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THE DEVELOPMENT OF A MATERIAL HANDLING SYSTEM USING WIRE ROPE– A CASE STUDY

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Abstract- To sustain in the today's globalized world, the manufactures need to adopt advanced technology to achieve the highest productivity. Material handling is the field concerned with solving problems involving the movement and storage of the materials pragmatically. The focus of this paper is on the design and development of a material handling system for small scale industries that have the raw materials, such as pipes.

Index Terms- Cycle time, labor consumption, Material Handling System, rope, storage rack.

I. Introduction to Material Handling System

Material handling is nothing but loading, moving and unloading of the raw materials such as the finished products etc. In small scale industries the material handling is generally done manually. In this Regard, the pipes' handling is very difficult. The precaution is taken that there is no damage to the pipes. Whenever, the specific pipe is required for the manufacturing of product that pipes is carried by labors manually up to the cutting machine. Due to the manually material handling a lots of time is consummated. So the cycle time of production increases which decreases productivity of the plant, also increases cost per unit product.

II. Problem Statement

The problem faced by small scale industries in material handling is time and labor consumption. In our case study we had found that around 3 to 4 hours are required to unloading the truck as well as 6 labors are required for manual transfer of pipes. As number of worker engaged in transferring the raw material towards cutting machine is large and also the time for transferring is more. It results into more working cost. To minimize this cost & time we are going to design the system which has inbuilt material handling system and storage rack.

III. Methodology to Address Problem

1. Industrial Survey of Manufacturing Plant:

The survey consists of total consumption per month of raw material in the plant and information about the various types of pipes required for manufacturing. Depending upon the consumption of various types of pipes, the position of those pipes in the rack is decided.

2. Deciding Parameters of Production Design:

Depending upon the human comfort and quick accesses of a regularly required pipes the design of rack and MHS is based, so as maximum amount of the raw material is stored into the rack.

3. Design of Actual System:

By Calculating the load, moment which are acting on the system we had find out the actual dimension on the system

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IV. Industrial Survey:

The survey consists of total consumption per month of raw material in the plant. Also getting information about the various types of pipes required for manufacturing, depending upon the consumption of various types of pipes, the position of that pipe in the rack is decided. When the truck of raw material is come into plant, two labors are required to unload the truck. These two people travels the distance of 15 m to store the pipe in storage rack whose position is

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fixed near the wall. To unload the Truck of 3 ton two people requires 3 hrs.

When the pipe of particular size is required for manufacturing, two labors are required to carry the pipes from storage rack to machine through the distance of 15 m. After that two more labors are required for perfect aligning of pipes with pipe cutting machine. Total 1 hour is required to carry the pipes from storage rack up to the cutting machine.

So the total 6 labors are required to unloading the pipes from the truck up to its loading to the machine.

a) Regarding the Cost Survey:

6 labors are required for the unloading and loading of the pipes they requires 4 hours to unload the 3 ton pipes per day. The salary of each worker is Rs. 200 /-daily that is half of the shift is going to waste on the material handling that is Rs 600/- are waste on material handling.

The plant is semi automated only 14 workers are working in the plant. If out of these 14 workers, 6 workers are busy for loading and unloading, it affects on production of the plant. So maximum 2 workers will be forwards the loading and unloading section. So it is desired to implement low budget material handling system in SSI.

V. Design of Actual System:

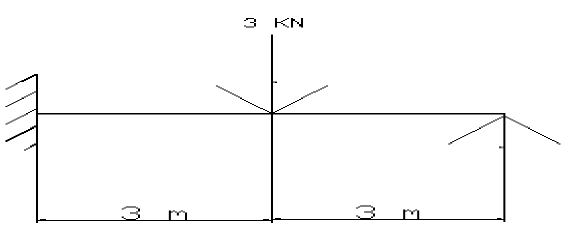

Fig. 1

The diagram shows the force acting on the single rack. We had total 7 racks and at the top one gantry crane.

Total load $= (7 \times 3000\,N)$ + wt of material handling system

$$= (7 \times 3000) + 2000N$$
=23,000N

with the reference of book strength of material by Ramamuratham. The moment at the end of single rack is given as

$$\text{Moment} = (\tfrac{3}{16}) \times W \times L$$

where, W=3000N, L=6m

Moment of the each cantilever at the end of each rack $= (\frac{3}{16}) \times W \times L$

$= (\frac{3}{16}) \times 3000 \times 6 = 3375$Nm ………(1)

Total moment due to 7 rack is given as

$7 \times 3375 = 23{,}625$Nm ………..(2)

Now, There is a moment due to material handling system.

When the load is at extreme condition and it is given as, moment $= 3000 \times 6$

=18,000Nm [span of the material handling system =6m] …….(3)

Due to the weight of MHS the moment is given as, wt. of material handling system =2000N

It is acted at the centre of span

& it is given as $= 2000 \times 3$

=6000Nm ……….(4)

Total moment acting on the column is the summation of eqn (2), (3), (4).

Total moment $= 23{,}625 + 18{,}000 + 6000$

=47625=48,000

a) Design of Column with Rope Drive: (Material =Yst 310 Grade)

To minimize the material consumption we had attached a rope in opposite direction of horizontal reaction and moment. So that total load and total moment acing on the column get reduced and material is saved.

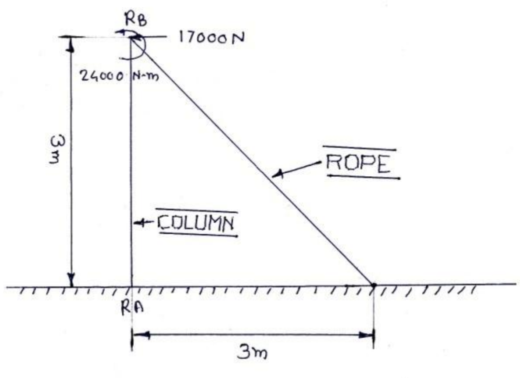

Fig. 2

Reaction at the end = 17000N

Moment at that end =24000 N

Now Design of column is done as

$$\frac{f_a}{F_b} + \frac{f_b}{F_b} < 1$$

By selecting 50mm internal & 4.5 thick

$$f_a = \frac{17000}{7.88 \times 10^2} = 21.57\ N/mm^2$$

$$f_b = \frac{M}{Z} = \frac{24000}{10.20 \times 10^3} = 2.35\ N/mm^2$$

K=1.98cm

$$\frac{l}{k} = \frac{300}{1.98} = 151.51$$

150=47, 160=42

By interpolation for $151.51 \rightarrow 46.245$

$$\frac{21.57 \times 1.5}{46.245} + \frac{2.35 \times 1.5}{205} = 0.71$$

Hence the design is safe.

b) Design of Rectangular Section:

choosing the cross section of (80×40)

Therefore properties of section are,

thickness =4mm,

$Z_{xx}=16.20cm^2$

$= 16.20 \times 10^3 mm^3$

Moment will be the the same

i.e. M=2250000 Nm

The induced stresses are calculated as

$\sigma_{max} = \frac{M}{Z}$

$= \frac{2250000}{(16.25 \times 10^3)}$

$= 138.88 N/mm^2$

There fore the induced stresses are less than allowable stresses. Therefore design is safe. By selecting the cross section $80 \times 40$for the rectangular section.

Weld Design: 1

Welding design between circular angle and rectangular section

Considering fillet weld

By referring the problem solved in V.B.Bhandari Book on welding design

We provide circular angle at a distance of 1m. internal therefore load on each angle is 3000/6 = 500N.

By taking factor of safety as 2

Therefore ,total load $500 \times 2 = 1000N$

Primary stresses are given as

$\tau_1 = \frac{P}{A}$

by selecting the circular section of 15mm diameter

$\tau_1 = \frac{1000}{\pi \times 15 \times t} = 21.22/t$ N/mm^2

Now the moment of inertia of weld is given as

$I_{xx} = \pi \times t \times r^3 = \pi \times t \times 7.53$

$=1325.35 \times t \quad mm^4$

Now bending stress is given as

$\sigma_b = \frac{M_b \times Y}{I_{xx}}$

$= 1000 \times 137.5 \times 7.5 / 1325.35 \times t$

= 778.09 / t N/mm2

From the maximum shear stress theory

$\tau = \sqrt{(\sigma_b / 2)^2 + \tau_1{}^2}$

$= = \sqrt{((778.09/2 \times t)^2 + (21.22 / t)^2)}$

$$= \sqrt{\frac{151356.072}{t^2} + \frac{450.28}{t^2}}$$

$\tau = 389.62/t$ N/mm2 …… 1

From the design data book &from the theory of weld design given by jenning C.H.

For fillet welds

Permissible shear stress =95 N/mm^2

From equation 1

$$95 = 389.62/t$$

t = 4.1 mm, t = h cos450

h = 4.1/cos45

h = 5.8 =6 mm

Weld Design: 2

Design between bush and rectangular lever

By referring the problem in V.B.Bhandari

The cross section of lever are 80×40

A = 2 $(80t + 40t)$

=240t

Primary shear stress

$\tau_1 = P/A$

$= 3000/240t$

$= 12.5/t$

$I_{xx} = t\,[\frac{bd^2}{2} + \frac{d^3}{6}]$

$= t \times 74.666 \times 103$ mm^4

$\sigma_b = \frac{M_b \times Y}{I_{xx}}$

$= 3000 \times 3000 \times 20 / t \times 74.66 \times 103$

$= \frac{2.41 \times 10^3}{t}$

Now From the maximum shear stress theory

$\tau = \sqrt{(\sigma_b / 2)^2 + \tau_1{}^2}$

$= \sqrt{(2.41 \times 10^3/2 \times t)2 + (12.5 / t)2}$

$= 1205.06 / t$

Now by C.H Jennings theory

τ =95 N/mm^2

$95 = 1205.06 / t$

t = 12.68 mm

t = h cos450

h = 12.68/cos45

h = 17.94 mm

c) Design of Pin:-

By selecting the material as steel of C45

σ_{ut} = 600 N/mm^2

τ_u = 300 N/mm^2

by using factor of safety 2

The pin is in shear and the load of 3000 N is acted on it

We know that

Shearing area =(π / 4) × $d_1{}^2$

d_1 = diameter of pin

$p = (\pi / 4) \times d_1{}^2 \times \tau$

assuming the diameter of pin as 20mm

$3000 = \pi / 4 \times 20 \times \tau$

τ = 9.54 N/mm^2

which is less than allowable stress there for design is safe

pin diameter = 20 mm

clearance = 3 mm on both side

internal diameter of bush + circular part

$= 20 + 2 \times 3$

=26

Considering $d_2 = 1.5\ d_1$

d_2 = outer diameter of circular part

$d_2 = 40$ mm, $d_1 = 26$ mm

d) Design of Circular Bush Type Part

(Same Material As Pin)

By using theory of knuckle joint

1. Design for tension

1. $P = (d_2 - d_1) \times t \times \sigma_t$

$3000 = (40 - 26) \times 100 \times \sigma_t$

$\sigma_t = 2.14$ N/mm^2

induced stress is less than allowable stress

2.Design in shearing

2. $P = (d_2 - d_1) \times t \times \tau$

$3000 = (40 - 26) \times 100 \times \tau$

$\tau = 2.14$ N/mm^2

3.Design in crushing

$P = d_1 \times t \times \sigma_c$

$3000 = 26 \times 100 \times \sigma_c$

$\sigma_c = 1.15$ N/mm^2

Design for circular support on column

1.For Tension

$P = (d_2 - d_1) \times t \times \tau$

$3000 = 44 \times 60 \times \tau$

$\tau = 1.13$ N/mm^2

Design is safe

2 .For Shearing

$P = (d_2 - d_1) \times t \times \tau$

$3000 = 60 \times 600 \times \tau$

$\tau = 1.13$ N/mm^2

3 .For Crushing

$P = d_1 \times t \times \sigma_c$

$3000 = 60 \times 600 \times \sigma_c$

$\sigma_c = 0.18$ N/mm^2

Design is safe

e) Design of Movable Support:

As this is the case of propped cantilever the reaction of movable support

$R = \frac{5}{16} \times W$

$= \frac{5}{16} \times 3000$

=937.5N

≈1000N

By taking the factor of safety as 1.5

The reaction at movable support is

$R = 1.5 \times 1000$

R=1500N

By keeping the distance of Rest point 0.5M from column

Total Moment=15000$\times$ 0.5 =750NM

R=1500N , M=750NM

Design of column

By selecting section 15mm inner diameter

3.20 mm thickness

Properties of section

$A_{cs} = 1.82 \times 10^2$ mm^2

$Z = 0.70 \times 10^3$ mm^3

Radius of gyration (k) =0.65cm

$F_a = \frac{1500}{1.82 \times 10^2} = 8.24$ N/mm^2

$F_b = \frac{M}{Z} = \frac{750}{0.70 \times 10^3}$

$= 1.071$ N/mm^2

Now, $\frac{L}{K}=\frac{2000}{6.5}$ =307.69

Now allowable direct stress for this ection

300→13,350→10

By interpolation for 307.69=12.53

Check for design

$\frac{f_a}{F_a}+\frac{f_b}{F_b}<1$

$=\frac{8.24}{12.53}+\frac{1.071}{205}$ =0.66

Hence design is safe

By keeping the distance between column and screw as .25 M

The load on the screw is calculated as per theory of lever

$W\times l_1 = p\times l_2$

1500× 0.5=p× 0.25

P=3000N

Design of Screw and Blot (Material Bolt→C.I) (Material Nut→hardened steel on C.I)

Nominal Dia(d_1)=40mm

Minor Dia(d_c)=33mm,D_0=40mm

Pitch= 7mm

The screw has triple start thread

μ=tanØ=0.15

Ø=11.30^0

Lead=no. of start $\times pitch$

=3 × 27=21mm

A_c=855mm^2

d=$\frac{d_0+d_c}{02}$, =$\frac{40+33}{2}$

D=36.5mm

Direct Stress =$\frac{W}{A_c}=\frac{3000}{855}$,σ_c=3.50N/mm^2

Tanα = $\frac{lead}{\pi\times d}=\frac{21}{\pi\times 36.5}$,Tanα=.02092, α=11.82^0

T=p× $\frac{d}{2}$ =W tan(α+Ø)$\frac{d}{2}$

T=3000 tan (11.82+11.30)$\frac{36.5}{2}$

T=23,375N-mm

For calculation of shear stress,

T=$\frac{\pi}{16}\times\tau\times {d_c}^3$

23375=$\frac{\pi}{16}\times\tau\times 33^3$, τ =3.33N/mm^2

According to the maximum shear stress theory

$\tau_{max}=\frac{1}{2}\sqrt{{\sigma_c}^2+4\tau^2}$

$=\frac{1}{2}\sqrt{3.50^2+4\times 3.31^2}$

= 3.74 N/mm^2

Ideal torque (T_0)= $Wtan\alpha\times\frac{d}{2}$

T_0 = 11457 Nmm

Efficiency (η)

$=\frac{T_0}{T}$ $=\frac{11457}{23375}$ =0.49 =49%

It is self locking screw

Dimension of nut , d_0=40.5 mm

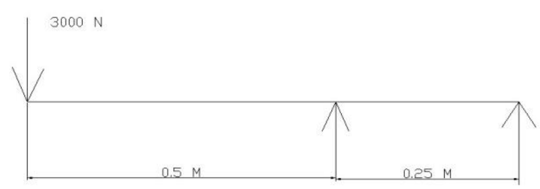

Fig. 3

R_f = 3000 – 1500 = 1500 N

Design of fulcrum pin

Given bearing pressure for the material 25 N/mm^2

d_p = dia of pin , l_p = length of pin

Bearing area = $d_p\times l_p$ ($l_p = 1.25d_p$)

Load on fulcrum pin = bearing area × bearing pressure = $1.25d_p^2\times P_b$

1500 = 31.25 d_p^2

$d_p = 6.92 \approx 8$mm

checking pin for shearing

$1500 = 2 \times \frac{\pi}{4} \times d_p^2 \times \tau$

$1500 = 2 \times \frac{\pi}{4} \times 8^2 \times \tau$

$\tau = 14.92$ N/mm^2

The value of induced stress is less than permissible value i.e $\tau = 500$N/mm^2

Hence design is safe

Thickness of bush = 2 mm

Total dia of hole = 12 + 2 × 2 = 16 mm

Moment = 750 Nm

We know that section modulus

$Z = \frac{1}{6} \times t \times b^2 \quad (b = 4t)$

Z = 2.67 t^3

$\sigma_b = 70\ N/mm^2$

$$\sigma_b = \frac{M}{Z} = \frac{750}{2.67 \times t^3}$$

$70 = \frac{750}{2.67 \times t^3}$

t= 5 mm , b= 4t = 20 mm

shear stress induced in the lever

$\tau = \frac{3000}{20 \times 5} = \frac{3000}{100} = 30$N/mm^2

Hence the Design is Safe.

f) Design of Material Handling Crane (Gantry Girder):

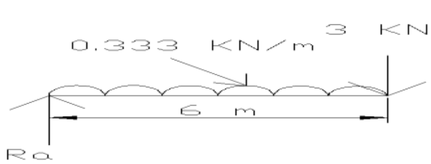

Fig. 4

Reaction of column = $(0.333 \times 6) + 3$

= 5 KN

Reaction on each wheel is $\frac{5}{2} = 2.5\ KN$

By taking section of side view of crane

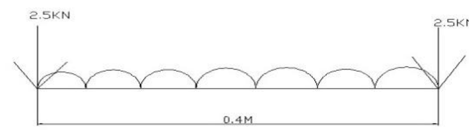

Fig.5

Bending moment is given as

B.M.$_1$ = $\frac{W \times l^2}{8} = \frac{0.25 \times 0.4^2}{8} = 5 \times 10^{-3}\ KNm$

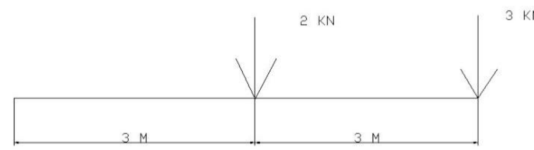

Fig. 6

B.M.$_2$ =6+18 = 24 KNm ,B.M.$_2$> B.M.$_1$

Design is based on B.M.$_2$

Now calculating section modulus, for steel $\sigma_{bc} = 165\ N/mm$

$$Z = \frac{M}{\sigma_{bc}}, = \frac{24 \times 10^6}{165} = 145.45 \times 10^3 mm^3$$

Depending upon this section modulus ,

Selecting the I section ISMB 200 from steel table

Properties of ISMB 200

1. Sectional area (a) = 32.33 cm^2
2. Thickness of web (t_w) = 5.7 mm
3. Thickness of flange (t_f) = 10. Mm
4. Moment of inertia (I_{xx}) = $235.4 \times 10^4 mm^4$
5. Moment of inertia (I_{yy}) = $150 \times 10^4 mm^4$
6. Width of flange = 100 mm

For selecting the 'C' channel , we have to consider width of the flange and keeping the 25 mm clearance on both side.

By selecting the ISMC 150 channel

From steel table

Properties of IMSC 150

1. Area of cross Section (a) = 2088 cm^2
2. Thickness of web (t_w) = 5.4 mm
3. Thickness of flange (t_f) = 9mm
4. Moment of inertia (I_{xx}) = $779.4 \times 10^4 mm^4$
5. Moment of inertia (I_{yy}) = $102.3 \times 10^4 mm^4$
6. Width of flange = 2.22 mm

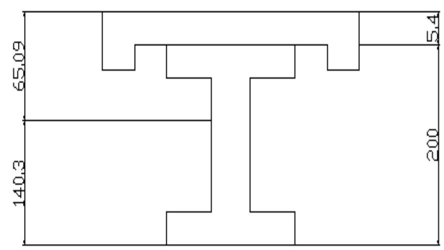

Fig. 7

To find out $\bar{Y}$ of built up section

We know that

$$\bar{Y} = \frac{a_1 y_1 + a_2 y_2}{a_1 + a_2}$$

$$\bar{Y} = \frac{32.33 \times 105.4 + 2088 \times 2.7}{32.33 + 20.88}$$

$$\bar{Y} = 65.09mm$$

Now moment of inertia about X-X axis , of total built up section

$I_{xx} = I_{xx} + a_1 h_1^2 + a_2 h_2^2 + I_{xx}$

$= 2235.4 \times 10^4 + 32.33 \times 40.31^2 + 102 \times 10^4 + 2088 \times 42.89^2$

$= 31.44 \times 10^6 mm^4$

$I_{yy} = I_{yy1} + I_{yy2}$

$= 150 \times 10^4 + 779.4 \times 10^4$

$= 9.294 \times 10^6 mm^4$

$\sigma_{bc} = \frac{M_{x\bar{y}}}{I_{xx}} = \frac{24 \times 10^6 \times 140.3}{31.44} = 1.1 \times 107.099 N/mm^2$

$= 117.8089 N/mm^2$

The design is safe

VI. Results

Table 1: Comparison of Conventional Method and Proposed Methos

Parameters	Conventional Method	Proposed Method
Time	3-4 hrs	½ hrs
Man power required	6	2
Working cost/day	600+6000= 6600	500+200= 700
Efficiency	60%	90%
Damage possibility	More	Less
Fatigue to labors	More	Less

VII. Conclusion

By implementing the above Design and Development in the material handling system, minimizes the total cycle time of production and number of labors. Design and Development of Material Handling System saves 66% manpower and 89% of cost required for material handling.

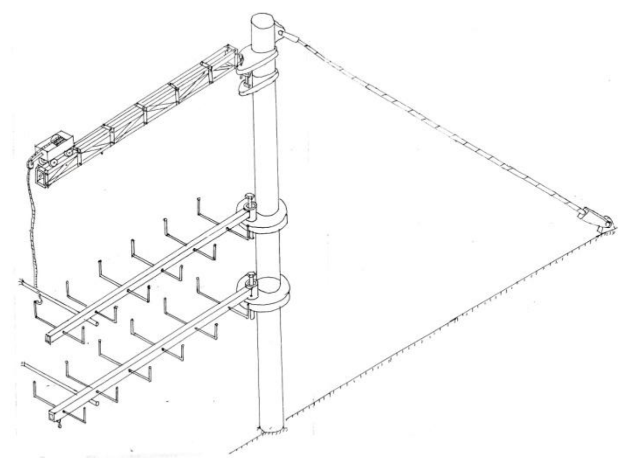

Fig. 8 Actual System

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