Design and Analysis of Bucket Lift

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Abstract- ***Mobile elevating devices are now widely used worldwide. Those are very useful in taking a work person to a certain height for various tasks such as construction, cleaning, and emergency cases. So there is lot of opportunities to develop such utility and to make use of it. There is need of balancing as well as swing mechanism for safety of worker and accessibility to desired location without any difficulty. Company need the balancing and swing mechanism, so we started working on that and developed our own mechanism to get the desire output. It's a hydraulically operated mechanism which will get the work person to a certain height and to achieve the desire work required. Working of the mechanism is as simple as it is in various aerial working platforms. We have provided control in the both work platform and cabin of the vehicle so any operator can operate the vehicle while in the bucket or in the vehicle cabin. Analysis of the mechanism is done on FEA software ANSYS and it showed the mechanism is safe to sustain within the load applied.***

Key Words: aerial work platform (AWP), cherry picker, elevated working platform (EWP).

1. INTRODUCTION

There are many ways people reach high heights to work on buildings, trees, airplanes, and other tall structures. In many cases, aerial lifts are used to provide the desired height and work environment. Aerial work lifts, like the one shown in Figure 1, provide many necessary benefits to users that need an elevated work platform. However, with those benefits come significant hazards. The first challenge is determining how to reduce fatalities that occur when using aerial lifts. Therefore, there is a need to identify the most common hazards of aerial lifts and how they occur. The second challenge is understanding the deferent aerial work lifts (i.e. bucket trucks, cherry pickers, scissor lifts, etc.), their respective hazards, and methods to reduce those hazards. Before determining how to reduce accidents, it is important to understand the different aerial lifts well enough to develop potential solutions that could be applied to the aerial work lifts under consideration.

2. LITERATURE REVIEW

Ehasan maleki et al 2 Studied that the Cherry pickers are a vital category of machines that transport humans to high heights. Understanding the dynamics and stability of the machines is crucial for economical and safe operation .The design of a portable cherry picker was given. A dynamic model was developed to capture the oscillating dynamics of the machine. Simulation studies illustrated the advanced dynamic behaviour of the machine. An input-shaping controller was added to the system and also the oscillating dynamics were greatly reduced. [1]

William K. Holmes, et al 2 has worked on Bucket Levelling System. He describes that In on Articulated boom assembly bucket is mounted at the outer end. Upper arm is extended by hydraulic cylinder with respect to lower arm. For rotational position of the bucket rotary actuator is provided .When arms are operated to raise and lower the assembly hydraulic fluid is provided to rotary actuator to maintain the bucket position .It also includes a chain and sprocket. It compensates upper boom angles and relatively bucket balance is maintained.[9]

Edward V. Garnett, et al 2 has successfully studied Extensible Ladder Assembly An Aerial Basket Therefore An extensive ladder is mounted on a vehicle to be pivotal upward and downward by piston mechanism positioned to the facet of the pivotal path of ladder travel. An aerial basket is pivotally mounted on the ladder that has its motion damped to stop abrupt changes in basket angle. Included are arrangements for mechanically storing the basket on ladder retraction and for supporting the ladder during a rest position over the vehicle roof. The ladder rest arrangement may be positioned to allow depression of the ladder to the vehicle roof.[5]

Robert A. Beucher found lifting mechanisms of bucket lift. Apparatus for raising and lowering workmen and tools into proximity with elevated structures throughout construction and repair thereof includes a platform, a frame and a hydraulically-actuated linkage assembly connecting the platform to the frame.[10] The linkage assembly includes an elongated boom assembly pivotally connected to one end of the platform, a compression member assembly pivotally connected to one end of the frame and to the boom assembly, and a tension member assembly pivotally connecting the opposite end of the boom assembly to the frame. A main hydraulic actuator is connected between the compression member assembly and also the frame and operates upon extension to pivot the compression member assembly in one direction to cause the tension member assembly to pivot the boom assembly within the different direction for raising the platform. Auxiliary hydraulic actuator means connects the boom assembly to the platform, and an automatic levelling system is provided to control the auxiliary actuator suggests that for maintaining the platform level throughout rising and lowering there from.[10]

Edward E. Griffith has invented Auto-Levelled Crane Boom Man Baskets. An automatic levelling device for crane boom supported work baskets includes a weighted and clamped plumb sensing element coupled to a. initial potentiometer and a second potentiometer for measure the relative angle between the Crane boom and also the basket pivotally hooked up thereto- The measured Output levels of the 2 Potentiometers are applied to a servo circuit that controls a linear power mechanism pivotally hooked up between the boom and basket to thereby maintain the basket vertical. The basket is also electrically isolated from grounded to be used on “live” wire maintenance once the basket carries a accumulator for powering the servo and mechanism and if the basket controls for boom movement are transmitted to the Crane through a fibre optic or radio remote control link.[6]

Nico zimmert, et al 2 has studied 2-DOF Control of a Fire-Rescue Turntable Ladder. Modern fire-rescue turntable ladders are build to be in light-weight of construction to extend their most operation velocities, maximum length, and reaching. Hence, the truss structure of the ladder set provides a restricted stiffness and is subject to bending oscillations in the numerous modes. To damp these oscillations with its hydraulic drives, a 2-degree-of-freedom control is planned during this paper. The feed forward control relies on the differential flatness of an easy multi body system by only considering the basic oscillations. Using Euler–Bernoulli beam theory, the dominant modes of oscillation are taken into account throughout feedback control design.[2] The model parameters are assumed discontinuous however piecewise constant over the ladder length while the cage at the free end is accounted for by dynamic boundary conditions. Based on the analytical sort of the Eigen functions the modal illustration of the system is derived. It is used to design a feedback controller and to merge the measuring information of the gyroscope with the measurements of the strain gauges. The planned control approach permits for damping of the dominant modes and for asymptotically stabilizing the system around a reference trajectory. a crucial demand on the planned approach is to derive a control law that accounts for the low machine power of the ladder's microcontroller. The proposed control conception is enforced in fixed-point arithmetic on the control unit running the turntable ladders created by the market leader IVECO Magirus Brandschutztechnik GmbH. [2]

3. OBJECTIVES

The main objectives by this research are:

- Understand the fundamental of boom lift.
- Checking the stresses and loads on boom lifts.
- Decision of balancing and swinging mechanism for smooth operation.

4. METHODOLOGY

- Acquiring dimensions:

The dimensions of bucket and boom for and mechanism will be used were acquired by measuring with engineers tape.

- Selection of mechanism:

Selecting the most feasible and economical mechanism for balancing as well as swing.

- creating cad model:

By dimensions acquired cad model of mechanism Is created using software's like CATIA , Creo, Solid Works, etc. The Cad model of the mechanism is created using CATIA V520

- material selection for various components of mechanism:

Suitable material selected or mechanism under the guidance of guide, research paper and company guide.

- Analysis of designed mechanism:

Analysis of the mechanism is done along with the design of mechanism to test for bear up load software's like ANSYS fluent is used to analyse the mechanism.

- Finalization of parts:

After successful analysis we would be certain that the parts be generated by using mechanism.

- Modification (if any) after testing:

After the testing of mechanism if any defects are found then we need to identify those and rectify using suitable measures

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5. MATERIAL SELECTION OR MECHANISM

Following materials are selected for mechanism

Table 1 table of material

Properties	40C8	Grey cast iron	EN36A
Chemical composition	C=0.4% Mn=0.8 %	(C) =2.8 - 3.9%, (Si)= 1.1 - 2.6%, (Mn) 0.5 - 1.2%, P ≤ 0.3%, S ≤ 0.15%.	C=0.16%, Si=0.4% ,Mn=0.6 %, Ni=3.75 %, Cr=1%
Tensile strength	660 MPa	400	700
Ultimate Tensile strength Yield	560 MPa	130-160	540
Elastic modulus	190 - 210 GPa	190 - 210 GPa	210
Poisson's ratio	0.27 - 0.30	0.28	0.27-0.3
Hardness brinell	197	286	385

Table 2 material selection for parts of mechanism

PART No.	Component Name	Quantity	Material
1	base	1	40C8
2	bucket	1	40C8
3	Plate 1	2	40C8
4	Plate 2	1	40C8
5	Cylinder 1	1	Grey Cast Iron
6	Piston 1	1	EN36A
7	Cylinder2	1	Grey Cast Iron
8	Piston 2	1	EN36A
9	Pin1	1	40C8
10	Pin2	1	40C8
11	Pin3	1	40C8
12	Pin4	1	40C8
13	boom	1	40C8

6. Design of balancing and swing mechanism:

Aerial working platforms are mostly Hydraulic or pneumatic operated .Our objective to design the swing and balance mechanism of aerial working platform. This system is operated or control only by hydraulics. It has two hydraulic cylinders one is for balancing means and other provided to have horizontal swing. With first cylinder bucket is balance to horizontal position even elevating the platform to certain height. And other cylinder provides it the required horizontal swing i.e. 45 degrees left and 45 degrees in right.

a. Working

When bucket is on the ground it is already in horizontal position. As the boom starts elevating we need to balance the bucket to maintain its horizontal position. So there is another cylinder connected for elevation of main boom. As this main cylinder goes on extending its rod working platform is elevating and bucket has to be balance. So as this cylinder is extended our cylinder in the mother boom starts extending as well in the ratio to keep the bucket in the required horizontal position. As it is a hydraulic operated system oil for both the cylinder is provided through same oil reservoir. So extension and retraction of both the cylinder are inter related so both will act simultaneously and horizontal position of work platform is maintained. Controls of these are provided in the cabin in vehicle carrying work platform or even in the bucket controls can be provided. Person in the cabin or person at certain height can operate the vehicle and elevation of work platform. So with respect to first main boom cylinder balancing cylinder is operated and bucket is balanced and work platform is maintained in the required position and ease of balance is achieved.

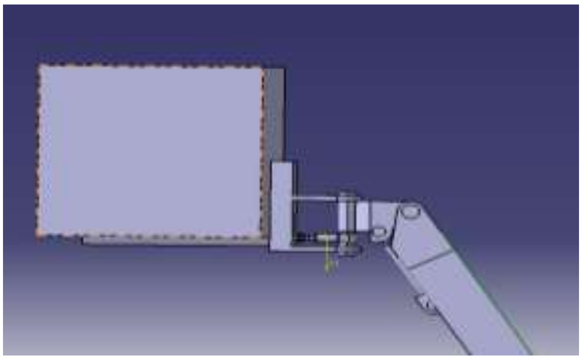

Figure 1 catia model of balancing mechanism

Swing mechanism is quite different from the balance mechanism, as it is not interconnected to any other cylinder. It individually controls the swing of work platform. As it is connected to bucket from one side and half rod extended. At this position bucket is at the Centre of boom and its axis with the boom coincide. Now to have swing to left this cylinder is retracted to full and horizontal swing of 45 degrees to left is achieved. As the bucket is now to its most left position cylinder is fully retracted to have a swing to right bucket must rotate from 90 degrees to right. To get the bucket right most position cylinder is extended fully and bucket rotates to 90 from left most position and 45 degrees from Centre of axis of boom and bucket. Controls of the swing mechanism are provided in the bucket itself and driver's cabin as well. As it is hydraulic operated its oil reservoir is there beside the cylinder. Operation of this cylinder is mostly controlled by the working person in the bucket.

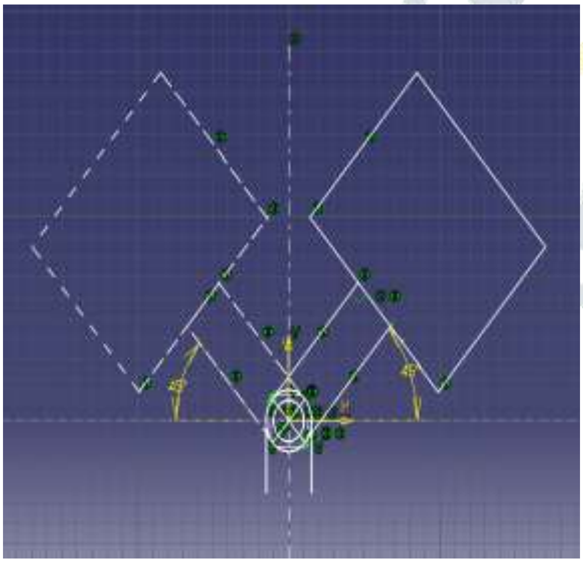

Figure 2 sketch of 45 degree swing

Hydraulic circuit :

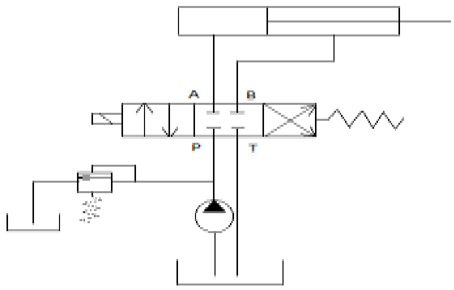

Figure 3 hydraulic circuit for balancing and swing mechanism

7. Calculations of hydraulic circuit:

Parameters given by company:

- **Maximum load** = 5000 N
- **Flow Rate** = 0.043 m^3/min
- **Feed Rate** = 1m/min

Calculations:

- **FOR BALANCING**

1. **BORE DIAMETER OF CYLINDER**:

Consider Maximum pressure =200 Bar

P= (f/a)

d=20mm

Bore diameter **D**=40 mm (1)

Full bore area:-

$=\frac{\pi}{4} * D^2$ $=1.256*10^{-3}$ m^2

Annulus Area:-

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

$=0.94247*10^{-3} m^2$

2. **MAXIMUM WORKING PRESSURE**:

$P_{max} = \frac{load}{area}$

=39.8 Bar≈40 bar

Stroke length for balancing: - 320mm

Flow requirement calculations:-

∴For 310 mm approach in 30 sec.

∴ Velocity of piston = $\frac{310*10^{-3}}{30}$

=0.0106 m/s

Q=flow required =area*velocity

$=1.256*10^{-3}*0.106$

$=1.339*10^{-5}$ m^3/sec

=0.787 lpm

Displacement of the cylinder:-

$=\frac{\pi}{4} * D^2 * stroke\ length$

= 10.05 litre

Hence total required oil.

=2*10.05

=20.1 litre

3. **PUMP:-**

Maximum flow required in the ciruit is 0.787 lpm and maximum pressure is 40 bar. So pump should provide the required flow against the required pressure,

Rod diameter = 20 mm

Bore diameter =40 mm

Stroke length =320 mm

Flow rate = 0.79 lpm

- **FOR SWING**

Stroke length for or swing = 120 mm

1. **VELOCITY OF PISTON** :-

$=\frac{120*10^{-3}}{10}$

=0.012 m/sec

2. **FLOW REQUIRED FOR SYSTEM**

Q = flow required

Q =area *velocity

=0.89 lpm

3. Displacement of cylinder:-

$= \frac{\pi}{4} * 0.02^2 * 120 * 10^{-3}$

= 3.76 litre

Rod diameter = 20mm
Bore diameter = 40 mm
Stroke length = 120 mm
Flow rate = 0.89 lpm
Pump = 0.89 lpm at 40 bar

Hence oil required:-
= 3.76+3.76
= 7.52 litre
Reservoir sizing:-
= 3*Q
= 60.3 litre
Total reservoir size:-
=60.33+7.52
=67.82 litre

- **CYLINDER THICKNESS:-**

$\sigma = p.\left(\frac{d_o^2+d_i^2}{d_o^2-d_i^2}\right)$

$\therefore d_o^2 = 0.0427m$

$\therefore d_o^2 = 42.7m$

$\therefore Thickness = 3mm$

- **BUCKLING LOAD:-**

$F_e = \frac{\pi * E * I}{l_e^2}$

F_e = 5060.09 N

Thrust on Rod

$= \frac{5060.09}{9.81}$

= 515.8 kg.

8. Analysis of bucket lift:

Structural analysis of the bucket balancing and swing mechanism by Finite Element Analysis (FEA) software ANSYS . Load on the surface of the bucket will be due to person working in the bucket by any means. The maximum stress developed and observed is at the opposite end of the bucket support. The maximum stress developed is at the free end and at hinged support stress developed is almost zero. The maximum stress developed is below yield strength of the material selected hence the design is in the safe region. Dynamic loading should be avoided by keeping the bucket at rest position.

Structural analysis of bucket lift:

TOTAL DEFORMATION

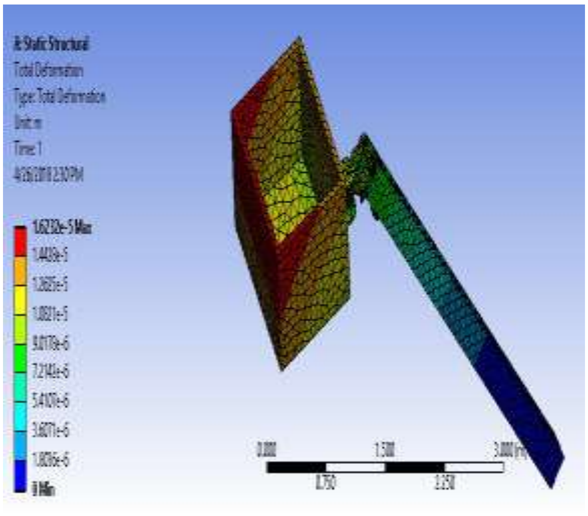

Figure 4 total deformation at extreme position

EQUIVALENT STRESS

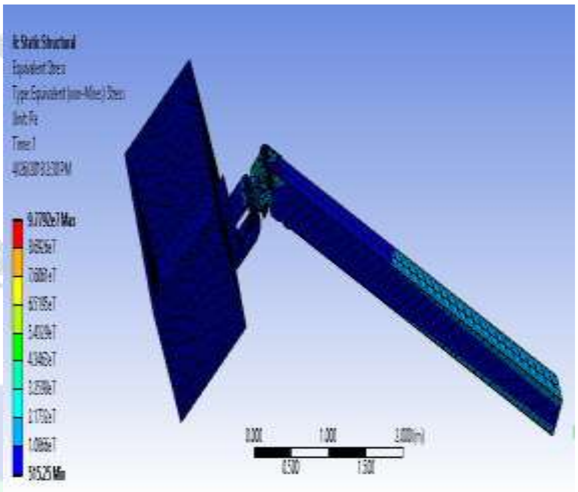

Figure 5 equivalent (von mises) stress

9. Scope:

This program applies to all Company employees and outlines a minimum set of standards for preventing employee incidents involving the use of Aerial Lifts. This program outlines a set of safety requirements to be followed using Elevating Work Platforms (EWP) and Aerial Devices (AD). All employees involved with EWP's and AD's will be trained to perform their task in a safe and efficient manner. Not all equipment to be operated or all regulations may be identified in this policy, and as such if the equipment or regulation is not listed in this policy refer to the Standards and/or the manufacturer for requirements for its safe operation. This program is not meant to take the place of knowledge of any and all applicable regulations as they pertain to this procedure.

10. CONCLUSION

The maximum stress developed is at the free end of the bucket and the magnitude of maximum stress developed in 0degree /rest position and 60 degree /extreme position is $8.5871e^{+}0079N/m^2$ and $9.7792e^{+007}$ N/m^2 respectively. Main reason of the stress developed at free end because it has total load of 5000 N is there. The yield strength of the material selected is far better than the maximum stress developed. Discussing result of deformation, maximum deformation under the load of impact applied i.e. 5kN at the surface of bucket is absorbed and sustained by piston and cylinder of the mechanism. Hence, we can conclude that the **whole mechanism can sustain** the given force of impact.

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