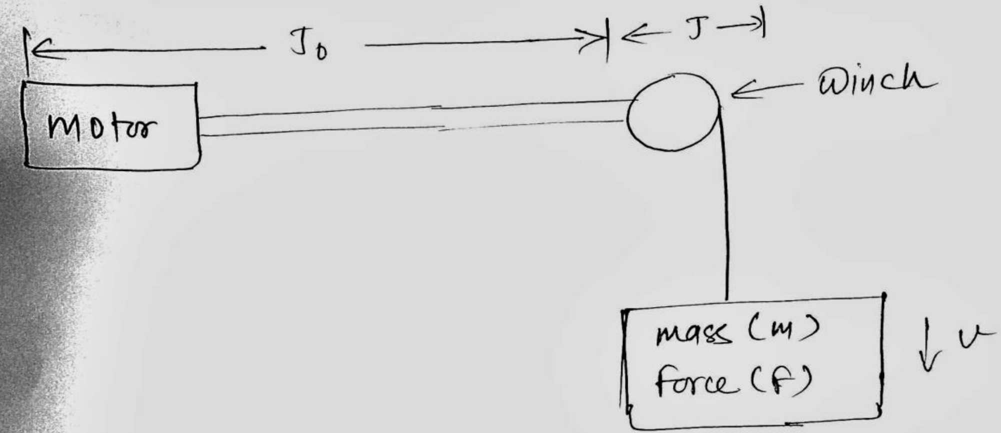
Q. A weight of 500 kg is being lifted up at uniform speed of 1.5m/s by a winch driven by a motor running at a speed of 1000 rpm. The moments of inertia of motor and winch are 0.5 and 0.3 kg-m^2 respectively. Calculate the motor torque and the equivalent moment of inertia referred to the motor shaft. In the absence of weight, motor develops a torque of 100N-m when running at 1000 rpm.

Solⁿ:-



Given,

mass (m) = 500 kg

velocity (v) = 1.5 m/s

inertia of motor (J_0) = 0.5 kg-m^2

" " winch (J) = 0.3 kg-m^2

motor torque at no load (T_0) = 100 N-m

motor speed (N) = 1000 rpm

Now, angular speed of motor (ω_m) = $\frac{\pi N}{30} = \frac{1000 \times \pi}{30}$

$= 104.72$ rad/sec

Equivalent moment of inertia referred to motor shaft is

$$J = J_0 + J + m\left(\frac{v}{\omega_m}\right)^2$$

$$= 0.5 + 0.3 + 500\left(\frac{1.5}{104.72}\right)^2$$

$$= 0.9026 \text{ kg-m}^2$$

Equivalent torque referred to motor shaft is

$$T = T_0 + \frac{Fv}{\omega_m} = 100 + \frac{m \times g \times 1.5}{104.72}$$

$$= 100 + \frac{500 \times 9.8 \times 1.5}{104.72}$$

$$= 170.187 \text{ N-m}$$

Q. In the mechanism shown in fig P2.5, motor drives the winch drum through a reduction gear with a gear tooth ratio of 0.1. The friction torque at winch shaft is 15N-m and at motor shaft is 10N-m. Motor speed is 1500 rpm. Calculate the equivalent moment of inertia of the drive referred to motor shaft and motor torque if gears have an efficiency of 90%

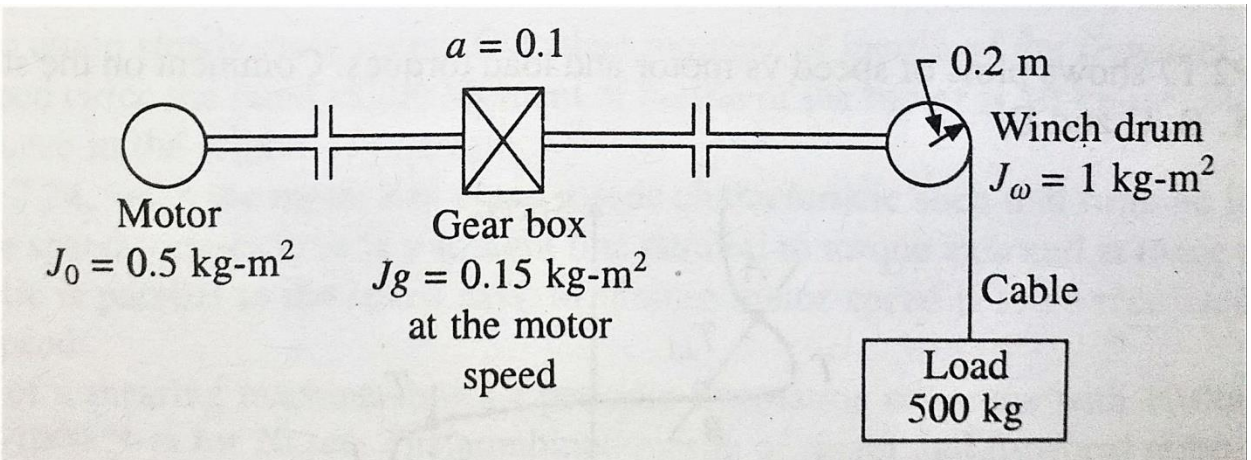


Fig. P2.5

Sol^n:

Given,

gear tooth ratio$(a) = 0.1$

moment of inertia of motor $(J_0) = 0.5\ kg\text{-}m^2$

" " " " gear box $(J_g) = 0.15\ kg\text{-}m^2$

" " " " winch drum $(J_w) = 1\ kg\text{-}m^2$

Friction torque at winch shaft $(T_w) = 15\ N\text{-}m$

" " " motor shaft $(T_m) = 10\ N\text{-}m$

efficiency of gears $(\eta_g) = 0.90$

Radius of winch drum $(r) = 0.2\ m$

mass of load for translational motion $(m) = 500\ kg$

Motor speed $(N_m) = 1500\ rpm$

Now,

angular speed of motor $(\omega_m) = \frac{\pi N}{30} = \frac{1500 \times \pi}{30}$

$= 157.08\ rad/sec$

Circumference of winch drum $= 2\pi r = 2\pi \times 0.2\ m$

$= 1.256\ m$

we have,

$\frac{N_{m1}}{N_m} = a \Rightarrow N_{m1} = 0.1 \times 1500$

$\therefore N_{m1} = 150$ rpm

= speed of winch shaft

i.e. 1 min → 150 revolution

So, total distance travelled by load in 1 min $= 150 \times 1.256$

$= 188.4$ m

$\therefore$ total distance travelled by load in 1 sec $= \frac{188.4}{60}$

$= 3.14$ m

$\therefore$ velocity of load $(v) = 3.14$ m/sec

Hence, ~~Equivalent moment of inertia referred to motor shaft~~ is

~~J=~~

If the transmission losses are neglected, then K.E due to equivalent inertia J must be same as K.E of various moving parts. Thus

$\frac{1}{2} J \omega_M^2 = \frac{1}{2} J_1 \omega_M^2 + \frac{1}{2} J_g \omega_M^2 + \frac{1}{2} J_w \omega_{m1}^2 + \frac{1}{2} M v^2$

$$\text{a. } J = J_0 + J_g + a_1^2 J_W + M\left(\frac{v}{\omega_m}\right)^2$$

$$\therefore J = 0.5 + 0.15 + (0.1)^2 \times 1 + 500\left(\frac{3.14}{157.08}\right)^2$$

$$= 0.86 \text{ kg-m}^2 \ \#$$

= equivalent moment of inertia referred to motor shaft

Similarly power at motor and load should be same

$$T\omega_M = T_m\omega_m + T_W \cdot \omega_{m1} + \frac{Fv}{\eta_g}$$

$$\text{a. } T = T_M + aT_W + \frac{Fv}{\omega_m \eta_g}$$

$$= 10 + 0.1 \times 15 + \frac{mg \times v}{157.08 \times 0.90}$$

$$= 10 + 1.5 + \frac{500 \times 9.8 \times 3.14}{157.08 \times 0.90}$$

$$= 120.33 \text{ N-m} \ \#$$

= equivalent torque referred to motor shaft

2.11 Calculate the starting time of a drive with following parameters:

$J = 10$ kg-m^2, $T = 15 + 0.5\ \omega_m$ and $T_l = 5 + 0.6\ \omega_m$

2.12 A drive has following parameters: $J = 10$ kg-m^2, $T = 15 + 0.05N$, N-m and $T_l = 5 + 0.06N$, N-m, where N is the speed in rpm.
Initially the drive is working in steady-state. Now the drive is braked by electrical braking. Torque of the motor in braking is given by $T = -10 - 0.04N$, N-m. Calculate time taken by the drive to stop.

2.13 A drive has following parameters: $J = 1$ kg-m^2, $T = 15 - 0.01N$, N-m and Passive load torque $T_l = 0.005N$, N-m; where N is the speed in rpm.
Initially the drive is operating in steady-state. Now it is to be reversed. For this motor characteristic is altered such that $T = -15 - 0.01N$, N-m for positive as well as negative values of N. Calculate the reversal time.