)}$$✓

$d = 19{,}094\ \text{mm}$✓ and $d \neq -28{,}007\ \text{mm}$

$\therefore d = 20\ \text{mm}$✓(std size)

$F_t = (p - d)t\sigma_{t-P} = (60 - 20)(10)(105) = 42\ \text{kN}$✓

$F_s = \frac{\pi}{4}d^2\,\tau_R n = \frac{\pi}{4}(20)^2(75)(2) = 47{,}124\ \text{kN}$✓

$F_c = dtn\sigma_{c-PR} = (20)(10)(2)(150) = 60\ \text{kN}$✓

$F_o = pt\sigma_{t-P} = (60)(10)(105) = 63\ \text{kN}$✓

$\eta = \frac{F_t}{F_o} \times 100\% = \frac{42}{63} \times 100\% = 66{,}667\%$✓ (12)

1.2 The maximum permissible diameter of the boiler:

$$\sigma_c = \frac{pD}{2t\eta_L} \checkmark$$

$$\therefore D = \frac{2t\sigma_c\eta_L}{p} = \frac{2(0{,}01)(105 \times 10^6)\checkmark(66{,}667 \times 10^{-2})\checkmark}{1\,250 \times 10^3} = 1{,}12 \text{ m}\checkmark$$

(4)
[16]

QUESTION 2

Data:

$F = 120 \text{ kN};\ \sigma_t = 115 \text{ MPa};\ \tau = 90 \text{ MPa};\ \sigma_c = 190 \text{ MPa}$

Solution:

2.1 The diameter of the rods:

$$F = \frac{\pi}{4}d^2\sigma_t$$

$$\therefore d = \sqrt{\frac{4F}{\pi\sigma_t}} = \sqrt{\frac{4(120 \times 10^3)}{\pi(115 \times 10^6)}}\checkmark = 36{,}45 \text{ mm}\checkmark$$

$$\therefore d = 38 \text{ mm}\checkmark(\text{std size})$$

(3)

2.2 The diameter of the pin:

$$F = 2\left(\frac{\pi}{4}d_1^2\tau\right)$$

$$\therefore d_1 = \sqrt{\frac{2F}{\pi\tau}} = \sqrt{\frac{2(120 \times 10^3)}{\pi(90 \times 10^6)}}\checkmark = 29{,}135 \text{ mm}$$

$$\therefore d_1 = 30 \text{ mm}\checkmark(\text{std size})$$

BUT $\therefore d_1 = 38 \text{ mm}\checkmark(\text{since } d_1 = d)$

(3)

2.3 The thickness of the fork ends considering only crushing:

$$F = 2d_1t_1\sigma_c$$
$$\therefore t_1 = \frac{F}{2d_1\sigma_c} = \frac{120 \times 10^3}{2(0{,}038)(190 \times 10^6)}\checkmark = 8{,}31 \text{ mm} = 9 \text{ mm}\checkmark$$

(2)

2.4 The thickness of the fork eye considering only tearing:

$$F = t(d_2 - d_1)\sigma_t$$

$$t = \frac{F}{(d_2 - d_1)\sigma_t} = \frac{120 \times 10^3}{[2(0{,}03) - 0{,}03](115 \times 10^6)} \checkmark = 34{,}783 \text{ mm} = 35 \text{ mm} \checkmark$$ (2)

2.5 The diameter of the pin head:

$$d_3 = 1{,}5d = 1{,}5(38) = 57 \text{ mm} \checkmark$$ (1)

[11]

QUESTION 3

Data:

$D = 60 \text{ mm};\ n = 12;\ N = 50 \text{ r/sec};\ h = 5 \text{ mm};\ L = 50 \text{ mm};\ p = 5 \text{ MPa}$

Solution:

3.1 3.1.1 The power that can be transmitted based only on the crushing strength of the splines:

$$d = D - 2h = 60 - 2(5) = 50 \text{ mm} \checkmark$$

$$T_x = p\left(\frac{1}{2}(D - d)Ln\right)\left(\frac{1}{2}(D - h)\right)$$

$$\therefore T_x = 5\left(\frac{1}{2}(60 - 50)(50)(12)\right)\left(\frac{1}{2}(60 - 5)\right) \checkmark = 412{,}5 \text{ kNm} \checkmark$$

$$P = 2\pi NT = 2\pi(50)(412{,}5 \times 10^3) \checkmark = 129{,}591 \text{ MW} \checkmark$$ (5)

3.1.2 The force required to slide the hub axially:

Data:

$\mu = 0{,}25$

Solution:

$$F_\mu = \mu N_R n = \mu(pLh)n \checkmark = (0{,}25)(5)(50)(5)(12) \checkmark = 3\,750 \text{ N} \checkmark$$ (3)

3.2 Data:

$D = 2d;\ P = 4\ 500\ kW;\ \ N = 300\frac{r}{min};\ \ T_x = 1{,}125T_m;\ \theta = 2{,}5°;\ L = 1\ m;\ G = 85\ GPa$

Solution:

The inside and outside diameters of the hollow shaft:

$$T_m = \frac{60P}{2\pi N} = \frac{60(4\ 500 \times 10^3)}{2\pi(300)}\checkmark = 143\ 239{,}449\ Nm\checkmark$$

$$J = \frac{TL}{G\theta}$$

$$\frac{\pi}{32}(D^4 - d^4) = \frac{T_x L}{G\theta}$$

$$\frac{\pi}{32}[(2d)^4 - d^4] = \frac{T_x L}{G\theta}\checkmark$$

$$\frac{15}{32}\pi d^4 = \frac{T_x L}{G\theta}\checkmark$$

$$d = \sqrt[4]{\frac{32T_x L}{15\pi G\theta}}\checkmark = \sqrt[4]{\frac{32(1{,}125 \times 143\ 239{,}449)\checkmark(1)\checkmark}{15\pi(85 \times 10^9)\left(2{,}5° \times \frac{\pi}{180°}\right)\checkmark}} = 73{,}701\ mm\checkmark$$

Say $d = 74\ mm\checkmark$ and $D = 148\ mm\checkmark$ (11)

3.3 Data:

$m_s = m_h;\ l_s = l_h;\ \rho_s = \rho_h;\ \tau_s = \tau_h$

Solution:

Compare the strength of the solid shaft to the hollow shaft:

$$m_s = \rho_s V_s = \rho_s A_s l_s$$

$$m_h = \rho_h V_h = \rho_h A_h l_h$$

Since $m_s = m_h$, then:

$$\rho_s A_s l_s = \rho_h A_h l_h\checkmark$$

$$\therefore A_s = A_h\checkmark\checkmark\ (\text{since } \rho_s = \rho_h \text{ and } l_s = l_h)$$

$$\therefore D_s^2 = D_h^2 - d_h^2\checkmark$$

$$\therefore D_s = \sqrt{D_h^2 - d_h^2} = \sqrt{148^2 - 74^2}\checkmark = 128{,}172 \text{ mm} = 130 \text{ mm (std size)}\checkmark$$

$$T_s = \frac{\pi}{16} D_s^3 \tau_s = \frac{\pi}{16}(0{,}13)^3 \tau_s\checkmark = 431{,}38 \times 10^{-6}\tau\checkmark$$

$$T_h = \frac{\pi}{16}\frac{D_h^4 - d_h^4}{D_h}\tau_h = \frac{\pi}{16}\frac{(0{,}148)^4 - (0{,}74)^4}{0{,}148}\tau_h\checkmark = 596{,}742 \times 10^{-6}\tau\checkmark$$

$$\%\text{ strength} = \frac{T_s}{T_h} \times 100\% = \frac{431{,}38 \times 10^{-6}\tau}{596{,}742 \times 10^{-6}\tau} \times 100\%\checkmark = 72{,}289\%\checkmark$$

(12)
[31]

QUESTION 4

Data:

$sl = 250 \text{ mm};\ D = 100 \text{ mm};\ L = 500 \text{ mm};\ p = 2{,}5 \text{ MPa};\ \sigma_t = 100 \text{ MPa};\ \sigma_c = 140 \text{ MPa}$

Solution:

4.1 The ratio of the connecting rod length to the crank radius length:

$$\frac{L}{r} = \frac{L}{\frac{1}{2}sl} = \frac{500}{\frac{1}{2}(250)\checkmark}\checkmark = \frac{4}{1}\checkmark$$

(3)

4.2 The diameter of the piston rod:

$$F_r = F_p$$

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

$$\therefore d = \sqrt{\frac{p}{\sigma_t}} \times D = \sqrt{\frac{2{,}5 \times 10^6}{100 \times 10^6\checkmark}} \times 0{,}1\checkmark = 15{,}811 \text{ mm} = 16 \text{ mm}\checkmark \text{ (std size)}$$

(3)

4.3 The angle between the piston rod centre line and the crank radius:

$$\tan\beta = \frac{L}{r} = \frac{4}{1}\checkmark$$

$$\therefore \beta = \tan^{-1}\frac{4}{1}\checkmark = 75{,}964°\checkmark$$

(3)

4.4 The angle between the piston rod centre line and the connecting rod:

$\alpha = 90° - \beta$✓ $= 90° - 75{,}964°$✓ $= 14{,}036°$✓ (3)

4.5 The force behind the piston:

$F_p = \frac{\pi}{4} D^2 p = \frac{\pi}{4}(0{,}1)^2(2{,}5 \times 10^6)$✓ $= 19\,634{,}954$ N✓ (2)

4.6 The force under the crosshead guide:

$\tan\alpha = \frac{R}{F}$

$\therefore R = F\tan\alpha$ ✓ $= 19\,634{,}954 \tan 14{,}036°$ ✓ $= 49\,08{,}739$ N✓ (3)

4.7 The force in the connecting rod:

$\cos\alpha = \frac{F}{k}$

$\therefore k = \frac{F}{\cos\alpha}$✓ $= \frac{19\,634{,}954}{\cos 14{,}036°}$✓ $= 20\,239{,}247$ N✓ (3)

4.8 The double shear stress in the crank pin:

Data: $D = 30$ mm; $d = 15$ mm

Solution:

$A_s = 2$✓ $\times \frac{\pi}{4}(D^2 - d^2)$✓ $= 2 \times \frac{\pi}{4}(0{,}03^2 - 0{,}015^2)$✓

$\therefore A_s = 1\,060{,}288 \times 10^{-6}$ m^2✓

$\tau = \frac{k}{A_s}$✓ $= \frac{20\,239{,}247}{1\,060{,}288 \times 10^{-6}}$✓ $= 19{,}088$ MPa✓ (7)

4.9 The crushing stress in the pin:

Data: $l = 75$ mm

Solution:

$A_c = D \times l = 0{,}03 \times 0{,}075 = 2{,}25 \times 10^{-3}$ m^2✓

$\sigma_c = \frac{k}{A_c} = \frac{20\,239{,}247}{2{,}25 \times 10^{-3}}$✓ $= 8{,}995$ MPa✓ (3)

[30]

QUESTION 5

Data:

$d = 50\ \text{mm};\ T_m = 4\ 500\ \text{Nm};\ n = 3$

Solution:

$d = 0{,}75D$✓

$R_m = \frac{1}{4}(D + d) = \frac{1}{4}[D + (0{,}75D)] = \frac{7}{16}D$✓

$T_x = 1.x \times T_m = 1{,}125 \times 4\ 500 = 5\ 062{,}5\ \text{Nm}$✓

5.1 The inside and outside diameters of the claws:

Data: $\tau = 11{,}25\ \text{MPa}$

$T_x = \frac{\pi}{8}(D^2 - d^2)\tau R_m = \frac{\pi}{8}[D^2 - (0{,}75D)^2$✓$]\tau \times \frac{7}{16}D$✓

$\therefore T_x = \frac{49}{2\ 048}\pi\tau D^3$✓✓

$5\ 062{,}5 = \frac{49}{2\ 048}\pi \times (11{,}26 \times 10^6)D^3$✓

$D = 181{,}579\ \text{mm}$

$\therefore D = 182\ \text{mm}$✓ and $d = 137\ \text{mm}$✓ (9)

5.2 The minimum length of the key:

Data: $\sigma_c = 124\ \text{MPa}$

For $d = 137\ \text{mm}$, $w \times t = 36 \times 20\ (\text{mm})$✓

$T_x = \frac{1}{4}dtL\sigma_c$

$5\ 062{,}5 = \frac{1}{4} \times (0{,}137)(0{,}02)L \times (124 \times 10^6)$✓

$L = 59{,}601\ \text{mm}$

$\therefore L = 60\ \text{mm}$✓ (3)

[12]

TOTAL: 100

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