higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

MECHANICAL DRAWING AND DESIGN N5

23 July 2021

This marking guideline consists of 12 pages.

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QUESTION 1

DATA: d = 20 mm; L = 380 mm;
N = 2000 rpm; $\theta = 3{,}06°; G = 82 \times 10^9 Pa;\ \ P = ?;\ \tau = ?$

Find maximum torque (T_{max})

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

$$T_{max} = \frac{G \times d^4 \times \theta}{584 \times L} \quad \checkmark$$

$$T_{max} = \frac{82 \times 10^9 (0{,}02)^4 \times (3{,}06)}{584 \times 0{,}38} \quad \checkmark$$

$$T_{max} = \boxed{180{,}91\ Nm} \checkmark$$

Find power (P)

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

$$P = \frac{2\pi(2000)(180{,}91)}{60} \quad \checkmark$$

$$P = 37889{,}37\ W$$

$$P = \boxed{37{,}9\ kW} \quad \checkmark$$

Find shear stress (τ)

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

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

$$\tau_s = \frac{16\ (180{,}91)}{\pi \times (0{,}02)^3} \quad \checkmark$$

$$\tau_s = 115169887\ Pa$$

$$\tau_s = \boxed{115\ MPa} \checkmark$$

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QUESTION 2

DATA: $t = 15\ mm;\ d = 6\sqrt{t};\ n = 2;\ \ \sigma_t = 463\ MPa;\ \sigma_c = 618\ MPa;$

$\tau = 386\ MPa\ \ looking\ for\ d; P; F_t;\ F_s;\ F_c;\ F_{safe};\ \eta_c;\ \eta_s;\ \eta_t; \eta_{joint}$

Find the diameter of the rivet (d)

$d = 6\sqrt{t}$

$d = 6\sqrt{15}$

$d = 23{,}24$

Use $d = 24\ mm$ ✓ *(Standard size)*

Find the pitch (P)

$F_t = F_s$

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

$(P - 24)(15) \times 463 \times 10^6 = 2 \times \frac{\pi}{4}(24)^2(386 \times 10^6)$✓

$(P - 24) = 50{,}29$ ✓

$P = 74{,}29\ mm$

$P = \boxed{74\ mm}$ ✓

Even if the candidate converted mm to m, did not use the Factor of safety and used P = 85,6 mm instead of 86 mm, full marks must be granted.

Find (F_t)

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

$F_t = (0{,}074 - 0{,}024)0{,}015 \times 463 \times 10^6$ ✓

$F_t = 354195\ N$

$F_t = \boxed{354{,}2\ kN}$ ✓

Find (F_s)

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

$F_s = 2 \times \frac{\pi}{4}(0{,}024)^2(386 \times 10^6)$ ✓

$F_s = 349245\ N$

$F_s = \boxed{349{,}25\ kN}$ ✓

Find (F_c)

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

$F_c = 2 \times 0{,}024 \times 0{,}015 \times 618 \times 10^6$ ✓

$F_c = 444960\ N$

$F_c = \boxed{444{,}96\ kN}$ ✓

Find (F_{Solid})

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

$F_t = (0{,}074)0{,}015 \times 463 \times 10^6$ ✓

$F_t = 513930\ N$

$F_t = \boxed{513{,}93\ kN}$ ✓

Calculate Tensile Efficiency $(\eta_{tensile})$

$\eta_t = \frac{F_t}{F_{Solid}} \times 100\%$

$\eta_t = \frac{354{,}2}{513{,}93} \times 100\%$ ✓

$\eta_t = \boxed{68{,}9\ \%}$ ✓

Calculate Shearing Efficiency $(\eta_{shearing})$

$\eta_s = \frac{F_s}{F_{Solid}} \times 100\%$

$\eta_s = \frac{349{,}25}{513{,}93} \times 100\%$ ✓

$\eta_s = \boxed{67{,}9\ \%}$ ✓

Calculate Crushing Efficiency $(\eta_{crushing})$

$\eta_c = \frac{F_c}{F_{Solid}} \times 100\%$

$\eta_c = \frac{444{,}96}{513{,}93} \times 100\%$ ✓

$\eta_c = \boxed{86{,}6\ \%}$ ✓

Find Safe load (F_{Safe})

The Safe load $= \boxed{349{,}25\ kN}$ ✓ the smallest force value

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Calculate Joint Efficiency (η_j)

$$\eta_j = \frac{F_{Safe}}{Strength\ of\ solid\ plate} \times 100\%$$

$$\eta_j = \frac{349{,}25}{513{,}93} \times 100\%$$ OR *Even if the candidate just wrote the smallest value from the above three efficiencies, full marks must be granted.*

$\eta_j = \boxed{67{,}9\ \%}$ ✓ **[20]**

QUESTION 3

DATA:

$D = 0{,}5\ m;\ L_{stroke} = 0{,}6\ m;\ L_k = 1{,}5m; P = 550\ kPa;\ F_r = ?;\ F_k = ?;\ \sigma_{cross\ head\ pin} = ?$

$d_{Cross\ Head\ pin} = 0{,}09\ m;\ L_{Cross\ head\ pin} = 0{,}114\ m;$

$\left\{NB: The\ crank\ is\ at\ right\ angles\ to\ connecting\ rod \rightarrow\ \ tan\theta = \frac{L_{crank}}{L_k}\ \&\ cos\theta = \frac{F_p}{F_k}\right\}$

3.1 Find the Force on the crosshead guide (F_r)

$F_p = P \times A$

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

$F_p = 550 \times 10^3 \times \frac{\pi}{4}(0{,}5)^2$ ✓✓

$F_p = 107992{,}248\ N$

$F_p = \boxed{107{,}992\ kN}$ ✓

$Stroke\ length = 2 \times L_{crank}$

$L_{crank} = \frac{0{,}6}{2}$ ✓

$L_{crank} = \boxed{0{,}3\ m}$ ✓

$\tan\theta = \frac{L_{crank}}{L_k}$

$\tan\theta = \frac{0{,}3}{1{,}5}$ ✓

$\theta = \boxed{11{,}31°}$ ✓

$\tan\theta = \frac{F_r}{F_P}$

$F_r = F_P \times \tan\theta$

$F_r = 107992{,}248 \times \tan 11{,}31$ ✓

$F_r = \boxed{21{,}599\ kN}$ ✓ (9)

3.2 Find the Force in the connecting rod (F_k)

$\cos\theta = \frac{F_P}{F_k}$

$F_k = \frac{F_P}{\cos\theta}$

$F_k = \frac{107{,}992}{\cos 11{,}31}$ ✓

$F_k = \boxed{110{,}131\ kN}$ ✓ (2)

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QUESTION 4

DATA: $F_t = 50\ kN;\ \sigma_t = 72\ MPa;\ \tau = 60\ MPa;\ \sigma_c = 180\ MPa; t = 9\ mm$

4.1.1 The diameter of the rod

$$F_t = \frac{\pi}{4} d^2 \sigma_t$$
$$d^2 = \frac{4 \times F_t}{\pi(\sigma_t)}$$
$$d^2 = \frac{4 \times 50 \times 10^3}{\pi(72 \times 10^6)} \quad ✓$$
$$d^2 = 8{,}8419 \times 10^{-4} \quad ✓$$
$$d = 0{,}02974\ m$$
$$d = 29{,}7\ mm$$
$$d = \boxed{30\ mm} \quad ✓ \quad \textit{(Standard size)}$$ (3)

4.1.2 The diameter of the rod end at the cotter hole.

$$F_t = \left[\frac{\pi}{4} {d_1}^2 - (d_1 \times t)\right] \sigma_t$$
$$50 \times 10^3 = \left[\frac{\pi}{4} {d_1}^2 - (d_1 \times 0{,}009)\right] 72 \times 10^6 \quad ✓$$

$$\left[0{,}785 {d_1}^2 - 0{,}009 d_1\right] = 6{,}944 \times 10^{-4}3$$

$$\left[0{,}785 {d_1}^2 - 0{,}009 d_1\right] - 6{,}944 \times 10^{-4} = 0 \quad ✓$$

$$d_1 = \frac{-\mathrm{b} \pm \sqrt{\mathrm{b}^2 - 4\mathrm{ac}}}{2\mathrm{a}}$$

$$d_1 = \frac{-(-0{,}009) \pm \sqrt{(-0{,}009)^2 - 4(0{,}785)(-6{,}944 \times 10^{-4})}}{2(0{,}785)} \quad ✓$$

$$d_1 = \frac{0{,}009 \pm 0{,}048}{1{,}57} \quad ✓$$

$$d_1 = 0{,}0363\ m$$

$$d_1 = 36{,}3\ mm$$

$\textit{Use the nearest value} \quad d_1 = \boxed{36\ mm}$ ✓ (5)

4.1.3 The outside diameter of the socket end at the cotter hole

$$F_t = \left[\frac{\pi}{4}(D^2 - d^2) - (D - d)t\right]\sigma_t$$
$$50 \times 10^3 = \left[\frac{\pi}{4}(D^2 - 0{,}036^2) - (D - 0{,}036)0{,}009\right]72 \times 10^6 \quad ✓$$
$$\left[\frac{\pi}{4}(D^2 - 0{,}036^2) - (D - 0{,}036)0{,}009\right] = 6{,}944 \times 10^{-4}$$
$$0{,}785D^2 - 1{,}018 \times 10^{-3} - 0{,}009D + 3{,}24 \times 10^{-4} = 6{,}944 \times 10^{-4} \quad ✓$$
$$0{,}785D^2 - 0{,}009D - 1{,}388 \times 10^{-3} = 0$$
$$D = \frac{-\mathrm{b} \pm \sqrt{\mathrm{b}^2 - 4\mathrm{ac}}}{2\mathrm{a}}$$
$$D = \frac{-(-0{,}009) \pm \sqrt{(-0{,}009)^2 - 4(0{,}785)(-1{,}388 \times 10^{-3})}}{2(0{,}785)} \quad ✓$$
$$D = \frac{0{,}009 \pm 0{,}067}{1{,}57} \quad ✓$$
$$D = 0{,}0482\ m$$
$$D = 48{,}2\ mm$$
$$Use\ the\ nearest\ value \quad D = \boxed{48\ mm} \quad ✓$$ (5)

4.1.4 The mean width of the cotter

$$F_s = 2bt\tau$$
$$50 \times 10^3 = 2b(0{,}009)(60 \times 10^6) \quad ✓$$
$$b = \frac{(50 \times 10^3)}{2(0{,}009)(60 \times 10^6)} \quad ✓$$
$$b = 0{,}0463\ m$$
$$b = 46{,}3\ mm$$
$$b = \boxed{46\ mm} \quad ✓$$ (3)

4.2.1 Test the crushing strength between cotter and rod

$$F_c = d_1 t\sigma_c$$
$$F_c = (0{,}036)(0{,}009)(180 \times 10^6) \quad ✓$$
$$F_c = 58320\ N$$
$$F_c = \boxed{58{,}32\ kN} \quad ✓$$ (2)

4.2.2 Test for crushing strength between cotter and socket flange

$$F_c = (\mathrm{D}_1 - d_1)t\sigma_c$$
$$F_c = (2{,}42\ \times 0{,}03 - 0{,}036)(0{,}009)(180 \times 10^6) \ ✓ \qquad (\mathrm{D}_1 = 2{,}42\ d) \ ✓$$
$$F_c = 59292\ N$$
$$F_c = \boxed{59{,}3\ kN} \quad ✓$$ (3)

[21]

QUESTION 5

DATA: $F = 80\ kN;\ \tau = 85\ MPa; t_1 = 28\ mm;\ t_2 = 16\ mm;$ $looking\ for: d_1;\ \sigma_{c_{Pin\ \&\ eye}};\ \sigma_{c_{Pin\ \&\ fork}}$

Find the diameter of the pin (d_1)

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

$80 \times 10^3 = 85 \times 10^6 \times 2 \times \frac{\pi}{4} {d_1}^2$ ✓

${d_1}^2 = \frac{80\ 000 \times 4}{\pi(85 \times 10^6)(2)}$ ✓

${d_1}^2 = 5{,}9917 \times 10^{-4}$ ✓

$d_1 = 0{,}02448\ m$

$d_1 = 24{,}48\ mm$

$d_1 = \boxed{25\ mm}$ ✓ *(Standard size)*

Crushing stress between the pin and the eye $\left(\sigma_{c_{Pin\ \&\ eye}}\right)$

$F = \sigma_c \times d_1 \times t_1$

$\sigma_c = \frac{F}{d_1 \times t_1}$

$\sigma_c = \frac{80 \times 10^3}{0{,}025 \times 0{,}028}$ ✓✓

$\sigma_c = 114285714{,}3\ Pa$

$\sigma_c = \boxed{114{,}29\ MPa}$ ✓

Crushing stress between the pin and the fork $\left(\sigma_{c_{Pin\ \&\ fork}}\right)$

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

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

$\sigma_c = \frac{80 \times 10^3}{2 \times 0{,}025 \times 0{,}016}$ ✓✓

$\sigma_c = 100\ 000\ 000\ Pa$

$\sigma_c = \boxed{100\ MPa}$ ✓ **[10]**

QUESTION 6

DATA: $d_s = 60\ mm; \tau_s = 62\ MPa; D = 160\ mm; d = 80\ mm; w = 32\ mm;$

$\tau_{key} = 50\ MPa; \quad \sigma_{c_{key}} = 148\ MPa; n = 3 \quad \tau = ?;\ \sigma_c = ?;\ L_{key} = ?;$

6.1 The shear and compressive stresses in the claws

$T_{max} = \frac{\pi}{16} {d_s}^3 \tau_s$
$T_{max} = \frac{\pi}{16}(0{,}06)^3(62 \times 10^6)$ ✓
$T_{max} = \boxed{2629{,}51\ Nm}$ ✓

Find Areas

$A_s = \frac{\pi}{8}(D^2 - d^2)$
$A_s = \frac{\pi}{8}(0{,}16^2 - 0{,}08^2)$ ✓
$A_s = \boxed{7{,}54 \times 10^{-3}\ m^2}$ ✓

$A_c = n \times w \times \frac{D-d}{2}$
$A_c = 3 \times 0{,}032 \times \frac{0{,}16-0{,}08}{2}$ ✓
$A_c = \boxed{3{,}84 \times 10^{-3} m^2}$ ✓

Find Mean radius

$R_{Mean} = \frac{D+d}{4}$
$R_{Mean} = \frac{160+80}{4}$ ✓
$R_{Mean} = \boxed{60\ mm}$ ✓

Find Forces

$\{T_{claws} = T_{shaft} = T_{max} = 2629{,}51\ Nm\}$

$T_{max} = F_s \times R_{Mean}$
$2629{,}51 = F_s \times 0{,}06$ ✓
$F_s = \frac{2629{,}51}{0{,}06}$ ✓
$F_s = 43825{,}17\ N$
$F_s = \boxed{43{,}825\ kN}$ ✓

$T_{max} = F_c \times R_{Mean}$
$2629{,}51 = F_c \times 0{,}06$ ✓
$F_c = \frac{2629{,}51}{0{,}06}$ ✓
$F_c = 43825{,}17\ N = F_s$
$F_c = \boxed{43{,}825\ kN}$ ✓ *{Even if the candidate just wrote this answer must be given full marks}*

Find the Stresses

$F_s = \tau \times A_s$

$\tau = \frac{F_s}{A_s}$

$\tau = \frac{43825,17}{7,54\times10^{-3}}$ ✓

$\tau = 5812356,76\ Pa$

$\tau = \boxed{5,8\ MPa}$ ✓

$F_c = \tau \times A_c$

$\sigma_c = \frac{F_c}{A_s}$

$\tau = \frac{43825,17}{3,84\times10^{-3}}$ ✓

$\tau = 11412804,69\ Pa$

$\tau = \boxed{11,4\ MPa}$ ✓

The minimum length of the key

From the table *(Where* $d_s = 60\ mm$*)* $w = 18\ mm\ \&\ t = 11\ mm$ (18)

6.2 For Shearing

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

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

$2629,51 = 0,018 \times l \times 50 \times 10^6 \times \frac{0,06}{2}$ ✓

$l = \frac{2629,51\times2}{0,018\times50\times10^6\times0,06}$ ✓

$l = 0,09739\ m$

$\boxed{l = 97,39\ mm}$ ✓

For Crushing

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

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

$2629,51 = \frac{0,11}{2} \times l \times 148 \times 10^6 \times \frac{0,06}{2}$ ✓

$l = \frac{2629,51\times2\times2}{0,11(148\times10^6)(0,06)}$ ✓

$l = 0,01077\ m$

$\boxed{l = 10,77\ mm}$ ✓

Answer: Use Length is equal to 97,39 mm ✓ (for Safety) (7)

[25]

QUESTION 7

DATA: $L_e = 252\ mm;\ \tau = 90\ MPa;\ t_1 = 6\ mm;$

Throat thickness (t)

$t = 0{,}707 \times t_1$

$t = 0{,}707 \times (0{,}006)$ ✓

$t = 0{,}004242\ m$

$t = \boxed{4{,}242\ mm}$ ✓

Area of weld (A)

$A = L_e \times t$

$A = 252 \times 4{,}242$ ✓

$A = 1068{,}984\ mm^2$

$A = \boxed{1{,}069 \times 10^{-3}\ m^2}$ ✓

Tensile load (F)

$F = \tau \times A$

$F = 90 \times 10^6 \times 1{,}069 \times 10^{-3}$ ✓

$F = 96210\ N$

$F = \boxed{96{,}210\ kN}$ ✓ **[6]**

TOTAL: 100

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