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VERTICAL MATERIAL HANDLING SYSTEM

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ABSTRACT: The purpose of this research is to design and suggest a new mechanism other than the very conventional methods used for material handling. Nowadays value and requirement of land in India has grown very rapidly. Thus effective space utilization is given prime importance in industrial design. Various manufacturing processes are carried out on multiple floors. For example while manufacturing wafers, soaps, biscuits and other cookies and also on various assembly lines different processes are carried out at multiple stations. These stations are built on multiple floors for optimizing the space utilization. Also the finished goods are stored at a higher level on racks. Thus the need of an efficient and compact material handling system in vertical direction is arising day by day which will transfer the material at higher rate than some existing material handling system. Organizations are trying to utilize every inch of space often consider vertical carousels and vertical lift modules because of high storage density they provide. The paper involves the design of an efficient system which will transfer the material from lower level to higher level. It also includes the static analysis carried out on the most critical component, crank using Solid works and Ansys.
Keyword: Material Handling, Static Analysis, Solidworks, Ansys.

I. INTRODUCTION

We are focusing on the material handling which takes place between two manufacturing stations which are placed one above the other. For doing so nowadays inclined conveyors are used. Conveyors take longer to transfer material and also consume more space. Thus we have developed a system working on a mechanism which is obtained by fixing the crank of a single slider crank chain. The system is compact and works on inversion of single slider crank chain similar to piston cylinder arrangement in I.C. engine. The system transfers the material vertically in n number of steps. Each step consists of crank, connecting rod and piston arrangement. As the crank rotates piston reciprocates inside the guides provided. Height of piston is increased in every step. Here six cranks are mounted on one crankshaft at 180 degree to each other. Resembles to six piston cylinder mounded on one crankshaft. The top of piston is inclined at an angle with the horizontal. The object is transferred from one piston to next piston after every 180 degree of crankshaft revolution. Thus after every step a certain height is achieved by object. After reaching the peak in every step the material is transferred to the next piston which is at its bottom most position. To move the material up, piston height is increased in every step by certain calculated value. The height achieved by piston in every step is equal to diameter of crank.

To transfer the objects with small width this system is more effective. As the width of the object goes on increasing the length of system will also increase. The length can be reduced by increasing the crank diameter which will reduce the number of steps required and thus reduces the length.

The model which we have prepared lifts a 50 mm wide object to a height of 1150 mm consuming 0.5 meter horizontal length. This system can be modified as per the applications. The system looks like staircase to climb from one floor to another with its steps reciprocating vertically.

1.1. About material Handling

Starting from the time, raw material enters the factory gate and goes out of the factory gate in the form of finished products, it is handled at all stages between, no matter it is in stores or on shop floor. It has been estimated that average material handling cost is roughly 20 to 60 % of the total cost. It thus, becomes clear that the cost of production of an item can be lowered considerably by making a saving in the material handling cost.

1.2. About slider crank mechanism

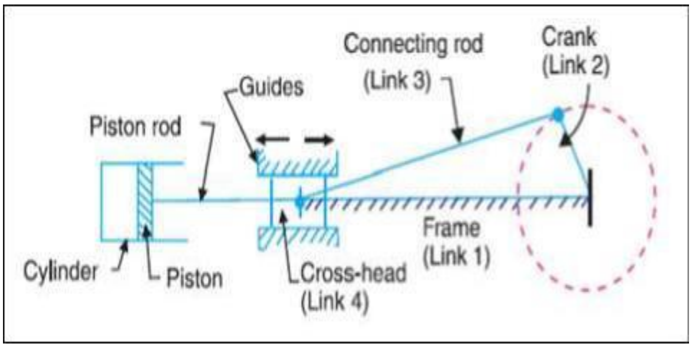

Figure 1 Single Slider Crank Chain

when one turning pair of a four bar chain mechanism is replaced by sliding pair, it becomes a single slider crank chain or simply slider crank chain. It is one of the cheapest mechanisms.

Applications of slider crank mechanism

- Reciprocating engine
- Rotary engine
- Oscillating cylinder engine
- Hand pump
- Scotch yoke
- Oldham coupling
- Eliptical Trammel

1.3. About the square cam mechanism

In this system the rotation of the motor is to be stopped after every haft revolution for certain time period so that the material gets transferred. Then motor should start and

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complete the next haft revolution and again stop. To achieve this square cam mechanism is used.

II. LITERATURE REVIEW

Several definition of material handling exists. Material handling is defined in Compton's Interactive Encyclopedia as "The moment of raw material, Semi-finished goods and finished article through various stages of production and warehousing is called material handling." Traditional view of material handling sees material handling operation as non-value adding and only contributing to the cost of product. The modern view recognizes the space and time utility of material handling operation. Material handling equipment is used to increase output, control costs, and maximize productivity. The various methods used for material handling in vertical direction are inclined conveyor, lift, robots, spiral conveyors etc. The angle of inclination in case of inclined conveyor is limited to certain value. The inclined conveyor also consumes large amount of space. The lift is another equipment to transfer the material from ground to first floor. The height achieved is higher compared to others. Robots are also used to transfer precise parts from one level to other. Lift and robot are effective but are expensive. Spiral conveyor is also an important development in vertical material handling system. Push bar conveyor is another system in which a bar supports the object on an inclined conveyor.

Recent development in material handling is automated storage and retrieval system. This includes:

- Unit load AS/RS
- Mini load AS/RS
- Micro-load AS/RS
- Vertical lift Modules
- Horizontal carousels
- Vertical carousels

AS/RS saves up to 85% + of otherwise wasted floor space. It also reduces the labor requirements and enhances product security. There is a need of improvement in these conventional methods. An alternative to all these methods is to be found. There is a need to achieve maximum height consuming minimum surface area.

Figure 2 Conveyor Layout

Figure 2 shows conveyor Layout. Consider the workers are working on ground and first floor. The scope of our system is to transfer the material from the conveyor on ground floor to the conveyor on first floor automatically and continuously.

A storage and retrival system is shown in figure 3. Our system can be used to transfer the material to these multi-level racks. The system can be made mobile so that it can be moved.

Figure 3 Storage and retrieval System Theory on crank and connecting rod mechanism

The invention of the crank and connecting rod system is considered by historians of technology to be the most important mechanical device of the early fifteenth century in Europe. Bertrand Gille says that this system was unknown before that date and this had considerably limited the applications of mechanization. Conrad Keyser (D. C. 1405) described in his book Bellifortis a hand mill operated by the crank and connecting rod system. But Francesco di Giorgio Martini (1439 – 1502) in his treatise on architecture illustrated a saw for timber driven by a water wheel in which the crank and connecting rod system was applied for the first time in a continuously rotating machine. Leonardo da Vinci (D.1519) incorporated a crank and rod in his designs. Ramelli also used the crank and connecting rod in a pump in his book of 1588. In 1206 the crank and connecting rod system was fully developed in two of al-Jazari's water raising machines.

III. DESIGN CALCULATION

Specifications of system designed and manufactured by us are given in table 1.

Table 1 Specification of designed system

Width of the object	50 mm
Radius of crank	100 mm
Weight carried by one piston	25 N

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RPM for Crank	30 RPM
Total surface area consumed	0,15 M2 (+ motor area)
Total height achieved	1150 mm
Number of steps required	6 steps

Assumptions
1) Crankshaft is supported by bearings at its two ends.
2) We have designed the system to transfer five objects having total weight of 25 N at a time.
3) The bottom surface area of 1 object will be equal to (50 x 50 mm).
4) All the parts except pistons are made up of Forged steel.
5) Coefficient of friction for wood is 0.5 (t = 0.5)

3.1. Crankshaft

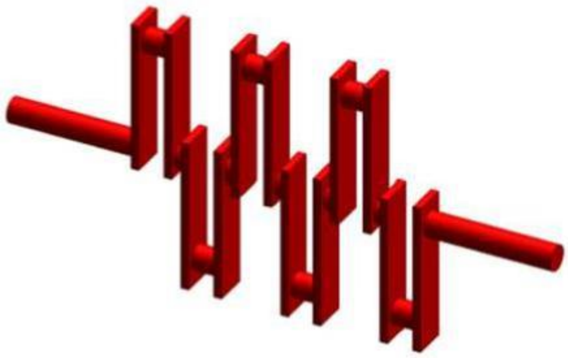

Figure 4 Crankshaft

When the piston is at bottom dead center the bending moment on the crankshaft will be maximum. In this position the radial force is maximum and tangential force is zero. A 3D model of Crankshaft is shown in figure 4. We have considered the crankshaft as a simply supported beam. The maximum bending moment will be at center. For this maximum bending moment crankshaft diameter is calculated using following formula.
Bending stress, (Sigma) b = --------------------- 1
Where M = Maximum Turning moment, Te = dc3 (tou)------ 2
Z = section modulus = (lIE / 32) x D3 Considering the crank at a position where tangential force is maximum. From the figure 5 when, 0 + = 90 tangential force will be maximum. Due to this maximum tangential force torsional shear stress will be developed in crankshaft.

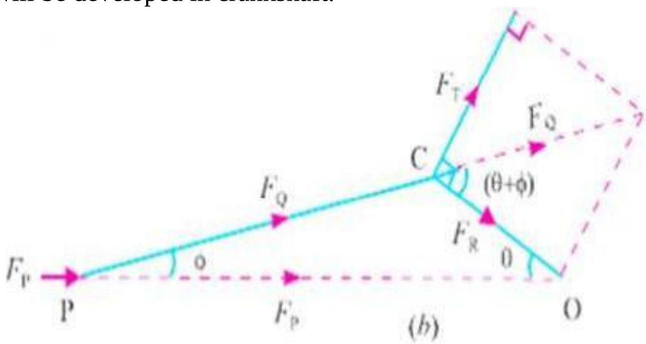

Figure 5 radial and tangential forces

Considering this torsional shear safe diameter is calculated using following formula.

Maximum turning moment,

Where, r = safe shear stress dc = Crankshaft Diameter.

3.2. Connecting rod

Connecting rod is subjected alternating tensile and compressive force. Compressive force for the connecting rod is much higher hence the connecting rod is designed for maximum compressive stress. We have considered connecting rod as a strut and used the Rankine formula considering both ends of the connecting rod as hinged. Following formula is used.

3.3. Pistons

Figure 6 Piston

A 3D model of Piston is shown in figure 6. Pistons are made up of wood with their height increasing gradually. The increase in height is selected in such a way that at the end of forward stroke of first piston the top surface of the piston should coincide with the top surface of the second piston which is at its bottom dead center. When top surfaces of the two pistons coincide with each other crank rotation is stopped and the object slides down from one piston to the other due to inclined surface of piston. The angel of inclination is calculated as given below.

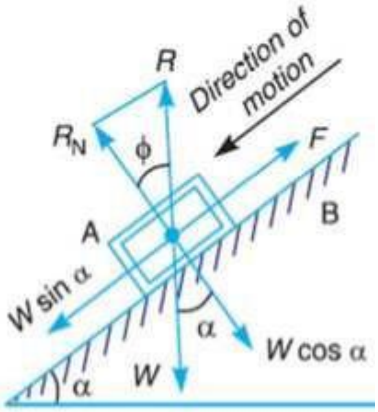

Figure 7 Radial and Tangential Forces

Consider a body A of weight W resting on inclined plane B as shown in figure 7. If the angle of inclination, a of the plane to the horizontal is such that the body begins to move down the plane then the angle a is called angle of repose. It is given by, tan a = t for t = 0.5, a = 26.56 °.
Thus we have considered 30° angle of inclination of the surface of piston with the horizontal.

3.4. Frame

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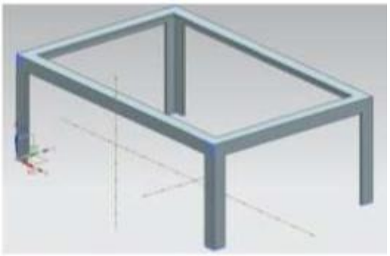

Figure 8 Frame

We have selected standard ISA2525 (L type) section for frame. We have checked it for bending due to loads coming on crankshaft. Frame model is shown in figure 8 to join the connecting rod with the piston we have used 0.5" bolt. We have considered double shear of the bolt due to load on piston. We have also considered the twisting moment due to tangential force on the bolt.

IV. ANALYSIS

4.1. Procedure of static analysis.

First, we have Prepared Assembly in Solid works for crankshaft and Save as this part as
IGES for Exporting into ANSYS Workbench Environment.
Import .IGES Model in ANSYS
Workbench Simulation Module.

4.2. Apply material for crankshaft as forged steel.

Material Details:
Material Type: - Forged Steel
Designation: - 42CrMo4
Yield strength (MPa):- 680
Ultimate tensile strength (MPa):- 850
Elongation (%):-13
Poisson ratio:-0.3

4.3. Mesh of the crankshaft

Mesh statics
Number of nodes = 15821
Number of elements = 7349
(586 number of contact elements and 6763 number of contact elements)

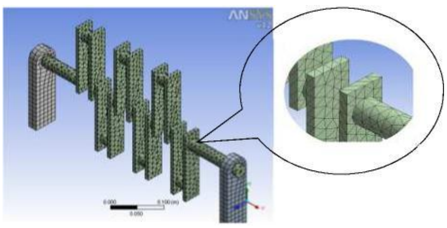

Figure 9 Meshing

4.4. Define boundary condition for Analysis

Boundary conditions play an important role in finite element calculation here; we have taken both remote displacements for bearing supports are fixed. (This has only one degree of freedom (Rotational))

We have done analysis of the crank. The crank is the most critical part of our system. We have considered the crank shaft as a simply supported beam. We have given rotation of 30 rpm to the crankshaft. Six loads are acting on the crankshaft. Figure 10 shows the loading of the crank shaft for doing the analysis.

4.5. Define type of analysis

Type of analysis: Structural analysis

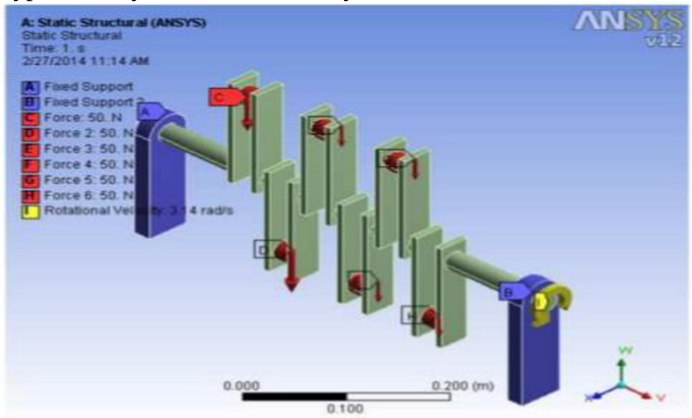

Figure 10 Loading

4.6. Run the analysis and get the result

Figure 11 shows the equivalent stress developed in the crank according to Von-Mises theory. The maximum value of equivalent stress is equal to 18.397 N/mm2.

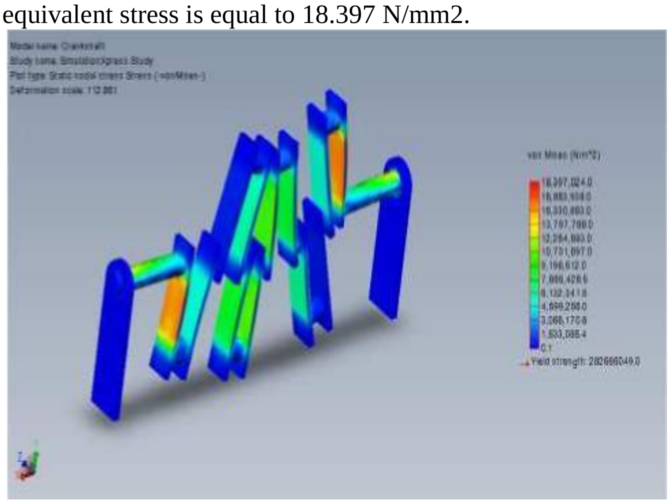

Figure 11 Equivalent Stress Analysis Using Von-Mises

The figure 12 shows the total deformation of the crankshaft due to above loading. The nature of deformation is also shown in figure 12. The maximum deformation caused by the load on the piston is equal to 5.466 e-001 mm

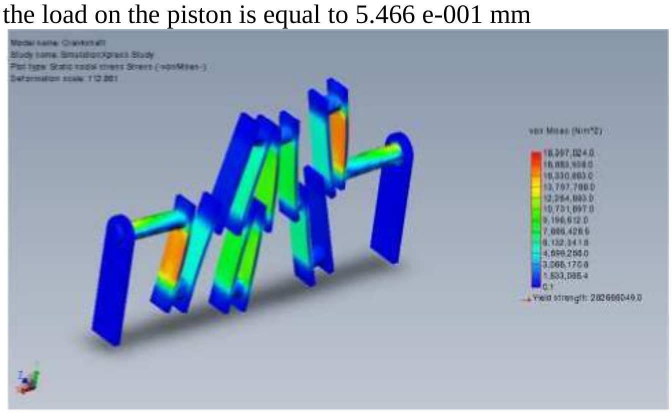

Figure 12 Total Deformation

4.7. Results

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Table 2 Analysis Result

Type	Result
Von-Mises stress	18.397 N/mm2
Deformation	5.466 x e-001 (1.009 mm)

V. WORKING

The figure 13 explains the working of the system.

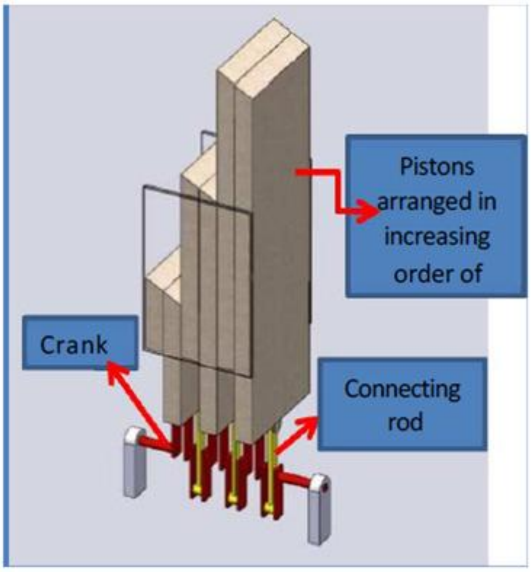

Figure 13 Assembly

Consider the smallest piston at the bottom most position it picks up the object to be transferred from lower level. Then its forward stroke begins when it reaches the top most position its top surface coincides with that of the next piston. At that time the second piston will be at its bottom most position. The crank rotation will stop until the object is transferred from first piston to second piston. As the transfer is complete the crank will start rotating and forward stroke of second piston starts. As the second piston reaches its top most position the object will slide down to third piston which will be at its bottom most position. Similarly material is transferred from one step to other till the last step. In this mechanism if the pistons at odd position are having bottom most position, the pistons at even position will have reached top most position and vice-versa. As explained above the crank rotation is to be stopped after every 180 degree of rotation. This is achieved by means of a limit switch arrangement which will stop the crank rotation for specified time after every 180 degree of crank rotation. The height achieved by the object will almost be equal to six times of crank diameter.

VI. . FUTURE SCOPE

As this is a new system developed there is a huge scope for improvement in future. Some of the improvements are listed below.

- Rollers can be mounted on the top of every piston so that objects with flat base can slide
- down easily. This will reduce the angel of inclination and the object can be transferred in
- horizontal position.
- A suitable mechanism if can be used to shift the object to the next piston. Using this we can transfer high quality precise objects without damaging them.
- This system can be designed according to its applications. Ex. to transfer spherical objects grooves can made on top of the piston.
- We can also increase the rpm so the material may be transferred at a higher rate (Ex. Some rigid objects).
- With some modifications this system can be effectively used in coal mines where we see long conveyors being used.
- This system can effectively be used to store the finished goods or inventory on multilevel racks.
- The system can be made mobile and used in industry at different sections.

VII. CONCLUSION

An efficient and fast system has been developed for material handling in vertical direction. The designing of each and every part has been carried out as per the standards used globally. The structural analysis of the crankshaft has been carried out using Ansys and Solid works. The system is a better option for current methods used for material transfer in vertical direction such as inclined conveyors, lifts etc. which consume more space, time and money. The figure 14 illustrates the disadvantages of a conveyor system. This system can be used to transfer fluids without spilling out.

Figure 14 Convention Conveyor

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