5

Chapter Five

Mechanical Design

5.1 Design of Conveyor

5.1.1 Design Bearing of Conveyor

In the design of conveyor bearing we consider that there is no thrust loading, and the loading is only radial.

Step 1: At first, we will compute F_x and F_y by applying static equilibrium equations to the shaft supported by the bearing.

$$s_f = s_i + v_i\, t + \frac{1}{2}\, a\, t^2 \qquad \text{………..…. Equation (5.1)}$$

Where s_f : The distance from the middle to the end of the conveyor.

s_i : The initial distance, and equal zero.

v_i : Initial velocity of the belt.

a : Acceleration of the belt.

For Checkweigher:

$$0.075 = \frac{1}{2} a t^2$$

$$0.15 = a(1.33)^2$$

$$a = \frac{0.15}{1.7689} = 0.084 \;\; m^2/sec$$

$$45 \rightarrow 60\ sec$$

$$1 \rightarrow t\ \ sec$$

$$t\ sec = \frac{60}{45} = 1.33\ sec$$

For Infeed and Outfeed Conveyor:

$$0.20 = \frac{1}{2}\ a t^2$$

$$0.40 = a(3.54)^2$$

$$a = \frac{0.40}{12.57} = 0.031 \;\; m^2/sec$$

$$F_x = m_1 * a$$

$$F_y = m_1 * g + \frac{1}{2} m_2 * g$$

$$1.33\ sec \rightarrow 0.15m$$

$$t\ sec \rightarrow 0.4m$$

$$t\ sec = \frac{0.4 * 1.33}{0.15} = 3.54\ sec$$

Where

F_x: Force on the x − axis.

F_y: Force on the y − axis.

a : acceleration of the belt.

m_1: mass of the object.

m_2: mass of the roller.

For Checkweigher:

F_x= 5 * 0.084 = 0.42 N

$F_y= 5 * 9.81 + \frac{1}{2} * 0.5 * 9.81$ =51.5 N.

For Infeed and Outfeed Conveyor:

F_x= 5 * 0.031 = 0.1589 N

$F_y= 5 * 9.81 + \frac{1}{2} * 0.5 * 9.81$ =51.5 N.

Step 2: Now we find the resultant radial load (F_r)

For Checkweigher:

$F_r = \sqrt{{F_x}^2 + {F_y}^2} = \sqrt{(0.42)^2 + (51.5)^2}$

$F_r = 51.5$ N.

$\theta = \tan^{-1}\frac{F_Y}{F_X} = \tan^{-1}\frac{51.5}{0.42} = 89.53°$

For Infeed and Outfeed Conveyor:

$F_r = \sqrt{{F_x}^2 + {F_y}^2} = \sqrt{(0.1589)^2 + (51.5)^2}$

$F_r = 51.5$ N.

$\theta = \tan^{-1}(\frac{F_Y}{F_X}) = \tan^{-1}(\frac{51.5}{0.1589}) = 89.82°$ Where F_r: Force resaltant.

Specifying FD

The design load can be defined by:

$F_D = a_f * V * Fr$ ……………. Equation (5.2)

Where: a_f is application factor (Table 5-1), used because loads are often variable (non-steady) and may increase during operation.

V rotation factor, takes into account whether the inner or outer race rotates ring outer rotating 1.2 ring inner rotating 0.1V usually the inner race of the bearing rotate (i.e., V=1).[8]

V = 1 (rotating inner ring).

a_f= 1 (machinery with no impact).

$F_D = 1 * 1 * 51.5 = 51.5$ N. **Are the same for Checkweigher, Infeed and Outfeed Conveyor.**

Step 3: Assuming the desired life (L_D) and Reliability (R_D), we find X_D

$X_D = \frac{L_{Dh}}{L_{10}}$ ……………Equation (5.3)

$L_{Dh} = L_{Dh} * N * 60$

$\ddot{\theta} = \frac{a}{r}$

Where: $\ddot{\theta}$: angular accelaration of the pully.

r: radious of the pully.

X_D: Life ratio.

L_D: Desired life (revolutions).

L_{10}: Rating life (revolutions) =1 million rev.

L_{Dh} =30000 (general industrial machinery). (Table 5-2)

N: speed motor.

$0.15\text{m} \rightarrow 0.05\text{m}$

$x \text{ rev} \rightarrow 1 \text{ rev}$

$x \text{ rev} = \frac{0.15}{0.05} = 3$

$= 3 \text{ rev/m}$

$0.05\text{m} \rightarrow 0.01\text{m}$

$y \text{ rev} \rightarrow 1 \text{ rev}$

$y \text{ rev} = \frac{0.05}{0.01} = 5$

$x_{rev} * y_{rev} = 3*5$

= 15 turn of motor per piece.

For Checkweigher:

Length of the conveyor = 0.15 m.

Diameter of the roller = 0.05 m.

Diameter of the rod = 0.01 m.

$$\ddot{\theta} = \frac{0.084}{0.01} = 8.4 \ \mathrm{m/s}$$

$$\mathrm{N} = 15 \ \frac{\mathrm{rev}}{\mathrm{m}} * \frac{1\mathrm{m}}{1.33 \ \mathrm{sec}} * \frac{60 \ \mathrm{sec}}{1 \ \mathrm{min}} = 676.67 \ \mathrm{rpm}$$

$$\mathrm{L_{Dh}} = 30000 * 676.67 * 60 = 1218.006 * 10^6$$

$$\mathrm{X_D} = \frac{1218.006 * 10^6}{1 * 10^6} = 1218.006\mathrm{Hp}$$

For Infeed and Outfeed Conveyor:

Length of the conveyor = 0.40 m.

Diameter of the roller = 0.05 m.

Diameter of the rod = 0.01 m.

$$\ddot{\theta} = \frac{0.031}{0.01} = 3.1 \ \mathrm{m/s}$$

$$\mathrm{N} = 40 \frac{\mathrm{rev}}{\mathrm{m}} * \frac{1\mathrm{m}}{3.54 \ \mathrm{sec}} * \frac{60 \ \mathrm{sec}}{1 \ \mathrm{min}} = 685.7 \ \mathrm{rpm}$$

$$\mathrm{L_{Dh}} = 30000 * 685.7 * 60 = 1234.28 * 10^6$$

$$\mathrm{X_D} = \frac{1234.28 * 10^6}{1 * 10^6} = 1234.28\mathrm{h}$$

$0.40\mathrm{m} \rightarrow 0.05\mathrm{m}$

xrev → 1 rev

$$\mathrm{x\ rev} = \frac{0.40}{0.05} = 8$$
$$= 3 \ \mathrm{rev/m}$$

$0.05\mathrm{m} \rightarrow 0.01\mathrm{m}$

yrev → 1 rev

$$\mathrm{y\ rev} = \frac{0.05}{0.01} = 5$$

x rev * y rev=8*5=40 turn of motor per piece

Step 4: Calculate the required catalog rating:

$C_{10} = X_D^{1/a} * F_D$ Where $C_{10:}$ is Catalog rating. a = 3 (ball bearing)

$$a = \begin{cases} 3 & for\ ball\ bearing \\ 3.33 & for\ roller\ bearing \end{cases}$$

For Checkweigher:

$C_{10} = (1218.006)^{1/3} * 51.5 = 549.99\text{N} \rightarrow 0.54999\text{ KN}$

For Infeed and Outfeed Conveyor:

$C_{10} = (1234.28)^{1/3} * 51.5 = 552.43\text{N} \rightarrow 0.55243\text{KN}$

Step 5: Check the catalog and select a suitable bearing from (Table 5-3)

For Checkweigher:

C10 =0.54999 KN, Bore=10 mm, OD = 30 mm.

For Infeed and Outfeed Conveyor:

C10 =0.55243 KN, Bore=10 mm, OD = 30 mm.

Figure 5.1: Angular Contact Ball Bearing

5.2 Calculating the Torque of the Conveyor

$$T = J_e\ddot{\theta} + F_r.r \qquad \text{……………. Equation (5.4)}$$

Where J_e: is equivalent moment inertia.
T: Torque.

5.2.1 Calculate the total moment inertia of checkweigher conveyor

- $J_{Bearing} = \frac{\pi}{2}(r_{out} - r_{inner})^4$ …………… Equation (5.5)

Where $\mathrm{r_{out}}$: is outradious.

$r_{inner}: is\ innerradious.$

For checkweigher:	For Infeed and Outfeed Conveyor:
$J_{Bearing} = \frac{\pi}{2}(0.028 - 0.01)^4$ $= 1.6489 * 10^{-7}\ Kg/m^2$	$J_{Bearing} = \frac{\pi}{2}(0.028 - 0.01)^4$ $= 1.6489 * 10^{-7}\ Kg/m^2$

- $J_{object} = V^2 * m$ …………… Equation (5.6)

Where V: is velocity of conveyor.

For Checkweigher:	For Infeed and Outfeed Conveyor:
$45\ object \rightarrow 60\ sec.$ $X\ object \rightarrow 60\ sec.$ $X = \frac{45 * 60}{60}$ $= 45\ object/s$ $v = \frac{0.15}{1.33} = 0.1127\ m/s$	$45\ object \rightarrow 60\ sec.$ $X\ object \rightarrow 60\ sec.$ $X = \frac{45 * 60}{60}$ $= 45\ object/s$ $v = \frac{0.40}{3.5} = 0.1142\ m/s$
$J_{object} = 0.1127^2 * 55$ $= 0.0635\ Kg/m^2$	$J_{object} = 0.1142^{\ 2} * 5$ $= 0.0653\ Kg/m^2$

- $J_{Belt} = \frac{V*m_3}{w}$ …………… Equation (5.7)

$Where\ m_3: is\ mass of the Belt.$
$w: angular velocity.$

For Checkweigher:	For Infeed and Outfeed Conveyor:
$w = \frac{2\pi N}{60}$ $w = \frac{2\pi * 676.67}{60}$ $= 70.8\ s^{-1}$	$w = \frac{2\pi N}{60}$ $w = \frac{2\pi * 685.7}{60}$ $= 71.8\ s^{-1}$
$J_{Belt} = \frac{0.1127 * 0.4}{70.8}$ $= 6.367 * 10^{-4}\ Kg/m^2$	$J_{Belt} = \frac{0.1142\ * 0.4}{71.81}$ $= 6.36211 * 10^{-4}\ Kg/m^2$

- $J_{roller} = \frac{1}{4} m_4\, r^2 + \frac{1}{3} m_4\, l^2$ …………… Equation (5.8)

Where $m_4: is\ mass of the roller.$
$l: length of the roller.$

For checkweigher:	For Infeed and Outfeed Conveyor:
$J_{roller} = \frac{1}{4} *\ 0.5 * (0.025)^2 + \frac{1}{3} * 0. * 0.14^2$ $= 3.344 * 10^{-3}\ Kg/m^2$	$J_{roller} = \frac{1}{4} *\ 0.5 * (0.025)^2 + \frac{1}{3} * 0.5 * 0.14^2$ $= 3.344 * 10^{-3}\ Kg/m^2$

For Checkweigher:

$J_e = 2 * J_{roller} + 4 * J_{Bearing} + J_{object} + J_{Belt}$ …………… Equation (5.9)

$J_e = (2 * 3.344 * 10^{-3}) + (4 * 1.6489 * 10^{-7}) + (0.0635) + (6.367 * 10^{-4})$
$= 0.0708\, Kg/m^2$

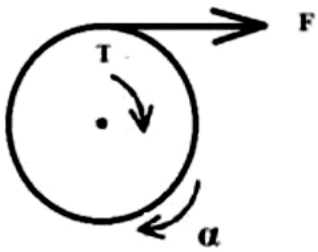

Figure 5.2: Free body Diagram of Cylinder

$\mathrm{T} = \mathrm{J_e}\ddot{\theta} + \mathrm{F_r}.\mathrm{r}$ …………… Equation (5.10)

$= 0.0708 * 8.4 + 51.5 * 0.01 = 1.109\ \mathrm{N.m}$

For Infeed and Outfeed Conveyor:

$J_e = J_{pully} + 2 * J_{roller} + 4 * J_{Bearing} + J_{object} + J_{Belt}$

$J_e = (1.5707 * 10^{-8}) + (2 * 3.344 * 10^{-3}) + (4 * 1.6489 * 10^{-7})$
$+ (0.0653) + (6.36211 * 10^{-4}).$

$= 0.07262\, Kg/m^2$

$J_{e(total)} = J_e * 2$

$J_{e(total)} = 0.07262 * 2 = 0.1452\, Kg/m^2$

$\mathrm{T} = \mathrm{J_{e(total)}}\ddot{\theta} + \mathrm{F_r}.\mathrm{r}$

$= 0.1452 * 3.1 + 51.5 * 0.01 = 0.9652\ \mathrm{N.m}$

5.3 Calculating the Power of the Motor

$$P_{out} = w.T \quad \ldots\ldots\ldots\ldots\ldots \text{ Equation (5.11)}$$

$$H_p = \frac{P_{out}}{746} \quad \ldots\ldots\ldots\ldots\ldots \text{ Equation (5.12)}$$

$$H_{p(safty\ factor)} = \alpha * H_p$$

Where H_p: $is\ hourse\ power.$

α: $isasaftyfactor\ equal$ 1.13

For Checkweigher:	**For Infeed and Outfeed Conveyor:**
$p_{out} = 70.8 * 1.109 = 78.58$ Watt.	$p_{out} = 71.81 * 0.9652 = 69.31$Watt.
$H_p = \frac{78.58}{746} = 0.105H_p$	$H_p = \frac{69.31}{746} = 0.0929H_p$
$H_{p(safty\ factor)} = 1.13 * 0.105$	$H_{p(safty\ factor)} = 1.13 * 0.0929$
$= 0.119H_p$	$= 0.104\ H_p$

After we make a calculation, we choose a motor 0.18 HP, 1500 rpm, 3-phase as shown in figure

Figure 5.3: Electrical Motor

5.4 Final Design Machine

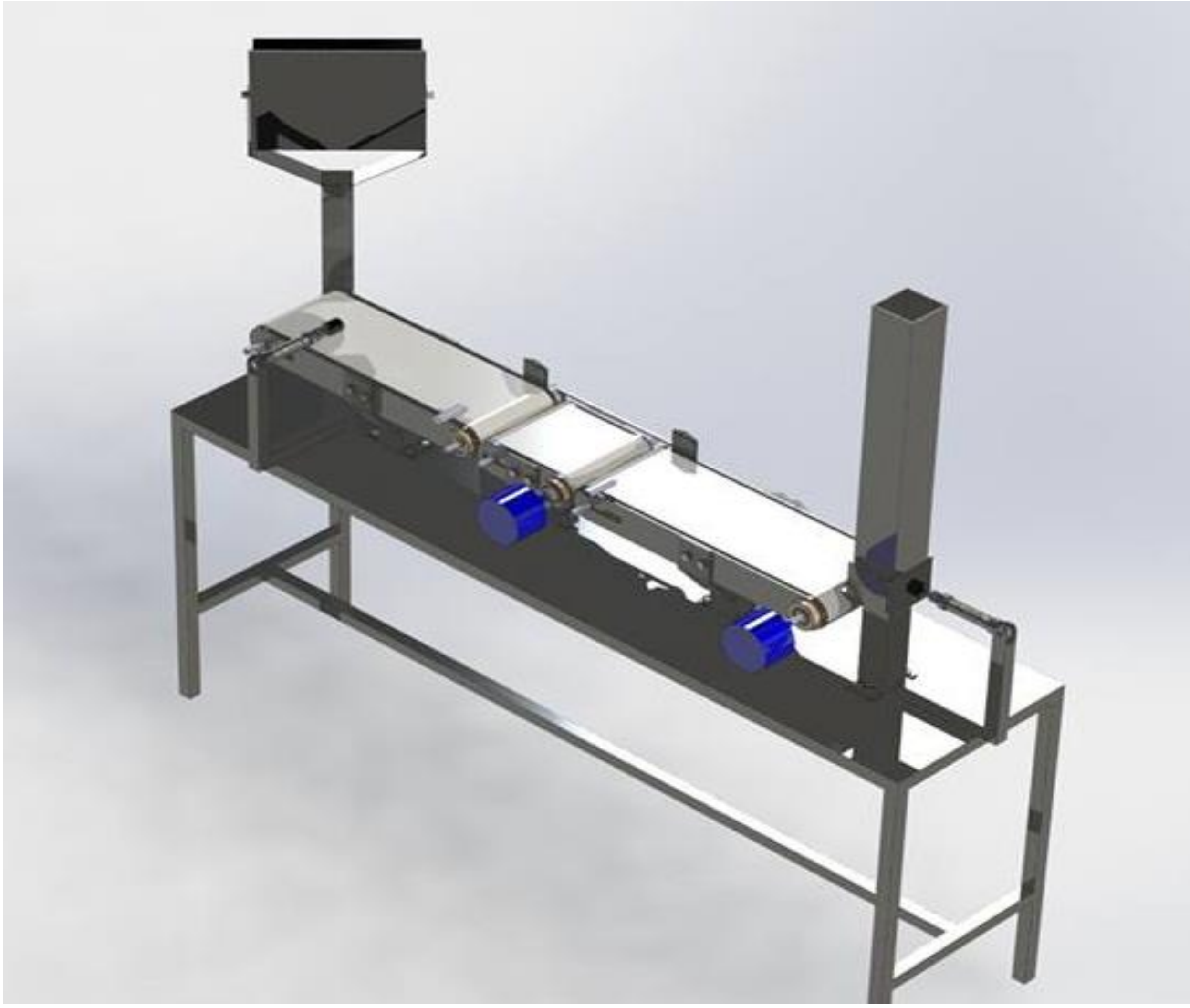

Figure 5.4: Final Design Machine