Vertical beam

mass of object = 15kg

Force $= 15 \times 9.81$

$= 147.15 N$

$= 150N$ (approx)

Gripper ⇒ PFS25E-4 can be selected

load - 1.8kg.

vertical beam

weight 10kg (assume)

Rack and pinion.

Force = object + Gripper + beam

$= 150 + (1.8 \times 9.81) + (10 \times 9.81)$

$= 265.7 N$

$= 270N$ (approx)

Power = $P \times V$

$= 270 \times 0.8$ (assume $V = 0.6$)

$=$ ~~162 Nm/s~~. $= 216 W$

$=$ ~~162 W.~~

$F_r = 270\ N$ $\qquad z_p = 18$ (no. of teeth)

$N = 300$ rpm (assume) $\qquad \alpha = 20°$ $\qquad \psi = 26°$ (assume)

$T_s = 1.25 \times T_1$ $\qquad$ [T_s - Starting torque]

* Material selection.

Pinion - 15Ni2Cr1Mo15 → UTS = 800 N/mm² (S_{up})

Rack - 55C8 → UTS = 720 N/mm² (S_u)

Lewis constant

$$Y' = 0.484 - \frac{2.87}{z'}$$

velocity const, $k_v = \frac{5.6}{5.6 + \sqrt{v}}$ $\qquad K = 0.16\left[\frac{BHN}{100}\right]^2$

Hardness const

For pinion

$$v = \frac{\pi d_p n_p}{60 \times 1000}$$

$$0.8 = \frac{\pi \times m_t \times z_p \times n_p}{60 \times 1000}$$

$$0.8 = \frac{\pi \times m_n \times z_p \times n_p}{\cos\psi \times 60 \times 1000}$$

$$m_n = 2.5$$

$$m_n = 2.5\ mm$$

Exact helical angle

$$0.8 = \frac{\pi \times 2.5 \times 18 \times 300}{\cos\psi \times 60 \times 1000}$$

$$\cos\psi = \frac{\pi \times 2.5 \times 18 \times 300}{60 \times 1000 \times 0.8}$$

$$\psi = 25^\circ 01'$$

$$\therefore \psi = 25.01^\circ$$

Dimensions of Rack and pinion.

normal module $m_n = 2.5mm$

no. of teeth $z_p = 18$

face width, $b = 12m_n = 12 \times 2.5 = 30mm$

Dia of pinion $d_p = \frac{m_n z_p}{\cos\psi} = \frac{2.5 \times 18}{\cos 25.01} = 49.6mm$

height of addendum. $h_a = 1m_n = 2.5mm$

" " dedendum $h_f = 1.25 m_n = 3.125mm$

Effective load

$$k_v = \frac{5.6}{5.6 + \sqrt{v}} = \frac{5.6}{5.6 + \sqrt{0.8}} = 0.8622.$$

$$F_{eff} = \frac{k_a \times k_m \times F}{k_v} = \frac{1.25 \times 1 \times 270}{0.8622}$$

$$F_{eff} = 391.44 N.$$

Beam strength

$$z_p' = \frac{z_p}{\cos^3\psi} = \frac{18}{\cos^3(25.01)} = 24.18$$

$$\sigma_{be} = \frac{S_{ut}}{3} = \frac{720}{3} = 240 N/mm^2$$

$\& \ \sigma_{bp} = \frac{S_{ut}}{3} = \frac{800}{3} = 266.66 \ N/mm^2$

$Y'_t = 0.484 - \frac{2.87}{Z'_p} = 0.484 - \frac{2.87}{\infty}$

$= 0.484$

$Y'_p = 0.484 - \frac{2.87}{Z'_p} = 0.484 - \frac{2.87}{24.18}$

$= 0.365$

$\sigma_{bp} \times Y'_p = 266.66 \times 0.365$

$= 97.3 \ N/mm^2$

$\sigma_c \times Y'_t = 0.484 \times 240$

$= 116.16 \ N/mm^2$

Pinion is weaker than rack in bending, Hence it is necessary to design the pinion for bending

$\therefore F_p = \sigma_{bp} * b * m_n * Y'_p$

$= 266.66 \times 30 \times 2.5 \times 0.365$

$= 7299.81 \ N$

Hence the factor of safety against bending failure

$= \frac{F_p}{F_{eff}} = \frac{7299.81 \ N}{391.44}$

$= 18.6 > 1.5$

FOS got is more than 1.5 so the design is safe.

wear strength
ratio factor $Q = \frac{2z_g}{z_g + z_p}$

$= \frac{2}{\frac{z_g}{z_g} + \frac{z_p}{z_g}}$

$= \frac{2}{1 + \frac{z_p}{z_g}} \Rightarrow \frac{2}{1 + \frac{18}{2}} = 2$

$k = 0.16\left[\frac{BHN}{100}\right]^2 = 0.16\left[\frac{350}{100}\right]^2$

$= 1.96\ N/mm^2$

wear force $= \frac{d_p \cdot b \cdot Q \cdot K}{\cos^2 \psi}$

$= \frac{49.6 \times 30 \times 2 \times 1.96}{\cos^2 25.01}$

$F_w = 7102.45\,N$

FOS available against pitting failure.

$N_{fw} = \frac{F_w}{F_{eff}} = \frac{7102.45\,N}{391.44}$

$= 18.14$

$N_{fw} = 18.14 > 1.5$

$\therefore$ The the pair is safe.

Power $= F \times V \Rightarrow$ ~~870~~

$= 270 \times 0.8 = 216\ W.$

Torque $= F_t \times d/2$

$= 270 \times 49.6/2$

$= 6.696\ Nm$

$=$