"Investigate and design an overload Protection system for a Powered Access Platform"

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ABSTRACT: *This paper aims to improve and design a safety device for overload protection of a boom access platform system. It also includes stopping avoidable movement of the cage. If the total weight inside the cage is reached its limit or over its limit than boom must stop working otherwise it may cause damage of boom or a person working inside the cage.*

This paper is to improve the safety device of a boom access platform. It provides a useful insight of safety devices. 3D design tools have been used to design a platform cage and to analyze it. The outcome of this work will be a critical assessment of the current projection device, bench marking of possible solutions and recommendations for implementation.

This will provide the benefit of safety of operator/s, quality of work as well as many other advantages to the manufacturer.

Keywords: Powered Access Platform; Overload Safety Device; Analysis in Solidworks; Benchmarking;

1. Introduction:

Powered Access means any form of personnel lift which has its own power source, either electric motor or internal combustion engine. In short, it is self contained machine that does not require on site assembly. The operator worked from an opened top cage (basket or platform) which can be raised or lowered as required. Usually it has been called by so many different names depends on its uses. Such as Mobile Elevating Work platform (MEWP), Cherry Pickers, Aerial lifts etc.

In general, lifting platform offer simplest operation and handling with maximum reliability. It facilitates rapid access to exposed and difficult to reach working position, while offering highest working convenience and maximum stability and safety. As per British Standard for Health and Safety series booklet a mobile work platform is capable of supporting persons, equipments or tools etc. a very common purpose is to raise personnel, equipment and material to elevated work areas.

The safe working load capacity of truck mounted hydraulic platforms is 230 kg, it means approximately two persons with 70 kg other weight of tools and equipments. It is based on the four bar mechanism. The operative condition of this platform is if the total load in the cage is reached its limit or over its limit then the boom must stop working. However, the main problem is if the total load is distributed unbalanced in this cage then the boom couldn't stop working. Means the safety switch could not work and system could not stop. Therefore, here we are going to solve this overload safety switch by investigating and redesigning it. One of the several powered operated platforms is shown as under.

Fig. 1: Platform

The primary purpose of this system is to prevent damage to the platform as well as operator in the event of an overload. If the platform is overloaded then the upper part of the switch goes down on bolt and the boom stop its work. But the condition is that the total load must be in balance in the cage otherwise it couldn't stop. So here we are going to break this condition.

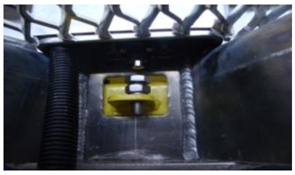


Fig. 2: Safety switch

2. Design Analysis

2.1Load Calculations:

Design load calculation is the process of calculating the load by theoretical methods. We need to analyze the effect on the overload safety device when the load acts at different place in the platform. The platform cage of the mobile elevating work platform (MEWP) has two beams in V shape. Both the beams are joined at the four bar linkage on the other end. Let us consider the beam as a cantilever beam. As we have to check the position of the load changes in the cage then what is the effect on the support or the fixed end or the four bar linkage of the beam. As per Benham P. et all (1999) that it is necessary to find out the main terms which are changes according to length like Deflection, Bending Moment, and Shear Stress.

1). Deflection of Cage.

In the subject of engineering mechanics the term Deflection is used to explain the degree and distance when the structural element is moved under load (Gere and Timoshenko, 2003). In general deflection means a twisting or deviation. In our case, it is crucial to find out the deflection of the beam over safety switch in different location of the load. It will show that what is the effect on the four bar linkage while overload at one position.

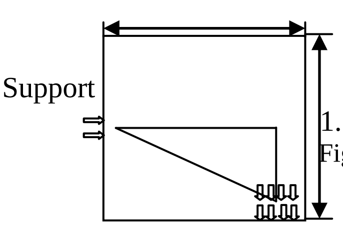


Fig 3:switch position

We considering this beam as a cantilever beam then the whole section from top will look like as under.

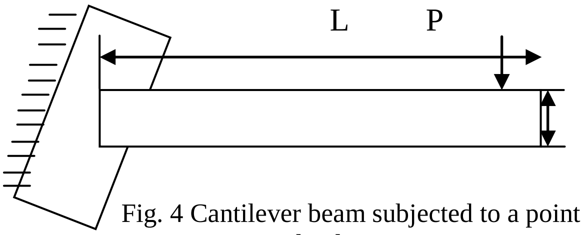


Fig. 4 Cantilever beam subjected to a point load

Above figure shows the load P acting at one point means one corner of the cage. As per specified in the problem description the total load (230 kg), 2 persons and required tools, positioned at one place on the cage than the cage could not stop. Load must be equally distributed to stop the system. To solve this problem let's first think about the current situation that how much deflection occurs by the point load.

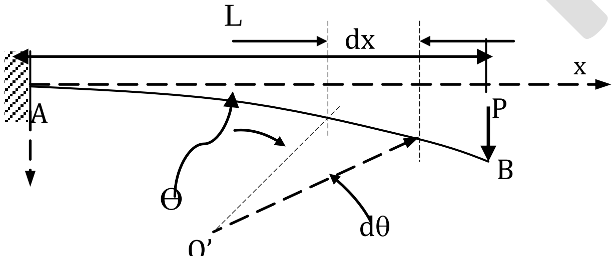


Fig. 5 Deflection of the cantilever Beam

Above fig shows the deflection while the load acting at point P at distance L and the angle of deflection Θ. Here, as per the given situation if the total load acting on the one end of the corner then the deflection of the beam can be defined as per given formulae.

$$\delta = \frac{FL^3}{3EI}$$

Where, δ = deflection of beam
F= force acting on the tip of the beam
L= length of the beam
E = Modulus of elasticity (Young's Modulus)
I = Moment of Inertia

F= 2.3 kN; E = 200 x 10^6 kN

$$I = \frac{bh^3}{12} = \frac{0.025(0.15)^3}{12} = 7.03 \times 10^{-6}\ m^4$$

$$L = AC^2 = \sqrt{AB^2 + BC^2} = \sqrt{0.85^2 + 0.4^2} = 0.9394\ m^2$$

Let us consider this value of L is the greatest and then put less than 0.9394m for the different location of the load in the cage.

Let's put all the values in the equation given below:

$$\delta = \frac{FL^3}{3EI}$$

b

$$= \frac{(2.3)(0.9394)^3}{3(200 \times 10^6)(7.03 \times 10^{-6})}$$

$$\delta = 0.0452\ m$$

With the deflection we can measure the angle of deflection as well. for the angle of deflection, the equation is:

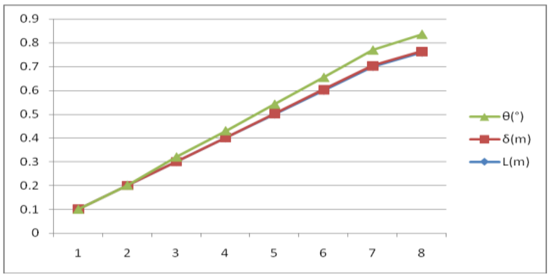
$$\theta = \frac{FL^2}{2EI} = \frac{2.3(0.9394)^2}{2(200 \times 10^6)(7.03 \times 10^{-8})} = 0.0722°$$

Now, put the different length (L) size to critically analyze the load on the different location of the cage,

L(m)	0.1	0.3	0.5	0.6	0.76
δ(m)	1.50E-05	6.80E-05	0.0019	0.0028	0.0039
θ(°)	7.40E-05	0.02	0.04	0.052	0.072

Table: 1

Above table gives the brief idea of the deflection of the beam under the cage as well as the deflection angle of the beam. Now if we draw the graph of the deflection and angle of deflection with respect to length then it is as below.



Graph 1

From the above graph we can say that when the length between the load and the switch is 0.9394, deflection δ is 0.00045 m and angle of deflection θ is 0.072°. as we go towards the safety switch value of L (length) decreases. Along with that it has been prove that the deflection and deflection angle also decreases. Hence if the total load in the cage is nearer to switch then there is minor in the beam.

2). Bending Stress:

R. C. Hibbler (2000) describe that to design any engineering structure over beam it is essential to calculate the bending stress. First of all we should have a cross section of the beam. From that cross-section we can calculate bending stress by this formula:

$$\sigma = \frac{My}{I}$$

Where, σ = bending stress of the beam

M = moment of inertia for the beam

b = bending moment of the beam

y = cross section area of the beam

I = Moment of Inertia

M= F x d = 2.3 x 0.76 = 1.748 kNm

y = L/2 = 0.075 m (∵ Half of the total Length)

$$I = \frac{bh^3}{12} = \frac{0.015(0.15)^3}{12} = 4.218 \times 10^{-6}\ m^4$$

Now find the bending stress by using above parameters, as distance d is greatest for the first situation.

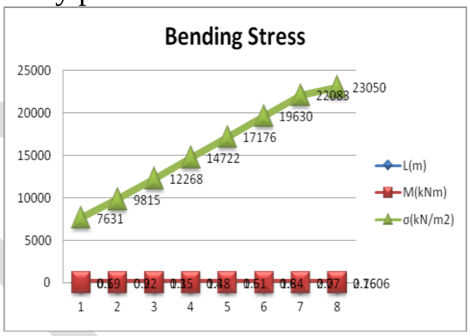
$$\sigma = \frac{My}{I} = \frac{1.748 \times 0.075}{4.218 \times 10^{-6}} = 31081.08\ kN/m^2$$

At this time, we are calculating the different bending moments at different situations of the load in the cage.

L(m)	0.76	0.7	0.6	0.5	0.3	0.2	0.1
M(kNm)	2.1606	2.07	1.84	1.61	1.15	0.92	0.69
σ(kN/m²)	23050	22083	19630	17176	12268	9815	7631

Table 2: Bending Stress

The above table illustrates that the stress varies by distance. If the distance is highest on the cantilever beam then the bending stress is also greatest. On the other hand, as we decrease the distant then we find that the stress also decreases. The bending stress in the nearest place of the beam is almost 10 times lesser than the far away point.



Graph 2

3). Shear Stress:

The stress which is applied as a parallel or tangential to a face of the material and to oppose a normal stress which is applied perpendicularly is called shear stress.

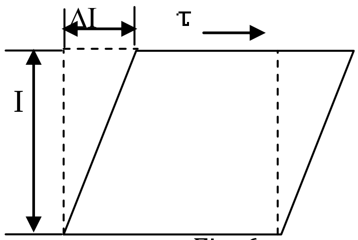


Fig. 6

$$\tau = \frac{VQ}{It}$$

Where, τ = shear stress

V= force

Q = Volume

t = thickness of the beam

V= force = F = 2.3 kN

Q = Ỹ x A

where, A = 0.00215 m^2

And Ỹ is variable so it is in the table.

$$I = \frac{bh^3}{12} = \frac{0.015(0.15)^3}{12} = 4.218 \times 10^{-6}\ m^4$$

t = 0.015 m

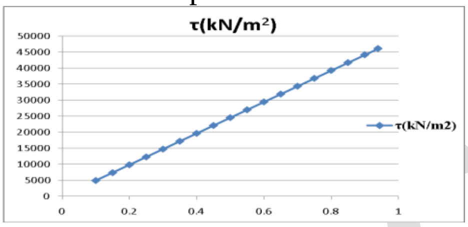
$$\tau = \frac{VQ}{It} = \frac{2.3 \times 0.00201}{4.218 \times 10^{-6} \times 0.015} = 48101.4\ kN/m^2$$

By using this equation, we can obtain different stress results of different position of the load in the beam.

Ỹ(m)	0.76	0.6	0.5	0.3	0.2
Q(m^3)	0.0028	0.002	0.002	0.001	0.001
τ(kN/m^2)	48101	34352	29445	19630	14722

Table 3. Shear Stress

The above table illustrates that the relation between Y and torque (τ). Torque decreases with respect of distance Y.



Graph 3

3. Three Dimensional (3D) Designs:

To improve any design it is necessary to understand the existing design first. It helps us to know that where the problem occurs and where we need to improve the existing system. The 3D model has to be designed by using a 3D solid modelling package called Solidworks. A 3D design modelling of the product is generated for better visualization in which it will allow refinement of the design based on aesthetics, functionality and analysis. Therefore, first test the current design that check that where it needs to improve.

The powered access platform's maximum safe working load is 230 kg. So it has overload protection device.

We got the two dimensional view and few picture of the platform. Hence, it helps to make the design in 3D. Firstly, we understand and check the current concept for the overload device of the platform. It has several parts. So they need to be designed as a separate part and then assemble it. First check the design of the platform itself.

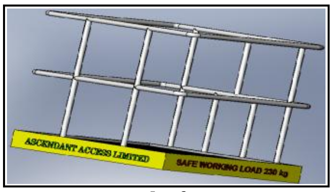


Fig 7. Platform

The whole platform is made by plain carbon steel. Its boundary is made with hollow pipe. It has a indication of maximum safe working load is 230 kg as per health and safety rule. This load includes two persons plus other tools, all must not be excluded 230 kg. The weight of the platform itself is 79 kg. It has a yellow color boundary. And as per Health and Safety Executive (2006) it is mandeary to write down the safe working load on the platform. Its size is 1000 mm X 800 mm. Its maximum side force is 400N.

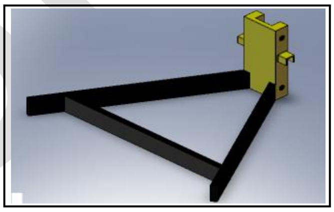


Fig. 8. Base

Fig. 9. Spring

The above figure shows the platform base for the current design. It has 'A' shaped base, made of plain carbon steel. It has four holes with threads to joint it with bracket by bolt. It also has a spring holder at both sides. So it can hold the spring from top end. It consist a safety switch at the front.

The figure besides the base, fig 9. is spring. Its length is about 60 mm. It can tolerate the load up to 2300 N. Hence if the weight goes more than 2300 N then spring presses and the automatic switch go down and power cut off to stop the platform.

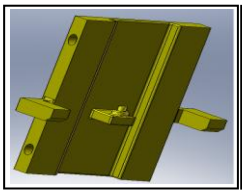
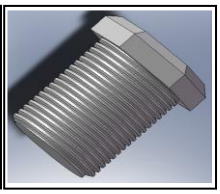
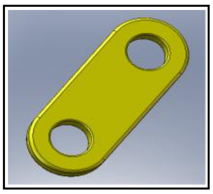




Fig. 10 Bracket Fig. 10. Bolt Fig. 11 Bar

The above fig. 10 shows the bracket which is the main support for the platform. It connects directly with the boom. It has two bars for holding the spring on it. It also contains one solid part to press the switch. As the platform goes down, the overload switch of the platform base goes on the bracket's solid support and switch is activated which in turn cuts power to stop the machine. It encompasses four threaded holes to hold the bars as four bar mechanism. Fig 10. shows the bolt. It is 30 cm long and it has pitch of 1 mm. There are 8 bolts used in the platform assembly.

Fig. 11. indicates the bar which is used to joint the bracket with the platform. Total four bars are used in the platform. The one end of the bar is joined with the bracket and the other end is with the platform. It is the only part which holds the total weight of the platform

Fig. 12. Platform Assembly

3. 'U' Base design with strain gauge (Improved Design):

After making range of concepts, we have decided to made 'U' shaped base with the strain gauge load cells. As described the load cells are the best instruments to measure the load. Especially strain gauge converts the load or deformation (strain) into electrical signals. The gauges are bonded directly to the beam. The platform cage comes over the load cells. And it deforms when load is applied. We are using four strain gauges at each corner of the base to obtain more load sensitivity as shown in below fig. 13.

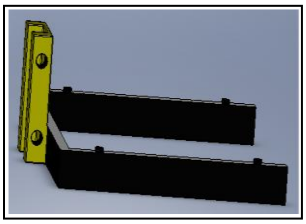


Fig 13. Improved Platform

4. Benchmarking:

Types	Current Design	After Improvement
Stress (MPa)	12.53	10.04
Strain	2.305 X 10^{-4}	1.424 X 10^{-3}
Displacement (m)	0.0034	0.0028
Factor of Safety	1.8	3.9
Weight (kg)	68	65

Table 4. Data Comparison

The above table 4 shows the practical figures obtained by the finite element analysis. It emphasis that not only theoretical but practical data also says that the 'U' base concept design is the best suitable. So we are going to select that design for new improved design.

We have all the data related to design analysis. By that data also we can check that which design is the best amongst all. So let's compare the stress from practical design of before improvement and after improvement.

BEFORE IMPROVEMENT AFTER IMPROVEMENT

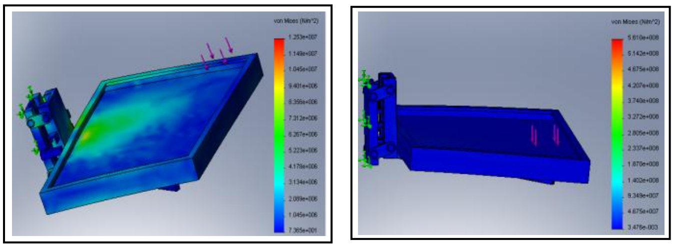


FIG. 14 **Stress Comparison**

From the figure it is emphasize that the stress before improvement was 12.53 MPa. And after improvement there is 5 MPa, even the load is at the corner of the platform and the stress is almost zero. So we can prove that the 'U' shape base design is the best design

BEFORE IMPROVEMENT AFTER IMPROVEMENT

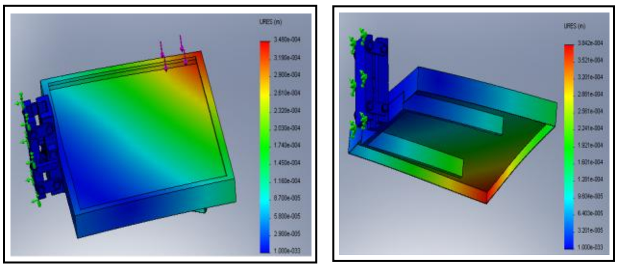


FIG. 15. **Displacement Comparison**

If check the displacement then the displacement before improvement in current design was 0.0038 m and after improvement it is 0.0034 m. it means that the beam are not much deflecting even the load is at one corner and U shape base has four strain gauge load cell at each corner. So it gives better result and it senses the load directly.

BEFORE IMPROVEMENT AFTER IMPROVEMENT

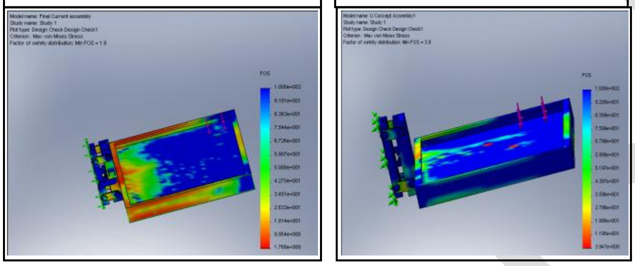


FIG. 5.3 **Factor Of Safety Comparison**

As we discussed above the factor of safety should be more for this type of risk involved designs. Current design has only 1.8 factor of safety and after design improvement the factor of safety becomes 3.8. Thus, the safety factor is improved much more for the selected design.

5. Conclusion:

Design of the safety cage and competitive benchmarking of the rivals products has been under taken. It helps to improve ideas and information about design and benchmarking process.

- ➢ This helps to understand the design of the mobile elevated work platform.
- ➢ It gives better understanding of the 3D solid modeling design and analysis process.
- ➢ In the final analysis, after undertaking range of concepts and experiment, can prove that how to do product design process and techniques and how to decrease the stress on the product.
- ➢ It also provides better knowledge about solid works and solid modeling and how to design the part in three dimensions and to analyze that part or assembly in COSMOS Works.
- ➢ This work gives better understanding of factor of safety. How the factor of safety differ by every objects.
- ➢ Benchmarking process gives the better outcome if we have more products to compare.
- ➢ It can also be concluded that it gives brief understanding of engineering mechanics and its uses.

It is possible to do the Finite element analysis of the platform through COSMOS in solidworks and find out the best design out of various concepts.

6. Future Work:

As per certain limitations and restrictions, further future work is recommended to be carried out.

- The platform is the instrument which is often used at open land area. Over there, wind speed is too much. Therefore wind load could be considered while calculating overload.
- Fatigue analysis can also be completed.
- Vibration frequency of the platform can be checked by using cosmos.
- It is also possible to put automated overload protection device in the platform cage. These devices are very sensitive against load; they are operated by the sensor. However it is costly.

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