



**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 12 pages.

QUESTION 1: POWER TRANSMISSION

1.1 Power transmission

$$\theta = \frac{584TL}{Gd^4}$$

$$T = \frac{\theta \times G \times d^4}{584 \times L} \checkmark$$

$$T = \frac{2 \times 80 \times 10^9 \times (0.03)^4}{584 \times 0,4} \checkmark$$

$$T = \boxed{555 \text{ Nm}} \checkmark$$

$$P = \frac{2\pi NT}{60 \times 10^3}$$

$$P = \frac{2\pi(2000)(555)}{60 \times 10^3} \checkmark$$

$$P = \boxed{116,24 \text{ kW}} \checkmark$$

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1.2 Shear stress

$$T = \frac{\pi}{16} d^3 \tau$$

$$\tau = \frac{T \times 16}{\pi d^3} \checkmark$$

$$\tau = \frac{555 \times 16}{\pi(0,03)^3} \checkmark$$

$$\tau = \boxed{104,7 \text{ MPa}} \checkmark$$

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1.3 Power transmitted under 12% overload

$$T_{max} = 1,12T_{mean}$$

$$555 = 1,12T_{mean} \checkmark$$

$$T_{mean} = \frac{555}{1,12} \checkmark$$

$$T_{mean} = \boxed{495,5 \text{ N.m}} \checkmark$$

$$P = \frac{2\pi NT_{mean}}{60 \times 10^3}$$

$$P = \frac{2\pi(2000)(495,5)}{60 \times 10^3} \checkmark$$

$$P = \boxed{103,8 \text{ kW}} \checkmark$$

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QUESTION 2: STEAM ENGINE

2.1 2.1.1 For bolt diameter

$$F = P \times A$$

$$F = P \times \frac{\pi}{4} \times D^2$$

$$F = 1,18 \times 10^6 \times \frac{\pi}{4} \times (0,62)^2 \checkmark$$

$$F = 356250,324 \text{ N}$$

$$F = \boxed{356,25 \text{ kN}} \checkmark$$

$$F = 0,75 \times \frac{\pi}{4} \times d_{\text{bolt}}^2 \times n \times \sigma_t$$

$$356250,324 = 0,75 \times \frac{\pi}{4} \times d_{\text{bolt}}^2 \times 20 \times 35 \times 10^6$$

$$d^2 = \frac{4(356250,324)}{0,75\pi(20)(35 \times 10^6)}$$

$$d = \sqrt{\frac{4(356250,324)}{0,75\pi(20)(35 \times 10^6)}} \checkmark$$

$$d = 0,29394 \text{ m}$$

Use $d = M30 \checkmark$ (Standard sizes) (4)

2.1.2 For wall thickness (with no liner)

$$t = \frac{PD}{\sigma} + 0,008$$

$$t = \frac{(1,18 \times 10^6)(0,62)}{35 \times 10^6} + 0,008 \checkmark$$

$$t = 0,028903 \text{ m}$$

Use $t = \boxed{29 \text{ mm}} \checkmark$ (2)

2.1.3 For circumferential pitch and steam tightness

$$PCD = D + 2t + 3d$$

$$PCD = 620 + 2(29) + 3(30) \checkmark$$

$$PCD = \boxed{768 \text{ mm}} \checkmark$$

$$CP = \frac{\pi PCD}{n}$$

$$CP = \frac{\pi (768)}{20} \checkmark$$

$$CP = \boxed{120,637 \text{ mm}} \checkmark$$

Checking steam tightness

$4d \leq CP \leq 6d$ in order to be steam tight

$$4(30) \leq 120,637 \leq 6(30)$$

$$120 \checkmark \leq 120,637 \leq 180 \checkmark$$

It is proven that CP is greater than 4d and smaller than 6d

\therefore Yes, steam tight \checkmark

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2.2 Data

$X = 520$; $Y = 420$; $p = 1,2 \text{ MPa}$; $C = 40 \text{ mm}$; $d = M18$; $\sigma_t = 78 \text{ MPa}$

2.2.1 For effective area of packing material

$$a = X + 2C - d$$

$$a = 520 + 2(40) - 18$$

$$a = \boxed{582 \text{ mm}} \checkmark$$

$$b = Y + 2C - d$$

$$b = 420 + 2(40) - 18$$

$$b = \boxed{482 \text{ mm}} \checkmark$$

$$A = a \times b = (0,582)(0,482) = \boxed{280,524 \times 10^{-3} \text{ m}^2} \checkmark$$

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2.2.2 For number of studs required

$$F = A \times p$$

$$F = 280,524 \times 10^{-3} \times 1,2 \times 10^6 \checkmark$$

$$F = 336628,8 \text{ N}$$

$$F = \boxed{336,63 \text{ kN}} \checkmark$$

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

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

$$n = \frac{4(336628,8)}{0,85\pi(0,018)^2(78 \times 10^6)} \checkmark$$

$$n = 19,953$$

$$\text{Use } n = \boxed{20 \text{ studs}} \checkmark$$

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QUESTION 3: BELT DRIVE

3.1 Belt speed

$$M = b \times t \times l \times \rho$$

$$M = 0,13 \times 0,009 \times 1 \times 1200 \checkmark$$

$$M = \boxed{1,404 \text{ kg/m}} \checkmark$$

$$T_c = Mv^2$$

$$v^2 = \frac{T_c}{M}$$

$$v^2 = \frac{864}{1,404} \checkmark$$

$$v^2 = 615,4 \checkmark$$

$$v = \boxed{24,81 \text{ m/s}} \checkmark$$

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3.2 Maximum transmissible power

$$T_1 = b \times t \times \sigma_t$$

$$T_1 = 0,12 \times 0,008 \times 2,7 \times 10^6 \checkmark$$

$$T_1 = \boxed{3510 \text{ N}} \checkmark$$

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

$$\theta = \frac{160}{57,3} = \boxed{2,792} \checkmark$$

$$\frac{3510 - 864}{T_2 - 864} = e^{0,32(2,792)} \checkmark$$

$$\frac{3510 - 864}{T_2 - 864} = 2,444 \checkmark$$

$$T_2 = \frac{3510 - 864}{2,444} + 864 \checkmark$$

$$T_2 = \boxed{1946,7 \text{ N}} \checkmark$$

$$P = (T_1 - T_2)v$$

$$P = (3510 - 1946,7)24,81 \checkmark$$

$$P = 38785,48 \text{ W}$$

$$P = \boxed{38,78 \text{ kW}} \checkmark$$

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3.3 Pulley diameter

$$v = \frac{\pi DN}{60}$$

$$D = \frac{60v}{\pi N}$$

$$D = \frac{60(24,81)}{\pi(1440)} \checkmark$$

$$D = 0,329 \text{ m}$$

$$D = \boxed{329 \text{ mm}} \checkmark$$

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QUESTION 4: RIVETTED JOINTS

4.1 The safe loads

$$d = 6\sqrt{t}$$

$$d = 6\sqrt{14}\checkmark$$

$$d = \boxed{22,45 \text{ mm}}\checkmark$$

$$\text{Use } d = \boxed{24 \text{ mm}}\checkmark \quad (\text{Standard size})$$

Finding the pitch (P)

$$F_t = F_s \quad \text{Working Stresses are: } \sigma_t = 90 \text{ MPa}; \sigma_c = 120 \text{ MPa}; \tau = 80 \text{ MPa}$$

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

$$(P - 24)(14) \times 90 \times 10^6 \checkmark = 2 \times \frac{\pi}{4} (24)^2 (80 \times 10^6) \checkmark$$

$$(P - 24) = 57,446 \checkmark$$

$$P = \boxed{81,4 \text{ mm}}\checkmark$$

Finding (F_t)

$$F_t = (P - d)t \times \sigma_t$$

$$F_t = (0,0814 - 0,024)0,014 \times 90 \times 10^6 \checkmark$$

$$F_t = 72,324 \text{ N}$$

$$F_t = \boxed{72,32 \text{ kN}}\checkmark$$

Finding (F_s)

$$F_s = n \times \frac{\pi}{4} d^2 \tau$$

$$F_s = 2 \times \frac{\pi}{4} (0,024)^2 (80 \times 10^6) \checkmark$$

$$F_s = 72383,29 \text{ N}$$

$$F_s = \boxed{72,38 \text{ kN}}\checkmark$$

Finding (F_c)

$$F_c = n \times d \times t \times \sigma_c$$

$$F_c = 2 \times 0,024 \times 0,014 \times 120 \times 10^6 \checkmark$$

$$F_c = 80640 \text{ N}$$

$$F_c = \boxed{80,64 \text{ kN}} \checkmark$$

Finding (F_{solid})

$$F_t = P \times t \times \sigma_t$$

$$F_t = (0,0814)0,014 \times 90 \times 10^6 \checkmark$$

$$F_t = 102564 \text{ N}$$

$$F_t = \boxed{102,56 \text{ kN}} \checkmark$$

Finding safe load (F_{safe})

The safe load = $\boxed{72,32 \text{ kN}}$ the lowest force value (15)

4.2 Efficiency (η)

$$\text{Efficiency} = \frac{\text{Strength of pierced plate}}{\text{Strength of solid plate}} \times 100\%$$

$$\eta = \frac{72,32}{102,56} \times 100\% \checkmark$$

$$\eta = \boxed{70,51\%} \checkmark$$

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QUESTION 5: FLANGE COUPLING

5.1 The shaft diameter

$$P = \frac{2\pi NT}{60}$$

$$T = \frac{60P}{2\pi N}$$

$$T = \frac{60(450 \times 10^3)}{2\pi(340)} \checkmark$$

$$T = 12638,77 \text{ N.m}$$

$$T = \boxed{12,639 \text{ kN.m}} \checkmark$$

$$T_{max} = T_{mean} \quad (\text{there is no overload})$$

$$T_{max} = 12638,77 \text{ N.m} \checkmark$$

$$T_{max} = \frac{\pi}{16} d_s^3 \tau_s$$

$$12638,77 = \frac{\pi}{16} d_s^3 (75 \times 10^6) \checkmark$$

$$d_s^3 = \frac{12638,77 \times 16}{\pi(75 \times 10^6)} \checkmark$$

$$d_s^3 = 0,00085825$$

$$d_s = 0,09503 \text{ m}$$

$$d_s = 95,03 \text{ mm}$$

$$\text{Use } d_s = \boxed{100 \text{ mm}} \checkmark$$

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5.2 The length of the key

$$\text{For } d_s = 100 \text{ mm} \rightarrow w = 0,028 \text{ m and } t = 0,016 \checkmark$$

For shearing

$$\text{Torque on shaft} = \text{Torque on key due to shear}$$

$$\text{Torque on shaft} = w \times l \times \tau \times \frac{d}{2}$$

$$12638,77 = 0,028 \times l \times 90 \times 10^6 \times \frac{0,1}{2} \checkmark$$

$$l = \frac{12638,77 \times 2}{0,028 \times 90 \times 10^6 \times 0,1} \checkmark$$

$$l = 0,1003 \text{ m}$$

$$\boxed{l = 100,3 \text{ mm}} \checkmark$$

For crushing

Torque on shaft = Torque on key due to crushing

$$T = \frac{t}{2} \times l \times \sigma_c \times \frac{d}{2}$$

$$12638,77 = \frac{0,016}{2} \times l \times 225 \times 10^6 \times \frac{0,1}{2} \checkmark$$

$$l = \frac{12638,77 \times 2 \times 2}{0,016(225 \times 10^6)(0,1)} \checkmark$$

$$l = 0,1404 \text{ m}$$

$$l = 140,4 \text{ mm} \checkmark$$

Answer: Use length is equal to 140,4 mm (for safety) (8)

5.3 The bolt diameter

$$PCD = 3D$$

$$PCD = 3(100)$$

$$PCD = 300 \text{ mm} \checkmark$$

For shearing

Torque on shaft = Torque on bolt due to shear

$$T = n \times \frac{\pi}{4} \times d^2 \times \tau \times \frac{PCD}{2}$$

$$12638,77 = 6 \times \frac{\pi}{4} \times d^2 \times 55 \times 10^6 \times \frac{0,3}{2} \checkmark$$

$$d^2 = \frac{12638,77 \times 2 \times 4}{6\pi \times 0,3 \times 55 \times 10^6} \checkmark$$

$$d^2 = 0,00032509$$

$$d = 0,01803 \text{ m}$$

$$d = 18,03 \text{ mm (M20)} \checkmark \quad (\text{Standard size})$$

For crushing

$$\text{Flange thickness} = \frac{D}{4}$$

$$\text{Flange thickness} = \frac{100}{4}$$

$$\text{Flange thickness} = \boxed{25 \text{ mm}} \checkmark$$

$$T = n \times d \times t \times \sigma_{\text{bolt}} \times \frac{PCD}{2}$$

$$12638,77 = 6 \times d \times 0,025 \times 35 \times 10^6 \times \frac{0,1}{2} \checkmark$$

$$d = \frac{12638,77 \times 2}{6(0,025)(35 \times 10^6)(0,1)} \checkmark$$

$$d = 0,04815$$

$$d = 48,15 \text{ m} \checkmark$$

$$\boxed{d = 56 \text{ mm} \quad (M56)}$$

Answer: $\boxed{\text{Use } (M56)} \checkmark$ (for safety)

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QUESTION 6: KNUCKLE JOINT

6.1 The rod diameter

$$F = \sigma_t / 6 \times \frac{\pi}{4} \times d^2$$

$$d^2 = \frac{4 \times F}{\sigma_t / 6 \times \pi} \checkmark$$

$$d^2 = \frac{4 \times 112 \times 10^3}{438,56 \times 10^6 / 6 \checkmark \times \pi} \checkmark$$

$$d^2 = 0,001951$$

$$d = 0,04416$$

$$d = \boxed{44,2 \text{ mm}} \checkmark$$

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6.2 The pin diameter

$$F = \tau/6 \times 2 \times \frac{\pi}{4} d_1^2$$

$$112 \times 10^3 = 219,28 \times 10^6 / 6 \times 2 \times \frac{\pi}{4} d_1^2 \checkmark$$

$$d_1^2 = \frac{112 \times 10^3 \times 4 \times 6 \checkmark}{2 \times \pi \times 219 \times 10^6} \checkmark$$

$$d_1^2 = 0,001951$$

$$d_1 = 0,04417$$

$$d_1 = \boxed{44,2 \text{ mm}} \checkmark$$

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6.3 Thickness of the fork

$$F = \sigma_c \times 2 \times d_1 \times t_2$$

$$t_2 = \frac{F \times 6}{\sigma_c \times 2 \times d_1}$$

$$t_2 = \frac{112 \times 10^3 \times 6 \checkmark}{469,7 \times 10^6 \times 2 \times 0,0442} \checkmark$$

$$t_2 = 0,01618$$

$$t_2 = \boxed{16,2 \text{ mm}} \checkmark$$

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TOTAL: 100