higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

MECHANICAL DRAWING AND DESIGN N6

8 AUGUST 2019

This marking guideline consists of 13 pages.

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QUESTION 1

1.1 FORCES ON FLYWHEEL

$$W_{FLYWHEEL} = m \times g$$
$$= 150 \times 9,81$$
$$W_{FLYWHEEL} = 1471,5N \quad (1)$$

FORCES ON BELT PULLEY

$$V_{Pulley} = \frac{\pi \times PCD \times N}{60}$$
$$= \frac{\pi \times 0,48 \times {}^{2100}/_{3}}{60}$$
$$= 17,59 \text{ m/s} \quad (1)$$

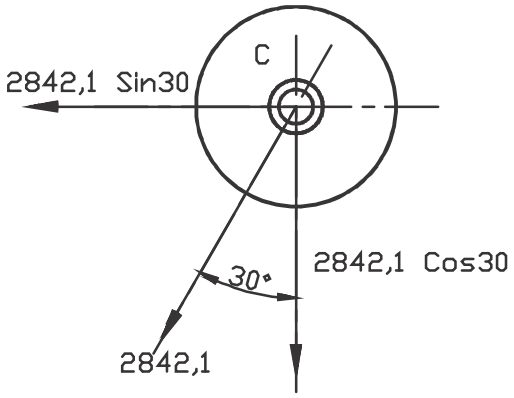
$$P = (T_1 - T_2)v$$
$$30 \times 10^3 = (T_1 - T_2)\ 17,59$$
$$(T_1 - T_2) = 1705,2 \text{ N} \quad (1)$$

$$\frac{T_1}{T_2} = 4$$
$$T_1 = 4 \times T_2 \quad (1)$$

$$(T_1 - T_2) = 1705,2$$
$$(4T_2 - T_2) = 1705,2$$
$$3T_2 = 1705,2$$
$$T_2 = 568,41N \quad (1)$$

$$T_1 = 4 \times T_2$$
$$= 4 \times 568,41$$
$$T_1 = 2273,6N \quad (1)$$

$$T_1 + T_2 = 2273,6+568,41$$
$$= 2842,1N \quad (1)$$



(1)

$$F_H = (T_1 + T_2)\sin 30$$
$$= 2842,1 \times 0,5$$
$$= 1421\,N \quad (1)$$

$$F_V = (T_1 + T_2)\,Cos30$$
$$= 2842,1 \times 0,866$$
$$= 2461,22N \quad (1)$$

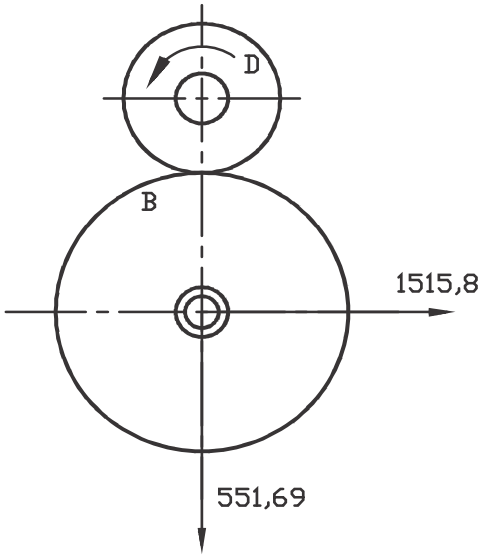
FORCES ON THE GEARS

$$V_{PINION} = \frac{\pi \times PCD \times N}{60}$$
$$= \frac{\pi \times 0,18 \times 2100}{60}$$
$$= 19,79\ m/s \quad (1)$$

$$Power = F_T \times v$$
$$30000 = F_T \times 19,79$$
$$F_T = 1515,8\ N \quad (1)$$

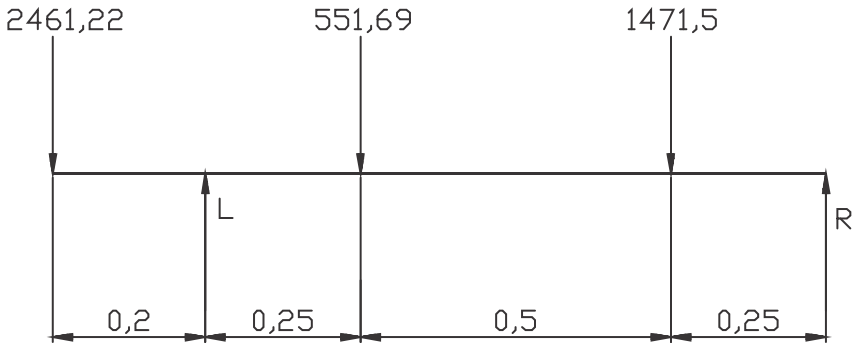
$$F_R = Tan20 \times F_T$$
$$= Tan20 \times 1515,8$$
$$F_R = 551,69\ N \quad (1)$$

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(1)

1.2 BENDING MOMENTS
VERTICAL REACTIONS



(2)

$$1 \times R_L = 2461,22 \times 1,2 + 551,69 \times 0,75 + 1471,5 \times 0,25$$
$$R_L = 3735,11 \text{ N} \quad (1)$$

$$1 \times R_R + 2461,22 \times 0,2 = 551,69 \times 0,25 + 1471,5 \times 0,75$$
$$R_R = 749,3 \text{ N} \quad (1)$$

Check

$$\uparrow F = \downarrow F$$
$$749,3 + 3735,11 = 2461,22 + 551,69 + 1471,5$$
$$4484,41 = 4484,41 \quad (1)$$

VERTICAL BENDING MOMENTS

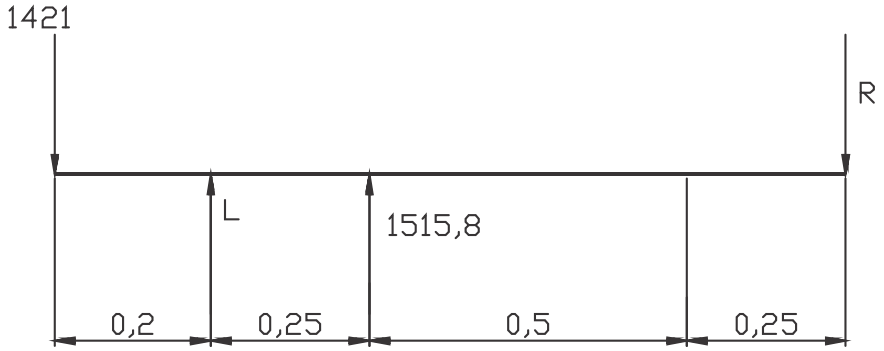
$$BM_L = -2461,22 \times 0,2$$
$$= \text{-492,24 Nm} \quad (1)$$

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$BM_B = 749,3 \times 0,75 - 1471,5 \times 0,5$
$= -173,78 \text{ Nm}$ (1)

$BM_A = 749,3 \times 0,25$
$= 187,31 \text{ Nm}$ (1)

HORIZONTAL REACTIONS



(2)

$1 \times R_L = 1421 \times 1,2 - 1515,8 \times 0,75$
$R_L = 568,35 \text{ N}$ (1)

$1 \times R_R = 1421 \times 0,2 + 1515,8 \times 0,25$
$R_R = 663,15 \text{ N}$ (1)

Check

$\uparrow F = \downarrow F$
$1515,8 + 568,35 = 1421 + 663,15$
$2084,15 = 2084,15$ (1)

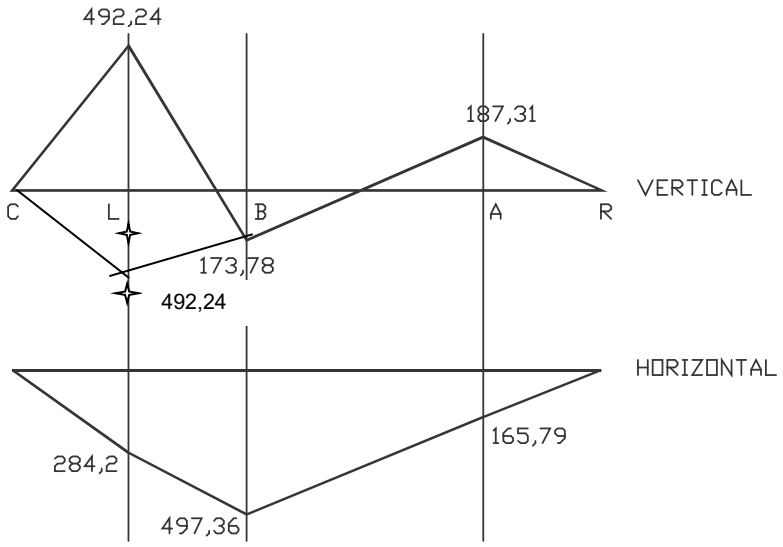
HORIZONTAL BENDING MOMENTS

$BM_L = -1421 \times 0,2$
$= -284,2 \text{ Nm}$ (1)

$BM_B = -663,15 \times 0,75$
$= -497,36 \text{ Nm}$ (1)

$BM_A = -663,15 \times 0,25$
$= -165,79 \text{ Nm}$ (1)

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(4)

1.3 MAXIMUM RESULTANT BENDING MOMENTS

$$BM_L = \sqrt{492,24^2 + 284,2^2}$$
$$= 568,4 \text{ Nm}$$

(1)

$$BM_L = \sqrt{497,36^2 + 173,78^2}$$
$$= 526,8 \text{ Nm}$$

USE 568,4 Nm (1)

1.4 TORQUE ON SHAFT

$$P = \frac{2 \times \pi \times N \times T}{60}$$
$$30 \times 10^3 = \frac{2 \times \pi \times 2100/3 \times T}{60}$$
$$T = 409,26 \text{ Nm}$$

(1)

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1.5 SHAFT DIAMETERS

$$\begin{aligned} T_E &= \sqrt{M^2 + T^2} \\ &= \sqrt{568,4^2 + 409,26^2} \\ &= 700,41 \text{ Nm} \end{aligned}$$ (1)

$$\begin{aligned} T_E &= \pi/16 \times \frac{\left(D^4 - d^4\right)}{D} \times \tau \\ 700,41 &= \pi/16 \times \frac{\left(\left[2d\right]^4 - d^4\right)}{2d} \times 50 \times 10^6 \\ d &= 0,0211 \\ &= 21\text{mm} \\ D &= 42\text{mm} \end{aligned}$$ (1)

$$\begin{aligned} M_E &= 0,5\left[M + \sqrt{M^2 + T^2}\right] \\ &= 0,5\left[568,4 + 700,41\right] \\ &= 634,4 \text{ Nm} \end{aligned}$$ (1)

$$\begin{aligned} M_E &= \pi/32 \times \frac{\left(D^4 - d^4\right)}{D} \times \sigma \\ 634,4 &= \pi/32 \times \frac{\left(\left[2d\right]^4 - d^4\right)}{2d} \times 60 \times 10^6 \\ d &= 0,0243 \\ &= 24\text{mm} \\ D &= 48\text{mm} \end{aligned}$$ (1)

USE 48 mm and 24 mm (1)

1.6 GEAR TEETH

$$\begin{aligned} PCD &= m \times T \\ 180 &= 4 \times T_A \\ T_D &= 45 \\ T_B &= 3 \times T_D \\ T_B &= 135 \end{aligned}$$ (1)

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1.7 FACE WIDTH

$$V = \frac{\pi \times D \times N}{60}$$
$$= \frac{\pi \times 0,18 \times 2100}{60}$$
$$= 19,79 \text{ m/s} \quad (1)$$

$$C_V = \frac{6}{6+V}$$
$$= \frac{6}{6+19,79}$$
$$= 0,23 \quad (1)$$

$$T = F_T \times R$$
$$409,26/3 = F_T \times 0,18/2$$
$$F_T = 1515,78 \text{ N} \quad (1)$$

$$y_D = 0,154 - \left(\frac{0,912}{T}\right)$$
$$= 0,154 - \left(\frac{0,912}{45}\right)$$
$$= 0,134 \quad (1)$$

$$y_B = 0,154 - \left(\frac{0,912}{T}\right)$$
$$= 0,154 - \left(\frac{0,912}{135}\right)$$
$$= 0,147 \quad (1)$$

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To find which gears govern the design i.e. the weaker gear:

$$\text{Gear}_D = \sigma_O \times C_V \times y$$
$$= 120 \times 10^6 \times 0,23 \times 0,134$$
$$= 3,6984 \times 10^6 \quad (1)$$

$$\text{Gear}_B = \sigma_O \times C_V \times y$$
$$= 110 \times 10^6 \times 0,23 \times 0,147$$
$$= 3,7197 \times 10^6 \quad (1)$$

$$b_{MIN} = 2,5 \times \pi \times m$$
$$= 2,5 \times \pi \times 4$$
$$= 31,4 \text{ mm} \quad (1)$$

$$b_{MAX} = 4 \times \pi \times m$$
$$= 4 \times \pi \times 4$$
$$= 50,3 \text{ mm} \quad (1)$$

$$F_T = \pi \times b \times m \times \sigma \times y$$
$$1515,8 = \pi \times 4 \times 10^{-3} \times b \times 3,6984 \times 10^6$$
$$b = 32,615 \text{ mm Say } 33 \text{ mm} \quad (1)$$

1.8 PULLEY ARMS

$$PCD_B = 3 \times 180$$
$$= 540 \text{ mm}$$
$$No\ arms = 5\ (from\ tables) \quad (1)$$

$$d_{BOSS} = 2 \times d_{SHAFT}$$
$$= 2 \times 48$$
$$= 96 \text{ mm} \quad (1)$$

$$L_{BENDING} = \frac{PCD}{2} - \frac{d_{BOSS}}{2}$$
$$= \frac{540 - 96}{2}$$
$$= 222 \text{ mm} \quad (1)$$

$$M = \frac{F_T \times L}{arms}$$
$$= \frac{1515,8 \times 0,222}{5}$$
$$= 67,3 \text{ Nm} \quad (1)$$

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$$M = \sigma \times Z$$
$$67,3 = 30 \times 10^{6} \times Z$$
$$Z = 2,2434 \times 10^{-6}\ \text{m}^3$$ (1)

$$Z = \frac{\pi}{64} a^3$$
$$2,2434 \times 10^{-6} = \frac{\pi}{64} a^3$$
$$a = 35,7\ mm$$
Say 36 mm (2)

$$a = 36\ mm$$
$$b = 18\ \text{mm}$$ (1)
[61]

QUESTION 2

2.1
$$Sin\alpha = \frac{R-r}{w}$$
$$Sin\,6 = \frac{125-r}{65}$$
$$r = 118,21 mm$$ (1)

$$R_F = \frac{R+r}{2}$$
$$= \frac{125+118,21}{2}$$
$$= 121,6\,mm$$ (1)

$$Power = \frac{2 \times \pi \times N \times T}{60}$$
$$28 \times 10^3 = \frac{2 \times \pi \times 1400 \times T}{60}$$
$$= 190,99\,Nm$$ (1)

$$Torque = F_T \times R_F$$
$$190,99 = F_T \times 0,1216$$
$$F_T = 1570,6\,N$$ (1)

$$F_T = \mu \times F_N$$
$$1570,6 = 0,2 \times F_N$$
$$F_N = 7853\,N$$ (1)

$$F_N = \frac{F_A}{Sin\alpha}$$
$$7853 = \frac{F_A}{Sin\,6}$$
$$F_A = 820,87\,N \quad (1)$$

2.2
$$F_{ENG} = F_N\left(Sin\alpha + \mu Cos\alpha\right)$$
$$= 7853\left(Sin6 + 0,2Cos6\right)$$
$$= 2382,87\ \text{N} \quad (2)$$

2.3
$$Area = 2\times\pi\times R_{MEAN}\times width$$
$$= 2\times\pi\times 0,1216\times 0,065$$
$$= 0,04966\,m^2 \quad (1)$$

$$P = \frac{F_N}{Area}$$
$$= \frac{7853}{0,04966}$$
$$= 158,128\,kPa \quad (1)$$

2.4
$$\text{Pr}essure_{MAX} = \frac{F_A}{2\pi\left(R-r\right)r}$$
$$= \frac{820,87}{2\pi\left(0,125-0,11821\right)0,11821}$$
$$= 162,768\,kPa \quad (1)$$

2.5
$$\sum M = 0$$
$$F\times 0,21 = 820,87\times 0,12$$
$$F = 469,1\ \text{N} \quad (1)$$

$$Z = \frac{b\times d^2}{6}$$
$$= \frac{b\times 2^2\times b^2}{6}$$
$$= \frac{4}{6}b^3 \quad (1)$$

$$M = F\times dis\tan ce$$
$$= 469,1\times 0,21$$
$$= 98,5\ \text{Nm} \quad (1)$$

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$$M = \sigma \times Z$$
$$98,5 = 30 \times 10^{6} \times Z$$
$$Z = 3,2835 \times 10^{-6}\ \text{m}^3 \quad (1)$$

$$\tfrac{4}{6} \times b^3 = 3,2835 \times 10^{-6}$$
$$b = 17\ \text{mm} \quad (1)$$

$$d = 2 \times 17$$
$$\text{b} = 34\ \text{mm} \quad (1)$$

2.6
$$M = F \times dis\tan ce$$
$$= 2382,87 \times 0,21$$
$$= 500,4\ \text{Nm} \quad (1)$$

$$M = \sigma \times Z$$
$$500,4 = \sigma \times \tfrac{4}{6} \times 0,017^3$$
$$\sigma = 152,78\ \text{MPa} \quad (1)$$

[19]

QUESTION 3

$$F = \frac{\sigma \times A}{1 + \frac{a}{n}\left(\frac{L}{k}\right)^2}$$
$$600 \times 10^3 = \frac{\tfrac{500 \times 10^6}{8} \times A}{1 + \frac{1}{6400}\left(\frac{4,5}{k}\right)^2}$$
$$1 + \frac{0,003164}{k^2} = 104,17A$$
$$k^2 + 0,003164 = 104,17 \times A \times k^2 \quad (5)$$

$$k^2 = \frac{BD^3 - bd^3}{12(BD - bd)}$$
$$= \frac{B^4 - b^4}{12(B^2 - b^2)}$$
$$= \frac{(B^2 - b^2)(B^2 + b^2)}{12(B^2 - b^2)}$$
$$k^2 = \frac{(B^2 + b^2)}{12} \quad (2)$$

$$A = B^2 - b^2 \quad (1)$$

$$\begin{aligned}
k^2 + 0,003164 &= 104,17 \times A \times k^2 \\
\frac{\left(B^2 + b^2\right)}{12} + 0,003164 &= 104,17 \times \left(B^2 - b^2\right) \times \frac{\left(B^2 + b^2\right)}{12} \\
\left(B^2 + b^2\right) + 0,037968 &= 104,17 \times \left(B^2 - b^2\right) \times \left(B^2 + b^2\right) \\
\left(0,25^2 + b^2\right) + 0,037968 &= 104,17 \times \left(0,25^4 - b^4\right) \\
0,1 + b^2 &= 0,41 - 104,17b^4 \\
104,17b^4 + b^2 - 0,31 &= 0
\end{aligned} \quad (5)$$

Say $b^2 = x$ (1)

$$\begin{aligned}
&= \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \\
&= \frac{-1 \pm \sqrt{1^2 - 4(104,17)(-0,31)}}{2(104,17)} \\
&= 0,0499
\end{aligned} \quad (3)$$

$$\begin{aligned}
b^2 &= 0,0499 \\
b &= 223,5\,mm
\end{aligned} \quad (1)$$

$$\begin{aligned}
t &= \frac{250 - 223}{2} \\
b &= 13,5\,mm
\end{aligned} \quad (2)$$

[20]

TOTAL: 100

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