



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.

**QUESTION 1**

Data:

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

Solution:

1.1 The diameter of the rods:

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

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

$$\therefore d = 38 \text{ mm} \checkmark (\text{std size}) \quad (3)$$

1.2 The diameter of the pin:

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

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

$$\therefore d_1 = 30 \text{ mm} \checkmark (\text{std size}) \quad (3)$$

1.3 The thickness of the fork ends:

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

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

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

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

$$\therefore t_2 = 12 \text{ mm} \checkmark \quad (3)$$

1.4 The thickness of the fork eye:

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

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

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

$$\therefore t = 35 \text{ mm} \checkmark \quad (2)$$

1.5 The diameter of the pin head and collar:

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

$$\bullet t_3 = 0,5d = 0,5(38) = 19 \text{ mm} \checkmark \quad (2)$$

1.6 The thickness of the curved section of the fork:

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

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

$$t_1 = 17,391 \text{ mm}$$

$$\therefore t = 18 \text{ mm} \checkmark$$

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## QUESTION 2

2.1 Data:

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

$$\mu = 0,25$$

Solution:

2.1.1 The power that can be transmitted:

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

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

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

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

2.1.2 The force required to slide the hub axially:

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

## 2.2 Data:

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

Solution:

The inside and outside diameters of the shaft:

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

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

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

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

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

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

Say,  $d = 72 \text{ mm} \checkmark$  and  $D = 144 \text{ mm} \checkmark$ 

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## 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:

$$A_s = A_h \checkmark$$

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

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

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

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

$$\therefore \% \text{ Strength} = 69,77\% \checkmark$$

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**QUESTION 3**

Data:

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

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

Solution:

The efficiency of the joint:

$$\bullet F_t = (p - d)t\sigma_{t-p} = (60 - d)(15)(105) = 94500 - 1575d \checkmark$$

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

$$\bullet F_t = F_s$$

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

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

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

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

$$\therefore d = 24 \text{ mm} \checkmark (\text{std size})$$

$$\bullet F_t = (p - d)t\sigma_{t-p} = (60 - 24)(15)(105) \checkmark = 56,7 \text{ kN} \checkmark$$

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

$$\bullet F_c = dtn\sigma_{c-PR} = (24)(15)(2)(150) \checkmark = 108 \text{ kN} \checkmark$$

$$\bullet F_o = pt\sigma_{t-p} = (60)(15)(105) \checkmark = 94,5 \text{ kN} \checkmark$$

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

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**QUESTION 4**

Data:

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

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

Solution:

4.1 The power that the drive can transmit:

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

$$\therefore \beta = 26,192^\circ \checkmark$$

$$\bullet \theta = 180^\circ + 2\beta = 180^\circ + 2(26,192^\circ) = 232,384^\circ = 4,056 \text{ rad} \checkmark$$

$$\bullet v = \frac{\pi N(D + t)}{60} = \frac{\pi(200)(0,96 + 0,005)}{60} \checkmark = 10,105 \text{ m/s} \checkmark$$

$$\bullet T_1 = wt\sigma_t = (0,02)(0,005)(4,5 \times 10^6) = 450 \text{ N} \checkmark$$

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

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

$$\therefore L = 5213,077 \text{ mm} \checkmark$$

$$\bullet \bar{m} = \frac{m}{L} = \frac{1,25}{5213,077 \times 10^{-3}} \checkmark = 0,24 \text{ kg/m} \checkmark$$

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

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

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

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

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

4.2 The minimum dimensions of a rectangular key:

Data:

$$d = 60 \text{ mm}$$

Solution:

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

$$\bullet L = \frac{3}{2}d = \frac{3}{2}(60) = 90 \text{ mm} \checkmark$$

$$\bullet w = \frac{1}{4}d = \frac{1}{4}(60) = 15 \text{ mm} \checkmark$$

$$\bullet t = \frac{1}{6}d = \frac{1}{6}(60) = 10 \text{ mm} \checkmark$$

$\therefore$  The dimensions are:  $90 \times 15 \times 10 \text{ mm} \checkmark (L \times w \times t)$

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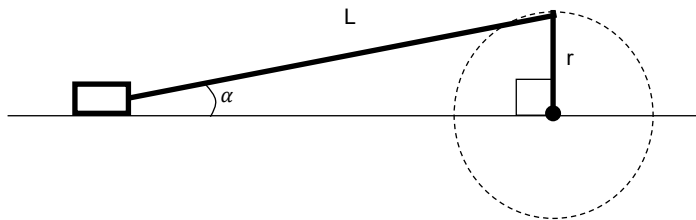
### QUESTION 5

Data:

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

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

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



Solution:

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

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

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

$$\therefore \alpha = 11,537^\circ \checkmark \quad (3)$$

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

$$\bullet \beta = 90^\circ - \alpha = 90^\circ - 11,537^\circ = 78,463^\circ \checkmark \quad (1)$$

5.3 The magnitude of the force acting on the piston:

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

5.4 The magnitude of the reaction force below the crosshead:

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

$$\tan 11,537^\circ = \frac{R}{29599,693} \checkmark \checkmark$$

$$\therefore R = 6042,012 \text{ N} \checkmark \quad (3)$$

5.5 The magnitude of the force in the crank arm:

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

$$\cos 11,537^\circ = \frac{29599,693}{k} \checkmark \checkmark$$

$$\therefore k = 30210,060 \text{ N} \checkmark \quad (3)$$

5.6 The outside and inside diameters of the crank pin:

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

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

$$\therefore D_p = 15,244 \text{ mm} \checkmark$$

$$\therefore D_p = 16 \text{ mm} \checkmark \checkmark \text{ (std)}$$

$$\bullet k = 2 \times \frac{\pi}{4} (D_p^2 - d_p^2) \tau_p \checkmark$$

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

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

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

$$\therefore d_p = 5,200 \text{ mm} \checkmark$$

$$\therefore d_p = 5 \text{ mm} \checkmark \checkmark$$

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

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**[22]****TOTAL: 100**