Answer Key

MACHINE DESIGN

Refresher 01

1

$$S_s = \frac{F}{A}$$

$$\left(180 \frac{N}{mm^2}\right)\left(\frac{1\ kN}{1000\ N}\right) = \frac{F}{\frac{\pi}{4}(25mm)^2}$$

$$\boxed{F = 88.3573\ kN}$$

2

$F = 1600 N$

$L = 130 mm$

Work done;

$W = FL = (1600 N)(0.130 m)$

$\boxed{W = 208 J}$

3

$S_s = 280 \text{ MPa}$

$d = 50 \text{ mm}$

$t = 8 \text{ mm}$

Force required to punch a hole

$$S_s = \frac{F}{A}$$

$$280 \frac{N}{mm^2}\left(\frac{1 kN}{1000 N}\right) = \frac{F}{\pi(50 mm)(8 mm)}$$

$$\boxed{F = 351.8584 \text{ kN}}$$

4

$S_s = 45\ MPa$

$d = 110\ mm$

Torque that can be applied

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

$$45\frac{N}{mm^2}\left(\frac{1\ kN}{1000\ N}\right) = \frac{16\ T}{\pi\ (110\ mm)^3}$$

$$\boxed{T = 11{,}760.3558\ kN\text{-}m}$$

5

$N_B = 8$

$h = 20mm$ (bolt diameter)

$T = 130\ N-m$

$H = 180\ mm$ (bolt circle diameter)

$$S_s = \frac{2T}{H\left[\frac{\pi h^2}{4}\right]N_B} = \frac{2(130\ N-m)\left(\frac{1000\ mm}{1m}\right)}{(180mm)\left[\frac{\pi}{4}(20mm)^2\right]8}$$

$$\boxed{S_s = 0.5747\ N/mm^2 \text{ or } MPa}$$

6

0.40 – 0.50

7

5500 to 6000 psi

8

45 deg

Decrease in centrifugal force due to the low speeds

10

Exponential LEAP ONLINE REVIEW

Thin Hollow Sphere pressure Vessel

$r = 12''$

$t = 0.10''$

$P = 120 \text{ psi}$

The maximum normal stress

$$S_s = \frac{Pd}{4t} = \frac{(120 \text{ lb/in}^2)(24 \text{ in})}{4(0.10 \text{ in})}$$

$$\boxed{S_s = 7200 \text{ psi}}$$

11

$d = 28\,mm$

$L = 1000\,mm$

$\delta = 1.0\,mm$

$$\delta = \frac{FL}{AE}$$

$$1.0\,mm = \frac{F\,(1000\,mm)}{\frac{\pi}{4}(28\,mm)^2\left(207 \times 10^3\,\frac{N}{mm^2}\right)\left(\frac{1\,kN}{1000\,N}\right)}$$

$$\boxed{F = 127.4607\,kN}$$

12

$L = 50\,mm$ (length of keyway)

milling tool = 20 teeth

$N = 140\,rpm$

$\text{Feedrate} = 0.130 \dfrac{mm}{tooth}$

Time to mill a key way

$$v = \frac{s}{t}$$

$$t = \frac{s}{v} = \frac{50mm}{\left(0.130 \frac{mm}{\cancel{tooth}}\right)\left(20\,\cancel{teeth}\right)\left(140 \frac{rev}{min}\right)}$$

$$\boxed{t = 0.1374\ min}$$

13

Unity

Saint-Venant's theory

15

James Clerk Maxwell theory
Hencky-Von Mises theory
Huber theory

16

Set screws

17

32 to 38 deg

SAE 1060 SHAFT

$d = 3.5''$

$S_d = 9000$ psi

Polar Section modulus

$$Z = \frac{J}{c} \quad ; \quad J = \frac{\pi d^4}{32} \quad ; \quad c = \frac{d}{2}$$

$$Z = \frac{\pi d^3}{16} = \frac{\pi (3.5 \text{ in})^3}{16}$$

$$\boxed{Z = 8.4185 \text{ in}^3}$$

19

Spindle speed to produce a cutting speed of 160 ft/min in 2.5" diameter bar

$$v = \pi d N$$

$$160 \frac{ft}{min} = \pi (2.5 \text{ in})\left(\frac{1 ft}{12 in}\right) N$$

$$\boxed{N = 244.4619 \text{ rpm}}$$

20

exponential LEAP
ONLINE REVIEW

$P = 50\,kW$

$N = 160\ rad/s$

$L = 4\ m$

$S_s = 50\ MPa$

$G = 68\ GPa$

Angle of Twist

$$\theta = \frac{TL}{JG} \quad ; \quad P = 2\pi T N$$

$$50\ \frac{kJ}{s} = 2\pi\, T\left(160\ \frac{rad}{s}\right)\left(\frac{180^\circ}{\pi\ rad}\right)\left(\frac{1\ rev}{360^\circ}\right)$$

$$T = 0.3125\ kN\text{-}m$$

Then; from

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

$$50\,000\ \frac{kN}{m^2} = \frac{16\,(0.3125\ kN\text{-}m)}{\pi d^3}$$

$$d = 0.03169\ m$$

Subst;

$$\theta = \frac{(0.3125\ kN\text{-}m)(4\ m)}{\frac{\pi\,(0.03169\ m)^4}{32}\left(68 \times 10^6\ kPa\right)}$$

$$\theta = (0.1857\ rad)\left(\frac{180^\circ}{\pi\ rad}\right)$$

$$\boxed{\theta = 10.6374^\circ}$$

21

$d = 3.0''$

$N = 280\ rpm$

$$v = \pi d N = \pi(3.0 in)\left(\frac{1 ft}{12 in}\right)(280 rpm)$$

$$\boxed{v = 219.9115\ fpm}$$

$$S_s = \frac{16T}{\pi d^3} = \frac{16\,(4.3\text{ kN-m})\left(\frac{1\text{ MN}}{1000\text{ kN}}\right)}{\pi\,(0.080\text{ m})^3}$$

$$\boxed{S_s = 42.7729\text{ MPa}}$$

23

Press forging

24

Extrusion

25

Stress cracking

26

29 deg

$N_p = 1900$ rpm

$P = 60$ hp

$D_p = 7$ in (pitch diameter)

$\theta = 14.5°$

Tangential load; F_t

$$F = \frac{F_t}{\cos\theta}$$; F = load (force) on line of action of tooth load

F_t = transmitted tangential load

Solving for the load on line of action; F

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

$$(60\ hp)\left(\frac{550\ \frac{ft-lb}{s}}{1\ hp}\right) = \frac{2\pi T (1900\ rpm)}{60}$$

$$T = 165.8562\ lb\text{-}ft$$

and then;

$$T = F\left(\frac{D_p}{2}\right)$$

$$165.8562\ lb\text{-}ft = F\left(\frac{7\ in}{2}\right)\left(\frac{1\ ft}{12\ in}\right)$$

$$F = 568.6498\ lb$$

Hence; substituting

$$568.6498\ lb = \frac{F_t}{\cos(14.5°)}$$

$$\boxed{F_t = 550.5370\ lbs.}$$

28

$$P = (30hp)\left(\frac{550\ \frac{ft\text{-}lb}{s}}{1hp}\right) = 16500\ \frac{ft\text{-}lb}{s}$$

$N = 320$ rpm

$$\frac{\theta}{L} = \frac{0.08°}{ft}$$

$G = 12500$ psi

Solving for the line shaft diameter

$$\theta = \frac{TL}{JG}\ ; \quad P = \frac{2\pi TN}{60}$$

$$16500\ \frac{ft\text{-}lb}{s} = \frac{2\pi T(320\,rpm)}{60}$$

$$T = 492.3856\ ft\text{-}lb$$

subst;

$$\left(\frac{0.08°}{ft}\right)\left(\frac{1\,ft}{12\,in}\right)\left(\frac{\pi\ rad}{180°}\right) = \frac{(492.3856\ ft\text{-}lb)\left(\frac{12\ in}{1\,ft}\right)}{\frac{\pi\ d^4}{32}\left(12500000\ \frac{lb}{in^2}\right)}$$

$$\boxed{d = 2.5363\ in}$$

29

$N_T = 26$ coils

$F = 150$ kgs

$G = 100$ GPa

$D_o = 8$ cm

$d = 8$ mm

Spring deflection; δ

$$\delta = \frac{8Fc^3 n}{dG}$$

For Square & Ground

$$N_T = n + 2$$

$$26 = n + 2$$

$$n = 24$$

and

$$c = \frac{D_m}{d} = \frac{D_o + d}{d} = \frac{0.08 - 0.008}{0.008} = 9$$

subst;

$$\delta = \frac{8(150\text{ kgs})\left(\frac{9.81\ m/s^2}{1000\ \frac{kg-m}{kN-s^2}}\right)(9)^3(24)}{(0.008\text{ m})(100 \times 10^6\text{ kPa})}$$

$$\delta = (0.2575\text{ m})\left(\frac{1000\text{ mm}}{1\text{ m}}\right)$$

$$\boxed{\delta = 257.5\text{ mm}}$$

30

$h = 2''$ (bolt diameter)

$S_t = 12000$ psi (working stress)

The working strength

$$W_t = S_t\left[0.55d^2 - 0.25d\right] \quad ; \text{lb}$$

substi;

$$W_t = (12000\text{ psi})\left[0.55(2\text{ in})^2 - 0.25(2\text{ in})\right]$$

$$\boxed{W_t = 20400 \text{ lbs}}$$

31

$$\rho_{STEEL} = 0.284 \ lb/in^3$$

from; $\rho = \frac{m}{V}$

$$0.284 \ lb/in^3 = \frac{m}{(1 in)(5 ft)(25 ft)\left(\frac{144 in^2}{1 ft^2}\right)}$$

$$\boxed{m = 5112.0 \ lbs}$$

32

$d = 2.5 \text{ in}$

$S_s = 8000 \frac{lb}{in^2}$

$N = \left(22 \frac{rad}{sec}\right)\left(\frac{180°}{\pi\, rad}\right)\left(\frac{1 rev}{360°}\right) = 3.5014 \text{ rev/sec}$

$P = 2\pi T N \quad ; \quad S_s = \frac{16 T}{\pi d^3}$

$8000 \frac{lb}{in^2} = \frac{16 T}{\pi (2.5 in)^3}$

$T = 24543.6926 \text{ lb-in}$

subst;

$P = 2\pi \left(24543.6926 \text{ lb-in}\right)\left(\frac{1 ft}{12 in}\right)\left(3.5014 \frac{rev}{sec}\right)$

$P = \left(44996.6574 \frac{lb-ft}{sec}\right)\left(\frac{1 hp}{550 \frac{ft-lb}{sec}}\right)$

$\boxed{P = 81.8121 \text{ hp}}$

33

$$\frac{\theta}{L} = \frac{0.65^\circ}{m}$$

$$S_s = 65\ \text{MPa}$$

$$G = 80\ \text{GPa}$$

Diameter of the shaft

$$\theta = \frac{TL}{JG} \quad ; \quad J = \frac{\pi}{32} d^4 \quad ; \quad T = \frac{\pi S_s d^3}{16}$$

subst;

$$\frac{\theta}{L} = \frac{\frac{\pi S_s d^3}{16}}{\frac{\pi}{32} d^4 G}$$

Then;

$$\left(\frac{0.65^\circ}{\cancel{m}}\right)\left(\frac{\pi\ \text{rad}}{180^\circ}\right)\left(\frac{1\ \cancel{m}}{1000\ \text{mm}}\right) = \frac{\frac{\cancel{\pi}(65\ \cancel{\text{MPa}})\, d^{\cancel{3}}}{16}}{\frac{\cancel{\pi}}{32} d^{\cancel{4}} (80 \times 10^3\ \cancel{\text{MPa}})}$$

$$\boxed{d = 143.2394\ \text{mm}}$$

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$P = 85\ hp$

$N = 1700\ rpm$

$S_s \leq 6500\ psi$

Diameter of the solid shaft

$$S_s = \frac{16T}{\pi d^3} \quad ; \quad P = 2\pi T N$$

$$(85\ hp)\left(\frac{550\ \frac{ft\text{-}lb}{s}}{1\ hp}\right) = 2\pi T \frac{(1700\ rpm)}{60}$$

$$T = 262.6057\ lb\text{-}ft$$

subst;

$$6500\ \frac{lb}{in^2} = \frac{16\,(262.6057\ lb\text{-}ft)\left(\frac{12\ in}{1\ ft}\right)}{\pi d^3}$$

$$\boxed{d = 1.3516\ in}$$

35

192

36

Hydrodynamic lubrication

Circular pitch

38

Varnish

39

Nominal diameter of 12mm and pitch of 1.75mm

40

660 deg

41

$D = 100\ cm$

$P = 8\ MPa$

$S_y = 250\ MPa$

$FS = 4$

Wall thickness

$$S_d = \frac{PD}{2t} \quad ; \quad S_d = \frac{S_y}{FS}$$

$$\frac{S_y}{FS} = \frac{PD}{2t}$$

$$\frac{(250\ \cancel{MPa})}{4} = \frac{(8\ \cancel{MPa})(100\ cm)}{2t}$$

$$\boxed{t = 6.4\ cm}$$

$F = 35000\ lb$

$S_s = 13000\ lb/in^2$

Diameter of the shaft

$S_s = \dfrac{16T}{\pi d^3}$; $T = F\left(\dfrac{d}{2}\right)$

subst;

$$S_s = \frac{16F(d/2)}{\pi d^3}$$

$$S_s = \frac{8F}{\pi d^2}$$

$$13000\ \frac{lb}{in^2} = \frac{8(35000\ lb)}{\pi d^2}$$

$$\boxed{d = 2.6184\ in}$$

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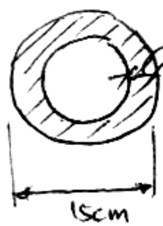
EXPONENTIAL LEAP ONLINE REVIEW



$P = 220\ kW$

$N = 380\ rpm$

$L = 6\ m$

$G = 12000000\ psi$

Angular Deflection

$$\theta = \frac{TL}{JG} \quad ; \quad J = \frac{\pi}{32}\left(D_o^4 - D_i^4\right)$$

$$D_o = D_i + 2t$$

$$0.15m = D_i + 2(0.0010m)$$

$$D_i = 0.148m$$

$$J = \frac{\pi}{32}\left(0.15^4 - 0.148^4\right)m^4$$

$$J = 2.5982 \times 10^{-6}\ m^4$$

for the torque transmitted

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

$$220\ kW = \frac{2\pi T\,(380\ rpm)}{60}$$

$$T = 5.5285\ kN\text{-}m$$

subst;

$$\theta = \frac{(5.5285\ kN\text{-}m)(6m)}{(2.5982 \times 10^{-6}\ m^4)(12000000\ psi)\left(\frac{101.325\ kPa}{14.7\ psi}\right)}$$

$$\theta = (0.1543\ rad)\left(\frac{180°}{\pi\ rad}\right)$$

$$\boxed{\theta = 8.8436\ deg}$$

44

Torque to produce angular acceleration

$$T = \frac{1}{2} I \omega^2 \quad ; \quad I = \frac{mR^2}{g_c}$$

$$T = \frac{1}{2} \frac{mR^2}{g_c} \omega^2$$

$$T = \frac{1}{2} \frac{(800\ kg)}{\left(1 \frac{kg\text{-}m}{N\text{-}s^2}\right)} (0.9\ m)^2 \left(100 \frac{rev}{min\text{-}s}\right)\left(\frac{1\ min}{60\ s}\right)\left(\frac{2\pi\ rad}{1\ rev}\right)$$

$$\boxed{T = 3392.92\ J}$$

45

$$P = \frac{D^3 N}{38} \quad ; \text{Hp}$$

$$P = \frac{(1\text{in})^3 (400\text{rpm})}{38}$$

$$P = (10.5263 \text{ hp})\left(\frac{0.746 \text{ kw}}{1\text{hp}}\right)$$

$$\boxed{P = 7.8526 \text{ kw}}$$

$$S_T = E\epsilon$$

$$43000 \frac{lb}{in^2} = E\left(0.00120 \frac{in}{in}\right)$$

$$\boxed{E = 35.8 \times 10^6 \, psi}$$

47

White

48

Low lead angle

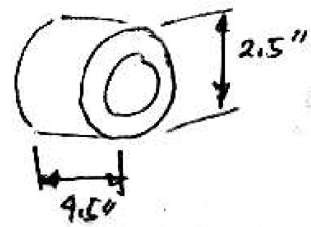
49

0.25 to 0.35

50

Medium alloy

51



F = 1200 lb

N = 1800 rpm

SAE40 lube oil

Bearing Pressure

$$S_d = \frac{F}{LD} = \frac{(1200\ \text{lb})}{(4.5\ \text{in})(2\ \text{in})}$$

$$\boxed{S_d = 133.33\ \text{psi}}$$

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exponential LEAP
ONLINE REVIEW

$$S_s = \frac{F}{\pi d t}$$

$$43000\ \frac{lb}{in^2} = \frac{F}{\pi(1in)(3/4\ in)}$$

$$\boxed{F = 101316.3631\ lbs}$$

53

Lead

54

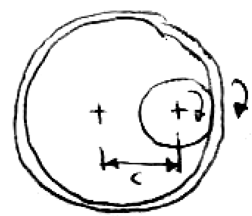
Chromium

55

0.25 to 0.50%

56

Nickel



$$\frac{n_1}{n_2} = 5$$

$$\frac{D_2}{D_1} = \frac{n_1}{n_2}$$

$$\frac{D_2}{8.5\text{ cm}} = 5$$

$$D_2 = 42.5\text{ cm}$$

and;

$$c = \frac{D_2 - D_1}{2} = \frac{(42.5 - 8.5)\text{ cm}}{2}$$

$$\boxed{c = 17\text{ cm}}$$

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exponential LEAP
ONLINE REVIEW

$$P = \frac{1}{\text{Thread/inch}}$$

$$\frac{2}{7} = \frac{1}{\text{Thread/inch}}$$

$$\boxed{\text{Thread/inch} = 3.5}$$

$$S_T = \frac{PD}{4t\eta}$$

$$60000 \text{ psi} = \frac{P(15 \text{ in})}{4(1/4 \text{ in})(0.80)}$$

$$\boxed{P = 3200 \text{ psi}}$$

60

Manganese
Molybdenum
Phosphorus

61

2.5

62

Clutch

63

Pitch

64

27

65

% carbon content

66

15

Anvil

68

Tooth thickness

$$t = \frac{1.5708}{P_d} = \frac{1.5708}{5}$$

$$t = (0.31416\ in)\left(\frac{25.4\ mm}{1\ in}\right)$$

$$\boxed{t = 7.9797\ mm}$$

69

$$F_e = \frac{S_y}{6} A_s^{3/2} \quad ; \text{lbs}$$

$$280\ \text{lbs} = \frac{55\,000\ \text{psi}}{6} A_s^{3/2}$$

$$\boxed{A_s = 0.09772\ \text{in}^2}$$

70

Pressure punching a hole

$$P = d * t * 80 \text{ ; tons}$$

$$P = (3.8 \text{ in})(1/2 \text{ in})(80)$$

$$\boxed{P = 152 \text{ tons}}$$

$$S_S = \frac{PD}{2t}$$

$$28000\ \frac{lb}{in^2} = \frac{(1900\ lb/in^2)(12\ in)}{2t}$$

$$t = (0.4071\ in)\left(\frac{25.4\ mm}{1\ in}\right)$$

$$\boxed{t = 10.3414\ mm}$$

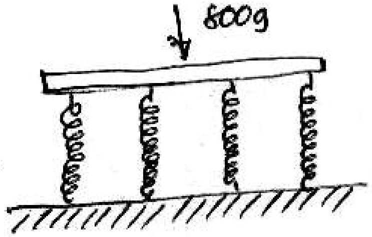
72

$$\frac{T_1}{T_2} = \frac{D_1}{D_2} = \frac{n_2}{n_1} \quad ; \quad \begin{array}{l} 1 - \text{pinion} \\ 2 - \text{gear} \end{array}$$

$$\frac{72}{180} = \frac{n_2}{460 \text{ rpm}}$$

$$\boxed{n_2 = 184 \text{ rpm}}$$

73



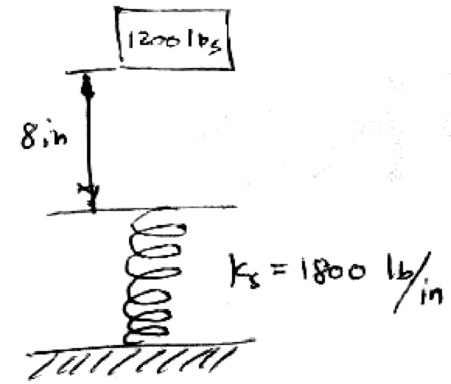
$k_s = 0.610\ g/mm$

Deflection in Spring

$$k_s = \frac{F}{\delta}$$

$$0.610\ g/mm = \frac{(800/4\ g)}{\delta}$$

$$\boxed{\delta = 327.8689\ mm}$$



Deformation on Spring

$$W(h+\delta) = \frac{F}{2}\delta$$

$$k_s = \frac{F}{\delta}$$

$$1800\,\frac{lb}{in} = \frac{F}{\delta}$$

Subst;

$$1200\,lbs\,(8\,in + \delta) = \frac{1800\,lb/in}{2}\,\delta^2$$

$$\frac{32}{3} + \frac{4}{3}\delta = \delta^2$$

$$\delta^2 - \frac{4}{3}\delta - \frac{32}{3} = 0$$

$$\delta_2 = -8/3\ in$$

$$\boxed{\delta_1 = 4\ in}$$

75

Exponential LEAP ONLINE REVIEW

$\frac{D_2}{D_1} = 4$

$C = 18 \text{ in}$

$T_2 = 80 \text{ teeth}$

circular Pitch

$P_c P_d = \pi$

$P_d = \frac{T_1}{D_1} = \frac{T_2}{D_2}$; $C = \frac{D_1 + D_2}{2}$

$18 \text{ in} = \frac{D_2/4 + D_2}{2}$

$D_2 = 28.8 \text{ in}$

Subst;

$P_d = \frac{80}{28.8} = 2.7778 \frac{\text{tooth}}{\text{in}}$

Hence;

$P_c \left(2.7778 \text{ tooth}/\text{in}\right) = \pi$

$P_c = (1.1309 \text{ in})\left(\frac{25.4 \text{ mm}}{1 \text{ in}}\right)$

$\boxed{P_c = 28.7267 \text{ in}}$

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STANDARD ROLLER CHAIN

$P = 3/4''$

$\text{ALLOWABLE LOAD} = 1900\,P^2 \quad ; \text{lbs}$

$\text{Allowable load} = 1900(3/4 \text{ in})$

$\boxed{\text{ALLOWABLE LOAD} = 1068.75 \text{ lbs}}$

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$N = 1300$ rpm

Standard known chain number

$$P \le \left(\frac{900}{N}\right)^{2/3}$$

$$P = \left(\frac{900}{1300\ \text{rpm}}\right)^{2/3}$$

$P = 0.7826$ in

Designation of chain sizes for $P = 0.7826$ in

$$\boxed{\begin{array}{l} \text{Chain \# } = 60 \\ \text{Pitch, in } = 3/4'' \end{array}}$$

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Basic Stress, $S_o = 12\,000 psi$

pitch line Velocity $v = 900 fpm$

Allowable stress, in psi

Barth Equation

$$S_{all} = S_o C_v$$

$$C_v = \frac{600}{600 + v}$$

$$C_v = \frac{600}{600 + 900 fpm} = 0.40$$

Hence;

$$S_{all} = 12{,}000 psi (0.40)$$

$$\boxed{S_{all} = 4800 psi}$$

$$d = D_g\left[0.5 + 0.0344\sqrt{T_g - 12}\right]$$

if no. of teeth = 12 ~ 24 use the Given T_g

no of teeth > 24 use $T_g = 24$

$$d = 3.2\text{ in}\left[0.5 + 0.0344\sqrt{24 - 12}\right]$$

$$\boxed{d = 1.9813\text{ in}}$$

80

$$T = wfPr^2\theta \text{ ; in-lb}$$

$$= (4\text{ in})(0.2)\left(45\ \frac{\text{lb}}{\text{in}^2}\right)(15\text{ in})^2\left(100\text{ deg} * \frac{\pi\text{ rad}}{180\text{ deg}}\right)$$

$$\boxed{T = 14{,}137.1669\text{ in-lb}}$$

Exponential LEAP ONLINE REVIEW

Wahl's factor

$$k_w = \frac{4c-1}{4c-4} + \frac{0.615}{c}$$

$$c = \frac{D_m}{d} \text{ ; spring index}$$

$$c = \frac{70\,mm}{10\,mm} = 7$$

Subst;

$$k_w = \frac{4(7)-1}{4(7)-4} + \frac{0.615}{7}$$

$$\boxed{k_w = 1.2129}$$

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Exponential LEAP ONLINE REVIEW

$$S_s = \frac{8Fc\,k_w}{\pi d^2}$$

$$c = \frac{D_m}{d} = \frac{32\text{ mm}}{5\text{ mm}} = 6.4$$

$$k_w = \frac{4c-1}{4c-4} + \frac{0.615}{c} = \frac{4(6.4)-1}{4(6.4)-4} + \frac{0.615}{6.4}$$

$$k_w = 1.23498$$

Substi

$$420\,\frac{N}{mm^2} = \frac{8F(6.4)(1.23498)}{\pi(5\text{ mm})^2}$$

$$\boxed{F = 521.6861\text{ N}}$$

$$\delta = \frac{8Fc^3n}{dG}$$

$$30\,mm = \frac{8(521.6861\,N)(6.4)^3 n}{(5\,mm)(90\times10^3\,N/mm^2)}$$

$$n = 12.3394$$

$$\boxed{n \approx 13 \text{ coils}}$$

centripugal Force;

$$F_c = \rho \frac{(bt)v^2}{g_c}$$

$$= \left(980\ kg/m^3\right)\frac{(0.120m)(0.0065)(18.5\ m/s)^2}{\left(1\ \frac{kg-m}{N-s^2}\right)}$$

$$\boxed{F_c = 261.6159\ N}$$

85

Shaft diameter

(Subjected to Torsion & Bending)

(a) Ductile material

$$S_{s_{max}} = \frac{16}{\pi D_o^3}\sqrt{M^2 + T^2}$$

$$50 \times 10^6 \frac{N}{m^2} = \frac{16}{\pi D_o^3}\sqrt{(350\ N\text{-}m)^2 + (230\ N\text{-}m)^2}$$

$D_o = 0.03494\ m$

$D_o = 34.94\ mm$

(b) For Brittle material

$$S_{t_{max}} = \frac{16}{\pi D_o^3}\left[M + \sqrt{M^2 + T^2}\right]$$

$$55 \times 10^6 \frac{N}{m^2} = \frac{16}{\pi D_o^3}\left[350\ N\text{-}m + \sqrt{(350\ N\text{-}m)^2 + (230\ N\text{-}m)^2}\right]$$

$D_o = 0.04145\ m$

$\boxed{D_o = 41.45\ mm}$

86

Belt width

$$F_1 - F_2 = bt\left[S_d - \rho\frac{v^2}{g_c}\right]\left[\frac{e^{f\theta}-1}{e^{f\theta}}\right]$$

$$v = \frac{\pi d n}{60} = \frac{\pi(2.5\ ft)(530\ rpm)}{60}$$

$$v = \left(71.9948\ \frac{ft}{s}\right)\left(\frac{12\ in}{1\ ft}\right) = 863.9379\ in/sec$$

and;

$$\left[\frac{e^{f\theta}-1}{e^{f\theta}}\right] = \frac{e^{(0.48)\left(145^\circ * \frac{\pi}{180^\circ}\right)} - 1}{e^{(0.48)\left(145^\circ * \frac{\pi}{180^\circ}\right)}} = 0.7032$$

solving for $F_1 - F_2$;

$$P = \frac{2\pi T_B n}{60};$$

$$(35\ hp)\left(\frac{550\ ft\text{-}lb/s}{1\ hp}\right) = \frac{2\pi T_B (530\ rpm)}{60}$$

$$T_B = 334.2254\ ft\text{-}lb$$

subst; to

$$T_B = F_1 - F_2\left(\frac{d}{2}\right)$$

$$334.2254\ ft\text{-}lb = (F_1 - F_2)\left(\frac{2.5\ ft}{2}\right)$$

$$F_1 - F_2 = 267.3803\ lbs$$

86 cont…

Hence;

$$267.3803\text{ lbs} = b\left(\tfrac{1}{4}\text{ in}\right)\left[600\,\frac{\text{lb}}{\text{in}^2} - 0.035\,\frac{\text{lb}}{\text{in}^3}\,\frac{\left(863.9379\text{ in/sec}\right)^2}{\left(32.2\,\frac{\text{ft-lb}}{\text{lbf-sec}}\right)\left(\frac{12\text{ in}}{1\text{ ft}}\right)}\right](0.7032)$$

$$\boxed{b = 2.8568\text{ in}}$$

Toughness

Exponential LEAP ONLINE REVIEW

Clutch Disc

Torque based on uniform pressure

$T = f F_n r_f N_c$

$$r_f = \frac{D^3 - d^3}{3(D^2 - d^2)} = \frac{(0.280\,m)^3 - (0.120\,m)^3}{3(0.280^2 - 0.120^2)\,m^2}$$

$$r_f = 0.1053\ m$$

subst;

$$T = (0.40)(1000\,N)(0.1053\,m)(1)$$

$$\boxed{T = 42.12\ N\text{-}m}$$

89

exponential LEAP
ONLINE REVIEW

torque based on Uniform wear theory

$$r_f = \frac{D+d}{4} = \frac{0.280\,m + 0.120\,m}{4} = 0.10\ m$$

subst;

$$T = (0.40)(1000N)(0.10m)(1)$$

$$\boxed{T = 40\ N\text{-}m}$$

90

$$S_s = \frac{16T}{\pi d^3} \quad ; \quad P = \frac{2\pi T N}{60}$$

$$(1.5\,hp)\left(\frac{550\ \frac{lb\text{-}ft}{s}}{1\,hp}\right)\left(\frac{12\,in}{1\,ft}\right) = \frac{2\pi T\,(120\,rpm)}{60}$$

$$T = 787.8169\ lb\text{-}in$$

Subst;

$$6500\ \frac{lb}{in^2} = \frac{16\,(787.8169\ lb\text{-}in)}{\pi d^3}$$

$$\boxed{d = 0.8514\ in}$$

91

$$\theta = \frac{TL}{JG} \; ; \; J = \frac{\pi D^4}{32}$$

$$\theta = \frac{32TL}{\pi D^4 G} = \frac{32T(25\cancel{D})}{\pi D^{\cancel{4}} G}$$

$$\theta = \frac{800T}{\pi D^3 G}$$

from; $P = \frac{2\pi TN}{60}$

$$(45\text{ hp})\left(\frac{550 \frac{\text{ft-lb}}{\text{s}}}{1\text{ hp}}\right)\left(\frac{12\text{ in}}{1\text{ ft}}\right) = \frac{2\pi T(220\text{ rpm})}{60}$$

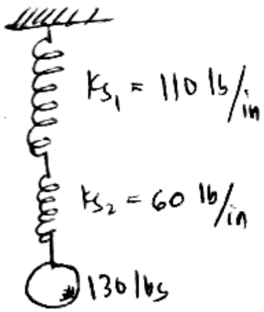
$$T = 12891.5504\text{ lb-in}$$

subst;

$$(1^\circ)\left(\frac{\pi\text{ rad}}{180^\circ}\right) = \frac{800(12891.5504\text{ lb-in})}{\pi D^3(11.5\times10^6\text{ psi})}$$

$$\boxed{D = 2.5384\text{ in}}$$

92



Deflection of the load

$$k_s = \frac{P}{\delta}\ ; \quad \text{For series Springs}$$

$$k_s = \frac{1}{\frac{1}{k_{s_1}} + \frac{1}{k_{s_2}}}$$

$$k_s = \frac{1}{\frac{1}{110\ lb/in} + \frac{1}{60\ lb/in}} = 38.82\ \frac{lb}{in}$$

Subst;

$$38.82\ \frac{lb}{in} = \frac{130\ lbs}{\delta}$$

$$\boxed{\delta = 3.3485\ in}$$

93

For parallel springs

$$k_s = k_{s_1} + k_{s_2} = (100 + 60)\frac{lb}{in} = 160\ \frac{lb}{in}$$

subst;

$$160\ \frac{lb}{in} = \frac{130\ lbs}{\delta}$$

$$\boxed{\delta = 0.8125\ in}$$

94

J-B Johnson theory

$$F_{crit} = \frac{\pi d^2}{4} S_y \left(1 - \frac{B}{4k^2}\right)$$

$$B = \frac{S_y L^2}{n\pi^2 E} = \frac{(480\times10^6\ N/m^2)(1.8\ m)^2}{(1)\ \pi^2 (207\times10^9\ N/m^2)}$$

$$B = 7.6123\times10^{-4}\ m^2$$

$$F_{crit} = (F_{max})(FS)$$

$$= (25000N)(5)$$

$$F_{crit} = 125000N$$

$$k = \sqrt{\frac{I}{A}}$$

for solid round cross section

$$k = \frac{d}{4}$$

Subst;

$$125\,000\,N = \frac{\pi d^2}{4}\left(480\times10^6 \frac{N}{m^2}\right)\left[1 - \frac{7.6123\times10^{-4} m^2}{4\left(\frac{d^2}{16}\right)}\right]$$

$$d = 0.05811\ m$$

Test:

if $\frac{B}{k^2} > 2$ JB Johnson Does not predic

$$\frac{7.6123\times10^{-4}\ m^2}{\frac{(0.05811\ m)^2}{16}} = 3.6069$$

$\therefore$ use Euler's Formula

94 cont…

Euler's Formula:

$$F_{crit} = S_y\left(\frac{A}{B}\right)k$$

$$125\,000\,N = \left(480\times10^{6}\frac{N}{m^2}\right)\left[\frac{\pi d^2}{4\left(7.6123\times10^{-4}m^2\right)}\right]\frac{d^2}{16}$$

$$d = 0.04483\ m$$

$$\boxed{d = 44.83\ mm}$$

95

Exponential LEAP ONLINE REVIEW

Square thread

Torque to rotate the screw Against the load

$T_T = T + T_c$

$T = W\frac{D_m}{2}\tan(\alpha + \phi)$

$\alpha = \tan^{-1}\frac{\text{Lead}}{\pi D_m}$

$D_m = D_o - h$; $h = \frac{1}{2}P$

$h = \frac{1}{2}(5\,mm) = 2.5\,mm$

$D_m = 35\,mm - 2.5\,mm$

$D_m = 32.5\,mm$

$\text{Lead} = 2(5\,mm) = 10\,mm$

subst;

$\alpha = \tan^{-1}\frac{(10\,mm)}{\pi(32.5\,mm)} = 5.5938°$

and;

$\phi = \tan^{-1}f = \tan^{-1}(0.09) = 5.1428°$

Subst;

$T = (6500\,N)\left(\frac{0.0325\,m}{2}\right)\tan(5.5938° + 5.1428°)$

$T = 20.0279\ N-m$

95 cont…

torque to overcome collar friction

$$T_c = \frac{W D_c}{2} f_c = 6500\,N \left(\frac{0.043\,m}{2}\right)(0.09)$$

$$T_c = 12.5775\ N\text{-}m$$

Hence;

$$T_T = (20.0279 + 12.5775)\ N\text{-}m$$

$$\boxed{T_T = 32.6054\ N\text{-}m}$$

Torque to rotate the screw w/ the load

$$T = \frac{W D_m}{2} \tan(\alpha - \phi)$$

$$T = 6500\,N \left(\frac{0.0325\,m}{2}\right) \tan(5.5938^\circ - 5.1428^\circ)$$

$$T = 0.8314\ N\text{-}m$$

Hence; from

$$T_T = T + T_c = 0.8314\,N\text{-}m + 12.5775\,N\text{-}m$$

$$\boxed{T_T = 13.4089\ N\text{-}m}$$

$$\frac{D_2}{D_1} = \frac{3}{2}$$

$M = 2.0$ mm

$C = 130$mm

Number of teeth for each Gear

$$C = \frac{D_2 + D_1}{2}$$

$$130\text{ mm} = \frac{1.5D_1 + D_1}{2}$$

$D_1 = 104$ mm

$D_2 = 156$ mm

from; $M = \frac{D_1}{T_1}$

$$2.0\text{ mm} = \frac{104\text{ mm}}{T_1}$$

$$\boxed{T_1 = 52\text{ teeth}}$$

and; $\frac{D_1}{T_1} = \frac{D_2}{T_2}$

$$\frac{104\text{ mm}}{52\text{ teeth}} = \frac{156\text{ mm}}{T_2}$$

$$\boxed{T_2 = 78\text{ teeth}}$$

98

Exponential LEAP ONLINE REVIEW

Flywheel (Cast iron)

Capacity of Flywheel

$$\Delta E = \frac{F_w}{g_o} C_f (V_a)^2$$

Volume of the rim

$V_{rim} = btL \quad ; \quad L = \pi D_m$

$V_{rim} = (12\,in)(0.75\,in)\pi(40\,in)$

$V_{rim} = 1130.9733\ in^3$

and;

$\rho_{rim} = \frac{M_{rim}}{V_{rim}}$; for cast iron: $\rho = 0.260\ \frac{lb}{in^3}$

$$0.260\,\frac{lb}{in^3} = \frac{M_{rim}}{1130.9733\,in^3}$$

$F_{rim} = M_{rim} = 294.0531\ lbs$

and;

$F_w = F_{rim} + F_H + F_A$

$F_w = F_{rim} + \frac{1}{8} F_{rim}$

$F_w = 1.125\,F_{rim} = 1.125\,(294.0531\ lbs)$

$F_w = 330.8097\ lbs$

98 cont...

Hence;

$$\Delta E = \frac{330.8097 \text{ lbs}}{32.2 \text{ ft/sec}^2}(0.12)(90 \text{ ft/sec})^2$$

$$\boxed{\Delta E = 9985.9326 \text{ lb-ft}}$$

99

Exponential LEAP ONLINE REVIEW

Cast iron Flywheel

$$S_H = \frac{12 \rho v^2}{g_c} \quad ; \quad \rho = 0.260 \frac{lb}{in^3} \text{ for cast iron}$$

$$v = \frac{\pi D_m N}{60} = \frac{\pi (40 in)(360 rpm)}{60} = \left(795.8701 \, in/sec\right)\left(\frac{1 ft}{12 in}\right) = 66.3225 \, ft/sec$$

substi;

$$S_H = \frac{(12)(0.260 \, lb/in^3)(66.3225 \, ft/sec)^2}{(32.2 \, ft/sec^2)}$$

$$\boxed{S_H = 426.2069 \text{ psi}}$$

Poisson's ratio

$$\mu = \frac{E}{2G} - 1$$

$$\mu = \frac{220\ GPa}{2(85\ GPa)} - 1$$

$$\boxed{\mu = 0.2941}$$