Design and development of Hydraulic Lift for fastening of a SPM (Special Purpose Machine)-Subsystem

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Abstract- *The conceptual block diagram shown below consist of 4 hydraulic castors which are intended to lift the cart.4 hydraulic castors are located at 4 extreme corners. The other main components include flow dividers which will be extensively used to transfer equal amount of fluid to all the castors. Oil tank is located at extreme back which will be used to store hydraulic oil and will surely it to flow dividers. The main component is the foot pump which will operate at around 70kg/cm sq. The pump will be operated by pressing the foot which will in turn generate the pressure required.*

***Key Words* : Hydraulic Castors, foot pump, flow dividers, cart, Oil tank.**

Fig 1 : Conceptual Block Diagram

1.INTRODUCTION

This project aims to design, develop and manufacture a hydraulic castor lifting mechanism customized for an industry specific SPM. The mechanism will consist of castors, flow dividers, hydraulic hand/foot pump, hoses etc. Alike proceeding of any general project, this will have a literature survey to have a glance on predated research on similar topics, it will include study of previously completed hydraulic castor projects, research paper on hydraulic pumps etc., in its first phase. Taking those inputs, tagged along with experience of industry personal, an initial feasible design will be made in the second phase. The design will mainly concentrate on assembly of components and compacting the actual assembly. In third phase of the project, the prior made design will be tested for optimization, if any. Selection of components will be done considering the literature survey, design considerations and industry personal advice and experience. Selected components procurement will be done considering the required specifications and the costing. Lastly, the optimum design will be followed to its manufacturing in the fourth phase. The complete assembly of hydraulic lifting mechanism will be attached to the specific SPM, which will be followed by trial and testing.
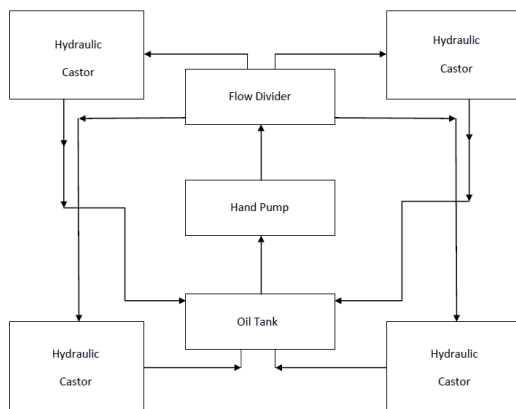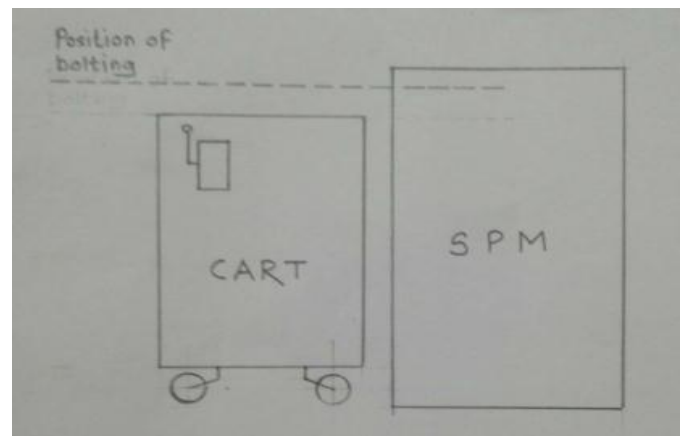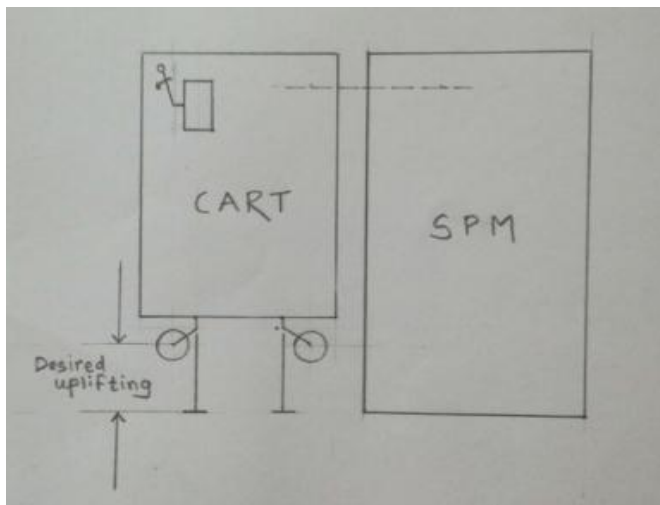

(a)

(b)

Fig. 2: Explanatory Structural Block Diagram

2. LITERATURE SURVEY

1. Bill DiMartino (July 1998)

Research Paper: Operation and maintenance manual for hydraulic lift caster system

According to the paper, Hydraulic lift caster system (HLCS) is a portable mobilizing product designed to lift and move containers on smooth paved surfaces. The main components used are lift assembly, base assembly, rotating toe lift lug, lock pin, front caster (small), rear caters (large), swivel locks, handle bars and kick stands. They deals with hydraulic hand pump assembly which is used for raising and lowering the container. In lift assembly, lock pins are used to prevent shock loads from affecting the hydraulic system. Base assemblies provide mounting for hydraulic cylinders. The main purpose of the small casters is to allow the lift caster assembly's hydraulic cylinder to be raised and lowered without the lift caster assembly being actually attached to the container. The paper also deals with the problems and their respective maintenance solutions regarding HLCS. For example: Consider a problem that you can't move individual lift caster assembly. The respective solution for this is that only roll the casters on smooth paved surfaces and grease all the fittings. Along with this, they have also provided with the maintenance regarding hydraulic hand pump in this paper.

2. M. Metwally et.al (December 2013)

Research Paper: Experimental and Theoretical Investigation of an Interlocked Spools Flow Divider

The paper deals with the experimental and theoretical investigation of an interlocked spool Flow dividers. According to the study, flow dividers or combiners valve dividers or combines the respective flow of a fluid in a respective ratio regardless of the load pressures at the outlet port. Basically, there are two types of flow dividers i.e. sliding spool and rotary gear type. In this present work, a mathematical model for interlocked type spool type flow dividers was formed and the static and dynamic characteristics were carried out at different load pressures. The comparison between experimental and simulated model for the flow dividers has showed good results for system pressure up to 50 bars. The static and dynamic characteristic carried out were plotted for experimental and simulation results. In this comparison for flow rate v/s load pressure variation, it was seen that the increase of load pressure has a significant effect on the flow divider valve static characteristics. Also, the dynamic characteristics shown that, the response time of the spool increased and this increase is not equal in both the spools, which means that the flow divider's dynamic responses reduce as the load pressure increases.

3. James J. Kauzlarich et.al (May/June 2000)

Research Paper: Wheelchair Caster shimmy II-Damping

The theory of shimmy damping is investigated including tire friction, spindle friction and hydraulic damping. They have presented a simplified model of caster wheel and here the free body diagrams of forces and moments can be solved to determine the bearing loads. In this paper they have considered various equations such as critical angular frequency equation and torsional deflection of caster wheel equation etc. to understand the damping of the caster wheels. As a part of this force analysis some parameters were examined and were plotted graphically. As per the information provided in the graph of shimmy speed versus load, it is seen that the speed increases linearly with load above a load of 100 N indicating that the frictional damping moment is changing with load. In the original paper on wheelchair caster shimmy there were some errors concerning the discussion of the theory. This error was overcome by adding a new concept in the damper design which suggests that a very viscous lubricant is used in the wheelchair caster spindle ball bearing, which is predicted to offer a significant increase in on set shimmy velocity.

4. John G. Thacker et.al (June 2000)

Research Paper: Wheelchair Caster shimmy and Turning Resistance

The analysis includes methodology and results of experiments developed to measure sliding friction turning moment of wheelchair caster wheel. The analysis of wheelchair caster shimmy present the shimmy equation for predicting critical speed at which wheelchair caster shimmy begins for frictionally damped caster, and to include the effect of grooved tire. In designing a wheelchair caster, consideration of strength and size as well as shimmy must be investigated. The result shows that increasing trail there is decrease in moment of inertia of wheel and by increasing

damping or adding groove in the tire, will inhibit onset of shimmy. All of these effects demonstrated experimentally and the results agreed well with the theory.

3. PROBLEM DEFINITION

The newly designed and developed SPM is equipped with an attachment. The attachment is of utmost importance to the SPM for its working at its full potential. The attachment weighs around 800 kg. The working of SPM demands the attachment to be attached and detached from the SPM for several time. The SPM and the attachment has a offset at the bolting position. So the procedure of attaching and detaching of attachment to the SPM demands the lifting of attachment from the ground level for the bolting purpose. Considering the weight of the attachment it is highly impossible to carry out lifting procedure manually.

So the company requires a fully designed and developed operated hydraulic lifting mechanism which will be operated by a hydraulic hand pump. The assembly of lifting mechanism will be attached to the attachment which will help for smooth lifting and lowering of the same.

Thus the project will help in saving time and efforts while attaching and detaching the attachment to the SPM.

4. OBJECTIVE

'To design, develop and manufacture a hydraulically operated castor lifting mechanism to provide a desired location for fastening of a SPM-subsystem.'

5. COMPONENT SURVEY

As any Hydraulics based project, this project too required a component survey in its first phase. Some critical components were studied for their application, which consists of the following:

1. Flow dividers- When you must to split a single hydraulic line into two or more identical flow paths, a tee or several tees can be the first solution. However, if the resistance in all the branches is not identical, flow can vary greatly in each path. Adding flow controls at the tee outlets makes it possible to change resistance and equalize flow in each branch, but as the machine operates, work resistance changes often require constant flow modifications. A device called a flow divider splits flow and compensates for pressure differences in most cases. A flow divider can split flow equally, unequally, and into more than two paths. One design maintains a constant flow for one outlet and directs any excess flow to a second outlet.

Need of flow dividers- The sole purpose of this mega-project is to provide a solution to lifting of the SPM subsystem to its location of bolting. Thus, level of each corner of that subsystem is an important aspect. While lifting the subsystem, each castor must be lifted to same height in order to achieve proper bolting position. Hence, each hydraulic castor must be provided with equal amount of fluid. For this very same reason, flow dividers are required in this project. Categories of flow dividers available in market:

 i. Spool type flow dividers

ii. Gear type flow dividers

i) Spool type flow dividers:

These flow dividing valves divide a flow in two usually equal parts. When flow passes through a valve in the opposite direction, the two part-flows are combined into one single flow (added). The dividing and combining functions are largely independent of the pressures of the two divided flows and of the fluid viscosity.

Advantages-
These valves do not require maintenance. This lowers costs and reduces the risk of a system failure. Flows can be split or merged with accuracy (divide/combine functions).The flow division ratio can be altered to suit customer requirements.

ii) Gear type flow dividers-

Gear type flow dividers, divide a flow into as many as four portions. The division ratios are constant and are unaffected by the loads at the actuators. They can be used, for example, to provide synchronised movement of unequally loaded cylinders. Several hydraulic motors can be driven at the same speed, irrespective of their external loads.

Advantages- They have high division accuracy. A very wide range of division ratios is available. The inlet flow can be divided into as many as four portions. It has high efficiency, long service life.

According to the survey, Gear type flow dividers are more suitable when lifting is the intended task than the valve type flow dividers. Thus, we select Gear type flow dividers in our project.

2. Foot Pump- Foot pumps are manually operated pumps driven by foot via a handle or lever. This manual external force actuates an internal mechanism, which increases pressure for moving fluids such as gas, chemicals, or water. Hand lever and foot pedals are pushed up or down to begin the pump cycle, often requiring one stroke to draw the fluid and another stroke to discharge it, as is typical in many displacement pumps. All hand pumps and foot pumps operate on a positive displacement principle. Positive displacement pumps use expanding and contracting cavities to move fluids.   Hand pumps and foot pumps can use a reciprocating or rotary mechanism. Most rotary types use a drive rather than a lever or crank. In reciprocating type hand

pumps, a hydraulic or pneumatic piston is used to create the pressure needed to move the media.

Need of foot pump- The subsystem of SPM, is cart which is to be designed so that, even when it is detached from the SPM, it has few functions to do. To complete those functions, the hydraulic castors must work with no power supply from the parent SPM. And the cart will not always have an electric power supply. So, the power is to given manually.

Again, the uplifting of the cart is to be done my not more than two people. So, the person doing that task has to perform many activities simultaneously. Thus providing a foot pump will surely provide a better solution than a pump in such a circumstance.

Categories of foot pumps available in market:

Hydraulic pumps - pumps which operate using hydraulic power. Hydraulic hand pumps and foot pumps are used to manually pressurize a hydraulic system and for instrument calibration.

Pneumatic pumps - pumps which operate using pneumatic power. Pneumatic hand pumps and foot pumps are designed for testing and instrument calibration.

Diaphragm pumps - displacement pumps that use a rubber disk to alternate air or fluid. The diaphragm is actuated by the pressures or vacuums created during the pump cycle. Diaphragm hand pumps and foot pumps are used in marine applications where seawater is pumped from the bilge.

3. Other components -
The remaining components are not much influencing as far as design of the hydraulic castor is considered. So, those components will be selected after the flow divider and foot pump is finalized from the manufacture's catalogue.
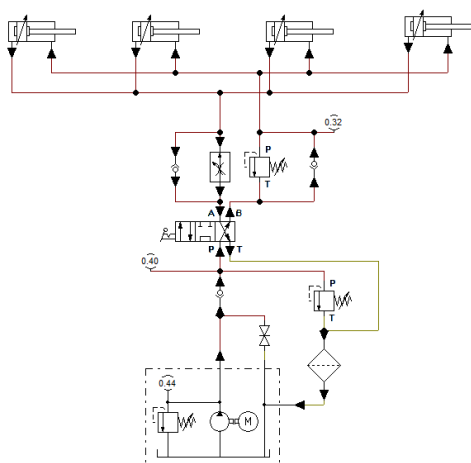
6.OPTIMIZED AND PROPOSED CIRCUIT :

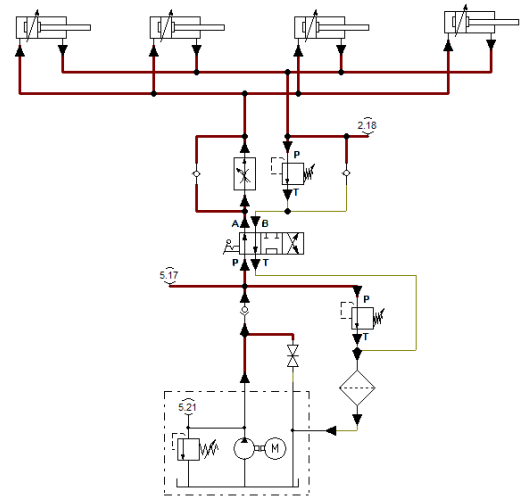Fig 3 : Switching position for lifting

Fig 4 : Switching position for lowering

7.CALCULATION FOR PISTON DIAMETER :

Mass of the beam cartridge (Beam + Cart) = 800 to 900 kg

☐ Maximum Permissible Mass = 900 kg

☐ Weight i.e. Net load on castors = 900×9.81

☐ F_o = 8829 N

Performing Surface area available
A_o = 4×100×100
☐ A_o = 4×10^4 mm^2

Thus, Net pressure on cylinders :

$$P_o = \frac{F_o}{A_o}$$
$$= \frac{8829}{(4 \times 10^4)}$$
☐ P_o = 2.207 N/mm^2
i.e. P_o = 22.07 bar

Thus, pressure on each cylinder,

$$P = \frac{P_o}{4}$$

$$= 22.07 / 4$$

☐ P = 5.5175 bar

Nominal working pressure, for which no special requirement of oil seals, hoses, actuators is needed is below 7 bar.

Thus, $P_{H1} = \dfrac{\text{Hydraulic pressure}}{\text{working pressure}}$

= 7 bar

Or   =0.7 N/mm^2

Thus, P_{H1} **>** P

Here, there is no such extra-ordinary requirement of oil seals and other parts.

Now, we know , $P_{H1} = \dfrac{F_{H1}}{A_{H1}}$

Where F_{H1} = Net load on each cylinder

$= \dfrac{F_0}{4}$

A_{H1} = Area of the piston

$A_{H1} = \dfrac{F_{H1}}{P_{H1}}$

$= \dfrac{\left[F_0 \times \left(\frac{1}{4}\right)\right]}{P_{H1}}$

$= \dfrac{\left[8829 \times \left(\frac{1}{4}\right)\right]}{0.7}$

$\Box$ A_{H1} = 3153.21 mm^2

But,

$A = \dfrac{\pi}{4} d^2$ (d = Dia. of piston)

$\Box$ $d = \sqrt{\left(\dfrac{4A}{\pi}\right)}$

$= \sqrt{\dfrac{4 \times 3153.21}{\pi}}$

$\Box$ $d \cong$ 57 to 60 mm

➢ *To Cross-check :*

Let, d = 57 mm

$\Box$ A = 2551.759 mm^2

$\Box$ Maximum Permissible system pressure,

$P_H = \dfrac{F}{A}$

$= \left\{ \dfrac{8829}{2551.759 \times 4} \right\}$

= 0.86499

i.e. P_H = 8.6499 bar **>** 7 bar

8.CONCLUSION:

This paper presents an optimum solution to the problem stated in the beginning. The hydraulic circuit developed in this paper will provide easy and simple lifting of the cart. The solution proposed by this paper is based on use of single hydraulic foot pump and flow dividers to actuate and control the necessary lifting. This mechanism if applied on practically, will enable a single person to assemble the cart to SPM, thus solving the major problem stated in the problem statement. The proposed solution, being deprived of electronic components or such any other controls, provides a very economical way for lifting the cart.

9.ACKNOWLEDGEMENT:

10.REFERENCES :

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