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.

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QUESTION 1: POWER TRANSMISSION

1.1 Power transmission

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

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

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

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

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

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

$$P = \boxed{116{,}24\ kW} \checkmark \quad (5)$$

1.2 Shear stress

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

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

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

$$\tau = \boxed{104{,}7\ MPa} \checkmark \quad (3)$$

1.3 Power transmitted under 12% overload

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

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

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

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

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

$$P = \boxed{103{,}8\ kW} \checkmark \quad (5)$$

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QUESTION 2: STEAM ENGINE

2.1 2.1.1 For bolt diameter

$F = P \times A$

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

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

$F = 356250{,}324\ N$

$F = \boxed{356{,}25\ kN}$✓

$F = 0.75 \times \frac{\pi}{4} \times {d_{bolt}}^2 \times n \times \sigma_t$

$356250{,}324 = 0.75 \times \frac{\pi}{4} \times {d_{bolt}}^2 \times 20 \times 35 \times 10^6$

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

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

$d = 0{,}29394\ m$

$Use \quad d = M30$ ✓ $\quad (Standard\ sizes)$ (4)

2.1.2 For wall thickness (with no liner)

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

$t = \frac{(1{,}18 \times 10^6)(0.62)}{35 \times 10^6} + 0{,}008$✓

$t = 0{,}028903\ m$

$Use \quad t = \boxed{29\ mm}$ ✓ (2)

2.1.3 For circumferential pitch and steam tightness

$PCD = D + 2t + 3d$

$PCD = 620 + 2(29) + 3(30)$✓

$PCD = \boxed{768\ mm}$✓

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

$CP = \frac{\pi\ (768)}{20}$✓

$CP = \boxed{120{,}637\ mm}$✓

Checking steam tightness

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

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

120✓ $\leq 120{,}637 \leq 180$✓

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

$\therefore Yes, steam\ tight$✓ (7)

2.2 Data

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

2.2.1 For effective area of packing material

$a = X + 2C - d$

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

$a = \boxed{582\ mm}$✓

$b = Y + 2C - d$

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

$b = \boxed{482\ mm}$✓

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

2.2.2 For number of studs required

$F = A \times p$

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

$F = 336628.8\ N$

$F = \boxed{336.63\ kN}$✓

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

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

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

$n = 19{,}953$

$Use \quad n = \boxed{20\ studs}$✓ (4)

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QUESTION 3: BELT DRIVE

3.1 Belt speed

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

$M = 0{,}13 \times 0{,}009 \times 1 \times 1200$✓

$M = \boxed{1{,}404\ kg/m}$✓

$T_c = Mv^2$

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

$v^2 = \frac{864}{1{,}404}$✓

$v^2 = 615{,}4$✓

$v = \boxed{24{,}81\ m/s}$✓ (5)

3.2 Maximum transmissible power

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

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

$T_1 = \boxed{3510\ N}$ ✓

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

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

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

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

$T_2 = \boxed{1946{,}7\ N}$ ✓

$P = (T_1 - T_2)v$

$P = (3510 - 1946{,}7)24{,}81$ ✓

$P = 38785{,}48\ W$

$P = \boxed{38{,}78\ kW}$ ✓ (9)

3.3 Pulley diameter

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

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

$D = \frac{60(24{,}81)}{\pi(1440)}$ ✓

$D = 0{,}329\ m$

$D = \boxed{329\ mm}$ ✓ (2)

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QUESTION 4: RIVETTED JOINTS

4.1 The safe loads

$d = 6\sqrt{t}$

$d = 6\sqrt{14}$✓

$d = \boxed{22{,}45\ mm}$✓

Use $d = \boxed{24\ mm}$✓ *(Standard size)*

Finding the pitch (P)

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

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

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

$(P - 24) = 57{,}446$✓

$P = \boxed{81{,}4\ mm}$✓

Finding (F_t)

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

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

$F_t = 72{,}324\ N$

$F_t = \boxed{72{,}32\ kN}$✓

Finding (F_s)

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

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

$F_s = 72383{,}29\ N$

$F_s = \boxed{72{,}38\ kN}$✓

Finding (F_c)

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

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

$F_c = 80640\ N$

$F_c = \boxed{80{,}64\ kN}$✓

Finding (F_{Solid})

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

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

$F_t = 102564\ N$

$F_t = \boxed{102{,}56\ kN}$✓

Finding safe load (F_{Safe})

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

4.2 Efficiency (ɳ)

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

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

$\eta = \boxed{70{,}51\%}$✓ (2)

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QUESTION 5: FLANGE COUPLING

5.1 The shaft diameter

$$P = \frac{2\pi NT}{60}$$
$$T = \frac{60P}{2\pi N}$$
$$T = \frac{60(450 \times 10^3)}{2\pi(340)} \checkmark$$
$$T = 12638{,}77\ N.\text{m}$$
$$T = \boxed{12{,}639\ kN.m} \checkmark$$

$T_{max} = T_{mean}$ *(there is no overload)*

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

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

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

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

$${d_s}^3 = 0{,}00085825$$

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

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

$$Use\ \ d_s = \boxed{100\ mm} \checkmark$$ (6)

5.2 The length of the key

$For\ \ d_s = 100\ mm \ \rightarrow\ \ w = 0{,}028\ m\ and\ t = 0.016 \checkmark$

For shearing

$Torque\ on\ shaft = Torque\ on\ key\ due\ to\ shear$
$$Torque\ on\ shaft = w \times l \times \tau \times \frac{d}{2}$$

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

$$l = \frac{12638{,}77 \times 2}{0{,}028 \times 90 \times 10^6 \times 0{,}1} \checkmark$$
$$l = 0{,}1003\ m$$

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

For crushing

$Torque\ on\ shaft = Torque\ on\ key\ due\ to\ crushing$

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

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

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

$l = 0{,}1404\ m$

$\boxed{l = 140{,}4\ mm}$ ✓

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

5.3 The bolt diameter

$PCD = 3D$

$PCD = 3(100)$

$PCD = \boxed{300\ mm}$ ✓

For shearing

$Torque\ on\ shaft = Torque\ on\ bolt\ due\ to\ shear$

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

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

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

$d^2 = 0{,}00032509$

$d = 0{,}01803\ m$

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

For crushing

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

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

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

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

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

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

$$d = 0{,}04815$$

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

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

Answer: $\boxed{Use\ \ (M56)\checkmark}$ (for safety) (9)

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QUESTION 6: KNUCKLE JOINT

6.1 The rod diameter

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

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

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

$$d^2 = 0{,}001951$$

$$d = 0{,}04416$$

$$d = \boxed{44{,}2\ mm}\checkmark$$ (4)

6.2 The pin diameter

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

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

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

$${d_1}^2 = 0.001951$$

$$d_1 = 0.04417$$

$$d_1 = \boxed{44{,}2\ mm} \checkmark$$ (4)

6.3 Thickness of the fork

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

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

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

$$t_2 = 0{,}01618$$

$$t_2 = \boxed{16{,}2\ mm} \checkmark$$ (3)

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TOTAL: 100

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