ISSN 2395-1621

Design, Development And Analysis Active Gravity Conveyor For Flexible Manufacturing Using Karakuri Mechanism

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ABSTRACT

The desire to increase productivity can effectively accomplished through the adoption of low cost automation by their characteristic small and medium size companies. The concept and principles of low cost automation are basically the same as those of full automation except that the former builds improvement around existing equipment and machine system rather than replacing whole system with automated processes. The primary activity of every manufacturing organization is material handling . It has been estimated that at least 15 to 25% of the cost of the product is attributable to material handling activities. Length of conveyor is to be adjustable to be able to connect any two machines spaced between 1 m to 1.8 m. also weight carrying capacity of conveyor to be varied from 5 kg to 12 kg in tray system. Karakuri mechanisms use a single force or motion to simultaneously perform multiple operations also lead directly to energy conservation and resource (facilities) savings. The proposed Active gravity conveyor for flexible manufacture system uses the principle of Converting the force from a dropped weight into gear rotation to activate a conveyor thereby saving the cost of motor and electricity. To perform material handling task conventionally gravity conveyors are used but they are more often of fixed layout type with a singular application.

Keywords— **gravity conveyor, low cost automation, material handling**

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

I.INTRODUCTION

The rapid growth of technology in the last two decades has been characterized by full automation. As only the affluent and developed countries can afford to adopt full automation, a large productivity gap has been created. This gap can be bridged through low cost automation.The concept and principles of low cost automation are basically the same as those of full automation except that the former builds improvement around existing equipment and machine system rather than replacing whole system with automated processes.

material handling is the primary activity of every manufacturing organization.Unlike many other operations, material handling adds to the cost of the product and not to its value. It is therefore important first to eliminate or at least minimize the need for material handling and second to minimize the cost of handling.A conveyor system is powerful material handling tool. Different types of conveyor are available such as gravity, roller, belt, chain, accumulation, sortation conveyors[4,5].In automobile, food processing, agriculture, aerospace etc. industries conveyor systems are used. Gravity roller conveyers are a convenient, low-cost, flexible tool that enables the powerless transport of various material. A gravity conveyor transfer the material with minimum effort in short time with minimum investment of cost[7]. Depending on type of conveying surface, weight of product and desired speed, etc the angle of decline is depend. Roller, sketewheel, ball type surfaces are available in gravity conveyor[4].

II.LITERATURE REVIEW

Belt and bucket conveyors are the media of transportation of material from one location to another in a commercial space. conveyor has huge load carrying capacity, large covering area simplified design, easy maintenance and high reliability of operation. Conveyor system is also used in material transport in foundry shop like supply and distribution of molding sand, molds and removal of waste [1] . According performance survey 85% industrial units face difficulties in handling bulk material packaging. The difficulties mainly arises when it is necessary to convey a bulk material through a certain distance and a linear distance.Conventional ways are responsible for material wasting, time wasting , etc.

To reduce the weight of existing roller conveyor by optimizing the critical parts ofconveyor without hampering its structural strength. Static analysis of roller of existing conveyor and optimized weight conveyor is carried out find out maximum deflection & stress. The comparison is done and conclusion is made.

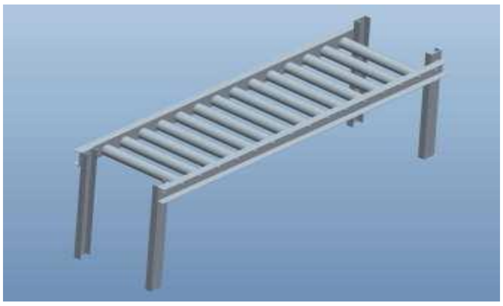


Fig.1 Roller Conveyor[2]

By using Karakuri mechanism the push pedal of rack descend enabling workers to comfortably complete stacking. The packing boxes (weighing 7kg) and stacking processat their several places gives a burden on the waists and backs of workers. Moreover, traditional liftingequipment employed mechanismsthat were operated with externally supplied energy and thus continually consumed energy such as electric motors and controlling equipmentwhile operating and on standby. By Utilizing own weight of products also levers and balance and to boxes onto each rack and to sequentiallylower the transmitted force from a foot pedal using a pulley, spring and weight. This mechanism requires no energy electricity and enables workers to comfortably complete stacking.[6] Mechanism as shown in fig.

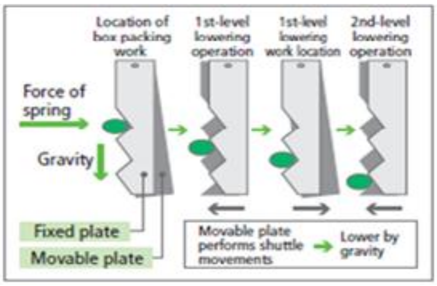


Fig.2 Lowering mechanism

III.RESEARCH METHODOLOGY

Mathematical model development of the gravity conveyor for modular design .

Design and selection of friction less tray slide mechanism by adoption of linear motion tools and tribology tools .

Design development of Friction –less pulley system for connection of the counter weight and tray, development of innovative counter weight system to cope with multiple permutations of weight of system

Design development of ‘ACTIVE’ friction angle adjustment mechanism ‘ using probe and comparator mechanism to control the hydraulic dashpot mechanism.

Development of hydraulic damper mechanism at end of stroke to absorb the momentum of tray bottom an top of stroke.

3-D modeling of set-up using Unigraphix

CAE of critical component and meshing using Hypermesh/ Ansys

Mechanical design validation using ANSYS …critical components of the system will be designed and validated

Validation of strength calculations of critical components viz, drive pulley , , counter weight pulley , Mainshaft , tray roller shaft , Tray rollers , damper piston , orifice plate etc using ANSYS.

IV.REVOLVING MATERIAL TRANSFER SYSTEM

It is always advisable to minimize or if possible eliminate operator’s involvement in transferring materials. There was a need to develop a simple, compact and robust material handling equipment that would suit almost any short distance material transfer task. Such a system would eliminate the need of power conveyors, chutes or roller conveyors that need operator attention and picking of jobs by hand to transfer it between two stations.The system would be of great use in manufacturing lines having U type or ZigZag type layouts where human handling of jobs is presently unavoidable, as use of powered conveyors or gravity conveyors cause interruption in line operations

V.Concept And Working:

Taking all the objectives into consideration a revolving material transfer system was conceptualized.

“The Revolving Material Transfer System” works on the principle of weights and counterweights.

The figure shown below demonstrates the concept of Revolving Material Transfer System

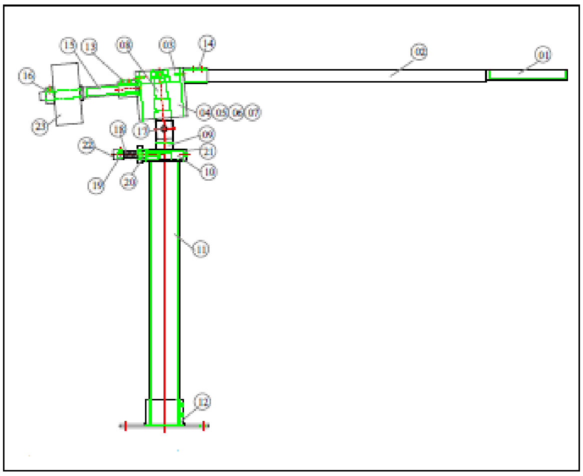


Fig.3 Assembly of Revolving material transfer system

As shown in the above figure, the tray that carries the job is connected to a rotating assembly by means of a arm. A counterweight is attached diametrically opposite arm. Both the arms, i.e., the tray and counterweight arm are free to revolve about central axis. The entire revolving assembly is pivoted with its axis of revolution having a small inclination with the vertical.The counterweight is selected such that it balances the weight of the empty tray at the topmost position (assuming negligible weight of arms). When the tray is empty, system has the tray arm at the top most position. When the part is kept on the kept on the tray the combined weight of the tray and part exceeds the counterweight and thus tries to attain a lower potential. This causes the tray to revolve by 180° about the axis of rotation, which results in transfer of jobs between two stations.

Thus the objective of the project was to develop material transfer equipment that:

Would eliminate the operators handling of jobs for transferring them between stations required in U type, circular type, or ZigZag manufacturing lines.

Would be simple, robust and compact, and would suit almost any short distance material transfer task.

Would consume no electrical power.

Would result in increase of effective productive time.

Would require negligible maintenance attention.

VI.DESIGN METHODOLOGY

Design of revolving material transfer system

In our attempt to design a special purpose machine we have adopted a very a very careful approach, the total design work has been divided into two parts mainly;System design

Mechanical designSystem design mainly concerns with the various physical constraints and ergonomics, space requirements, arrangement of various components on the main frame of machine no. of controls position of these controls ease of maintenance scope of further improvement; height of m/c from ground etc.

In Mechanical design the components are categoried in two parts.

Design parts Parts to be purchased.

For design parts detail design is done and dimensions thus obtained are compared to next highest dimension which are readily available in market this simplifies the assembly as well as post production servicing work.

The various tolerances on work pieces are specified in the manufacturing drawings. The process charts are prepared& passed on to the manufacturing stage .The parts are to be purchased directly are specified &selected from standard catalogues.

System Design

General considerations

In system design we mainly concentrate on the following parameter

System selection based on physical constraints:-

While selecting any m/c it must be checked whether it is going to be used in large scale or small scale industry In our case it is to be used in small scale industry So space is a major constrain .The system is to be very compact. The mechanical design has direct norms with the system design hence the foremost job is to control the physical parameters.

Arrangement of various components

Keeping into view the space restriction the components should be laid such that their easy removal or servicing is possible moreover every component should be easily seen & none should be hidden every possible space is utilized in component arrangement.

Components of system

As already stated system should be compact enough so that it can be accommodated at a corner of a room. All the moving parts should be well closed & compact A compact system gives a better look & structure.

Following are some example of this section

Design of machine height

Energy expenditure in hand operation

Lighting condition of m/c

Chances of failure

The losses incurred by owner in case of failure of a component are important criteria of design. Factor of safety while doing the mechanical design is kept high so that there are less chances of failure. Periodic maintenance is required to keep the m/c trouble free.

Servicing facility

The layout of components should be such that easy servicing is possible especially those components which required frequent servicing can be easily dismantled.

Height of m/c from ground

For ease and comfort of operator the height of m/c should be properly decided so that he may not get tired during operation .The m/c should be slightly higher than that the level also enough clearance be provided from ground for cleaning purpose.

Weight of machine

The total wt of m/c depends upon the selection of material components as well as dimension of components. A higher weighted m/c is difficult for transportation & in case of major break down it becomes difficult to repair.

Mathematical analysis for design of revolving material transfer system

System design of the revolving material transfer system involve the design of the system components as to the geometrical and mass consideration as to the following :

$m1$ = Mass of empty pan in kg

Pw = Weight of parts in N

$m2$ = Mass of counter weight needed to be attached in kg

θ = Angle of inclination of the conveyor track

x = Length of tray arm from axis of rotation in mm

y = Length of counter weight arm from axis of rotation in mm

a = Diameter of bearing housing in mm

Taking into consideration that this is an material transfer system with major human intervention in loading and unloading of components the ergonomics of these operation is of prime importance hence according to principles of ergonomic height of system is decided to be as follows:

Height of counterweight from datum = 900 mm

Height of pan from datum = 913 mm

The length of the pan arm is governed by the system or plant layout which is taken as;

x = Length of tray arm from axis of rotation in mm =1000mm

y = Length of counter weight arm from axis of rotation in mm = 300mm

Assumptions

m1 = Mass of empty pan in kg = 3Kg

θ = Angle of inclination of the conveyor track = 50

To compensate for the shift of cg of the tray side due to significant weight of tray arm the value of 'x' is taken to be 900mm.

Counter weight required to balance the empty tray is calculated as follows:

m1(h + a sin θ) g x = m2 y h g

m2 = 3 x 900 x 913 /300 x 900 =3.04 kg

m2 = 9.13 kg

Verification for system travel upto 1800 by equation:

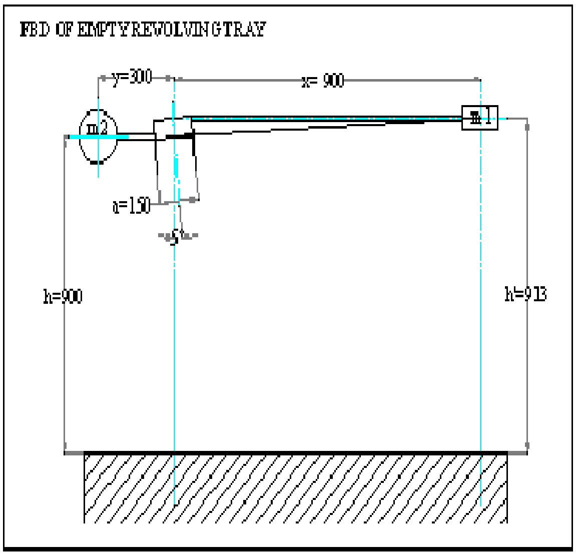
Pwg≥(m1 x2 + m2 y2) sin2 θ / [x(h-xsin2 θ)]

LHS = weight of pan + weight of arm=4.85 (refer telescopic pipe weight details)

RHS = (3 x 0.92 + 9.13 x 0.32) sin 10 / [0.9(0.9 – 0.9 sin10)]

RHS = 1.7246/0.669 = 2.567

As LHS > RHSthe system will freely rotate upto 180^0



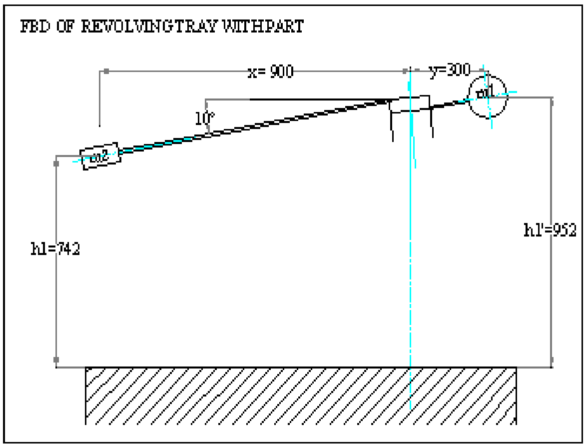


Fig.4 Inclination frame

VII.MECHANICAL DESIGN

DESIGN OF MAIN SHAFT

The main shaft carries the entire load of the material transfer system , as well as it is subjected to torsion and direct shear under given system of forces, hence the main shaft will be designed considering all the above criterion.

a) Design of main shaft in compression

Design of Main shaft considering pure axial load in the form of dead weight of system which will cause compressive stress in the shaft material .

Note : The shaft is fitted with ball bearings 6004 ZZ and 6005 ZZ which are held in the bearing bush mounted on this shaft.

MATERIAL SELECTION : -

The load acting on shaft is summation of the weights of the pan , arm , part weight , counter weight , bearing housing, bearing bush which is maximum upto (approximately) 10 kg = 100 N

The smallest section on shaft = 20 mm

DESIGNATION	ULTIMATE TENSILE STRENGTH N/mm2	YEILD STRENGTH N/mm2
EN 24	800	680

$$\text{Compressive stress} = \frac{\text{Force}}{\text{area}}$$

$$= \frac{100}{\Pi/4 \times (d^2)}$$

$$= \frac{100 \times 4}{\Pi \times (20)^2}$$

b) Design of main shaft in torsion

Using ASME code of design ;

Allowable shear stress;

Fsall is given stress ;

Fsall = 0.30 syt = 0.30 x 600

=180 N/mm2

b) Design of main shaft in torsion

Using ASME code of design ;

Allowable shear stress;

Fsall is given stress ;

Fsall = 0.30 syt = 0.30 x 600

=180 N/mm2

Fsall = 0.18 x Sult = 0.18 x 720

= 130 N/mm2

Considering minimum of the above values ;

fsall = 130 N/mm2

Considering pure torsional load;

IsI No	Bearing of basic design No (SKF)	d	D1	I	D2	F	Basic capacity	
20A C05	6005	25	28	47	44	12	5200	7800

$$\text{Tdesign} = \frac{\Pi f_{sact}\ d^3}{16}$$

Torque is owing to the movement of dead weight or pan with part, which is given by,

T = 3.04 X 300 = 912 N-mm

Assuming 100 % overload

Tdesign = 2 T = 1824 N-mm

$$\text{Fsact} = \frac{16 \times T_{design}}{\Pi\ d^3}$$

fsact = 1.16 N/mm2

As fsact<fsall

The shaft is safe in torsion

c) Check for direct shear of main shaft

$$\text{Shear stress} = \frac{\text{shear force}}{\text{Shear area}}$$

The shaft supports the entire material transfer system and vertical component of force which is same as the force as angle is small ie, 100 N

$$= \frac{100}{\Pi/4 \times (d^2\ )}$$

The connecting rod is an standard part with the small end pin of diameter 8 mm

$$= \frac{100 \times 4}{\Pi \times\ (20)^2}$$

shear stress = 0.318 N/mm 2

Shaft is safe in shear

2. DESIGN OF HINGE PIN

Hinge pin connects the main shaft to the base holder fork , hence the entire load of the system acts on the base holder through this pin, this pin will be subjected to double shear failure.

MATERIAL SELECTION :

The pin is 14 mm in diameter .

Check for direct shear of main shaft

$$\text{Shear stress} = \frac{\text{shear force}}{\text{Shear area}}$$

The shaft supports the entire material transfer system and vertical component of force which is same as the force as angle is small ie, 100 N

$$= \frac{100}{2 \times \Pi/4 \times (d2\ )}$$

The connecting rod is an standard part with the small end pin of diameter 8 mm

$$= \frac{100 \times 4}{2 \times \Pi \times\ (14)\ 2}$$

shear stress = 0.325 N/mm

Pin is safe in shear

SELECTION OF BEARING 6005ZZ

Shaft bearing will be subjected to purely medium radial and axial loads; hence we shall use ball bearings for our application.

Selecting ; Single Row deep groove ball bearing as follows.

Series 62

P = X Fr + Y F a

For our application F a =Dead weight load =100 N

$\Rightarrow$P = X Fr+ Y F a

As; F a/ Fr< e $\Rightarrow$ X =1,Y=1

In this case the radial load is negligible hence;

$\Rightarrow$P = Fa = 100 N

$\Rightarrow$ P= 100 N

Calculation dynamic load capacity of brg

$$L = \left(\frac{C}{p}\right)^{p},$$

where p= 3 for ball bearings

When P for ball brg

For m/c used for intermittent operation hence,

L_H = 2000Hr

$$\text{But ; } \frac{L- 60\ n\ L_H}{10^6}$$

L=1.2 mrev

$$\text{Now;}1.2 = \frac{(C)^3}{100}$$

$\Rightarrow$C= 106.26 N.

$\Rightarrow$As the required dynamic capacity of brg is less than the rated dynamic capacity of brg;

SELECTION OF BEARING 6004ZZ

Shaft bearing will be subjected to purely medium radial and axial loads; hence we shall use ball bearings for our application.

Selecting ; Single Row deep groove ball bearing as follows.

Series 62

P = X Fr + Y F a

For our application F a =Dead weight load =100 N

$\Rightarrow$P = X Fr+ Y F a

As; F a/ Fr< e $\Rightarrow$ X =1,Y=1

In this case the radial load is negligible hence;

$\Rightarrow$P = Fa = 100 N

$\Rightarrow$ P= 100

Calculation dynamic load capacity of brg

$$L = \frac{(\ \ C\ \ )\ p}{P},$$ where p= 3 for ball bearings

When P for ball brg

For m/c used for intermittent operation hence,

LH = 2000Hr

$$\text{But ; } \frac{L- 60\ n\ LH}{10\ 6}$$

L=1.2 mrev

Now; $1.2 = \frac{(C)\ 3}{100}$

$\Rightarrow$C= 106.26 N.

$\Rightarrow$As the required dynamic capacity of brg is less than the rated dynamic capacity of brg;

DESIGN OF DAMPER SPRING

Damper spring is provided at the stopper end to stop the revolving tray the second station, the object of the spring is to absorb the shock owing to the arrest of the revolving tray

Specifications of spring

Wire diameter d = 2 mm

Mean coil diameter D = 18 mm

No of turns n = 10

$\Rightarrow$ c = D/d =18/2 = 9

Maximum deflection of spring:-

Deflection δ = 25 mm

Where;

δ = 25 mm

Now;

$$\delta = \frac{8\ W\ C3\ n}{Gd}$$

$$\Rightarrow 9 = \frac{8 \times W \times (9)3 \times 10}{0.89 \times 105 \times 2}$$

W = 27.5 N

The weight of the empty pan is approximately 3Kg, hence the spring will easily deflect under the load weight of pan+ weight of material in tray, hece the damping action is achieved.

ADVANTAGES

Low fabrication, running and maintenance cost.

Reduces operators handling thus reduces operators fatigue.

Robust, simple, compact and flexible design makes it suitable for almost all short distance material transfer application.

Consumes no electrical power as works on counterweight principle.

The effective productive time increases as the operator can utilize time for loading or unloading jobs from machine which was otherwise wasted material transfer.

If intelligently mounted online it does not block the passages for operator's movement

.

LIMITATIONS

Application is restricted to small distance material transfer

The revolving long arms demands more space and may obstruct the operators movement

Not suitable for heavier components

Result Table

The parameters derived in the above calculation of system design of the Revolving material transfer system are as follows :

m1 = Mass of empty pan in kg	3 kg
m2 = Mass of counter weight needed to be attached in kg	9.13 kg
θ = Angle of inclination of the conveyor track	50
x = Length of tray arm from axis of rotation in mm	900
a = Diameter of bearing housing in mm	150
h' = Height of pan from datum mm	913
h = height of counter weight from datum mm	900

VIII.CONCLUSION

We can eliminate the operators handling of jobs for transferring them between stations required in U type, circular type, or ZigZag manufacturing lines. Equipment would be simple, robust and compact, and would suit almost any short distance material transfer task. No consumption of electrical power. By using karakuri mechanism increase the result of effective productive time alsorequire negligible maintenance attention.

ACKNOWLEDGMENT

I wish to express my appreciation and gratefulness for the most cooperative attitude of Dr. C. R. Sonawane for their able guidance thoughtful suggestions and the constant moral support. I also thankful to Principal Dr. A. N. Gaikawad, Head of the Mechanical Department Prof. B.D. Aldar as well as Dr. B. M. Shinde for encouraging me to undertake such work

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