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Design of continuous loading vertical chain conveyor

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ABSTRACT

A conveyor system is a common piece of mechanical handling equipment that moves materials from one location to another. The main purpose of this project is to safely lift the load at the rate of 6m/min. This paper consist of, selection, the design of basic mechanical elements. This system is able to overcome the drawbacks of inclined belt conveyor, achieves desired height and occupies less floor space as the material is transformed in vertically upward direction. This Chain Conveyor utilizes a continuous chain arrangement, carrying a series of the single pallet for lifting the load. The chain arrangement is driven by a motor, and the material suspended on the pallets is conveyed to the next floor.

Keywords— *Roller chain, Sprockets, Roller chain flexible coupling, Pedestal bearing*

1. MATERIAL HANDLING

Material handling involves short-distance movement within the confines of a building or between a building and a transportation vehicle. It uses a wide range of manual, semi-automated, and automated equipment and includes consideration of the protection, storage, and control of materials throughout their manufacturing, warehousing, distribution, consumption, and disposal. Material handling can be used to create time and place utility through the handling, storage, and control of material, as distinct from manufacturing, which creates form utility by changing the shape, form, and makeup of the material.

1.1 Types of material handling

1.1.1 Manual Handling: Manual handling refers to the use of a worker's hands to move individual containers by lifting, lowering, and filling, emptying, or carrying them. It can expose workers to physical conditions that can lead to injuries that represent a large percentage of the over half a million cases of musculoskeletal disorders reported in each year, and often involve strains and sprains to the lower back, shoulders, and upper limbs. Ergonomic improvements can be used to modify manual handling tasks to reduce injury.

1.1.2 Automated handling: Whenever technically and economically feasible, equipment can be used to reduce and sometimes replace the need to manually handle material. Most existing material handling equipment is only semi-automated because a human operator is needed for tasks like loading/unloading and driving that are difficult and/or too costly to fully automate, although ongoing advances in sensing, machine intelligence, and robotics have made it possible to fully automate an increasing number of handling tasks.

2. CONVEYOR SYSTEM

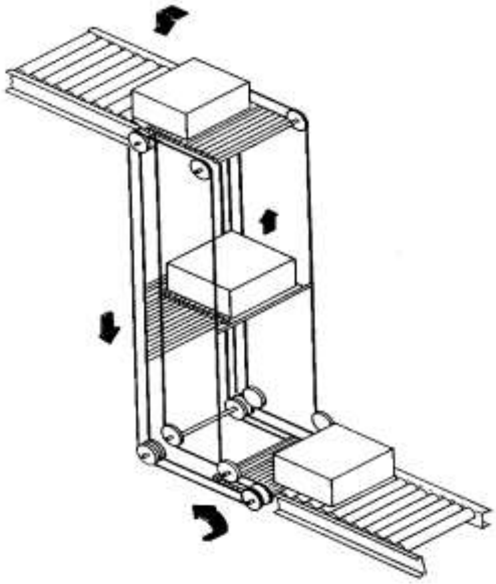


Fig. 1: Proposed conveyor system [1]

A conveyor system is a common piece of mechanical handling equipment that moves materials from one location to another. Conveyors are especially useful in applications involving the transportation of heavy or bulky materials. Conveyor systems allow quick and efficient transportation for a wide variety of materials, which make them very popular in the material handling and packaging industries. Many kinds of conveying systems are available and are used according to the various needs of different industries. There are chain conveyors (floor and overhead) as well. Chain conveyors consist of enclosed tracks, I-Beam, towline, power & free, and hand-pushed trolleys.

3. CHAIN CONVEYOR

A chain conveyor is a type of conveyor system for moving material through production lines. Chain conveyors utilize a powered continuous chain arrangement, carrying a series of single pendants. The chain arrangement is driven by a motor, and the material suspended on the pendants is conveyed.

Chain conveyors are used for moving products down an assembly line and/or around a manufacturing or warehousing facility. Chain conveyors are primarily used to transport heavy unit loads, e.g. pallets, grid boxes, and industrial containers. These conveyors can be single or double chain strand in configuration. The load is positioned on the chains; the friction pulls the load forward. Chain conveyors are generally easy to install and have very minimum maintenance for users.

4. DESIGN

4.1 Design considerations

Speed of conveyor = 6m/min

Material weight to be lifted = 20kg

Two pallets with one carrying material to be handled at any instant

M = Material weight= 20kg

C= Additional weight which includes attachment, crossbars, fixings=20kg

4.2 Selection of chain

Chain pull:

$$P = \frac{9.81\times(C+M)\times S.F}{\text{Number Of Chains}}$$

$$= \frac{9.81(40)\times1.2\times1\times1}{4}$$

$$= 117.2 \text{ N}$$

Thus from standard catalogue of chains, chain number 40 with a maximum allowable load of 4.17 KN is selected.

Specifications:

Pitch=12.7 mm

Roller Diameter=7.92 mm

Inner Width=7.95 mm

Pin Dimensions:

Diameter=3.96 mm

Length=17.9 mm

Link Plate

Height = 8.8 mm

Thickness = 1.5 mm

Table 1: Selection of chain [5]

Chain No.	Pitch P (mm)	Roller Outer Dia d (mm)	Inner Width W (mm)	Pin Dia D (mm)	Pin Length L (mm)	Pin Length L1 (mm)	Pin Length L2 (mm)	Link Plate Height H (mm)	Link Plate Thickness T (mm)
*35	9.525	5.08	4.8	3.58	13.2	7.5	5.7	8.8	1.25
40	12.70	7.92	7.95	3.96	17.9	9.6	8.3	11.7	1.5
50	15.875	10.16	9.53	5.08	22.0	11.8	10.2	14.6	2.0
60	19.05	11.91	12.7	5.96	26.8	14.1	12.8	17.5	2.3
80	25.40	15.88	15.88	7.93	35.5	19.1	16.4	23.4	3.2
100	31.75	19.05	19.05	9.53	43.0	23.3	19.7	29.3	4.0
120	38.10	22.23	25.4	11.10	53.4	28.6	24.8	35.1	4.8
140	44.45	25.4	25.4	12.70	58.3	31.3	27.3	40.9	5.6

4.3 Selection of Sprocket

Assuming no. of teeth as 19

Thus from standard catalogue of SKF sprocket,

No of teeth=19

Pitch diameter = 77.16 mm

Material−En8−carbon steel

According to B.S 970 chemical composition of En8

Carbon→0.36 to 0.44

Manganese→0.6 to 1

Phosphorous→0.05

Sulphur→0.005

4.4 Selection of bearing

Radial load = 400N

Shaft Diameter= 25 mm

$$K_a = 1.5$$

$$\text{Dynamic capacity} = 14\text{KN}$$

$$L_{h10} = 10000$$

Rating life of bearing

$$L_{10} = \frac{L_{h10} \times 60 \times N}{10^6}$$

$$L_{10} = \frac{10000 \times 60 \times 32}{10^6}$$

$$L_{10} = 15 \text{ Million Revolutions}$$

$$P_e = F_b \times K_a$$

$$= 400 \times 1.5$$

$$= 600 \text{ N}$$

$$L_{10} = \left(\frac{C}{P_e}\right)^3$$

$$14 = \left(\frac{C}{600}\right)^3$$

$$C = 1446.08 \text{ N} > 7.8 \text{ KN}$$

This design is safe and selecting bearing number UCP205 with 25 mm diameter.

Fig. 2: Bearing dimensions

Table 2: Bearing Specifications [8]

L	J	A	N	N1	H1	W	L1	B	S	Bolt Dimensions	Bearing Type	House Type	With Shield	With Shield	[illegible]	Za	Wo	Zc
140	105	38	12	19	16	71	42	34.1	14.3	M10	UC205	P205	S(SM)-UCP205	C(CM)-UCP205	2	48	76	70
165	121	48	14	21	18	84	54	38.1	15.9	M12	UC206	P206	S(SM)-UCP206	C(CM)-UCP206	2	53	88	75
167	126	48	14	21	19	93	54	42.9	17.5	M12	UC207	P207	S(SM)-UCP207	C(CM)-UCP207	3	59.5	99	80
184	136	54	14	21	19	98	54	49.2	19	M12	UC208	P208	S(SM)-UCP208	C(CM)-UCP208	3	69	105	90
190	146	54	14	21	20	106	60	49.2	19	M12	UC209	P209	S(SM)-UCP209	C(CM)-UCP209	3	69	113	95
206	159	60	18	23	22	114	65	51.6	19	M16	UC210	P210	S(SM)-UCP210	C(CM)-UCP210	3	74.5	119	100
219	172	60	18	23	22	125	65	55.6	22.2	M16	UC211	P211	S(SM)-UCP211	C(CM)-UCP211	4	76	130	100
241	186	70	18	23	25	138	70	65.1	25.4	M16	UC212	P212	S(SM)-UCP212	C(CM)-UCP212	4	89	143	115

4.5 Design of key

Material: Mild Steel

$$\tau_S = 56.25 \text{ N/mm}^2$$

Selecting square key, Hence

$$h = w = \frac{d}{4} = \frac{25}{4} = 6.25 \text{ mm}$$

Selecting next standard value = 8 mm

Considering crushing of key

$$\sigma_c = \frac{4T}{dhl}$$

$$l = \frac{4 \times 108.9 \times 10^3}{25 \times 6.25 \times 112.5}$$

$$l = 24.576 \approx 30\text{mm}$$

Considering sharing of key

$$\tau_s = \frac{2T}{dhl}$$

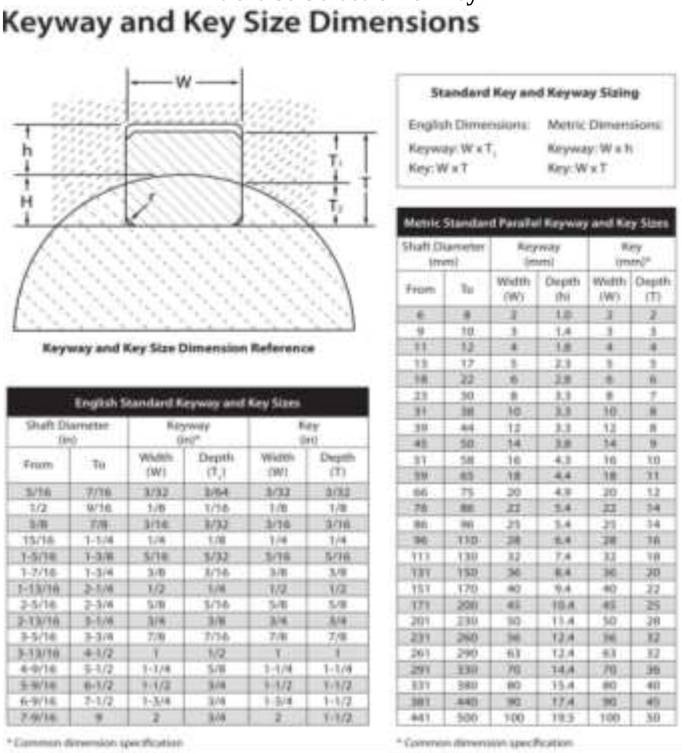
$$l = \frac{2 \times 108.9 \times 10^3}{25 \times 6.25 \times 56.25}$$

$$l = 24.57 \approx 30\text{mm}$$

Key Dimensions $h = w = 8mm$

$$l = 30mm$$

Table 3: Selection of key



Keyway and Key Size Dimensions

Keyway and Key Size Dimension Reference

Standard Key and Keyway Sizing

English Dimensions: Keyway: W x T1; Key: W x T

Metric Dimensions: Keyway: W x h; Key: W x T

English Standard Keyway and Key Sizes

Shaft Diameter (in)		Keyway (in)*		Key (in)	
From	To	Width (W)	Depth (T_1)	Width (W)	Depth (T)
5/16	7/16	3/32	3/64	3/32	3/32
1/2	9/16	1/8	1/16	1/8	1/8
5/8	7/8	3/16	3/32	3/16	3/16
15/16	1-1/4	1/4	1/8	1/4	1/4
1-5/16	1-3/8	5/16	5/32	5/16	5/16
1-7/16	1-3/4	3/8	3/16	3/8	3/8
1-13/16	2-1/4	1/2	1/4	1/2	1/2
2-5/16	2-3/4	5/8	5/16	5/8	5/8
2-13/16	3-1/4	3/4	3/8	3/4	3/4
3-5/16	3-3/4	7/8	7/16	7/8	7/8
3-13/16	4-1/2	1	1/2	1	1
4-9/16	5-1/2	1-1/4	5/8	1-1/4	1-1/4
5-9/16	6-1/2	1-1/2	3/4	1-1/2	1-1/2
6-9/16	7-1/2	1-3/4	3/4	1-3/4	1-1/2
7-9/16	9	2	3/4	2	1-1/2

* Common dimension specification

Metric Standard Parallel Keyway and Key Sizes

Shaft Diameter (mm)		Keyway (mm)		Key (mm)*	
From	To	Width (W)	Depth (h)	Width (W)	Depth (T)
6	8	2	1.0	2	2
9	10	3	1.4	3	3
11	12	4	1.8	4	4
13	17	5	2.3	5	5
18	22	6	2.8	6	6
23	30	8	3.3	8	7
31	38	10	3.3	10	8
39	44	12	3.3	12	8
45	50	14	3.8	14	9
51	58	16	4.3	16	10
59	65	18	4.4	18	11
66	75	20	4.9	20	12
76	85	22	5.4	22	14
86	95	25	5.4	25	14
96	110	28	6.4	28	16
111	130	32	7.4	32	18
131	150	36	8.4	36	20
151	170	40	9.4	40	22
171	200	45	10.4	45	25
201	230	50	11.4	50	28
231	260	56	12.4	56	32
261	290	63	12.4	63	32
291	330	70	14.4	70	36
331	380	80	15.4	80	40
381	440	90	17.4	90	45
441	500	100	19.5	100	50

* Common dimension specification

4.6 Design of coupling

Service factor:

Selecting service factor of 1.5 for an electric motor with uneven load- 4hrs/day used for service classification number B for conveyors Multiply horsepower of driver unit by the service factor

Design horsepower = motor horsepower × service factor

= 0.373×1.5

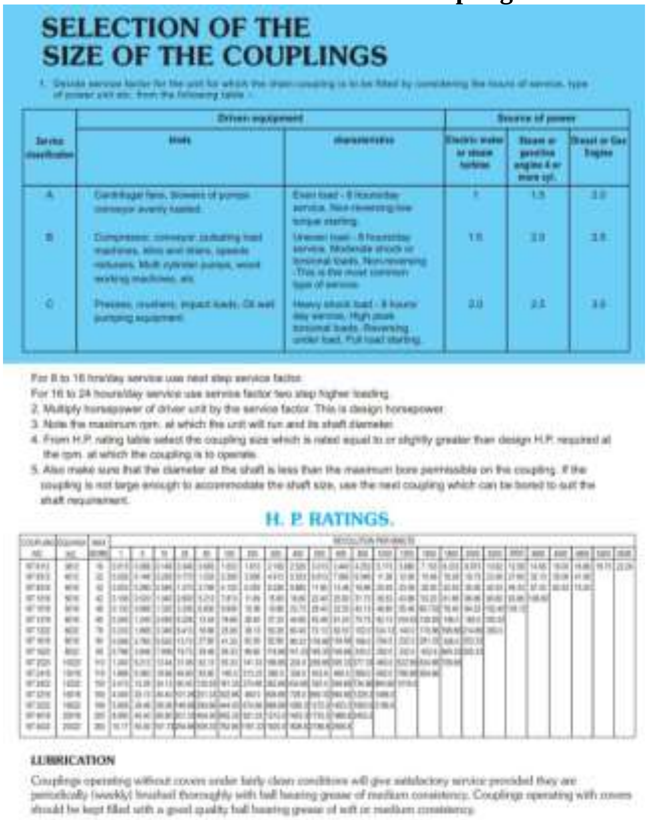
= 0.5595

Max RPM = 32 RPM

Power = 1/2 HP

Hence selecting coupling number-NT 8316 with a max bore diameter of 32mm and max design power of 2 KW.

Table 4: Selection chain flexible coupling [9]



SELECTION OF THE SIZE OF THE COUPLINGS

Service classification	Driven equipment: Kinds	Driven equipment: characteristics	Source of power: Electric motor or steam turbine	Source of power: Steam or gasoline engine 4 or more cyl.	Source of power: Diesel or Gas Engine
A	[illegible]	[illegible]	1	1.5	2.0
B	[illegible]	[illegible]	1.5	2.0	2.5
C	[illegible]	[illegible]	2.0	2.5	3.0

For 8 to 16 hrs/day service use next step service factor

For 16 to 24 hours/day service use service factor two step higher loading

2. Multiply horsepower of driver unit by the service factor. This is design horsepower

3. Note the maximum rpm. at which the unit will run and its shaft diameter

4. From H.P. rating table select the coupling size which is rated equal to or slightly greater than design H.P. required at the rpm. at which the coupling is to operate

5. Also make sure that the diameter at the shaft is less than the maximum bore permissible on the coupling. If the coupling is not large enough to accommodate the shaft size, use the next coupling which can be bored to suit the shaft requirement.

H. P. RATINGS.

LUBRICATION

4.7 Design of shaft

Material selection

Mild steel of the following composition is selected

Carbon-0.16 to 0.18 % (max allowable 0.25 %)

Manganese- 0.7 to 0.9 %

Sulphur-0.04%

Phosphoros-0.04%

UTS = 840 MPa

Yield stress = 247 MPa

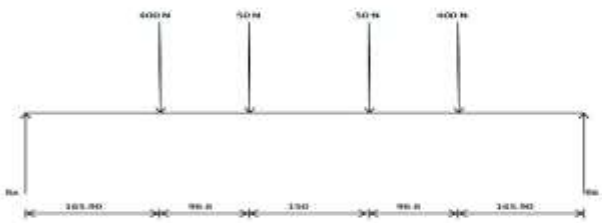


Fig. 3: Shaft loading diagram

F_{TB} = 400 N, F_{TC} =50N = F_{TD}

R_B=R_C =R_D = R_E = 38.58 mm=39 mm

T_B =T_E =15600 N-mm, T_C = T_D = 1950 N-mm

T_S =0.75(0.18 S_{ut}) =113.4 N/mm2

= 0.75(0.3 S_{yt})

= 56.25 N/mm2

T_s =56.25 N/mm2

R_F×675 = 400×509.1+50×412.5+50×262.5+ 400×165.9

=450.22 N

R_A = 450.22 N

B_{MB} = 74691.498 N-mm

B_{MC} = 450.22×262.5 − 400×96.6

= 79542.75 N-mm

B_{MD}=450.22×412.5 −400×246.6 − 50×150

= 79575.75 N-mm

B_{ME} = 450.22×509.1 − 400×343.2 − 50×246.6

= 79597.002 N-mm

$$T_e = \sqrt{(1 \times 79597)^2 + (1.5 \times 15600)^2}$$
$$= 82965.30847 \text{ N-mm}$$

$$\tau_{max} = \frac{16T_e}{\pi d^3}$$

$$56.25 = \frac{16 \times 82965.30487}{\pi d^3}$$

$$d = 19.5845 \text{ mm}$$

$$V = r\omega$$
$$6000 = 39 \times 2\pi N$$

N=31.4853 rpm
≈32 rpm

P=283 W

$$P = \frac{2\pi NT}{60}$$

$$0.283 = \frac{2\pi(32)T}{60 \times 10^3}$$

$$T = 108.0698 \text{ Nm}$$

$$\frac{T}{J} = \frac{\tau}{R}$$

$$\frac{108.098 \times 10^3}{\frac{\pi}{32} \times (19.5845)^4} = \frac{\tau}{9.79225}$$

$\tau = 73.2909$ N/mm² >56.25

Hence, design is not safe.

Selecting shaft diameter as 25 mm

$$\frac{108.098 \times 10^3}{\frac{\pi}{32} \times (25)^4} = \frac{\tau}{12.50}$$

$\tau = 35.23$ N/mm²

Hence design is Safe

4.8 Selection of geared motor

Power transmitted by the chain can be expressed by equation

$$K_w = \frac{P \times V}{1000}$$

Where P=allowable tension =120× 10 =1200 N

V=6m/min =6/60=0.1m/sec

$$K_w = \frac{1200 \times 0.1}{1000}$$

$$K_w = 0.12$$

Ks considering service factor as 1 for uniform driven load with an electric motor

K_1 = tooth correction factor as 0.53 for 19 number of teeth

K_2 = Multiple Strand Factor as 1 for 1 strand

$$\text{KW rating of chain} = \frac{K_w \times Ks}{K_1 \times K_2}$$

$$= \frac{0.12 \times 1}{0.53}$$

= 0.2264 KW

Selecting service factor as 1.1 for electric motor working 8 hrs per day with moderate shock

Output rpm is 32 rpm

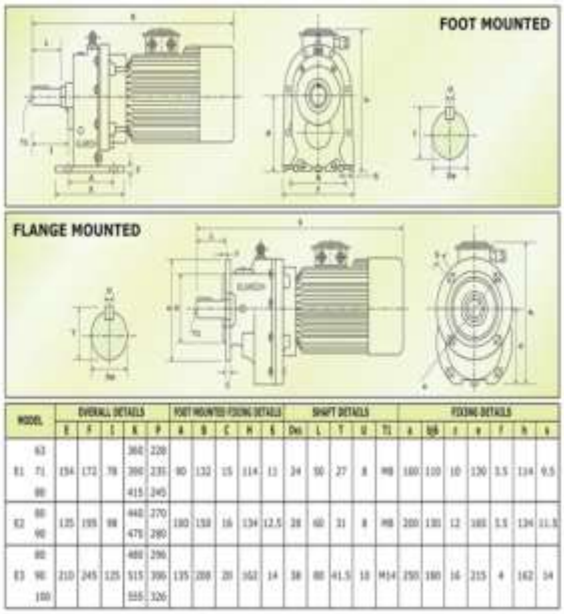
Hence according to output rpm and service factor, we select motor of 0.5 Hp [E-37-71-4 (30 kg)]

Thus, Standard geared motor with following Specifications is selected 3 Phase, AC, 0.5 HP (0.3728 KW) geared motor with output speed 32 rpm

Mounting→ Foot Mounted

Table 5: Selection of geared motor [7]

Table 6: Geared Motor Specification [7]



4.9 Specifications

Table 7: Specifications

Parts	Material	Specifications
Frame	Mild Steel	Square Tube (50mm ×50mm×2mm)
Shaft	Mild Steel	-
Sprocket	En8 (Carbon Steel)	19 Teeth, ½ Inch Pitch
Roller Chain	Stainless Steel	½ Inch Pitch
Bearing	Standard	ID = 25mm
Geared Motor	-	½ HP, 3 Phase, Foot Mounted, Output Speed = 32 RPM
Roller chain flexible coupling	En8(Carbon steel)	NT 8316

5. CONCLUSION

Thus we can conclude that the designed Chain Conveyor is able to safely transport materials from one floor to another floor, which when done by human labour would be strenuous and expensive.

The designed Chain Conveyor is able to occupy less space and this system is less complex as compared to Inclined Belt Conveyor.

6. FUTURE SCOPE

Rubber Blockchain can be used which has outstanding features, that it has no links, silent running, wear resistant and virtually maintenance free, all excellent qualities further enhanced by its corrosion-free design.

With advanced automation, no operator supervision will be required.

A number of pallets can be increased for increasing rate of material transport.

Sensors can be used such as proximity sensors to detect approaching goods and stop the in feed conveyor until the platforms are incorrect position.

7. REFERENCES

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