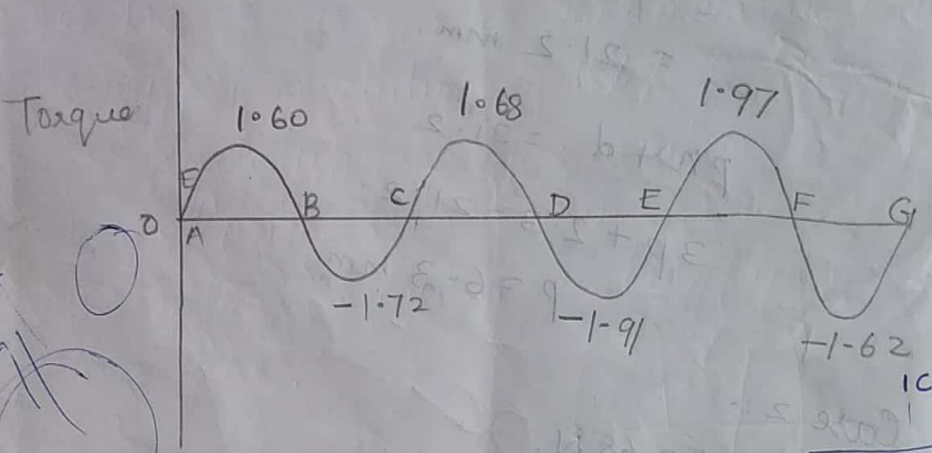
# FLYWHEEL

1. A multi cylinder engine is to have constant load and run at 500 rpm on the crank effort drawing of scale 1 cm = 2500 N-m. & 1 cm = 60°. The area above and below the mean torques are measured in order +1.60, −1.72, +1.68, −1.91, +1.97, −1.62. Coefficient of fluctuation is 0.02. Assume density of flywheel is 7200 kg/m³. Allowable tensile stress is 6 MPascal.




$\Delta E = E_{max} - E_{min}$

Energy at A = E

B = E + 1.60

C = E + 1.60 − 1.72

= E − 0.12

D = E − 0.12 + 1.68

= E + 1.56

E = E + 1.56 − 1.91

= E − 0.35

F = E − 0.35 + 1.97

= E + 1.62

$E$ at $G = E$.

$\Delta E = E_{max} - E_{min}$

$= (E + 1.62) - (E - 0.35)$

$= 1.97 \times 2617.99$

$= 5157.4$ N·m

$1 cm^2 = 60 \times \pi \times \frac{2}{180}$

$= 2617.99$.

$\Delta E = E \times 2C_s$

$5157.4 = E \times 2(0.02)$

$E = 128935$ N-m

$b/h = 2$

$m = A \times \pi \times D \times \rho$

$= b \times h \times \pi \times D \times \rho$.

$\sigma_t = \rho v^2$

$6 \times 10^6 = 7200 \times v^2$

$v = 28.87$.

$E = \frac{1}{2} m v^2$

$\sigma_t = \rho v^2$

$E = \frac{1}{2} m v^2$

$128935 = \frac{1}{2} m v^2$

$v = m/.$

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

$\Delta E = E \times 2C_s$

$\Delta E = E_{max} - E_{min}$

$\frac{128935 \times 2}{833.33} = m$.

$m = 310$ kg.

$m = A \times \pi \times D \times \rho$

$E = \frac{1}{2} m v^2$

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

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

$28.87 = \frac{\pi \times 500 \times D}{60}$

$D = 1.1$ m

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$$310 = 2h \times h \times \pi \times 1.1 \times 7200$$

$$h^2 = \frac{310}{2 \times \pi \times 1.1 \times 7200}$$

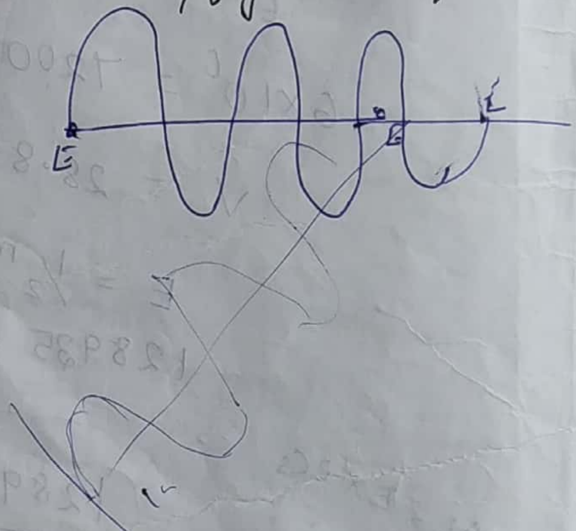
$h = 0.0789\ m$

$h = 78\ mm$

$b = 2h$

$= 156\ mm$

1 A single cylinder double acting steam engine delivers 185 kW at 100 rpm. The maximum fluctuation energy per revolution is 15% of energy developed per revolution. Speed variation is limited to 1% neither from mean. Mean dia of rim is 2.4 m Design a cast iron flywheel for the engine.



$P = 185\ kW$

$N = 100\ rpm$

$C_s = \pm 1\%$

$= 2\%$

$= 0.02$

$D = 2.4\ m$

$\Delta E = 0.15 \times E$

$\Delta E = E \times 2C_s$

$= mv^2 C_s$

$= m \times (12.56)^2 \times 0.02$

Design of Rim :-

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

$$= \frac{\pi \times 2.4 \times 100}{60}$$

$$= 12.56 \text{ m/s}$$

$$E = \frac{60 \times P}{N}$$

$$= \frac{60 \times 185 \times 10^3}{100}$$

$$= 111000 \text{ N·m.}$$

$$0.15 \times 111000 = m(12.56)^2 \times 0.02$$

$$m = 5277.2 \text{ kg}$$

$$5277.2 = 2h \times h \times 7200 \times \pi \times 2.4 \quad \frac{N \cdot m}{sec}$$

$$h = 220.46 \text{ mm}$$

$$b = 440.9 \text{ mm.}$$

Shaft Design

$$T_{mean} = \frac{60 \times 185 \times 10^3}{2\pi \times 100} \qquad T_{mean} = \frac{60 P}{2\pi N}$$

$$T_{mean} = 17666.19 \text{ N·m.}$$

$$= 17666.19 \times 10^3 \text{ N·mm.}$$

$d_1$ - dia of shaft.

$$\tau = \frac{16 T_{max}}{\pi d_1^3}$$

Mild steel Allowable shear stress – 40 MPas
shaft → Mild steel.

$$40 = \frac{16 \times 35332.4 \times 10^3}{\pi d^3}$$

$d_1 = 165$ mm.

Outer dia of hub = 2 × shaft dia
= 330 mm.

1. Design rim type cast iron flywheel for an ic engine to store 10,000 N.m energy speed of engine is to be 500 rpm. Coefficient of fluctuation is 0.02. Assume the suitable stresses if necessary.

Density of grey cast iron = 7200 kg/m³.
Tensile stress of grey cast iron = 6 MPas

$E = 10,000$ N.m
$C_s = 0.02$
$N = 500$ rpm

Considering 2-stroke engine

$\Delta E = E \times K_E$ $\qquad K_E = 0.5 - 1.5$

Consider $K_E = 1$

$\Delta E = E$

$\Delta E = 10,000$

Tensile stress

$\sigma_t = \rho v^2$

$6 \times 10^6 = 7200 \times v^2$

$V = 28.86\ m/s$

$= 28.86 \times 10^3\ mm/s$

$$28.8 = \frac{\pi \times D \times 500}{60}$$

$D = 1.1\ m$

$\Delta E = m v^2 C_s$

$\Delta E = m \times (28.86)^2 \times 0.02$

$10,000 = m \times (28.86)^2 \times 0.02$

$m = 600\ kg$

$m = A \times \pi \times D \times \rho$

$m = b \times h \times \pi \times D \times \rho$

$600 = 2h^2 \times \pi \times 1.1 \times 7200$

$h = 0.109\ m$

$b = 0.219\ m$

$$E = \frac{60 \times P}{N}$$

$$10,000 = \frac{60 \times P}{500}$$

$P = 84\ kW$

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

$$= \frac{60 \times 84 \times 10^3}{2\pi \times 500}$$

$= 1604.2\ N \cdot m$

$T_{max} = 1.15 \times T_{mean}$

$= 1844.8\ N\text{-}m$

$\tau = \frac{16\, T_{max}}{\pi d^3}$

$10^6 \times 50 = \frac{16 \times 1844.6}{\pi d^3}$

$d = 0.0572\ m$

diameter of hub $= 2 \times 0.0572$

$D = 0.1145\ m$

$\approx 114\ mm$

Elliptical Cross Section (Design of arms)

$\frac{c}{a} = 0.5$ a – major axis, c – minor

~~$Z = \frac{\pi}{32} a^2 c$~~

$\sigma_b = \frac{M_b}{Z}$

$M_b = \frac{T_{mean}}{D \times n} [D - d]$

$= \frac{1604.2}{1.1 \times 4} [1.1 - 0.114]$

$= 359.48\ N\text{-}m$

$Z = \frac{\pi}{32} a^2 c$

$$Z = \frac{\pi}{32}(2c)^2(c^2)$$

$$\sigma_b = \frac{359 \cdot 4}{\frac{\pi}{32}(4c^3)}$$

Assume $\sigma_b = 14\ N/mm^2$

$$14 \times 10^6 = \frac{359 \cdot 4 \times 32}{\pi \times 4 \times c^3}$$

$c = 0.0402$

$c = 40\ mm$

$\frac{c}{a} = 0.5$

$a = 80\ mm$

Previous Problem

$\frac{c}{a} = 0.5$

$\sigma_b = \frac{M_b}{Z}$

$$M_b = \frac{T_{mean}}{D \times n}[D - d]$$

$$M_b = \frac{17666 \cdot 19 \times 10^3}{2.4 \times 10^3 \times 4}[2.4 \times 10^3 - 330]$$

$= 380 \times 10^4\ N \cdot mm.$

$$\sigma_b = \frac{380 \times 10^4}{\frac{\pi}{32}(4c^3)}$$

$$14 \times 10^6 = \frac{380 \times 10^4 \times 32}{\pi \times 4 \times c^3}$$

Design a flywheel for a punching maching to punch 30 holes of 20 mm dia per minute in a steel plate of 18 mm thickness. The ultimate shear strength for plate material is 300 MPas. The actual punching operation is to be 1/5 th angular rotation of crank shaft. Crank shaft is powered by flywheel having a ratio of 1:10. The flywheel is made of cast iron (Density = 7250 kg/m³) and having a working stress of 6 MPascal. Hub and spokes provide 5 percentage of rotational moment of inertia of the wheel. The diameter of flywheel is not to exceed by 1 m. Estimate the power required for driving the motors. Assume the mechanical efficiency is 70%.

Given:-

$d = 20\ mm$

No. of holes = 30/min

$t = 18\ mm$

$\tau = 300\ MPa$

$\rho = 7250\ Kg/m^3$

$\eta = 0.70$

$= 70\%$.

$i = 10$

$D = 1.0\ m$

$F_s = \tau \times A$

$= \tau \times \pi \times d \times t$

$= 300 \times \pi \times 20 \times 18$

$= 340$ KN.

$E_1 = \frac{1}{2} F_s \times t$

$= \frac{1}{2} \times 340 \times 10^3 \times 18$

$= 3.05 \times 10^6$ N-mm.

$E = 30 \times 3.05 \times 10^6$

$= 91.8 \times 10^6$ N-mm

$F_s = \tau \times A$

$P = \frac{E}{\eta_{max} \times 60}$

$= \frac{91.8 \times 10^6}{0.70 \times 60}$

$= 2.2$ kW.

Punching machine takes 1/5 revolution of crank

Then 4/5 revolution of crank shaft energy stored in flywheel is.

N = 30 rpm (Assume)

$\Delta E = 4/5 \times E_1$

$= 2.4 \times 10^6$ N·mm

$\Delta E_{(rim)} = 0.95 \times \Delta E$

$= 2.3 \times 10^6$ N·mm

Crank speed = 30 rpm

$N = 30 \times 10$
$= 300$ rpm

$\omega = \frac{2\pi N}{60}$

$= \frac{2 \times \pi \times 300}{60}$

$= 31.41$ rad/s.

$C_s = 0.02$

$\Delta E = mR^2 \times \omega^2 C_s$

$2.3 \times 10^6 = m \times (500)^2 \times (31.42)^2 \times 0.02$

$2300 = m \times (0.5)^2 \times (31.42)^2 \times 0.02$

$m = 465$ kg

$m = \pi D \times \rho \times A$ $\qquad b/h = 2$

$465 = \pi \times 1 \times 7250 \times 2h^2$

$h = 101$ mm.

$b = 202$ mm

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