



**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

$$\theta = \frac{584 TL}{G d^4}$$

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

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

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

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

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

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

(5)

1.2 Shear stress

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

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

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

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

(3)

1.3 Power transmitted under 12% overload

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

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

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

$$T_{mean} = 495,5 \text{ N} \cdot \text{m}$$

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

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

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

(5)

QUESTION 2: STEAM ENGINE

2.1 2.1.1 For bolt diameter
 $F = P \times A$

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

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

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

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

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

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

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

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

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

Use $d = M 30$ (Standard sizes) (4)

2.1.2 For wall thickness (with no liner)

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

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

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

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

2.1.3 For circumferential pitch and steam tightness

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

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

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

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

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

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

Checking steam tightness

$$4d \leq CP \leq 6d \text{ order to be steam tight}$$

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

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

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

$\therefore$ Yes, steam tight

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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

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

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

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

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

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

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

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

(3)

2.2.2 For number of studs required

$$F = A \times p$$

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

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

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

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

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

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

$$n = 19,953$$

Use $n = 20$ studs

(4)
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QUESTION 3: BELT DRIVE

3.1 Belt speed

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

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

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

$$T_c = M v^2$$

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

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

$$v^2 = 615,4$$

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

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3.2 Maximum transmissible power

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

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

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

$$\frac{T_1 - T_c}{T_2 - T_c} = e^{\mu \theta} \theta = \frac{160}{57,3} = 2,792$$

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

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

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

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

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

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

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

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

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3.3 Pulley diameter

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

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

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

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

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

(2)
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QUESTION 4: RIVETTED JOINTS

4.1 The safe loads

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

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

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

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

Finding the pitch (P)

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

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

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

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

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

Finding (F_t)

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

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

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

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

Finding (F_s)

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

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

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

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

Finding (F_{cc})

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

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

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

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

Finding (F_{Solid})

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

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

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

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

Finding safe load (F_{Safe})

The safe load 72,32 kN the lowest force value

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4.2 Efficiency (η)

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

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

$$\eta = 70,51\%$$

(2)

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QUESTION 5: FLANGE COUPLING

5.1 The shaft diameter

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

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

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

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

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

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

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

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

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

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

$$d_s^3 = 0,00085825$$

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

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

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

(6)

5.2 The length of the key

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

For shearing

Torque on shaft = Torque on key due to shear

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

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

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

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

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

For crushing

Torque on shaft = Torque on key due to crushing

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

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

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

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

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

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

5.3 The bolt diameter

$$PCD = 3 D$$

$$PCD = 3(100)$$

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

For shearing

Torque on shaft = Torque on bolt due to shear

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

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

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

$$d^2 = 0,00032509$$

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

$$d = 18,03 \text{ mm (M 20)} \quad (\text{Standard size})$$

For crushing

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

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

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

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

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

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

$$d = 0,04815$$

$$d = 48,15 \text{ mm}$$

$$d = 56 \text{ mm (M 56)}$$

Answer: Use (M 56) (for safety)

(9)

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QUESTION 6: KNUCKLE JOINT

6.1 The rod diameter

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

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

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

$$d^2 = 0,001951$$

$$d = 0,04416$$

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

(4)

6.2 The pin diameter

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

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

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

$$d_1^2 = 0.001951$$

$$d_1 = 0.04417$$

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

(4)

6.3 Thickness of the fork

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

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

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

$$t_2 = 0,01618$$

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

(3)

[11]**TOTAL: 100**