

Modeling and Simulation of Gravity based Zig-zag Material Handling System for Transferring Materials in Multi Floor Industries

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Abstract

Transferring materials from a higher place to a lower place is a challenging task. Conveyers, lifts and many more material handling devices are difficult to construct, install and operate. Thus a simple gravity based zig-zag material handling system which requires no external power to drive them has been developed. The buckets which are used are made to rotate about a certain axis thereby enabling them to transfer the materials efficiently. This system can be used in places where the space is limited. The system has been modeled using SOLIDWORKS™ and simulated using MSC ADAMS™. A prototype has been made which shows how the system works. The results indicate that it is an efficient way for material transfer in vertical direction. It can be used in industries and machining centers where there are multi floors and materials need to be transferred from top to bottom floors.

Keywords: Gravity Based MHS, Limiters, Powerless MHS, Top-Down Material Transfer, Transfer Buckets, Vertical Material Transfer, Vertical Projection

1. Introduction

Material handling is defined by the Material Handling Industry of America (MHIA) as “the movement, storage, protection, and control of materials throughout the manufacturing and distribution process including their consumption and disposal”. This must be done safely, efficiently, at low cost, in right time, accurately and without damage⁸.

A modular approach for simulation is done for evaluating the automated material handling system¹. Generic planning and control of automated material handling systems are needed in case of powered systems². Conveyers can be used, but the strength of the adhesive sealed joints decreases due to ageing³ and dynamic wear⁴. Further the use of impact plates in conveyors is needed because they reduce the wear due to friction⁵. In chain drives, link tension⁶ and deformation in tooth profile of rollers⁷ are noted. Gravity flow rack's material handling system¹⁰ was

implemented to reduce the material transfer activities while reducing the occupied space. Screw conveyors are used to transfer materials horizontally or at an inclined angle. The performance is affected by the operating conditions such as the rotational speed of the screw and inclination of screw conveyor¹¹. Spiral conveyors require a drive motor to operate¹². There are devices for transferring materials up and down multi floor industries. But they need power in some form or the other to transfer materials down¹³. These are few of the problems faced in the current material handling systems.

In our research, the time taken to transfer the materials from one floor to another is reduced and by without the use of any power systems. The gravity plays a major role in transferring the materials from one floor to another. More over in places where there is space constrain, this type of zig-zag material handling system can be used. First the parts of the system are explained. Then the mechanism of material handling system is explained.

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The modeling of the gravity based zig-zag material handling system was done using SOLIDWORKS™. Following that the simulation of the system was done using MSC ADAMS™ and the results are presented. Then the prototype of the material handling system was done and the working of it is shown. The material to be transferred can be of any shape and size but the system must be designed accordingly. The number for transfer buckets depend on the vertical distance to which the material has to be transferred. In this case, it is taken to be 5.

2. Nomenclature

L – Length of the pin.

L_{xy} – Limiter.

x – Transfer bucket number.

y – Limiter number.

D – Diameter of the bucket.

H – Height of the bucket.

H_{vp} – Minimum height of the vertical projection.

P – Point of projection.

R – Distance between the two points of projection in the horizontal direction.

S – Distance between the two points of projection in the vertical direction.

T – Thickness of the bearing.

θ – Angle between the horizontal and the limiter L_{x2} .

3. Parts of the Gravity based Zig-Zag Material Handling System

3.1 Vertical Projection

It is a stand on which the transfer buckets and limiters are fixed. The height of the vertical projection depends on the distance from which the material has to be transferred. It can be made of a metal if the system has to be moved on the floor. Otherwise it can be made of concrete structure. The material used to construct it depends on the weight and size of the material to be transferred. The structure of the vertical projection is as shown in Figure 1. There are pins at the point of projection on the vertical projection which holds the transfer bucket. The position of the pins on the vertical projection depends on its vertical height.

$$L = D + [2 * (T)]$$

3.2 Transfer Buckets

These are buckets that are used to handle the material. They have a point of projection where the transfer bucket is subjected to rotate. There is a rotation limiter which limits the rotation of the transfer bucket which transferring the materials. There are two holes on the bucket through which the pins are passed. The material of the transfer buckets depend on the material to be transferred. There is a dead load on the left side as shown in the Figure 2. The purpose of the dead load is to bring back the transfer bucket to normal position after transferring the material. It is slightly less than the weight of the material to be transferred. The transfer buckets rotate clockwise and anti-clockwise. The dead load is on the left side when the transfer buckets rotate clockwise and the dead load is on the right side when the transfer buckets rotate anti-clockwise. There are two bearings, attached one on each of the transfer buckets in order to reduce friction between the pins and the transfer buckets.

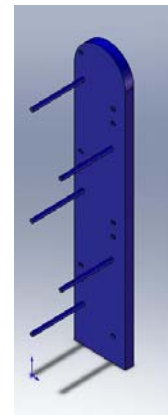


Figure 1. SOLIDWORKS™ model of the vertical projection.

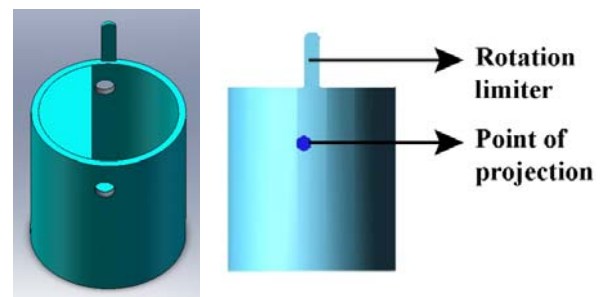


Figure 2. SOLIDWORKS™ model of the transfer bucket and parts.

3.2.1 Calculation of the Point of Projection in the Transfer Bucket

The calculation is based on the model created and simulated using MSC ADAMS™. It is shown in Figure 3. Let the height of the transfer bucket be “H” and the width of the transfer bucket be “D”. The height of the rotation limiter is represented as “c”. With reference to the point of projection, the values of D and H are

$$D = a + b$$

$$H = c + d$$

based on the simulation and experiments conducted, for the ratio of H:D = 10:7,

‘a’ and ‘b’ divides the diameter D in the ratio, a:b = 11:24

$$(a:b=2.2:4.8 \Rightarrow a:b=22:48 \Rightarrow a:b=11:24) \text{ and}$$

‘c’ and ‘d’ divides the height H in the ratio c:d = 3:7

thus by using these ratios, the transfer bucket can be designed for any size.

3.3 Limiters

There are extensions which are attached to the vertical projection. They are called as limiters. These limit the rotation of the transfer buckets. Each transfer bucket has two limiters. One of them is for keeping them stay in the vertical position and the other is used to limit the rotation of the transfer bucket when the material falls on them. The position of the limiters depends on the position of the pin and size of bucket. They are made along with the vertical projection or fixed later. These limiters

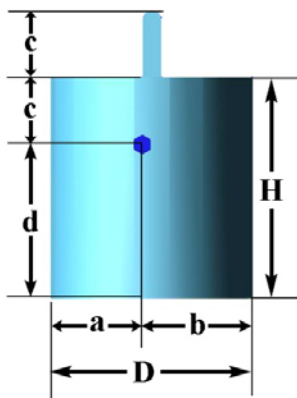


Figure 3. Representation of the dimensions of the transfer bucket using MSC ADAMS™.

play an important role in material transfer. The points of projection are represented as P1, P2...P5. They are as shown in the Figure 4.

The position of the limiters and points of projections are fixed as shown in Figure 5. The angle θ between the horizontal and the limiter L_{12} is based on the friction (μ) between the transfer bucket and material to be transferred.

$$\theta = \tan^{-1}(\mu)$$

The distance (R) between the two points of projections in the horizontal direction are based on the diameter of the transfer bucket. Hence it can be written as,

$$R = 0.5b + 0.5b$$

The distance (S) between the two points of projections in the vertical direction are based on the height of the transfer bucket. Therefore it can be written as,

$$S = 2c + d$$

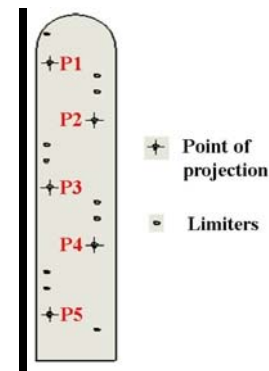


Figure 4. Representation of the limiters and point of projection.

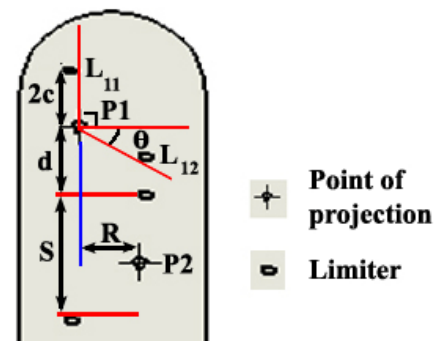


Figure 5. Representation of the position of limiters and point of projections.

If there are “n” transfer buckets, then the minimum height of the vertical projection can be given as

$$H_{vp} = n(2c + d).$$

4. Geometric Parameters of the Gravity based Material Handling System

The ratio between the various dimensions of the gravity based material handling system is as given in Table 1.

5. Mechanism of the Gravity based Zig-Zag Material Handling System

5.1 Construction

There is a vertical projection which holds the limiters and transfer buckets. This vertical projection is placed in the area where the material has to be transferred from a top floor to the bottom floor. The transfer buckets are those which hold the material for a certain period of time. These transfer buckets are capable of rotating at an axis. They have rotation limiters which limit the angle of rotation. There are limiters on the vertical projection which stop the movement of the rotation limiters present in the transfer bucket. There is a base plate over which the material falls. They are as shown in Figure 6.

Table 1. Geometric parameters of the gravity based material handling system

Set	D	H	R	S	H_{vp}
1	0.7	1	0.48	1.3	$n \times 1.3$

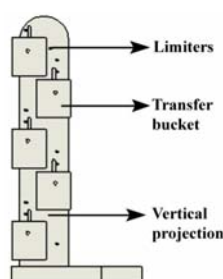


Figure 6. Construction of the gravity based zig-zag material handling system.

5.2 Working of the gravity based zig-zag material handling system

The material to be transferred exerts a force F_1 on the transfer bucket 1. The transfer bucket 1 is rotated by a torque T_1 . The material then falls on the transfer bucket 2. This bucket rotates due to a torque T_2 and the material falls on the transfer bucket 3. This continues and finally the material falls on the base plate. This is as shown in Figure 7.

6. Modeling of the Gravity based Zig-Zag Material Handling System using SOLIDWORKS™

The vertical projection with limiters, transfer buckets and the base plate was modeled using SOLIDWORKS™. The point of projection is constructed based on the size of the transfer buckets and the transfer buckets were aligned with respect to the pin. Then they were assembled together by constraining the hole on the transfer bucket and the point of projection on the vertical projection. It is as shown below in Figure 8.

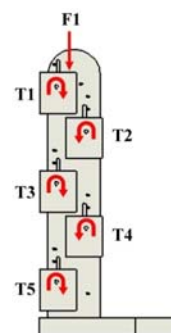


Figure 7. Forces and torques exerted on the system.

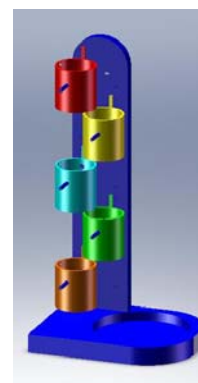


Figure 8. Modeling of the gravity based zig-zag material handling system.

7. Simulation of the Mechanism using MSC ADAMS™

The simulation was done using MSC ADAMS™⁹. The model was imported from SOLIDWORKS™. Then the transfer buckets and the pins in the vertical projection were connected by revolute joints. Solid contacts were given between the transfer buckets and the pins of the vertical projection. Then the mass, material and friction were assigned as shown in Table 2. Then the simulation was carried out for 50 steps and 5 seconds. The screenshot of the simulation environment is shown in Figure 9.

Here the mass is calculated by the MSC ADAMS™. It is based on the relation $\text{Mass} = \text{Volume} \times \text{Density}$. The value of density is pre-built and the volume is calculated based on the geometry of the part.

8. Results of Simulation

The simulation was carried out using a spherical shaped object as a material. But in reality the material can be of any shape and size. The material got transferred from one transfer bucket to another and finally fell on the base. It is shown in Figure 10. It was quite difficult to predict the friction between the pin on the vertical projection and the point of projection of the transfer bucket. By trial and error method the least value of co-efficient of friction was found to be 0.1.

Table 2. Mass and material of the part

Part Name	Mass (Kg)	Material
Vertical projection	17.56	Steel
Transfer bucket	1.36	Plastic
Base	27.69	Steel
Material (Sphere)	0.75	Aluminum

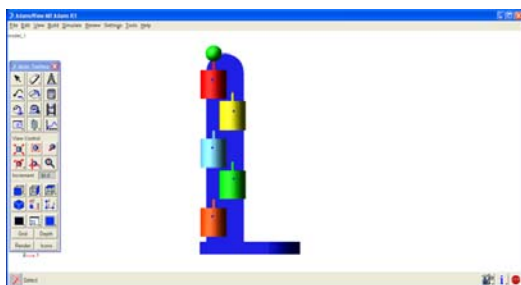


Figure 9. MSC ADAMS™ screen where the simulation was done.

After the simulation was over, the force and torque generated in the point of projection of the transfer buckets were plotted against time. These are as shown in Figure 11.

9. Prototype of the Gravity based Zig-Zag Material Handling System

The prototype of the gravity based zig-zag material handling system was made using plastic. The transfer buckets were made of plastic caps of bottles. Then point of projection was made using a heated thin rod of steel. Then these were fixed to the vertical projection. The

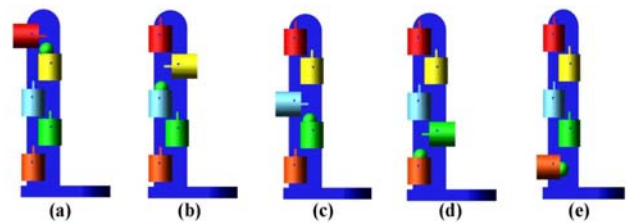


Figure 10. The results of the simulation using MSC ADAMS™.

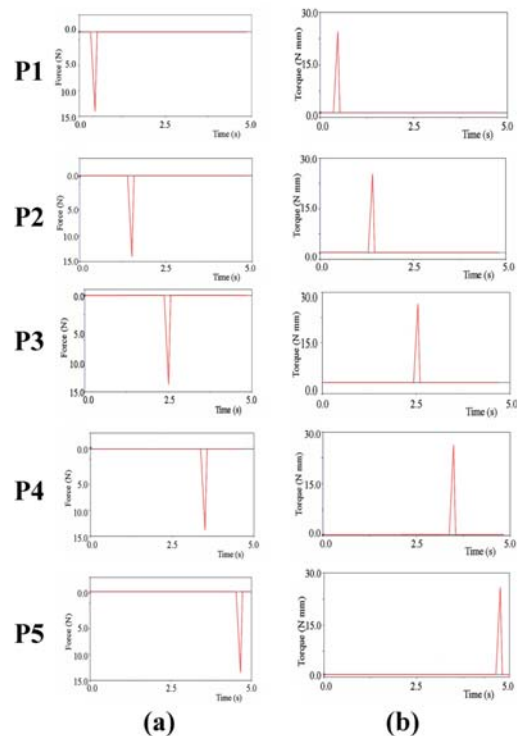


Figure 11. P1 to P5 refers to the point of projection of transfer buckets (a) Force vs Time and (b) Torque vs. Time.

mechanism was tested and the prototype worked to the expected level. Thus the expected results were obtained. It is as shown in Figure 12.

10. Layouts

There are three possible layouts in which the gravity based zig-zag material handling system can be arranged. They are inline layout, S layout and mixed layout. In the inline layout as shown in Figure 13(a), the work piece starts from the top and comes to the bottom is a single straight line. In this layout, some of the floors can be bypassed. In the S layout as shown in Figure 13(b), the work piece passes through all the machines in each floor. In the mixed layout, both inline and S layout are present combined together.

11. Applications

It can be used in industries where there are many floors on top of each other. The starting of the process can be on the top floor and the ending can be on the bottom floor. This can be done using the gravity based zig-zag material handling system in between each floor. In industries where there are many operations to be performed on a component and the machines are in different floors above each

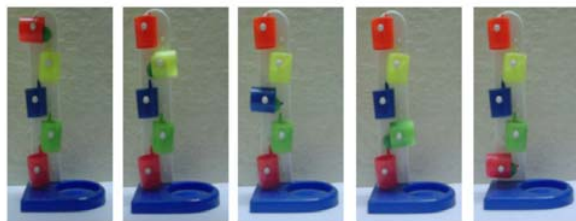


Figure 12. Testing the prototype of gravity based zig-zag material handling system.

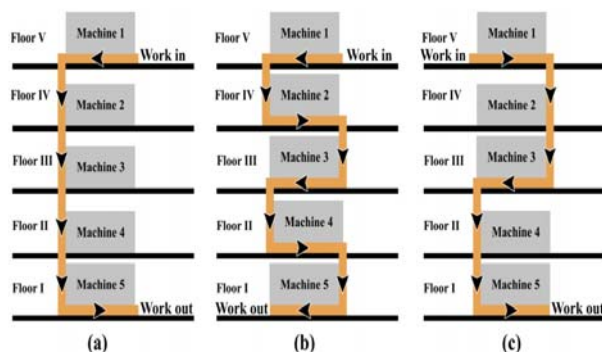


Figure 13. (a) Inline layout, (b) S layout and (c) Mixed layout.

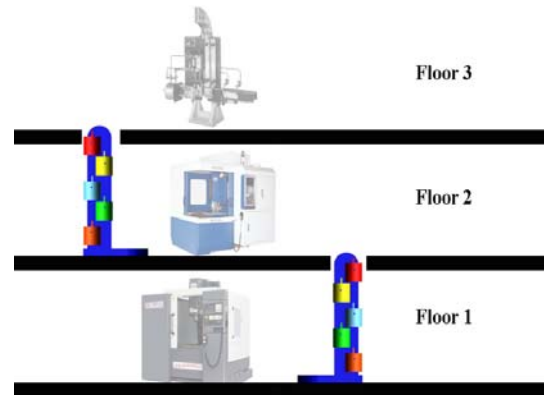


Figure 14. A possible application of the gravity based zig-zag material handling system in an industry.

other, then the operator after finishing the operation can drop the component in the gravity based zig-zag material handling system. It can be repeated till the component gets finished. An example is as shown in Figure 14.

12. Conclusion

A new type of material handling system which works based on gravity was modeled using SOLIDWORKS™ and simulated using MSC ADAMS™. The forces and torques obtained during simulation were plotted against time. Then a prototype was made using plastic and its working was shown. There is no necessity of using any power source which means that no electric power is used. It can be easily designed and installed. It will be of great use to industries where they have many floors that are above each other. It requires very less ground space and hence compact. It can be made movable or fixed in a place. But it can be used to transfer materials only from the top to the bottom floor because it works on gravity. Moving the material up must be done using lifts or conveyors. Aging and wear of joints are reduced by using bearings between the transfer bucket and the pin. Therefore the gravity based zig-zag material handling system can play a vital role in industries in future due to its simple and robust design.

13. Acknowledgment

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