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Design of Automated Outriggers for Self-Propelled Hydraulic Scissor Lift - A Case Study At Air India

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Abstract —— Outriggers are used to provide support to the Scissor Lifts when its platform is raised, during loaded condition. When Lift has reached its maximum height and if it is loaded, it may tend to topple or over-turn due to Bending Effect which is usually produced due to the change in the overall centre of gravity of the vehicle. To prevent this phenomena, outriggers are provided which reduce the overall toppling effect on the vehicle by providing necessary counter reaction forces. Up till now these outriggers were clamped to the ground surface manually, which resulted in wastage of valuable operational or equipment setting time. Hence, we have designed an automatic outrigger mechanism which works on hydraulic system and takes very less time for its deployment as compared to manual outrigger. This is a part of our BE project which includes design and modification of self-propelled scissor lifts at Air India. This type of design is yet to be explored and commercialized.

Keywords— Scissor Lifts, Automated Outriggers, Hydraulics, Bending effect, Air India.

I. INTRODUCTION

Maintenance of aircrafts has many issues related to machines, hangers, ground support equipments etc. One such equipment in ground support includes Scissor Lifts. These lifts are used to reach the spots where maintenance are required. These lifts are equipped with outriggers devices which provide external support to these scissor lifts; which has an operating height over 6 meters and above. When the Scissor Lift is raised to its maximum height from the ground, the overall centre of gravity of the system shifts away from original position which causes action of unbalanced forces on the system. These forces usually create Bending moments which tend to topple or over-turn the whole system to ground. This phenomena can cause serious injuries or even death of the person working on the platform. To prevent this, properly designed outriggers are mounted in the system.

Current paper is based on case study done at Air India which is a part of Design and Development of Scissor Platform which will assist in maintenance of aircrafts.

II. PROBLEM IDENTIFICATION

Outriggers were manually deployed and then clamped to the ground, which used to take lot of time as each outrigger has to be operated individually with reference to the ground surface. But now there is a need to fasten up this process, which will also save operational time. So our objective is to design a fully automatic Outrigger mechanism, which works on principle of hydraulics. We have selected hydraulics because of its dynamic response and reliability under designed environments.

III. DESIGN CRITERIA

FIG: The Scissor Lift Designed by us.

As shown in figure ; our criteria is to design outriggers for a scissor lift of loading capacity 500 kilograms, maximum height of 8 meters, its dimension of base of machine are 2.5 X 1.2 meters and overall weight of the machine is expected to be around 3000 kilograms.

IV. DESIGN METHODOLOGY

It includes selection of standard components based on our system requirement. Which is followed by design of hydraulic circuits in Fluidsim and modeling of the same in Autodesk Inventor software.

Outrigger mechanism includes a total of eight hydraulic cylinders. Four cylinders to extend the mechanism beyond the boundary of the system and four cylinders to move downwards and thus lift the machine off its wheels. All these are controlled via a switch on the control panel.

The selection of the cylinders for the scissor lift is carried out via following calculations.

A. Total Weight of the System

An important aspect is determining the total weight of the system as this cannot be done accurately at present, we make an estimated guess and check its validity. We approximate the weight of the system with complete payload to about 3000 kg = 3 tonne.

Assuming a factor of safety = 4. (As per OSHA-USA Standards)

Number of cylinders = 4.

Therefore force on each cylinder = $\frac{3\ tonne\ \times 4(fos)}{4(number\ \ of\ cylinders\ )} = 3\ tonne$

B. Selection of Horizontal Cylinder

Determining Stroke of Horizontal Cylinders

These are the cylinders which provide necessary extension to the outrigger vertical cylinder which is helpful in increasing the projected base area of the machine which in turn generates the required counter forces to tackle toppling :

$$Moment\ due\ to\ weight\ of\ payload = \ Opposing\ moment\ produced\ by\ cylinders$$

$$\therefore Weight\ \times g\ \times distance\ from\ center\ \times fos = 2\ \times Force\ \times Cylinder\ Stroke$$

$$\therefore 500\ \times 10 \times \frac{1.3}{2} \times 4 = 2\ \times 3000\ \times 10\ \times stroke$$

$$\therefore stroke = \frac{500\ \times 10 \times \frac{1.3}{2} \times 4}{2\ \times 3000\ \times 10} = \ 0.2167\ m$$

$$\therefore stroke = 216.67\ mm$$

Minimum Area of Horizontal Cylinder Rod

The Horizontal Cylinder Rod will have shear stress. We have to make sure that the rod is capable of handling the shear stress without failure.

Shear Stress = $\tau = {Force}/{Area}$

$$\therefore \tau = {30000}/{\left(\pi d^2/4\right)}$$

$$\therefore 108.1875\ = {30000}/{\left(\pi d^2/4\right)}$$

Area $_{min}$ = 277.2964 mm^2

diameter $_{min}$ = 18.79 mm = 1.88 cm.

Available Space for Horizontal Cylinder

The space available for placing the cylinders is 940mm, hence the cylinders must be within 460mm for operation.

Selection of Horizontal Cylinder

Based on all the above conditions, we select the following cylinder and check for its safety.

1. Bore diameter = 60 mm
2. Rod diameter = 30 mm
3. Outer Diameter = 70 mm
4. Closed Length = 450 mm
5. Stroke = 250 mm
6. Weight = 7.70 kg

Calculations for the cylinder:

According to the requirements, the cylinder must extend to full length in 30 seconds.

Velocity = ${Distance\ Extended}/{Time}$

$= {0.250}/{10}$

= 0.025 m/s

Area = $\frac{\pi}{4}\left(D^2 - \ d^2\right)$

$= \frac{\pi}{4}\left(0.06^2 - \ 0.03^2\right)$

= 2.1206 X 10^{-3} m^2

Pressure = ${Force}/{Area}$

$= {30000}/{2.1206\ \times 10^{-3}}$

=.14147106.05 N/m^2

= 141.471 bar

This is less than 210 bar which is the safety limit as given by the manufacturers.

Discharge = Area X Velocity

= 2.1206 X 10^{-3} X 0.025

= 5.3015 X 10^{-5} m^3/s

= 0.53015 liter/s

= 3.1809 liter/min

Power = $Pressure \times Discharge/_{600}$

= $141.471 \text{ X } 3.1809/_{600}$

= 0.75 kW

C. Selection of Vertical Cylinder

Determining Stroke of Vertical Cylinder

The total distance from base of frame to the base of tire is approximately 350mm, hence we select cylinder which has a combined height of closed length and stroke greater than 350 mm.

Based on the above conditions, we select cylinder with following specifications:

1. Bore diameter = 60 mm
2. Rod diameter = 30 mm
3. Outer Diameter = 70 mm
4. Closed Length = 300 mm
5. Stroke = 100 mm
6. Weight = 5.60 kg

Calculations for the cylinder:

According to the requirements, the cylinder must extend to full length in 30 seconds.

Velocity = $Distance\ Extended/_{Time}$

= $0.100/_{10}$

= 0.01 m/s

Area = $\frac{\pi}{4}(D^2 - d^2)$

= $\frac{\pi}{4}(0.06^2 - 0.03^2)$

= 2.7 X 10^{-3} m^2

Pressure = $Force/_{Area}$

= $30000/_{2.7 \times 10^{-3}}$

=.11111111.11 N/m^2

= 111.11 bar

Discharge = Area X Velocity

= 2.7 X 10^{-3} X 0.01

= 2.7 X 10^{-6} m^3/s

= 0.027 liter/s

= 1.62 liter/min

Power = $Pressure \times Discharge/_{600}$

= $111.11 \text{ X } 1.62/_{600}$

= 0.2999 kW ≈ 0.3 kW

Now, checking that the rod does not fail under compression.

$Compressive\ Stress = \sigma = Force/_{Area}$

$\sigma = 30000/\left(\pi d^2/_4\right)$

$\sigma = 30000/\left(\pi \times 30^2/_4\right)$

$\sigma =$ 42.4413 N/mm^2

Hence it is safe under compressive force.

Based on our requirement, we have selected double acting hydraulic cylinders. As we do not have to design the cylinders and only have to select them. We have carried out the necessary analysis and selected standard available hydraulic cylinders from the catalogue of Interfluid Hydraulics Limited. We have used a total of ten hydraulic cylinders, which we have named as:

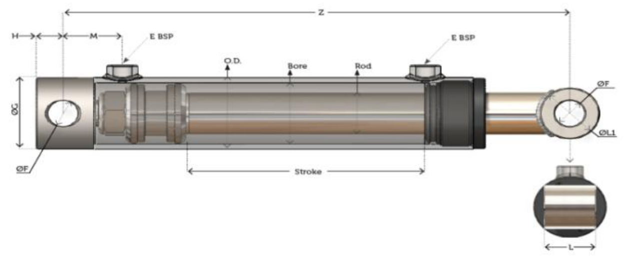

Fig: Hydraulic Cylinder Dimensions

Cylinder Type	Total Length	D	d	Stroke	Rod	Weight (kg)
Horizontal Cylinder	450	70	60	250	30	7.70
Vertical Cylinder	300	70	60	100	30	5.60

Table : Hydraulic Cylinder Dimensions (All dim. are in mm.)

C. Selection of Oils and Power pack

a) Selection of Oil

Base on Air India standards we have selected URSA- Extra Duty SAE 10 oil as fluid to be used in the system.

b) Calculating volume of oil required

Theoretical Volume of oil = Volume $_{\text{Scissor Cyl.}}$ + Volume $_{\text{Hor. Cyl.}}$ + Volume $_{\text{Ver. Cyl.}}$

= (2 X 2.0106) + (4 X 0.7069) + (4 X 0.2827)

= 7.9798 liters

Actual Volume of oil = 1.25 X Theoretical Volume.

= 9.974 ≈ 10 liters

c) Selection of Standard Power Pack

The selection of the power pack is based on three main criteria, which are

1. Power Capacity: The total power capacity required for the hydraulic system is around 3kW.

2. Total volume of oil (Tank Capacity): The required tank capacity as calculated in article 3.7.2. is 10 liters.

3. Type of Power Supply: According to Air India specifications, we have selected 24V DC supply.

Based on all these three criteria, we select, Power Pack No. ZZ001516, of Flowfit Hydraulic Powehhr Unit Ltd. It has the following specifications:

Type of Supply	24V DC
Power Capacity	3.5kW
Flow Rate	3.5 l/min
Maximum Pressure	200 bar
Reservoir Size (Tank Capacity)	10 liters

Table : Power Pack Specifications

D. Design of Electro-Hydraulic Circuit

It consist of Horizontal Cylinders such as A, B,C,D as shown in the diagram. Two similar ports are coupled and connected to the power pack via 4/3 Double solenoid spring return Valves .

Similarly it has four vertical cylinders designated as E, F, G, H as shown in the diagram which are also connected to the power pack via 4/3 double solenoid spring return valve.

As soon as the “OUT" button is pressed it energizes Relay "K1" and Delayed Relay "K2" further K1- Energises Solenoid Y1 & Y2 which causes the Horizontal cylinders to Extend outward .

The time required for extension is calculated and the after stipulated time, K2 Gets activated and it energizes solenoid Y5 & Y7 which causes vertical cylinders to extend downwards and touch the ground surface.

Similarly As "IN" button is pressed the whole cycle is restored to its initial position which done by energizing solenoid Y3,Y4 and Y6,Y8 simultaneously.

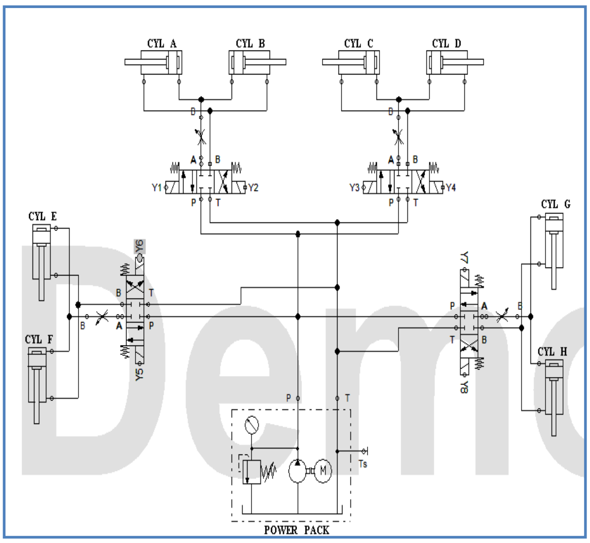

FIG : Hydraulic Circuit

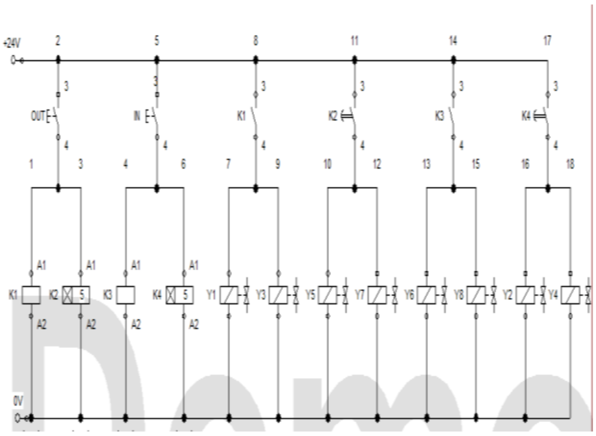

FIG : Electrical Circuit

V. DATA ANALYSIS

The operation of this Hydraulic circuit is tested in FESTO fluid simulation , where circuit's operational characteristics' were studied following and following are the representation of the same :

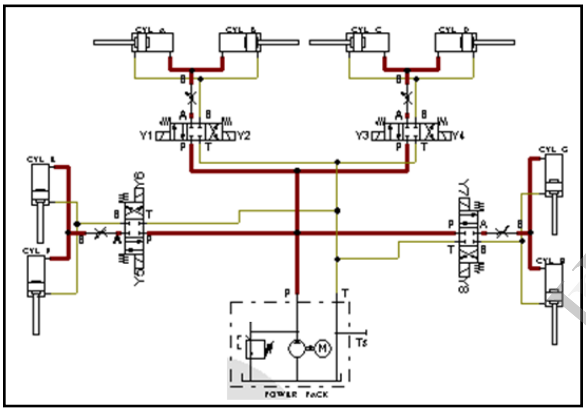

FIG: Forward or Power Stroke of all Cylinders.

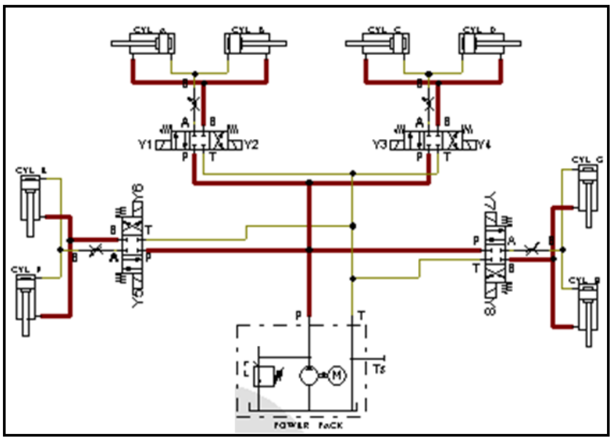

FIG: Return Stroke of all Cylinders.

VI. FUTURE SCOPE

Since this type of automated system is currently not present and our design reduces the operational time successfully it has good chance of getting commercialize worldwide for different application purpose.

VII. CONCLUSION

This paper leads to many conclusions among them the most suitable and as per requirement or design criteria's are following:

- Less Operational Time as compare to manual outrigger.
- Less labor work.
- More efficient and gives better dynamic control over the system.

However, the only limitation of the system is that it is a costly as compare to existing one.

VIII. ACKNOWLEDGMENT

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