DESIGN AND DEVELOPMENT OF PNEUMATICALLY ROTATING TROLLEY

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Abstract - Conventional trolley mechanism an unload materials only at the backside of the trolley using hydraulically operated cylinder which may cause the problems of road blockage in the limited space area. This paper has mainly focused on above difficulty. The Unidirectional trolley is developed and tested for its movement in all possible angle to unload the materials in the trolley. This concept saves time & energy which leads to efficient working.

Key Words - Design Optimization of Rack & Pinion Gear drive, Pneumatic Cylinder, Rack & Pinion Gear

I. INTRODUCTION

In daily uses the transport of material from one place to another place, so many methods are adopted in such application. The pneumatically operated rotating trolley will overcome the previous problem of rotation of the trolley. The main problem in the existing trolleys is that the material is dump towards back side only; this requires more man power to scatter the material drained. Such types of difficulties are overcome, if we use a rotating trolley which can rotate and enables to deliver the material towards all sides. It consumed extra time for complete material unloading process. Dumpers are also the most common cause of accidents involving construction site and plant also.

A typical dump truck is equipped with a hydraulically operated open box dead hinged at rear. The front of which can be lifted up to allow the contents to be deposited on the ground behind the truck at side of delivery. Nowadays dumpers with swivel skips could be rotated to sideways (3 directional dumper) which become popular, especially for working in narrow sites such as road works. But still this technology is insufficient for fulfilling our requirement for complete unload. This technology concerns only on solving the problem of unloading on directional sides of dumper.

A pneumatically operated rotating trolley has three directions. This can be operated with the help of air pressure. The solenoid valves are used in order to regulate the air pressure, so that the trolley can rotate, by rotating the spur gear over the rack gear. At the required position it is stopped. The cylinder piston arrangement is used to lift the trolley with the help of air pressure; so as to set the trolley in inclined position and the material inside is dropped down.

The proper direction to dump the material carrying in it hence the need of project work riser was is about unidirectional dropping dumpers which dump the material in any direction with moving trolley in any direction. With rise of chances in technology, it is become essential to find a viable alternative to 3 way dumper system. This concept saves time & energy which leads to efficient working.

II. LITERATURE REVIEW

A. Design and Fabrication of Unidirectional Dumper [1] Design of unidirectional mechanism is done to help unloading loose material on 1800 of the tipper as per the availability of space. We have been able to increase the easiness in unloading trolley. Here combined objective function is considered, which minimizes the weight and center distance and maximizes power and efficiency.
B. Modelling and Analysis of Tractor Trolley Axle Using Ansys\(^2\) The possible loads acting and the place of loads are noted. According to the dimensions tractor trolley axle is modelled using CATIA V5 software and their specification.

C. Design and Development of 3-Way Dropping Dumper \(^3\) The Direction control valves which activate the ram of the hydraulic cylinder which lifting the trailer cabin in require side. Further modifications and working limitations will put this work in the main league of use. This concept saves time & energy which leads to efficient working.

D. Design and Fabrication of 3 Way Tipper Mechanism \(^4\) Hydraulic jacks use a plunger mechanism and no compressible fluid, typically a hydraulic oil to create required pressure and resulting lifting capability. In this project hydraulic jack is attached below whole setup to lift the trolley for backside unloading. Another early hydraulic dump body that was power-driven by steam.

E. Wood, Donald. Dump Trucks \(^5\) Dump Trucks. 729 Prospect Ave. Osceola, WI 54020: MBI Publishing Company. pp. 11–30.

Truck owners call their trailing axle-equipped trucks Super dumps because they far exceed the payload, productivity, and return on investment of a conventional dump truck. The Super dump and trailing axle concept was developed by Strong Industries of Houston, Texas.

### III. METHODOLOGY

![Methodology Diagram](image)

**Fig. 1: Methodology**

**IV. DESIGN**

**Design of Rack & Pinion**

Given: \( Z_g = 18, \quad Z_r = 18, \quad b = 20 \text{ mm}, \quad m = 20 \text{ kg}. \)

Let, we select the rack and pinion gear of plain carbon steel.

Gear material as 40C8

\[ \text{Sut}=580 \text{ N/mm}^2, \quad \text{Hardness}=217 \text{ BHN}, \]

\[ \text{F.S.}=1.5....................... \text{ (from design data table)} \]

Assume grade of 6, \( C = 11500 \text{ N/mm} \)

\[ [1] \text{ Find Module:-} \]
\[ b = 10 \text{ mm} \quad m = 2 \text{ mm} \]

\[ \sigma_Z = \frac{580}{3} = 193.33 \text{ N/mm}^2 \]

Lewis form Factor for 20° full depth involute
\[ y = 0.404 - \left( \frac{2.87}{Z_g} \right) \]
\[ y = 0.2445 \]

Beam Strength
\[ f_b = \sigma_Z \times b \times m \times y \]
\[ F_b = 193.33 \times 20 \times 2 \times 0.2445 \]
\[ F_b = 1891.19 \text{ N} \]
\[ F = 196.2 \times 10^3 \text{ N} \]

We assume \( v = 0.12 \text{ m/s} \)
\[ d_g = m \times Z_g = 2 \times 18 = 36 \text{ mm} \]
\[ Q = 2 \times \left( \frac{Z_g}{Z_g + Z_r} \right) \]
\[ Q = 1 \]
\[ K = 0.16 \times \left( \frac{BHN}{100} \right)^2 \]
\[ K = 0.753 \]

Wear Strength:
\[ f_w = d_g \times b \times Q \times k \]
\[ = 36 \times 20 \times 1 \times 0.753 \]
\[ = 542.16 \text{ N} \]

Effective Load:
\[ f_{eff} = \frac{k_a \times k_m \times f_v}{k_v} \]
\[ = \frac{(1 \times 1 \times 196.2) / 0.9615}{1} \]
\[ = 204.056 \text{ N} \]

Dynamic Load:
\[ e = 8.0 + 0.63 \times \left[ m + 0.25 \sqrt{d_g} \right] \]
\[ = 10.25 \times 10^{-3} \text{ mm} \]
\[ f_d = \left[ 21v \times (bc + f_v) \right] / \left[ 21v + \sqrt{bc + f_v} \right] \]
\[ = 121.29 \text{ N} \]

\( F_d \) is less than \( F_w \) & \( F_b \). Hence design is safe.

To avoid pitting failure
\[ f_w = f_{.s} \times f_{eff} \]
\[ \text{F.S.} = \frac{542.16}{204.056} \]
\[ = 2.65 > 1.5 \]

As available factor of safety is higher than the required factor of safety, the design is safe.
Design of Shaft:

D= 50mm
F= 196.22×10³ N

Selecting 1045 as a material of shaft with factor of safety (FOS) 3,
For,

\[ S_y = 310 \text{N/mm} \]
\[ \tau_p = \frac{310}{3} = 103.33 \text{N/mm} \]

1) \[ A = \frac{\pi}{4} \times d^2 = 1963.49 \text{mm}^2 \]

2) \[ \tau = \frac{F}{A} = 99.93 \text{N/mm} < \tau_p \]

Hence safe.

Design of Ball Bearing

Given:
N=23 rpm, \( F_r = 15 \text{kN} \)
Fr=0
L_{hr} = 195 hr

\[ K_{rel} = 1.0, k_s = 1.5 \]

1) Equivalent load
\[ F_e = (X \times F_r + Y \times F_a) \times k_s \]
\[ X = 1, Y = 1 \]
\[ F_e = 23 \text{kN} \]

2) Dynamic load capacity
\[ L_{10} = \frac{(c \times F_e)^n \times K_{rel}}{F_e} \]
Where, n=3 (for ball bearing)
\[ L_{10} = 0.2691 \text{ million revolution} \]
\[ C = 14849.063 \text{ N} \]

Thus, selecting bearing with bore 50mm for required application.

V. DESIGN OF CAD MODEL
Layout of Pneumatic system used in Project:

Advantages of pneumatic systems:

- **High effectiveness**
  Many factories have equipped their production lines with compressed air supplies and movable compressors. There is an unlimited supply of air in our atmosphere to produce compressed air. Moreover, the use of compressed air is not restricted by distance, as it can easily be transported through pipes. After use, compressed air can be released directly into the atmosphere without the need of processing.

- **High durability and reliability**
  Pneumatic components are extremely durable and cannot be damaged easily. Compared to electromotive components, pneumatic components are more durable and reliable.

- **Simple design**
  The designs of pneumatic components are relatively simple. They are thus more suitable for use in simple automatic control systems.

- **High adaptability to harsh environment**
  Compared to the elements of other systems, compressed air is less affected by high temperature, dust, corrosion, etc.

- **Safety**
  Pneumatic systems are safer than electromotive systems because they can work in inflammable environment without causing fire or explosion. Apart from that, overloading in pneumatic system will only lead to sliding or cessation of operation. Unlike electromotive components, pneumatic components do not burn or get overheated when overloaded.

- **Easy selection of speed and pressure**
  The speeds of rectilinear and oscillating movement of pneumatic systems are easy to adjust and subject to few limitations. The pressure and the volume of air can easily be adjusted by a pressure regulator.

- **Environmental friendly**
  The operation of pneumatic systems do not produce pollutants. The air released is also processed in special ways. Therefore, pneumatic systems can work in environments that demand high level of cleanliness. One example is the production lines of integrated circuits.
Economical
As pneumatic components are not expensive, the costs of pneumatic systems are quite low. Moreover, as pneumatic systems are very durable, the cost of repair is significantly lower than that of other systems.

VI. TYPES OF PNEUMATIC CYLINDERS

Although pneumatic cylinders will vary in appearance, size and function, they generally fall into one of the specific categories shown below. However there are also numerous other types of pneumatic cylinder available, many of which are designed to fulfill specific and specialized functions.

A. Single Acting Cylinders:
Single-acting cylinders (SAC) use the pressure imparted by compressed air to create a driving force in one direction (usually out), and a spring to return to the "home" position. More often than not, this type of cylinder has limited extension due to the space the compressed spring takes up. Another downside to SACs is that part of the force produced by the cylinder is lost as it tries to push against the spring.

B. Double Acting Cylinders:
Double-acting cylinders (DAC) uses the force of air to move in both extends and retracts strokes. They have two ports to allow air in, one for outstroke and one for in stroke. Stroke length for this design is not limited; however, the piston rod is more vulnerable to buckling and bending. Additional calculations should be performed as well.

VII. CONSTRUCTION

The prototype of unidirectional dumper is thoroughly based on pneumatic system for light weight load and for heavy weight load hydraulic system is suitable. This prototype model consists of Air compressor, air reservoir, Pressure gauge, 5/3 solenoid valve, pneumatic cylinder, etc.

An operating system consists of rack & pinion gear mechanism to rotate the trolley horizontally in required direction. Two Chassis (Frame) is provided on which trolley is mounted, where first frame of chassis is stationary & attached to the rack & pinion to rotate the trolley horizontally in required direction. Second frame of chassis consists, one end of Pneumatic cylinder which is hinged with this frame of chassis and other end of pneumatic cylinder is also hinged but to the one end of trolley to give vertical movement

VIII. WORKING

It is mainly based on rotation of trolley and divided in two parts Rotation and Dumping. For rotation of trolley, we used rack and pinion gear mechanism. Rack is directly coupled with pneumatic cylinder which is at horizontal position. On the lower side of trolley, the spur gears are meshed with rack and the axis of rotation of spur gear is vertical, which is directly attached to trolley.

The vertical shaft which is connected directly to the center of trolley. Rack which having 18 teeth on its profile. When 18 teeth of gear are moved forward then trolley gets rotated from its initial position in 20 second. The rotating direction of trolley is changed or reversed by switch.

When the trolley completes its required angle then material is dumped with the help of pneumatic cylinder. The compressed air is supplied by air compressor to cylinder. The air flow direction is controlled by solenoid valve. On the cylinder two forces are provided one on upper side & other on one side. For the upper movement of trolley air is supplied through the lower port and for downward movement of trolley air is released from the same port.

IX. CONCLUSION

Further modifications and working limitations will put this work in the main league of use. This concept saves time & energy which leads to efficient working .The constructional work or the
infrastructural work demands efficient and user friendly machinery which will lead to more and more use of unidirectional trolley.

We have obtained most of the objectives and goals that we set for ourselves at the start of our project. We have been able to increase the easiness in unloading trolley. Problems occurred at the time of unloading the trolley in critical areas are eliminated. And thereby reducing overall time and fuel required for unloading the trailer.

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