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 10 pages.

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QUESTION 1

Data:

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

Solution:

1.1 The diameter of the rods:

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

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

$$\therefore d = 38\ mm \checkmark (std\ size)$$ (3)

1.2 The diameter of the pin:

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

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

$$\therefore d_1 = 30\ mm \checkmark (std\ size)$$ (3)

1.3 The thickness of the fork ends:

$$F = 2bt_2\sigma_t = 2(1{,}2d)t_2\sigma_t$$

$$120 \times 10^3 = 2[1{,}2(0{,}038)]t_2(115 \times 10^6) \checkmark$$

$$120 \times 10^3 = 2t_1[2(0{,}03) - 0{,}03](115 \times 10^6) \checkmark$$

$$t_2 = 11{,}442\ mm$$

$$\therefore t_2 = 12\ mm \checkmark$$ (3)

1.4 The thickness of the fork eye:

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

$$120 \times 10^3 = t[2(0{,}03) - 0{,}03](115 \times 10^6) \checkmark$$

$$t = 34{,}783\ mm$$

$$\therefore t = 35\ mm \checkmark$$ (2)

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1.5 The diameter of the pin head and collar:

●$d_3 = 1{,}5d = 1{,}5(38) = 57\ mm$✓

●$t_3 = 0{,}5d = 0{,}5(38) = 19\ mm$✓ (2)

1.6 The thickness of the curved section of the fork:

$F = 2t_1(d_2 - d_1)\sigma_t$

$120 \times 10^3 = 2t_1[2(0{,}03) - 0{,}03](115 \times 10^6)$✓

$t_1 = 17{,}391\ mm$

$\therefore t = 18\ mm$✓ (2)
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QUESTION 2

2.1 Data:

$D = 60\ mm;\ n = 12;\ N = 50\dfrac{r}{sec};\ h = 5\ mm;\ L = 50\ mm;\ p = 5\ MPa;$
$\mu = 0{,}25$

Solution:

2.1.1 The power that can be transmitted:

$d = D - 2h = 60 - 2(5) = 50\ mm$✓

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

$T = 5\left(\frac{1}{2}(60-50)(50)(12)\right)\left(\frac{1}{2}(60-5)\right)$✓ $= 412{,}5\ kNm$✓

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

2.1.2 The force required to slide the hub axially:

$F_\mu = \mu Nn = \mu(pLh)n$✓ $= (0{,}25)(5)(50)(5)(12)$✓ $= 3750\ N$✓ (3)

2.2 Data:

$D = 2d; P = 4500\ kW;\ N = 300\frac{r}{min};\ T_x = 1{,}125T_m;\ \theta = 2{,}5°;$ L = 1 m;
G = 85 GPa

Solution:

The inside and outside diameters of the shaft:

●$\mathrm{T} = \frac{60\ P}{2\ \pi N} = \frac{60(4500 \times 10^3)}{2\pi(300)} = 143239{,}449\ Nm$✓

●$J = \frac{TL}{G\theta}$

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

$\frac{\pi}{32}[(2d)^4 - d^4] = \frac{TL}{G\theta}$✓

$\frac{15}{32}\pi d^4 = \frac{TL}{G\theta}$✓

$d = \sqrt[4]{\frac{32TL}{15\pi G\theta}}$✓ $= \sqrt[4]{\frac{32(143239{,}449)(1)}{15\ \pi(85 \times 10^9)\left(2{,}5° \times \frac{\pi}{180°}\right)}}$✓✓ $= 71{,}562\ mm$✓

Say, $d = 72\ mm$✓ and $D = 144\ mm$✓ (10)

2.3 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:

● Since $m_s = m_h, l_s = l_h\ and\ \rho_s = \rho_h, then$:

$A_s = A_h$✓

$\therefore D_s^2 = D_h^2 - d_h^2$✓

$\therefore D_s = \sqrt{D_h^2 - d_h^2} = \sqrt{144^2 - 72^2}$✓ $= 124{,}708\ mm = 125\ mm\ (std\ size)$✓

●$\%\ \text{Strength} = \dfrac{T_s}{T_h} \times 100\% = \dfrac{\frac{\pi}{16} D_s^3 \tau_s}{\frac{\pi}{16} \frac{D_h^4 - d_h^4}{D_h} \tau_h} \times 100\% = \dfrac{D_s^3}{\frac{D_h^4 - d_h^4}{D_h}} \times 100\%$✓

$\%\ \text{Strength} = \dfrac{125^3}{\frac{144^4 - 72^4}{144}} \times 100\%$✓

$\therefore\ \%\ \text{Strength} = 69{,}77\%$✓ (7)

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QUESTION 3

Data:

$t = 15\ mm;\ n = 2;\ p = 60\ mm;\ \sigma_{t-P} = \frac{420}{4}\ MPa = 105\ MPa;\ \tau_R = \frac{300}{4}\ MPa = 75\ MPa$

$\sigma_{c-PR} = \frac{600}{4}\ MPa = 150\ MPa$

Solution:

The efficiency of the joint:

● $F_t = (p-d)t\sigma_{t-P} = (60-d)(15)(105) = 94500 - 1575d$✓

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

●$F_t = F_s$

$94500 - 1575d = \frac{75}{2}\pi d^2$✓

$\frac{75}{2}\pi d^2 + 1575d - 94500 = 0$✓

$$d = \frac{-1575 \pm \sqrt{1575^2 - 4\left(\frac{75}{2}\pi\right)(-94500)}}{2\left(\frac{75}{2}\pi\right)}$$✓

$d = 22{,}416\ mm$✓ $and\ d \neq -35{,}785\ mm$

$\therefore d = 24\ mm$ ✓$(std\ size)$

● $F_t = (p-d)t\sigma_{t-P} = (60-24)(15)(105)$✓ $= 56{,}7\ kN$✓

● $F_s = \frac{\pi}{4}d^2\ \tau_R n = \frac{\pi}{4}(24)^2(75)(2)$✓ $= 67{,}858\ kN$✓

● $F_c = dtn\sigma_{c-PR} = (24)(15)(2)(150)$✓ $= 108\ kN$✓

● $F_o = pt\sigma_{t-P} = (60)(15)(105)$✓ $= 94{,}5\ kN$✓

●$\eta = \frac{F_t}{F_o} \times 100\% = \frac{56{,}7}{94{,}5} \times 100\%$✓ $= 60\%$✓

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QUESTION 4

Data:

$w = 20\ mm;\ t = 5\ mm;\ m = 1{,}25\ kg; N = 200\ r/min;\ d = 320\ mm;\ D = 960\ mm$

$C = 1450\ mm;\ \sigma = 4{,}5\ MPa;\ \mu = 0{,}25$

Solution:

4.1 The power that the drive can transmit:

● $\sin\beta = \dfrac{D+d}{2C} = \dfrac{960+320}{2(1450)}$

$\therefore \beta = 26{,}192°$✓

●$\theta = 180° + 2\beta = 180° + 2(26{,}192°) = 232{,}384° = 4{,}056\ rad$✓

●$v = \dfrac{\pi N(D+t)}{60} = \dfrac{\pi(200)(0{,}96+0{,}005)}{60}$✓ $= 10{,}105\ m/s$✓

●$T_1 = wt\sigma_t = (0{,}02)(0{,}005)(4{,}5\times10^6) = 450\ N$✓

●$L = \dfrac{1}{2}\pi(D+d+2t) + \dfrac{(D+d+2t)^2}{4C} + 2C$

$L = \dfrac{1}{2}\pi[960+320+2(5)] + \dfrac{[960+320+2(5)]^2}{4(1450)} + 2(1450)$✓

$\therefore L = 5213{,}077\ mm$✓

●$\bar{m} = \dfrac{m}{L} = \dfrac{1{,}25}{5213{,}077\times10^{-3}}$✓ $= 0{,}24\ kg/m$✓

●$T_c = \bar{m}v^2 = (0{,}24)(10{,}105)^2 = 24{,}486\ N$✓

● $\dfrac{T_1 - T_c}{T_2 - T_c} = e^{\mu\theta}$

$\dfrac{T_1 - T_c}{e^{\mu\theta}} = T_2 - T_c$

$T_2 = T_c + \dfrac{T_1 - T_c}{e^{\mu\theta}}$✓✓ $= 24{,}486 + \dfrac{450 - 24.486}{e^{(0{,}25)(4{,}056)}}$✓ $= 178{,}853\ N$✓

$P = (T_1 - T_2)v = (450 - 178{,}853)(10{,}105)$✓ $= 2740{,}067\ W$✓ (16)

4.2 The minimum dimensions of a rectangular key:

Data:

$d = 60\ mm$

Solution:

Since no information is known regarding the key material, empirical ratios are to be used.

●$L = \frac{3}{2}d = \frac{3}{2}(60) = 90\ mm$✓

●$w = \frac{1}{4}d = \frac{1}{4}(60) = 15\ mm$✓

●$t = \frac{1}{6}d = \frac{1}{6}(60) = 10\ mm$✓

$\therefore The\ dimensions\ are$: $90 \times 15 \times 10$ mm✓ $(L \times \mathrm{w} \times \mathrm{t})$ (4)
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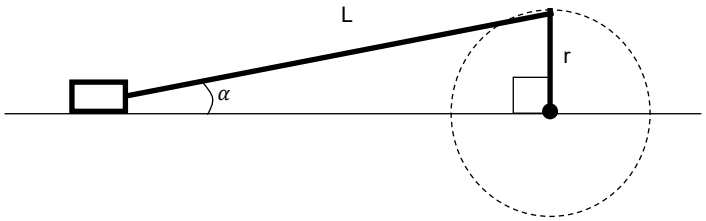
QUESTION 5

Data:

$D = 150\ mm;\ sl = 200\ mm;\ L = 500\ mm; p = 1{,}675\ MPa$

$\sigma_{c-p} = 100\ MPa;\ \tau_p = 84\ MPa$

$The\ angle\ between\ the\ crank\ and\ the\ piston\ rod\ centre\ line\ \theta =\ 90°.$



Solution:

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

$\bullet \mathrm{r} = \frac{1}{2}sl = \frac{1}{2}(200) = 100\ mm$✓

$\bullet \sin\alpha = \frac{r}{L} = \frac{100}{500}$✓

$\therefore \alpha = 11{,}537°$✓ (3)

5.2 The angle between the crank arm and the connecting rod centre:

$\bullet \beta = 90° - \alpha = 90° - 11{,}537° = 78{,}463°$✓ (1)

5.3 The magnitude of the force acting on the piston:

$\bullet \mathrm{F} = \frac{\pi}{4}D^2\mathrm{p} = \frac{\pi}{4}(0{,}15)^2(1{,}675 \times 10^6)$✓ $= 29599{,}693\ \mathrm{N}$✓ (2)

5.4 The magnitude of the reaction force below the crosshead:

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

$\tan 11{,}537° = \frac{R}{29599{,}693}$✓✓

$\therefore R = 6042{,}012\ N$✓ (3)

5.5 The magnitude of the force in the crank arm:

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

$\cos 11.537° = \frac{29599{,}693}{k}$✓✓

$\therefore k = 30210{,}060\ N$✓ (3)

5.6 The outside and inside diameters of the crank pin:

$\bullet \mathrm{k} = 1{,}3D_p^2\sigma_{c-p}$

$30210{,}060 = 1{,}3D_p^2 \times (100 \times 10^6)$

$\therefore D_p = 15{,}244\ mm$✓

$\therefore D_p = 16\ mm$✓✓ (std)

●$\mathrm{k} = 2 \times \frac{\pi}{4}\left(D_p^2 - d_p^2\right)\tau_p$✓

$30210{,}060 = \frac{\pi}{2}\left(0{,}016^2 - d_p^2\right)(84 \times 10^6)$✓

$$\frac{30210{,}060}{\frac{\pi}{2}(84 \times 10^6)} = \left(0{,}016^2 - d_p^2\right)$$✓

$$d_p = \sqrt{0{,}016^2 - \frac{30210{,}060}{\frac{\pi}{2}(84 \times 10^6)}}$$✓

$\therefore d_p = 5{,}200\ mm$✓

$\therefore d_p = 5\ mm$✓✓

$\{NB: d_p = 6\ mm\ is\ NOT\ acceptable\ as\ it\ reduces\ the\ cross-sectional\ area\ more\ and\ therefore\ weakens\ the\ pin\}$

(10)
[22]

TOTAL: 100

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