

Design and Fabrication of Efficient Material Transport Equipment

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Abstract - In material handling, the movement or transport of work parts or other materials is the most crucial aspect. Here, work part can be referred to the raw material under processing/operation, a finished product or other heavy loads. Material transport equipment should be standardized within the limits of achieving overall performance objectives and without sacrificing needed flexibility, modularity, and throughput. The designer should select an equipment that can perform a variety of tasks under a variety of operating conditions and in anticipation of changing future requirements. We have developed a efficient material transport equipment, which moves forward by converting the potential energy of the load into kinetic motion of model. Our project is designed for applications in industrial area for distributing material in manufacturing plants around a manufacturing facility.

Keywords – Material Handling and Material Transport.

1. INTRODUCTION

Material handling is defined by the Material Handling Industry of America as "the movement, storage, protection and control of materials throughout the manufacturing and distribution process including their consumption and disposal". The handling of materials must be performed safely, efficiently, at low cost, in a timely manner, accurately (the right materials in the right quantities to the right locations), and without damage to the materials. Material handling is an important yet often overlooked issue in production. The cost of material handling is a significant portion of total production cost, estimates averaging around 20-25% of total manufacturing labor cost. The proportion varies, depending on the type of production and degree of automation in the material handling function.

Material handling cannot be avoided in logistics, but can certainly be reduced to minimum levels. The productivity potential of logistics can be exploited by

selecting the right type of handling equipment. The selection of material handling equipment cannot be done in isolation, without considering the storage system. Investment in the material handling system will be sheer waste if it is not compatible to the warehouse layout plan. The layout will create obstacles for free movement of equipment and goods, resulting in poor equipment productivity. Recent trends indicate preference for automated system with higher logistics productivity to enhance the effectiveness of human energy in material movement.

2. OBJECTIVE OF THE PROJECT

The objective and scope of this project is to create a material transfer model that can advance forward on a flat surface horizontally. This model obtains the drive to move forward by the potential energy of the load to be carried. In other words, the vertical downward movement of the load rotates a shaft by means of rack and pinion mechanism, thus the rotation of pinion is converted into linear motion of the model. The model is a four-wheeled carrier that has the ability to move along a straight line. There are four wheels including two driving wheels driven by a chain drive and two free wheel in front that are constrained to move in one direction. This project consists of two main stages, which are theoretical design and mechanical fabrication followed up by project closure.

3. LITERATURE SURVEY

Deepak K, Vivek S and Anand S [2], Comfort coupled with safety and simplicity is what man strives for. This project has been to bring about both. The culmination of their effort has resulted in development of a new Design & fabrication of flexible conveyor. The project present a basic as well as very professional treatment of the subject in a very comprehensive, based on learning effort and understanding capability of today as per their levels. The device is simple and comfortable. The salient features of

this machine can be listed as the mechanism used is very simple, easy for operation; no skill is required to operate the machine.

Amit S, Inayattulla K, Salim B and Pandurang V [3],

The production lines and assembly lines are referred to as material handling systems. The material handling is the movement, storage of materials and products throughout the process of their manufacture, assembly and distribution. Broadly material handling is a system that does the material handling operations. Conveyor is one of the systems used in industries. The aim of this project is to design and develop a conveyor system, which should work only when an object is placed on it and count the number of objects passed on it. Also a feature is added in this system that the number of objects to be handled is programmed, thus the conveyor works only for the programmed number of objects.

4. WORKING

This proposed idea of material transport equipment uses the potential energy of the load to transport it from one station to another, meanwhile it compresses the spring placed under it. The load will unloaded at the final station. During the return journey of the model, the spring releases its stored energy and this energy is used to drive the model back to the loading station.

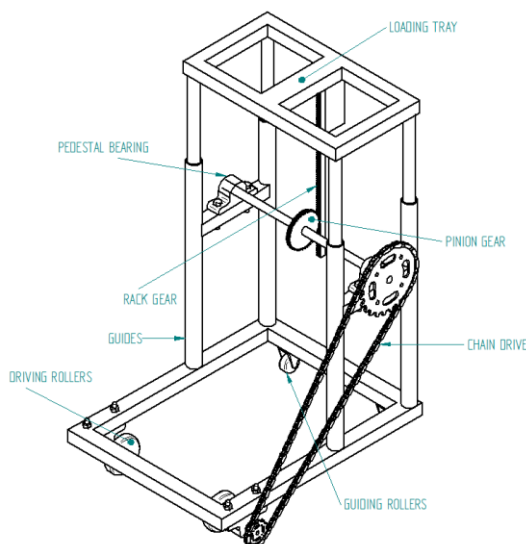


Fig - 1: Schematic diagram of proposed model.

At the loading station, we place the load on the loading tray of the equipment. A rack and pinion arrangement is arranged below the tray. The load has potential energy and hence it compresses the spring located under the tray.

During the downward motion of the load, the rack gear moves down which causes rotation of the pinion gear. The pinion gear shaft is connected to the model drive shaft by means of a chain drive, thus results in a linear movement of equipment from the loading station to the unloading station. The chain drive has a velocity ratio of 1:3 causing the model to cover more distance for every revolution of pinion gear. At the unloading station, the load is unloaded from the tray, thus the springs release their energy causing the rack to move vertically upward. This causes the pinion gear and its shaft to rotate in opposite direction causing the equipment to return back to the loading station.

The material transport equipments can be used to transport a variety of materials and products. Thus it is necessary to indicate what is being transported. One of the way to achieve this is to incorporate an electrical display. The electrical power required to operate this display is obtained from a dynamo. The dynamo obtains its drive from one of the shaft through a belt drive or chain drive. A battery is necessary to store the current generated by dynamo, to ensure continuous operation of the display board.

5. DESIGN

5.1 Problem Definition (Load)

- Total mass to be carried = 10 Kgs = 98.1 N
- Minimum linear distance to be covered by model = 1.5 Feet = 457.2 mm

5.2 Design of Spring

- Aim - To obtain deflection of spring for above load and check for failure.
- Specifications of spring selected,
 - (i) Diameter of spring wire = $d = 2 \text{ mm}$
 - (ii) Outer diameter = $OD = 25 \text{ mm}$
 - (iii) Inner diameter = $ID = 21 \text{ mm}$
 - (iv) Mean diameter

$$D = \frac{OD+ID}{2} = \frac{25+21}{2} = 23 \text{ mm}$$
 - (v) Free Length = $L = 500 \text{ mm}$
 - (vi) Number of turns = $N = 55$
- Total applied load = 98.1 N
- Number of springs to be used = 2
 - (i) Load on each spring

$$F = \frac{98.1}{2} = 49.05 \text{ N}$$
- Spring material
 - (i) Material = Spring Steel

(ii) Ultimate strength = $\sigma u = 1700 \text{ Mpa}$

(iii) Tensile strength

$$\sigma t = \frac{\sigma u}{2} = \frac{1700}{2} = 850 \text{ Mpa}$$

(iv) Shear stress

$$\tau = \frac{\sigma t}{2} = \frac{850}{2} = 425 \text{ Mpa}$$

- Spring index = $C = \frac{D}{d} = \frac{23}{2} = 11.5$
- Stress correction factor

$$K = \frac{4C - 1}{4C - 4} + \frac{0.615}{C} = \frac{4 * 11.5 - 1}{4 * 11.5 - 4} + \frac{0.615}{11.5} = 1.12$$

- Check for shear,

$$T = F * \frac{D}{2} = \frac{\pi}{16} d^3 \tau$$

$$\tau = 49.05 * \frac{23}{2} * \frac{16}{\pi} * \frac{1}{2^3} = 359.1 \text{ Mpa} \leq 425 \text{ Mpa}$$

Thus safe.

- Spring deflection,

$$y = \frac{8FC^3N}{Gd} = \frac{8 * 49.05 * 11.5^3 * 55}{84 * 10^3 * 2} = 195.38 \text{ mm}$$

- Stiffness of spring,

$$K = \frac{F}{y} = \frac{49.05}{195.38} = 0.251 \text{ N/mm}$$

5.3 Problem Definition (Linear Motion)

- Aim – To determine linear motion of the model for the above found spring deflection.
- Deflection of spring = 195.38 mm
- Gear,

(i) Outer Dia of gear selected = 90 mm

(ii) Linear distance covered for one complete revolution = $\pi * 90 = 282.74 \text{ mm}$

(iii) Thus for a deflection of 195.38 mm, angular deflection of the gear is,
 $= 195.38 * \frac{360^\circ}{282.74} = 248.77^\circ$

- Sprocket,

(i) Gear and sprocket are mounted on a same shaft, thus sprocket also covers the same angular deflection, i.e. 248.77° for 195.38 mm deflection of spring.

(ii) Pinion sprocket and sprocket have a speed ratio of 3.07, thus the pinion rotates $248.77^\circ * 3.07 = 763.73^\circ$.

(iii) Number of revolutions of pinion sprocket $\frac{763.73}{360} = 2.12$ revolutions.

- Rollers,

(i) Pinion sprocket is connected to the final drive rollers,

(ii) Diameter of roller = 80 mm

(iii) Distance covered by roller for one revolution = $\pi * 80 = 251.33 \text{ mm}$

(iv) Distance covered by roller for 2.12 revolutions
 $= 2.12 * 251.33 = 532.82 \text{ mm}$

- Conclusion – The selected components provide our necessary requirement of 457.2 mm linear motion. Thus we can move with the further design process.

Note = The most important component in the above analysis is the gear. While checking the gear for induced stresses, if we find that gear has failed for given loads, some different specification gear may have to be selected and the above analysis has to be repeated.

5.4 Power Calculation

- Load carried = 98.1 N
- Vertical travel of rack gear = 195.38 mm
- Power = $98.1 * \frac{0.19538}{60} = 0.3194 \text{ W}$

5.5 Design Of Pinion

- Specifications of gear selected,
 - Outer Diameter = OD = 90 mm
 - PCD = D = 86 mm
 - Number of Teeth on pinion = Z = 43
 - Width of gear = b = 8 mm
 - Module = $m = \frac{D}{Z} = \frac{86}{43} = 2$
 - Assumed Speed of Pinion = N = 30 rpm
- Torque Transmitted

$$T = \frac{P * 60}{2\pi N} = \frac{0.3194 * 60}{2\pi * 30} = 0.1017 \text{ Nm} = 101.7 \text{ Nmm}$$

- Module = $m = \sqrt[3]{\frac{2.T}{Y*\beta*Z*Sd*Kv}}$

Assumptions and calculations

- (i) Velocity factor = $K_v = 0.5$

(ii) $\beta = 10$

(iii) Lewi's form factor = y

$$y = 0.154 - \left(\frac{0.912}{Z}\right) = 0.154 - \left(\frac{0.912}{43}\right) = 0.1327$$

(iv) Form factor = Y = $y\pi = 0.1327 * \pi = 0.4172$

(v) Allowable Stress = Sd

$$Sd = \frac{\sigma_{yield}}{FOS} = \frac{247Mpa}{3} = 82.33 Mpa$$

Therefore,

$$Module = m = \sqrt[3]{\frac{2*101.7}{0.4172*10*43*82.33*0.5}} = 0.3019$$

The module of gear selected is 2, while module required is 0.3019. Thus safe.

- Check for Dynamic Strength,

$$Wt = Sd * Kv * b * m * Y$$

(i) Pitch line velocity

$$V = \frac{\pi DN}{60,000} = \frac{\pi * 86 * 30}{60,000} = 0.1351 \text{ m/s}$$

(ii) Velocity factors

$$Kv = \frac{3}{3 + V} = \frac{3}{3 + 0.1351} = 0.9569$$

(iii) Tangential load

$$Wt = \frac{2T}{D} = \frac{2*101.7}{86} = 2.37 \text{ N}$$

Therefore,

$$Wt = Sd * Kv * b * m * Y$$

$$Sd = \frac{2.37}{0.9569 * 8 * 2 * 0.4172}$$

$$= 0.371 \text{ Mpa} \leq 82.33 \text{ Mpa}$$

Thus Safe

- Dynamic tooth load

$$Wd = Wt + \frac{[21V(bC + Wt)]}{21V\sqrt{bC + Wt}}$$

(i) Dynamic factor

$$C = \frac{a * e}{\left[\left(\frac{1}{E}\right) + \left(\frac{1}{ER}\right)\right]}$$

Where, a = 0.111

Error = e = 0.0960 mm

Modulus of elasticity of pinion = E = 200 Gpa

Modulus of elasticity of rack = ER = 200 Gpa

$$C = \frac{0.111 * 0.0960}{\left[\left(\frac{1}{200 * 10^3}\right) + \left(\frac{1}{200 * 10^3}\right)\right]} = 1065.6 \frac{N}{mm}$$

Therefore,

$$W = 2.37 + \frac{[21 * 0.9569(8 * 1065.6 + 2.37)]}{(21 * 0.9569) * \sqrt{8 * 1065.6 + 2.37}} = 62.36 \text{ N}$$

- Wear load

$$Ww = k * b * D * Q$$

(i) Load stress factor

$$k = \left[\frac{Sfe^2 * \text{Sin}\phi}{1.4}\right] * \left(\frac{1}{E} + \frac{1}{ER}\right)$$

Where, Surface endurance limit = $S_{fe} = 360 \text{ Mpa}$

Pressure angle = $\Phi = 20^\circ$

$$K = \left[\frac{360^2 * \text{Sin}(20)}{1.4}\right] * \left(\frac{1}{200 * 10^3} + \frac{1}{200 * 10^3}\right) = 0.3166$$

(ii) Ratio factor

$$Q = \frac{2DR}{DR + D}$$

Where, $D_R =$ Equivalent diameter of rack

$$DR = \frac{L}{\pi} = \frac{500}{\pi} = 159.15 \text{ mm}$$

And,

$$Q = \frac{2 * 159.15}{159.15 + 100} = 1.23$$

Therefore,

$$Ww = 0.3166 * 8 * 86 * 1.23 = 267.92 \text{ N} \geq 62.36 \text{ N}$$

Thus Safe

5.6 Chain Design

- Aim - To select a chain drive and check for failure.

- Power to transmit = P = 0.3194 W

- Selecting standard sprockets

(i) Pinion sprocket

- Z1 = 14 Teeth

- PCD = D1 = 60 mm

(ii) Sprocket

- Z2 = 43 Teeth

$$\circ \text{ PCD} = D2 = 180 \text{ mm}$$

- Velocity ratio = $VR = \frac{43}{14} = 3.07$
- Speeds,
 - (i) $N2 = 30 \text{ rpm}$
 - (ii) $N1 = 30 * 3.07 = 92.1 \text{ rpm}$
- Selecting rollers chains with following specifications for applications below velocity 25m/s,
 - (i) Roller diameter = 8.51 mm
 - (ii) Roller width = 7.85 mm
 - (iii) Pitch = 12.7 mm
 - (iv) Break load = 20KN
 - (v) Weight per meter weight = $W = 7.1 \text{ N/m}$
 - (vi) Bearing stress = 31.5 Mpa
- Check for velocity,

$$V = \pi * d1 * \frac{N1}{60,000} = \pi * 60 * \frac{92.1}{60,000} = 0.2893 \text{ m/s}$$

$$\leq 25 \text{ m/s. Thus safe.}$$
- Steady load = $F = \frac{P}{V} = \frac{0.3194}{0.2893} = 1.1 \text{ N}$
- Centrifugal load on chain = FC

$$FC = W * \frac{V^2}{g} = 7.1 * \frac{0.2893^2}{9.81} = 0.0606 \text{ N}$$
- Load on chain due to sagging = Ff = $Kg * W * C$
 - (i) Centre distance = $C = 640 \text{ mm}$
 - (ii) Co-efficient of sag = $Kg = 2$ (for chain position above 40°)
$$Ff = 2 * 7.1 * 0.64 = 9.09 \text{ N}$$
- Total load on chain,

$$Ft = 1.1 + 0.0606 + 9.09 = 10.25 \text{ N}$$
- Check for bearing stress,

$$Pb = \frac{Ft}{\text{Roller Width} * \text{Roller Diameter}} = \frac{10.25}{8.51 * 7.85}$$

$$= 0.1534 \text{ Mpa} \leq 31.5 \text{ Mpa}$$

Thus safe.

5.7 Design of Shafts

- Aim - To select a shaft and check for failure under shear stress.
- Ultimate tensile strength of shaft material

$$\sigma u = 490 \text{ Mpa}$$
- Allowable tensile strength,

$$\sigma a = \frac{\sigma u}{FOS} = \frac{490}{2} = 245 \text{ Mpa}$$
- Shear stress,

$$\tau_s = \frac{\sigma a}{2} = \frac{245}{2} = 122.5 \text{ Mpa}$$

5.7.1 Shaft with Pinion Sprocket

- Speed = $N = 92.1 \text{ rpm}$.
- Power transmitted = $P = 0.3194 \text{ W}$
- Length of the shaft = $L = 600 \text{ mm}$
- Torque transmitted,

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

$$T = \frac{0.3194 * 60}{2\pi * 92.1} = 0.0327 \text{ Nm} = 32.7 \text{ Nmm}$$

- Shaft diameter selected = $d = 10 \text{ mm}$
- Check for shear,

$$\tau = \frac{16T}{\pi d^3} = \frac{16 * 32.7}{\pi * 10^3} = 0.1665 \text{ Mpa} \leq 122.5 \text{ Mpa}$$

Thus safe.

5.7.2 Shaft with Sprocket

- Speed = $N = 30 \text{ rpm}$.
- Power transmitted = $P = 0.3194 \text{ W}$
- Length of the shaft = $L = 600 \text{ mm}$
- Torque transmitted,

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

$$T = \frac{0.3194 * 60}{2\pi * 30} = 0.1017 \text{ Nm} = 101.7 \text{ Nmm}$$

- Shaft diameter selected = $d = 20 \text{ mm}$
- Check for shear,

$$\tau = \frac{16T}{\pi d^3} = \frac{16 * 101.7}{\pi * 20^3} = 0.0647 \text{ Mpa} \leq 122.5 \text{ Mpa}$$

Thus safe.

5.8 Rack Specifications

- Cross sectional area = 25 mm X 10 mm
- Length of the rack = 500 mm
- Number of teeth on rack gear = 80 Teeth.

5.9 Bearings

- Bearings used to support the shafts are pedestal bearings.
- The specifications of the bearing are,
 - (i) Housing number - P204
 - (ii) Shaft size = $\frac{3}{4}$ inch = 19.05 mm
 - (iii) Bolt size = M10.

6. ASSEMBLY MODEL

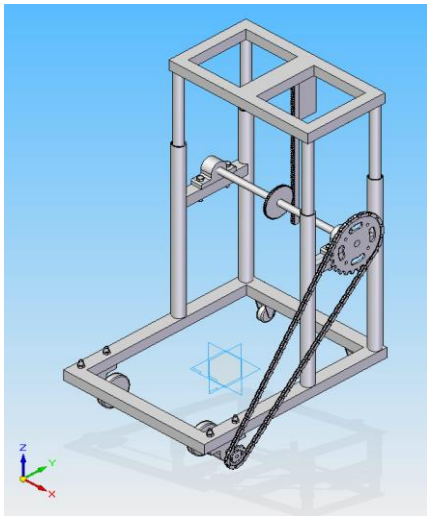


Fig -2: Final 3D assembled model of equipment

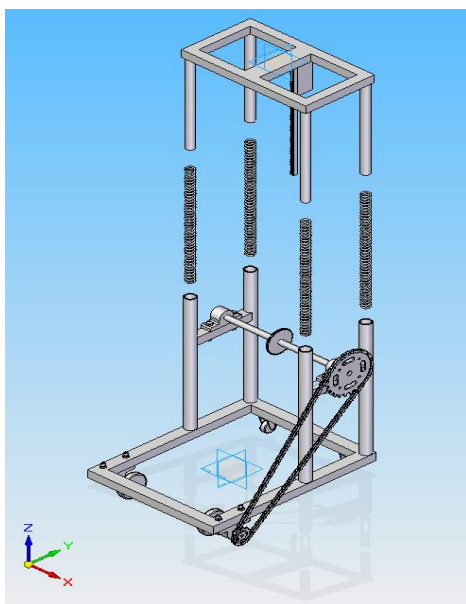


Fig -3: Explode view showing springs, upper part and rest of model separately

7. APPLICATIONS

An effective method of handling various goods. They can find applications in,

- (a) Manufacturing plants,
- (b) Factory floors,
- (c) Warehouse facilities,
- (d) Retail stores,
- (e) Food service industries,
- (f) Chemical factories,

They can also be used as baggage carts in train stations and airports.

8. FUTURE SCOPE

The equipment can be implemented in a firm where loads are to be transported between stations. However they have few disadvantages, which can be overcome by further research and development of the project.

To increase the distance covered by the model, reduction gears can be employed, so that the equipment can cover additional distance for every rotation of the model.

In case of curved paths, the rollers can be adjusted at an angle with respect to the model. However this holds only for paths which are continuously curved i.e. having a certain radius and not involving any straight paths.

To accompany various weights, the springs have to be designed accordingly. Thus this requires different spring design for different weights.

Also by incorporating a dynamo in the model, it can generate power which may be used to run an electrical display or other electronic equipments mounted in the equipment. The dynamo can be operated by coupling its shaft to the pinion gear shaft.

9. CONCLUSION

The material transport is important activity in the logistics system. The speed of the material flow across the supply chain depends on the type of the material handling equipment and the sophistication in the system. In the logistics operation the material transport system is designed in and around the warehouse.

A mechanized transport system shifts the fatigue to machine and brings effectiveness to human efforts. The selection of the appropriate system depends on the factors such as volumes to be handled, speed in handling, product characteristics (weight, size, shape) and nature of the product (hazardous, perishable, crushable).

The project "Design and fabrication of Efficient Material Transfer Equipment" is successfully tested and implemented which is both economical and an affordable energy solution to material transport. This can be used for many applications as listed earlier. As this project uses no external source of power for its operation, this project

can prove to be a boon in disguise for material transport requirement in industries.

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