Design of Multiside Tipper Tilting Mechanism

Hemant A. Gaikwad, Nilesh P. Awate

Abstract

Truck, tipper, dump truck are used to transport loose material from one place to another place at construction site in mines or in dump yards to accomplish the actual site requirement. If one can understand the ground condition and availability of space in mines and on construction site, it is very tough task to unload loose material at appropriate place, adjustment of truck is needed which take considerable time and effort to unload loose material. As everyone knows that tipper is mostly used for unloading loose material on construction site, mines and dump yards. The Existing system available is to unload material on back side. As considering the mines space available is very less due to which unloading material on left or right side is not possible to take this as a problem Multiside tipper tilting is the need of time. To overcome one side tilting of trolley, multiside tilting mechanism is come into focus. This will help to reduce the efforts to unload loose material one side of tipper. Propose work is on placing three hydraulic cylinders each on front side, right side and left side of trolley to unload loose material on back side, left side and right side of trolley respectively. Some design modification is needed in existing system to work on multiside tipper tilting mechanism.

Keywords: Design, Mechanisms, Hydraulic power pack

1 Overview of Present Work

In this work area of concentration is to design of tipper mechanism to facilitate multisided tilting of trolley, which will help to unload material on all three side of tipper i.e. on back, left and right side of tipper. For this CAD model of the tipper is design, and according to new design instead of using one hydraulic cylinder as per tilting the design requirement three hydraulic cylinders are use. For the left side and right side cylinders used are of same capacity and stork, but the hydraulic cylinder used for backside tilting is of more capacity and large stroke length. For the operation of these cylinders hydraulic power pack is design to smooth and easy operation of the system. Hinge design is also one of the most important part of tipper trolley is place over six hinges all the hinges are loose fit for easy removal of pin to unload material on desired side of tipper. Here six hinges are used to place trolley to its initial position two hinges are on each side of tipper chassis .when tipper transporting the loose material from one site to another site at that time all the hinges are in closed position. After selection of dumping place the pins from hinges remove to unload loose material, for this every time four hinges must be unlock manually by the operator to unload loose material. After CAD design of tipper tilting mechanism on Pro-E software its analysis is done on Ansys to check failure criteria for safe operating condition of the model.

2 Tipping Mechanism

2.1 Hydraulic cylinder: A hydraulic cylinder is placed below the body of truck longitudinally at one end of the truck; the piston end of the hydraulic cylinder is connected by the means of a pivot joint to the trolley of truck as well as with the chassis. In the forward stroke of the cylinder it pushes the truck trolley upward thus gives necessary lift for tipping. So, in forward stroke of the cylinder truck gets unloaded. In the return stroke of the cylinder the body of the truck comes to its original position figure 2.1

Hemant A. Gaikwad, Mechanical Engineering Department ,Nagpur Institute of Technology, survey no,13/2 Mahurzari Katol road, Nagpur. Email: hemant_gaikwad1091@rediffmail.com

Nilesh P. Awate, Mechanical Engineering Department G. H. Raisoni, College Of Engineering, Digdoh Hill, CRPF,Campus ,Nagpur. Email: nileshawate@indiatimes.com

shows working of existing mechanism. The geometric features in the automotive system are first reviewed in this project. The parameters regarding various driveline components are reviewed. The material properties of driveline components are referred from design data handbooks, material handbooks. The failure theories for different load condition are considered in analyzing the driveline components. The ultimate strengths that are exhibited by the materials are taken into consideration to predict about the failure criteria.

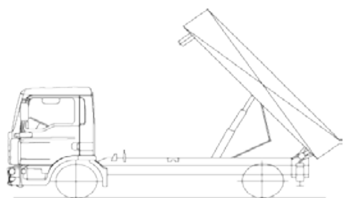

Fig2.1 Existing Tipper Mechanism (one side Tilting)

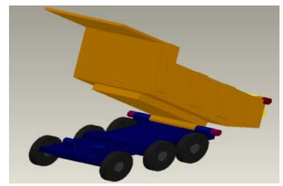

Fig.2.2 Existing Tipper Trolley

2.2 How Typical Tipper Trucks Works: - The tipping mechanism is the heart of a three way tipper construction truck. Tipping mechanism works basically on the followings:

2.2.1 Hydraulic cylinder: A hydraulic cylinder is placed below the body of truck longitudinally at one end of the truck; the piston end of the hydraulic cylinder is connected by the means of a pivot joint to the chassis of truck as well as with the chassis. In the forward stroke of the cylinder it pushes the truck body upward thus gives necessary lift for tipping.

2.2.2 Three way tipper mechanism

Three way tipper can unload materials in all three sides. Also we require special types of hinge joints in this case. It will be having three hydraulic piston cylinders one on cabin side (as in existing system), one each on lateral sides. Six hinges- 2 on each side to give degree of motion on that side. The framing will be rigid enough to sustain the reactive forces generated, refer the attached picture of 3-way tipper arrangement. Main hydraulic cylinder is placed at middle of front side of chassis i.e. 1 for back side tilting of the trolley and other two (2,3) cylinders are placed on along lateral side of the chassis at appropriate distance as shown in fig.3.4 for left and right side tilting of the trolley. Trolley is connected with chassis with the help of six hinges .Two hinges on each lateral side for left and right side tilting of trolley, two hinges on back side of chassis for back side tilting of trolley. Above figure 3.4 shows the hinge position. Now with this mechanism it is possible to tilt trolley on all three sides i.e. back, left and right side. For backside dumping of material, hydraulic cylinder no. 1 is in operation and hinge no.H1,H2,H5 and H6 must be disconnected manually by pulling pin from the hinge, for this hole of 8 mm. diameter is provided on pin head to facilitate manual pulling by inserting rope inside the pin hole. For this operation cylinder 2 and 3 are not in working. The maximum angle of turn made by trolley with horizontal for effective backside unloading of loose material is 45^0.

For right side dumping of material hydraulic cylinder no. 2 i.e. left side cylinder is in operation and hinge no. H1, H2, H3, and H4 are to be disconnected manually by pulling pin from the hinge. For this operation cylinder 1 and 3 are not in working. The maximum angle made by trolley with horizontal for effective right side unloading of loose material is 20^0 .Same procedure is adopted for left side dumping of material only change is with hinge disconnection i.e. H3, H4, H5 and H6 are disconnected and hydraulic cylinder no.3 i.e. right side cylinder is in operation. Other two cylinders are in not working position. Here also maximum angle of side tilt of trolley is 20^0 for safely unloading the material. Hydraulic cylinder 2 and 3 is not directly connected with the trolley, on the top of the cylinder cushioning pad is provided to push the trolley, for side tilting and at the time of return stroke due to self weight trolley will come to its initial position. Automation of tipping will be possible by using a power pack with plc control or some similar kind of automation devices.

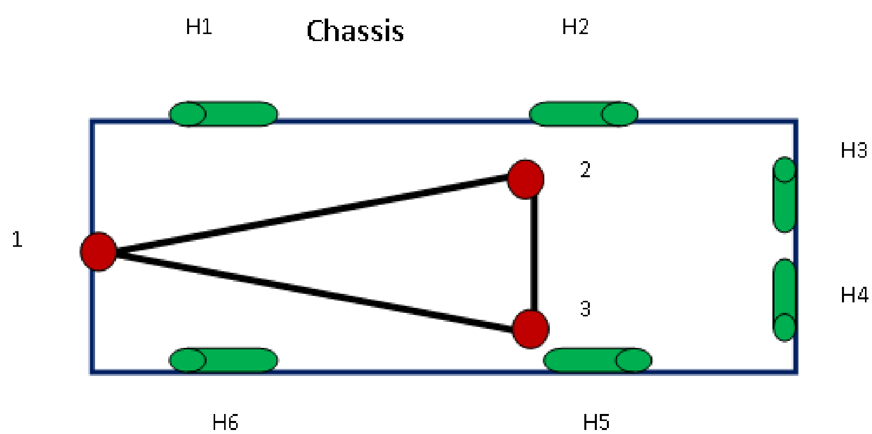

Fig 2.3 Three way tipper mechanism

3 Design of Hydraulic Power Pack

3.1 Design of hydraulic system:-Design of hydraulic system start with the mode of energy transferred in the system. The energy transfer in the system is done by the pump which draws the oil from the reservoir and transfers the same to the system. We know that energy transfer occurs due to changes in potential energy inside the reservoir.

3.2 Hydraulic circuits diagram:-A circuit diagram may be defined as the graphical representation of the hydraulic components in a hydraulically operated machine. It gives an idea how control valves, actuators, pumps etc. are interconnected. The symbols used in a hydraulic system as per IS: 7513-1974 are shown. Circuit diagram shown below is for multiside tilting of trolley. Where hydraulic cylinders place over the chassis and all the cylinders get connected through house pipe for definite motion of the cylinder, here telescopic hydraulic cylinders are preferred to accommodate the desired length of stroke. As the length of stroke is large due to which telescopic hydraulic cylinder is the best option as far as performance and space is concerned.

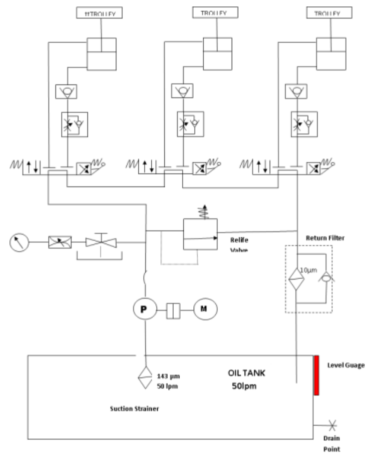

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Fig 3.1: Hydraulic circuit

3.3 Design procedure for hydraulic power pack

Considering tipper trolley size for calculating in hydraulic design as follows: Capacity of tipper = 16 MT

Load / weight of body is body – 1150 kg, tipper gear – 200 Kg, sheet system – 1650 kg

Total weight for design of pin and hinge is 19000 kg.

Width of trolley = 2000 mm

Length of trolley = 3600 mm (12 feet)

Maximum load to be operated including trolley weight = 19 MT

Assumptions:-

Right & left side tilting hydraulic cylinder will be kept in the centre of trolley length on their respective edges as indicated. Cylinder will be of fixed/rigid type mounting in vertical position. Though two guide rods can be provided

Backside tilting hydraulic cylinder will be kept in the centre of trolley width. Cylinder will be of intermediate trunion mounting type.

Calculation of Stroke for Side Tilting Cylinder:

$$\text{Stroke}(L) = \sin 20^0 \times 2000$$
$$L = 0.345 \times 2000$$
$$L = 684\text{mm}$$

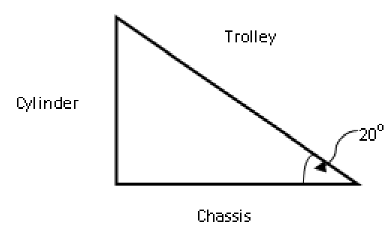


Fig 3.2 side tilting stroke

Fig.3.2 shows the position of tipper trolley and hydraulic cylinder and assume that the maximum angle of side tilting = 20°. Now to calculate side tilting stroke,

$\{\text{Sin}20^0 = x / \text{Hypotenuse} = x / 2000,\quad \text{Therefore, } x = \text{Sin}20^0 * 2000 \text{ mm}\}$

Stroke of hydraulic cylinder for left side as well as right side tilting L = 684 mm.

Calculation of Stroke for Backside tilting hydraulic cylinder:

$$L = \tan 45^{0} \times 3600$$
$$L = 1 \times 3600$$
$$L = 3600\text{mm}$$

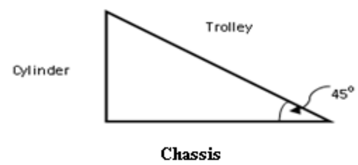


Fig 3.3 : Back side tilting stroke

Length of trolley = 3.6 meter
Cylinder will be operated at full length and thus stroke of hydraulic cylinder will be calculated accordingly.
Therefore, Stroke of hydraulic of hydraulic cylinder (L)
To find working pressure**:**
Considering max working pressure of 210 bar (3000 psi) due to limitation of working of many hydraulic valve at 250 bar

To calculate area of hydraulic cylinder

$$P = \frac{F}{A}$$
$$210 = \frac{19000}{A}$$
$$A = \frac{19000}{210}$$
$$A = 90.76\text{cm}^2$$
$$A = \frac{\Pi}{4} \times d^2$$
$$90.76 = \frac{\Pi}{4} d^2$$
$$d = 10.78\text{cm}$$
$$d = 107\text{mm}$$

As per ISO standards for hydraulic cylinder of standard bore sizes
Therefore, Bore dia. will be equal = 100 mm as per std sizes

Exact working pressure = 19000 / 90.76 = 208 kg/cm^2

To calculate volume flow – liter/min :
Assuming the maximum evacuation time of 2 min in which the complete hydraulic cylinder will operate to its maximum stroke. Also the stroke of backside tilting hydraulic cylinder is being considered for flow calculation (Q) owing to maximum oil volume usage.

$$\text{Speed V} = \frac{\text{Max. stroke of backside tilting hydraulic cylinder}}{\text{Max. evacuation time}}$$

$$= \frac{3600}{3}$$

$$= 1200 \text{ mm}$$

$$= 120 \text{ cm}$$

$$\therefore \text{Flow Quantity} \quad Q = \text{Area} \times \text{Speed}$$

$$= 90.76 \times \frac{120}{1000}$$

$$= 10.89 \text{ lpm}$$

Q = 10 lpm considering ISO Std. for hydraulics

Power calculation for Motor :-Backside tilting hydraulic cylinder will be telescopic type in nature having each step stroke of 800 mm as per bore diameter mentioned below. Bore diameters of backside tilting hydraulic cylinders are 50,63 & 100 mm as per ISO standard for hydraulics.

$$\text{Horse Power, HP} = \frac{P \times Q}{600}$$

$$= \frac{210 \times 10}{600}$$

$$= 3.5 \text{ KW}$$

$$= 5 \text{ hp}$$

This will be the HP of motor needed for operating 10 lpm hydraulic pump at std. 1440 rpm and no load condition.

Hydraulic pump will be of Fixed Displacement Vane Pump

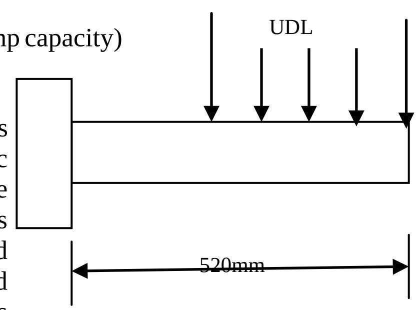
Calculation of hydraulic power pack tank :

Breather Capacity = 5 cfm air flow

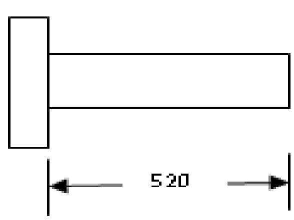
Suction Strainer capacity = 50 lpm

Tank Capacity = 50 liters (5 to 6 times of pump capacity)

Hydraulic oil to be used in tank Servo system HLP46



Power Pack is design by considering the back side tilting as stroke length is maximum for backside tilting. The Hydraulic cylinder use is telescopic cylinder with three equal stroke length of 1200mm. whose cylinder diameter is as follows 50mm, 63mm and 100mm as per ISO standard. Selected hydraulic pump for operation of hydraulic cylinder is fixed Displacement Vane Pump. Tank capacity for the power pack is 50 liters and the hydraulic oil recommended is servo system HLP46 (IOCL make).



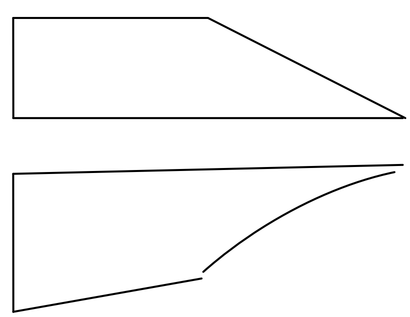


Fig 4.1 : Pin

4 Design of Hinge for Tipper Trolley

4.1 Design of pin

1. Effective length of pin = 600 mm
   Half position insert in hinge and rest of position hold the tipper

   Operation
   Design the pin for bending, shearing, crushing

2. Main load acting on pin in bending
3. Shearing and crushing load both are combine
4. Capacity of tipper = 16 MT
5. Load of / weight of body is body – 1180 kg, tipper gear –230 Kg sheet system – 1650 kg
6. Total weight for design of pin and hinge is 19060 kg.
   This load will share by both pin and hydraulic Cylinder
   Calculate the load on pin

$$\text{FORCE} = \text{Weight of trolley} + \text{Material carring capacity of trolley}$$
$$F = W$$
$$\text{Bending moment} = M_b = \frac{\frac{WL^2}{L}}{2}$$
$$\text{Total trolley load} = 186.97 \times 10^3 \text{ KN}$$
$$\text{Load acting on each pin} = 186.97 \times 10^3 \cos\frac{45}{2}$$
$$= \frac{132207.75}{2}$$
$$= 66103 \text{ N}$$
$$= 66.103 \text{ KN}$$

Bending Stress

$$\sigma_b = \frac{M_b}{Z}$$
$$M_b = \frac{WL}{2}$$
$$M_b = \frac{66103 \times 260}{2}$$
$$M_b = 8593390 \text{Nmm}$$
$$Z = \frac{\Pi}{32} \times d^3$$

Table 1 Material Table

SN	MATERIAL	BENDING STRESS	SHEAR STRESS
1	St 42 – alloy stress/bending steady	74 MPa,	46 MPa
2	EN - 8 (c-40)hardened and tempered	147 MPa	93 MPa

Consider material IS 1570 – St 42 high carbon steel EN8

Referred a book Cmti(Central machine tool inst. Angle Machine Tool Design Handbook)

Calculation of diameter of pin

For steel :-

$$\sigma_b = \frac{M_b}{\frac{\Pi}{32} \times d^3}$$

$$73.575 = \frac{8593390}{\frac{\Pi}{32} \times d^3}$$

$$d^3 = 1189691.49 mm^3$$

$$d = 106 mm$$

For EN8

$$147 = \frac{8593390}{\frac{\Pi}{32} \times d^3}$$

$$d^3 = 595452.73 mm^3$$

$$d = 84 mm$$

As the diameter of EN8 is less as compared to st42 and material property of EN8 is suite to the pin capacity and manual removal of pin due to this criteria EN8 is select as pin material. Now checking pin for shear failure and crushing failure.

Shear failure of pin

$$\tau = \frac{W \frac{d}{2}}{\frac{\Pi}{16} \times d^3}$$

$$\tau = \frac{66103 \frac{84}{2}}{\frac{\Pi}{16} \times 84^3}$$

$$\tau = 23.85 MPa$$

Since the induced shear stress (23.84 MPa) is less than the permissible stress (93MPa) of EN8 . Hence the design of pin is safe under shear.

Crushing stress is 2 times the shearing stress therefore

$$\sigma_{cr} = 2 \times 93 = 186 \text{ MPa}$$

Checking for crushing failure of pin

$$F = \text{Surface area of pin} \times \sigma_{cr}$$

$$F = (L \times \Pi d)\sigma_{cr}$$

$$66103 = 520 \times \Pi \times 84 \times \sigma_{cr}$$

$$\sigma_{cr} = 0.482 \text{ MPa}$$

Since the induced crushing stress (0.482 MPa) is less than the permissible stress (186MPa) of EN8 . Hence the design of pin is safe under crushing .

4.2 Design of hinge

Load acting on Hinge = 66103 N

Moment acting on Hinge = 66103 × 340

= 22475 × 10^3KN mm

Hinge fail in bending and shearing

Mainly fail in shearing moment = 22475 × 10^3KN mm

$$\therefore d = 107 \text{ mm}$$

$$\tau = \frac{W}{\frac{\Pi}{16} \times d^3}$$

$$93 = \frac{22475 \times 10^3}{\frac{\Pi}{16} \times d^3}$$

$$d^3 = 1230798.22 mm^3$$

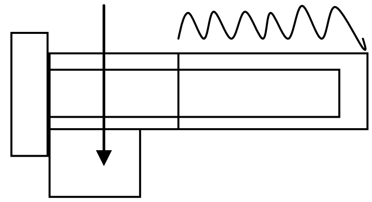


Fig 4.3 Hinge Loading

Hinge and pin for trolley is design for the maximum load condition. It is found that the pin is safe in shear and crushing according to this material En8 selected for the pin to avoid bending failure of pin. Outside Diameter of pin is 84 mm for EN8 and diameter of hinge is 107mm as per calculation but as per standard diameter selected is 100 mm.

5 Proposed Model

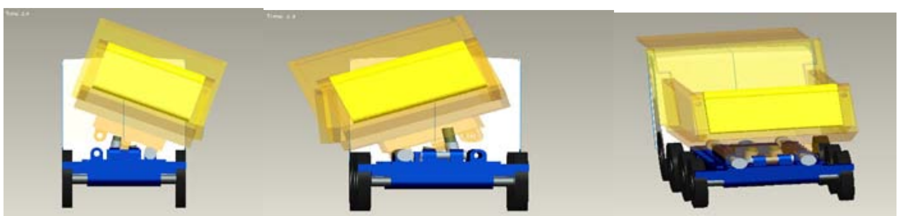


Fig. 5.1

6 Conclusion

Design of multiside tipper tilting mechanism is done to help unloading loose material on three side of the tipper as per the availability of space. The design is safe for the maximum load of 16 MT which is rigid enough to transport loose material from one site to another site. Design of hinge is the most important part for side tilting of the trolley. Selection of material is also important factor for design of pin ,EN8 material is selected which is having tempered and hardened capacity which is reducing the size of pin for The narrow work space and insufficient loading access restricted the parking position of the tipper. Design and development of mining operations should take into consideration the safe positioning of tipper vehicles on soft or undermined benches particularly where risks are increased by the loading operations. The construction truck with the three way tipper mechanism helps unloading easier. The benefits of 3D CAD and FEA packages can be taken for designing of three way tipper construction trucks. Three way tipper can unload materials in all three sides. To control the sides of tipping there needs to be required one more pneumatic cylinder apart from the main hydraulic cylinder. Also we require special types of hinge joints in this case.

- Study and analysis of existing Tipper system, its design constraints, limitations.
- Mechanism to be used and its workability.
- Actual designing and balancing of system.
- Modifications to overcome the remedies.
- Comparative analysis of Multiside tipper with the existing Tipper system.

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