Design and Fabrication of Universal Dumper

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***Abstract* – The universal dumper was conceived by observing difficulty in unloading of the material. The prototype was designed and fabricated for reducing the difficulty in unloading of material. The materials can be unloaded in any direction between the angle 0-180 degrees. The protype of a tractor trolley was used, which can be rotated with the use of chain and sprocket powered by the double acting cylinder which is operated by hydraulic hand pump. Two hydraulic cylinders are connected through valves for actuation according to the requirements. A double acting cylinder is used to achieve rotation in either direction i.e. left or right side movement and single acting cylinder with spring is used for retraction of the trolley. The lift mechanism for trolley is powered by hand operated hydraulic reciprocating pump. The hydraulic power is used to lift the trolley with the help of a piston against the spring.**

***Key Words*—Dumper, material Handling, Hydraulic system**

I. INTRODUCTION

A material handling system is an integrated system involving activities such as handling and storing of materials. The primary objective of material-handling system is to ensure that the material in the right amount is delivered to the desired destination at the right time and at the minimum cost. Material handling is an integral part of any industrial or commercial activity. The material handling cost component can vary form 10-80% of the total cost and the equipment is also prone to accidents. Thus it is important that the material handling system is properly designed from efficiency as well as safety point of view.

The application of hydraulic systems in modern machines for power transmission evolved few decades earlier in the western world. There has been a significant increase in use of hydraulics in Indian industries and hence, there is an immense urgency and importance to master the art of its application and maintenance. Hydraulic systems are now extensively used in material handling devices, transport and mobile equipments, machine tools, aviation systems, etc. At the movement there exist a big gap between the availability and requirement of trained man power in this vital field of the modern engineering. The operational efficiency of machineries can be maintained at an optimum level, by bridging the gap that our design, application and maintenance engineers are given extensive on job training from the lowest to the highest level. Apart from the fluid power system design, a good maintenance engineer and right mechanic should also have basic theoretical knowledge of installation, operation and maintenance of the hydraulic system which enables him to tackle practical problems encountered.

The basic principles that are associated with the science of the oil hydraulics are to be explained in a manner so as to inculcate a sense of confidence needed to tackle problems without any ambiguity. Dumper vehicles are designed for carrying bulk material. These are distinguished by configuration: dumper is usually a 4-wheeled open vehicle with the load skip in front of the driver. The skip can tip to dump the load this is where the name "dumper" comes from. Normally they are diesel powered. Towing eye is fitted for secondary use as a site tractor.

Earlier dumpers were 2-wheel drive, driving on the front axle and steered at the back wheels with payload of about a ton. A single cylinder diesel engine was started by hand cranking. The vehicle is steered by rear wheels, without aid of electric or hydraulic means. The skip was secured by a catch by the driver's feet. If the catch is released for unloading, and after being emptied is raised by hand. Modern dumpers have payloads up to 10,000kg and usually steered by articulating at the middle of the chassis (pivot steering). Typical dump trucks are meant for transporting loose material such as sand, gravel, dirt, etc. which are open-box bed hinged at the rear operated hydraulically, the front is lifted to allow the contents be deposited on the ground behind the truck.

Modern dumpers have multi-cylinder diesel engines, some turbocharged, electric start and hydraulics for tipping and steering. A Roll-Over Protection frame is provided over the seat to protect the drivers if the dumper rolls over as well as some dumpers have Falling Object Protection. For discharging above ground level lifting skips are available. In the 1990s dumpers with swivel skips became popular, which could be rotated to tip sideways, especially for working in narrow sites such as road works.

II. PROBLEM DEFINITION & METHODOLOGY

A. Problem Statement

The present material handling automobiles are having the trolley which has the lifting system to dump the material towards one side i.e., rear side. For dumping the material at a particular point, the vehicle has to be positioned properly to affect the exact dumping point. At some places it will not be possible to position the vehicle according to the dumping point. Since the roads or the space might be congested. So the material is not dumped in a required place which again needs some manpower to shift it.

We are proposing to make the hydraulic rotating trolley which can rotate to any required angle (0-180^0) and lift it to dump the material in that position. All the hydraulic actuations are by the hydraulic reciprocating pump operated by hand lever and in actual the hydraulic pump is operated by the engine. This mechanism can provide faster work rate, less human interaction and makes easy for the driver to unload and reduce time and fuel consumption.

B. Conceptual Design

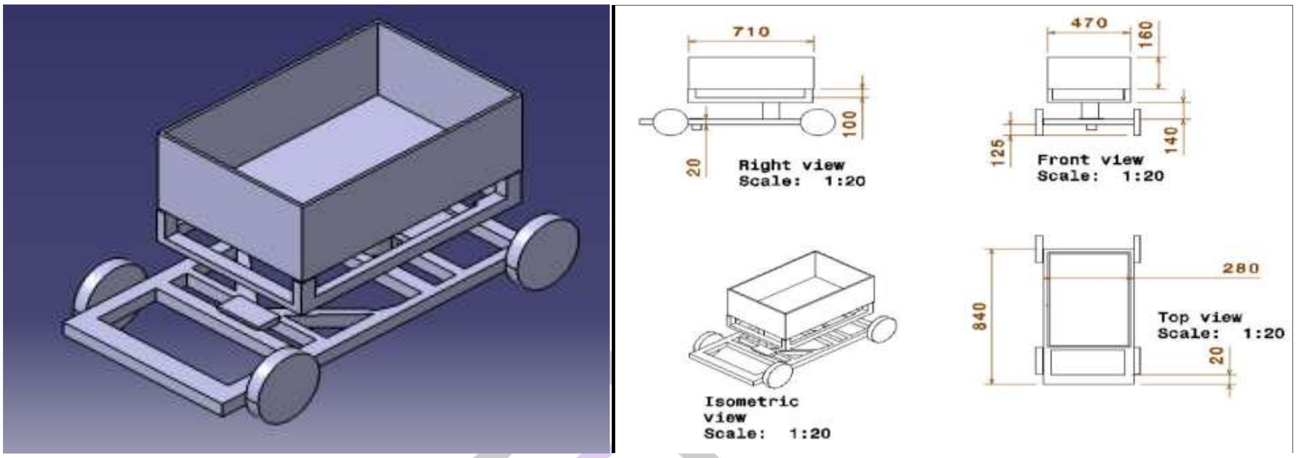

Figure 1: 3D and 2D Model of Universal Dumper

The tractor shaped trailer is being held on the pivots and the center. The center is pivoted with the center axle and the rotating mechanism being actuated by the chain and sprocket which is powered by the hydraulic pump held at the base. The tray is mounted on this assembly which is pivoted at the rear end and is hinged to the cylinder ram yoke for lifting it. The tray which rests on the supports and the front portion is lifted by the cylinder actuation. For rotations, the chain and sprocket mechanism is used; the sprocket is rotated by the chain which is being powered by the hydraulic double acting cylinder. The sprocket is held with the help of ball bearings.

The outward movement of the double acting cylinder ram to which chain is attached gives a linear outward movement to the sprocket, which converts linear outward movement to leftward rotational movement (anticlockwise). This outward movement of the ram is done by opening the left ball valve which allows the oil to flow inside the double acting cylinder. The oil flowing into the double acting cylinder can be controlled by varying the pressure applied on hydraulic reciprocating pump. To return to the original position left ball valve should be closed and directional control valve (DCV) is operated and right ball valve is to be opened. The oil moves to the other side of the double acting cylinder which gives inward movement to the ram which intern rotates sprocket in clockwise direction (right side) and the dumper will come to its original position.

In order to lift the tray or to dump the material, the hand pump lever of the reciprocating pump is operated to pump the hydraulic oil from the pump to the single acting cylinder through outlet port to lift the tray for the required height and when it is required to retract, the release valve of the pump is operated to save the path for return of the oil from the cylinder by the spring pressure back to the oil tank dropping the tray to the original position.

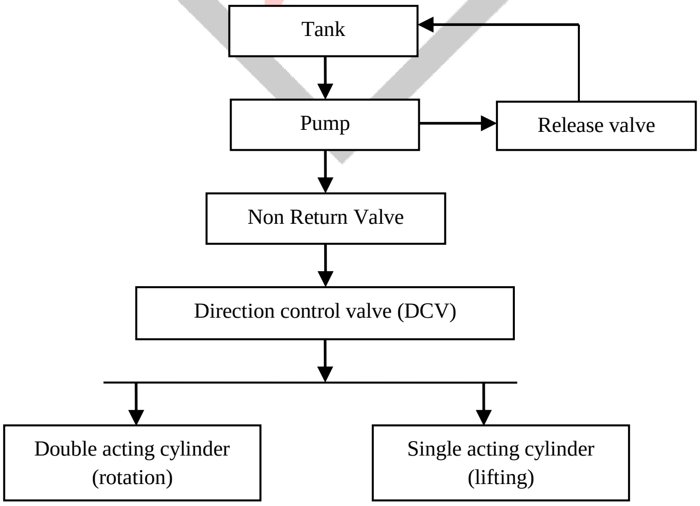

Figure 2: Block diagram of working principle

III. DESIGN AND CALCULATIONS

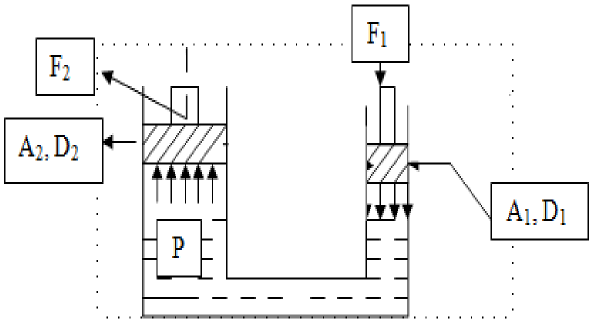

Figure 3: Forces in Hydraulic Systems

Force Multiplication in Hydraulic Systems; let us assume two oil containers both cylindrical in form and connected together. The two cylinders are of different diameters say D_1 and D_2 respectively, where D_1 is smaller than D_2. Both the cylinders have a piston with piston rod as shown. If a force F_1 is exerted on the smaller piston, then according to Pascal's law, pressure p will be generated in the oil and this will be constant and act equally in all directions.

Mathematically, we can determine this pressure by,

$$p = \frac{F_1}{A_1} \qquad -1$$

Where, p = Intensity of the pressure

A_1 = Area of the smaller piston= $(\pi/4)\times D_1^2$

F_1 = force applied on the smaller piston

As this pressure will also act at the bottom surface of the bigger piston, we can calculate force F_2 which will be generated by the bigger piston.

$$F_2 = p \times A_2$$

Where A_2=area of the bigger piston = $(\pi/4)\times D_2^2$

$$p = \frac{F_2}{A_2} \qquad -2$$

From equation 1 and 2 –

$$p = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$F_2 = F_1 \left[\frac{A_2}{A_1}\right]$$

But as A_2 is greater than A_1, $\left[\frac{A_2}{A_1}\right]$ is also greater than 1or F_2 is higher than F_1.

It can therefore be concluded that by applying a smaller force F_1 on the smaller piston, a bigger force F_2 can be generated in the bigger piston.

By applying the equation for work done,

Work done by the smaller piston = $F_1 \times S_1$ -3

Work done by larger piston = $F_2 \times S_2$ -4

Where S_1 and S_2 are the distances moved by the smaller and larger pistons respectively.

Equating 3 and 4 we can write,

$$F_1 \times S_1 = F_1 \times S_1$$

$$\frac{F_1}{F_2} = \frac{S_2}{S_1} \qquad -5$$

Therefore energy input to the system is equals to the energy output from the system.

The pressure on the piston of the pump is to be calculated considering the hand lever length and pressure applied on the hand lever. Say approximately 2kg is applied on the hand lever, considering the average approximate force on the piston may be 20kg which is to be termed as the pressure on the piston. Calculating the area of the piston of the pump with force, we will get the working pressure of the fluid which is to be used for the cylinder ram force resulted at the shaft.

Diameter of the pump piston = 1.5cm

Area of pump cylinder = $\frac{\pi d^2}{4}$ = 1.7671cm^2

Pressure lever length = 35cm

Pressure arm pivoted at (force arm) = 4cm

For Example,

Say pressure applied on hand lever = 2kg

Therefore; Pressure lever length x pressure = force arm x force

35 x 2 = 4 x Force

Force = $\frac{35\times2}{4}$ = **17.5kg**

Pressure in the pump

Fluid pressure = $\frac{\text{Force}}{\text{Area}} = \frac{17.5}{1.7671} = \mathbf{9.903}\ \frac{\mathbf{kg}}{\mathbf{cm^2}}$

Area of cylinder ram = 3.142 cm^2 (considering 20mm cylinder diameter)

Force on the cylinder ram = pressure x area of cylinder ram = 9.903 x 3.142 = **31.11 kg.**

IV. FABRICATION

A. Chassis base frame

Chassis is made by mild steel square tube of 20mm x 20mm cut for the lengths of 840mm of 2nos, 280mmof 4nos, 180mm of 2nos and then being joined by arc welding to make the frame of width 280mm and length 840mm with ground clearance of 125mm. Then at the distance of 400mm a triangle is formed to reach the pivot center. 15mm diameter ball bearing housing is welded to this joint to make the frame. Cross members are welded at the distance of 100mm from this triangle point and second at 60mm distance from the first member.

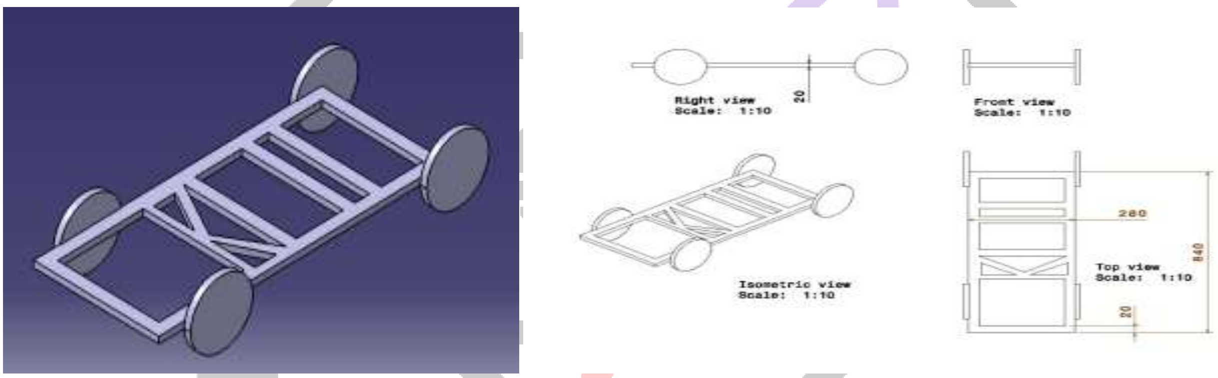

Figure 4: 3D and 2D Model of Chassis base frame

Front axle - It is made by C30 steel round bar being cut from the diameter of 20mm and length 485mm.This is turned on lathe machine to make the diameter as 15mm for the entire length and then faced from the other side to make the total length as 480mm. Such one number of axles is made for this project.

Front pivot axle - It is made by C30 steel round bar being cut from the diameter of 20mm and length 110mm. This is turned on lathe machine to make the diameter as 15mm to suit the ball bearing inner diameter and then faced from the other side to make the total length as 100mm. Such one number of front pivot axle is made for this project.

Center axle - It is made by C30 steel round bar being cut from the diameter of 30mm and length 180mm. This is turned on lathe machine to make the diameter as 25mm for the entire length and then holding on the other side step turned to make the diameter as 20mm to suit the ball bearing inner diameter for the length of 50mm by which 25mm diameter remains for 125mm. Such one number of center axles is made for this project.

Rear axle - It is made by C30 steel round bar being cut from the diameter of 20mm and length 130mm. This is turned on lathe machine to make the diameter as 15mm to suit the wheel lock plate's inner diameter and then faced from the other side to make the total length as 120mm. Such two number of rear axles are made for this project.

Bearings - 15mm diameter ball bearings are the standard roller type ball bearings of inner diameter 15mm, outer diameter 35mm and thickness 10mm being used in this project. Such 5 number of ball bearings are used in this project. 20mm diameter ball bearings are the standard roller type ball bearings of inner diameter 20mm, outer diameter 42mm and thickness 10mm being used in this project. Such 2 number of ball bearings are used in this project.

Wheels - Plastic readymade wheels are brought and centre bore is made to 15 mm. The outside diameter is 225mm and the width is 100 mm. Total four numbers of wheels are used, two for front and two for rear side.

Wheel lock plates - These are made from the standard washer plates being brought from the store of thickness 3mm with diameter 40mm being turned on lathe machine to make the inner diameter as 15mm. Such eight numbers of plates are made for this project.

B. Tray rest frame

It is made by mild steel square tube of 20mm x 20mm cut for the lengths of 610mm of 2nos, 60mm of 2nos, 50mm of 2nos and then joined to make the tray rest frame.

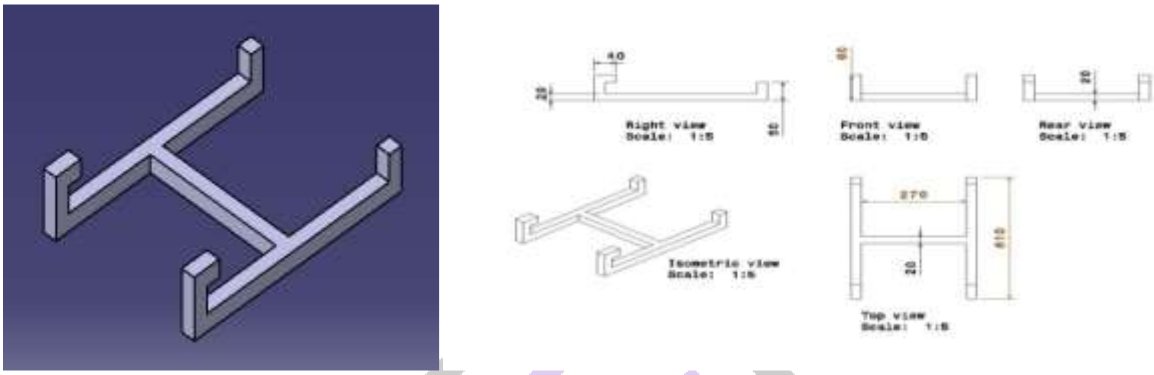

Figure 5: Tray rest frame

Tray - It is made by mild steel tube of 20mm x 20mm cut for the lengths of 470mm of 3nos, 710mm of 4nos and then rectangular frame is made by arc welding to make the frame of outer size as 710mm x 510mm. On this the railing and base is welded as per the requirement.

Tray railing - It is made by mild steel square tube of size 20mm x 20mm cut for the lengths of 710mm of 4nos, 470mm of 3nos, 140mm of 10nos and then welded to the tray to form the tray railing.

Sheet metal covers for the tray - These are made by CRCA (cold roller closed annealed) steel sheet of 1.2mm thick being cut for the size of 500mm x 700mm of 1nos, 160mm x 700mm of 2nos and 160mm x 470mm of 1nos. All are hammered by using supports to flatten and then welded to the tray railing to form the trolley to hold the materials in it.

Tray door - It is made by plywood of thickness 1mm cut for the length of 550mm and width of 140mm and it is hinged to the tray.

Tray pivot bush - It is made by mild steel hollow round bar being cut from the diameter of 25mm with the inner diameter of 10mm and length 30mm. Then it is turned on lathe machine to make the outer diameter as 20mm for the entire length and then faced from the other side to make the total length as 20mm. Such two numbers of bushes are made for this project.

Tray Pivot pin - It is made by C30 steel round bar being cut from the diameter of 15mm and length 50mm. Then it is turned on lathe machine to make the diameter as 10mm for the entire length to suit the pivot bush inner diameter.

Lift cylinder pivot bush - It is made by mild steel round hollow bar being cut from the diameter of 25mm with inner diameter of 10mm and length 35mm. Then it is turned on lathe machine to make the outer diameter as 20mm and faced from the other side to make the total length as 30mm.

Lift cylinder pivot pin - It is made by C30 steel round bar being cut from the diameter of 12mm and length 65mm. Then it is turned on lathe machine to make the diameter as 10mm for the entire length to suit the lift cylinder pivot bush inner diameter.

Sprocket and Chain arrangement - It is a standard sprocket being used in the automobile with the diameter of 25mm and 10 numbers of teeth. The chain has 7 links and its length is 210mm.

DCV clamp - Mild steel flat is taken of size 25mm x 5mm for the length of 225mm and it is bent to the circle to maintain the diameter of 75mm to hold the DCV. Such two number of DCV clamps are made. It is welded at its ends.

Tubular connections - It is being brought from the store for the required length and connected to the requisite connectors and joined to the master cylinder and then through the non return valve to the jack and from there to the release valve to the tank.

V. RESULTS AND DISCUSSION

On the basis of theoretical calculations, the dumper can carry a load of 31.11 kg. It has been evaluated for carrying and rotating (0 to 180^0) the calculated load. Constructional or infrastructural work demands efficient and user friendly machineries which will lead to more and more use of universal dumpers. This concept saves time & energy which leads to efficient working. Further modifications and working limitations will put this work in the main league of use.

After testing, objectives and goals were achieved. It is able to increase the easiness in unloading of the trolley. At the time of unloading the trolley, problems occurred in critical areas are eliminated. Thereby reducing overall time and space required for unloading the materials from the dumper.

Figure 6: Final Model

VI. CONCLUSION

In the existing system, tipper can unload only in one side. So it is difficult for the driver to unload at only one place and also it consumes more fuel, time, space etc. Design of universal dumper is done to help the unloading of materials from 0-180^0 as per the availability of space. The design is safe for the maximum load of 31.11 kg which is rigid enough to transport material from one site to another site. The chain and sprocket is the most important part for the rotation of dumper. Selection of material is also important factor for design of other parts which adds flexibility to the dumper in reducing time and energy. This concept can be implemented for the lorry, tractors and material handling tippers etc.

Some of the advantages are as follows-

1. Reduces extra cost paid on unloading of material by labours or machines like cranes or any other pick and placer.
2. Saves time and energy.
3. Material unloading at the particular point and the shortage of space is eliminated, since the material can be placed at the required place without disturbing the vehicle position where it is not possible to change the position of the vehicle.
4. Man control and convenience since the material can be dumped wherever required for the ease of usage.
5. Ease of driving and carrying, since the effort of the driver is reduced.
6. Flexibility is more in this than any other material handling system. This flexibility helps in the saving of man hours.
7. This system permits better utilization of the existing space.
8. The operating costs of this system do not increase than the present system of one side lifting.
9. Precise hydraulic controls allow fast, efficient control of lifting and holding the pressure.
10. Generate step less motion and variable speed and force to a greater accuracy.

Some of the disadvantages are as follows-

1. Increased Complexity, as it requires complex mechanism to get desired output.
2. Maintenance Increases, more parts in working leads to more maintenance.
3. Cost Increases, as more will be the complications to perform the operation, more will be the cost encountered with it.

This work demonstrates the working of protype universal dumper, not for showing the load carrying capacity.

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