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Design and Structural Analysis of Platform Stair Lift Using Finite Element Method

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]**Abstract:** *The foldable Platform lift is similar to a lightweight lifting rectangular platform that allows human to sit, stand or get their wheelchair on it anywhere on it in any suitable position. The traditional type of wheelchair is difficult to move through the inclined stairs due to its large size and rigid structure and thus, they are inappropriate for letting patients with inability to climb stairs using a wheelchair or any other source. Platform Stairlift has a total weight of 25 kg as it utilizes lightweight aluminum alloy members. Unlike the traditional wheelchair, it consists of a rectangular platform which enables patients with a wheelchair to use that platform to move through stairs and thus able to let patients with walking disability to move across stairs without many efforts. The aim of this research paper is to focus on mechanical design of a model and finite element analysis (FEA) of the mechanism using CATIA software and ANSYS® software. The present work, all the elements of the mechanism are designed under static load condition. The results of the FEA analysis indicate that the Platform Stairlift satisfies equilibrium and stability criterion and is capable of helping patients with walking disability move across the stairs.*

Keywords: *Block and Tackle mechanism, CATIA, cable drive, Finite Element Analysis (FEA), Walking disability*

I. Introduction

In modern developed society, the more welfare measure and more consideration to the handicapped are given. The law of barrier-free came into force, elevators, wheelchairs, and rail-type stair climbing support equipment are being installed in public spaces and railway stations, in order to enlarge the outdoor moving space for the handicapped that can move long distance under the help of wheelchairs only. But as the cost and space limitation, not in all public space can such equipment's be installed, such as small stations, theaters, or hospitals. On the other hand, nearly all public space where exists several small steps or obstacles besides the normal long stairs.[1] In order to help the handicapped move across these kinds of barriers easily, the development of a kind of safe, simple, automatic, cheap and no need to convert the environment, cable drive platform , in other words, try to develop a kind of mobile vehicle, which can help people climb the stairs/move across obstacles just by sitting on it, or can carry people as while as wheelchair to climb the stairs, can be thought of a great contribution to the society. [1, 2]A Platform stair lift is a mechanical device used for lifting people up and down the stairs. The lift assembly includes a chassis supporting a load bearing member such as a seat or a platform. The chassis is formed by the main member on which are mounted a platform with a horizontal frame to keep the platform leveled as the lift assembly moves along the guide. Various mechanisms have been developed over time for different purposes in the industry. [1]

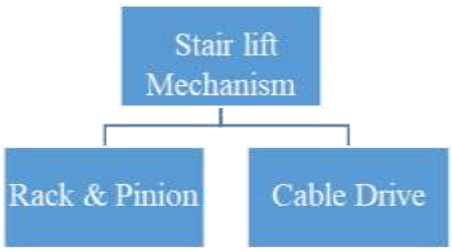

Fig.1:– Flowchart for different drive mechanism. [5]

Ultimately, though, both rack and pinion motors and cable drive motors work perfectly fine in practice. They each have some unique advantages and disadvantages. This paper focuses on the mechanism optimized for platform stairlift with a cable drive mechanism to lift a wheelchair considering standard safety features and other functionality.Also, the material used and dimensions considered are cost-effective for designing the platform stairlift.

II. Literature Review

S. Hirose and J. Yuan proposed to develop a certain type of stably stair climbing mobile vehicle in order to assist the physically handicapped in moving along the stairs. They first proposed a novel leg-wheel hybrid stair climbing vehicle, Zero Carrier consisting of eight prismatic joint legs, providing significant stability during stair climbing motion since the mechanism is based on eight simplified legs. A trial model of zero carrier is developed by them using necessary sensors required by them for stable motion.A. Bijalwan, A. Misra developed a prototype on flexible wearable chair, more like a light weight exoskeleton allowing people to sit in any working position and anywhere, having a gross weight of 3Kg which utilizes light weight aluminium alloy elements. the prototype used kinematic pairs enabling it to take halts in between continuous moments and in any working position. The authors mainly focused on the mechanical design and and FEA analysis of the prototype. Johanne L Mattie described about stairs into buildings being a significant barrier for those with mobility impairments.So the author proposed to develop anovel, inclusive solution that combines staircase and lift into one device.Michael Hinderer explained technical aid required by people where there is staff shortages.Thus introducing 'autonomous stair- climbing wheelchair'with independent mobility for moving limited people. The autonomous stair- climbing wheelchair is based on a leg mechanism consisting of two legs one with lower leg support and other with upper leg support.

III. Methodology

The design of the Platform Stairlift was based on a structured, user-driven design process based on cable drive (Rope and Tackle mechanism). A simple and convenient way of lifting handicapped patients through stairs is by using a motorized rope based pull mechanism. In this, the platform will be attached to a vertical frame which would be attached to a roller mechanism through a rigid support. The rigid support creates a link between the whole platform body and the roller mechanism. The roller will be moving in a straight inclined guide.The basic mechanism is based on pulling force. The motorized rope will be attached to the link of the platform body and roller. The motor will be at the top of the inclined platform and the rope attached to the link either directly or with the help of a pulley. [2]*Electronic components in Platform Stairlift.* Includes the necessary safety components like sensors and limit switches.

1. Limit Switch

As these limit switches have electrical contacts in the body. Therefore, we will use a non-plug-in switch due to the protective gasket for safety, and as the circuit does not require any regular change. A lever or roller plunger type normally closed limit switch can be used, as we need large travel to account for the slowing down of the unit. [7]

Fig. 2:- Limit Switches [7]

2.Sensors

The stair lift will be used to move humans. Therefore, as human life is being handled by the machine, the lift must be safe to ensure safety during operation.

To ensure safety and smooth operation, the following safety features are employed.

I. Infrared sensors
II. Emergency stops
III. Limit switches

I. Infrared sensor

Principle: The transmitter emits an infrared light beam and this reflects back from an obstruction on to the receiver. It is similar to an if-else statement. If the light is detected by the sensor means there is an obstruction in the range and if the receiver doesn't have. The feedback from this sensor will be used for the stopping of the stair lift in case of obstructions.

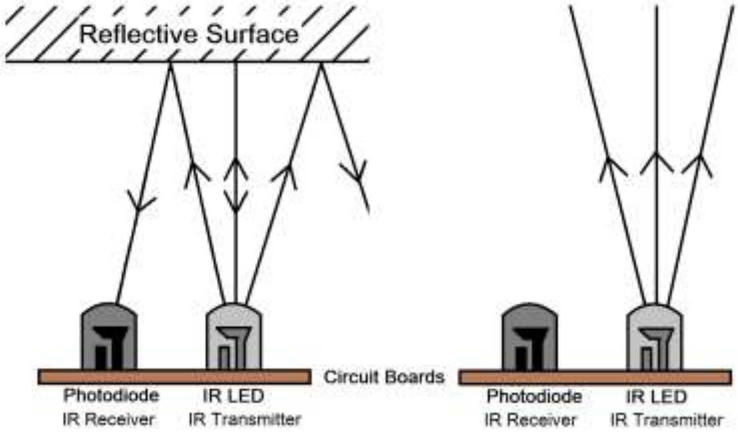

Fig. 3:- Sensing Obstruction. [6]

A series of infrared sensors that will detect any obstructions that are in the path of the carriage along the width of the Platform stair lift. Any obstruction that is present along the path of the Platform stair lift will be detected and the Platform stair lift will be stopped due to the feedback submitted to the motor controller.

Infrared Proximity Sensor Long Range - Sharp GP2Y0A02YK0F

Fig. 4:- Infrared Proximity Sensor [6]

Table no 1 – Specification for infrared proximity sensor

Distance measuring range	20 to 150 cm
Output type	Analog
Package size	29.5×13×21.6 mm.
Consumption current	33 mA.
Supply voltage	4.5 to 5.5 V.

According to the specs, there is a maximum delay for output to stabilize after the first measurement of 43.3ms+-9.6ms as shown in the timing chart below.

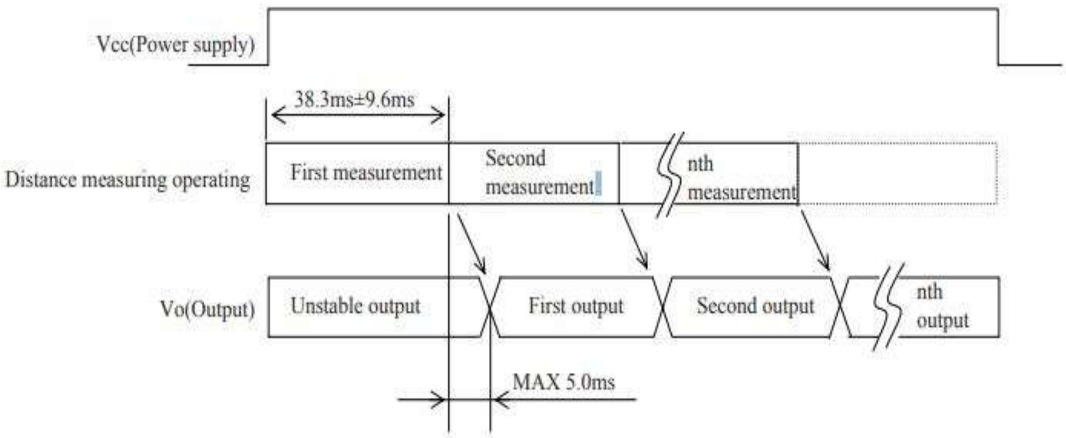

Fig. 5:-Timing Chart of IR Sensor [6]

IV. The Trial model of Platform Stairlift

]Fig. 7 shows the designed trial model of the Platform Stairlift, based on the above mentioned proposal. Its specifications are shown in Table 2.

Table no 2 – Specification of platform stairlift

Base Platform Dimensions (L x B x T)(mm)	850 x 750 x 2
Upper Frame Dimensions (L x B)(mm)	1040 x 585
Material	Aluminum Alloy
Weight	27 Kg
Platform Lift Capacity	160 Kg
Actuator	220/230V/50Hz 1000 W
Drive	Cable Drive

4.1 Calculation for forces acting on platform stair lift

The below diagram shows a layout of forces acting on platform stairlift. On resolving these forces it is possible to calculate the standard winch capacity required for pulling platform stairlift across the stairs

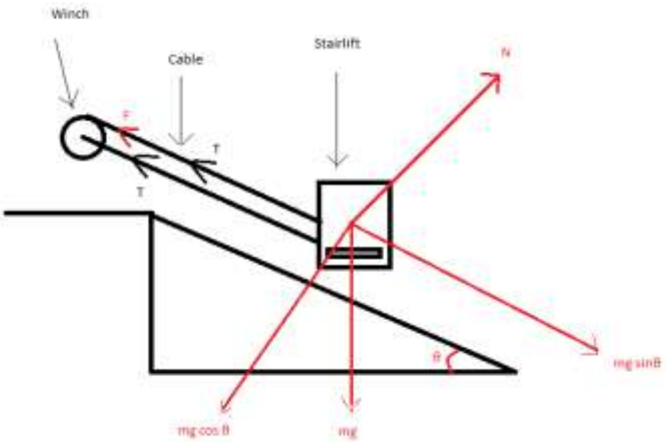

Fig. 6:– Force Components acting on the stairlift

From the figure,

1) Maximum Frictional Force

$F_f = \mu s \times mg \times \cos\theta$

2) Force required to pull the mass

$mg \sin\theta + \mu s \times mg \times \cos\theta = 2T$

$(mg \sin\theta + \mu s \times mg \times \cos\theta)/2 = T$

We know that in this system,

$F = T$

So,

$F = (mg \sin\theta + \mu s \times mg \times \cos\theta)/2;$

3) Mechanical Advantage = Load/Effort

$= (mg \sin\theta + \mu s \times mg \times \cos\theta) \times 2 / (mg \sin\theta + \mu s \times mg \times \cos\theta)$

$= \underline{2}$

Calculation for a load of 250 kg in inclined direction:-

1) Maximum Frictional Force

Since the pulley and track has a point contact we will assume frictional force to be 0

$F_f = \mu s \times mg \times \cos\theta = 0$

2) Force required to pull the mass

$mg \sin\theta + \mu s \times mg \times \cos\theta = 2T$

$mg \sin\theta = 2T$

$T = (mg \sin\theta) / 2$

$T = (250 \times 9.81 \times \sin 37^o) / 2$

T = 738 N

So pulling force required on the effort side is,

F = T

F = 738 N

3) Mechanical Advantage = Load/Effort

$= (mg \sin\theta + \mu s \times mg \times \cos\theta) \times 2 / (mg \sin\theta + \mu s \times mg \times \cos\theta)$

= 2

4) Factor of Safety

Consider a FOS of 5: 1

FOS = maximum strength / intended load

5 / 1 = maximum load / 738;

Maximum load = 5 x 738;

Maximum load = 3690 N = 376.14 Kg

Thus, the next Standard size for the above load-based motor is 500 Kg.

V. Design

The designing system used in our project is 'Four Pulley and Four Rails'. This system is optimal, for safety, price and compact design with the unique double pulley system, the weight of the patient, and the moment of the force in the x-direction will be compensated by the Four-Pulley-System. This design is used to keep the patient in a straight position while going up and down stair. Four-pulley design of the chair will allow for a slim design for family members to easily and safely move past up and down the stairs. The mechanism is based on cable mechanism. The cable from the winch is passed around the fifth pulley located on the vertical rectangular pipe. This pulley enables the use of tackle and block mechanism with a mechanical advantage of 2 thus making the required force to pull the platform to half. This design of platform stair lift will use a remote control device which will be used to move platform stair lift upwards and downwards.[2].

Parts like pulley, frames, pivot system and many small parts are used to perform several tasks. Considering the long-term usage of the platform stairlift, each part will be made using a non-corrosive material. The pulley and the rack system of the chair will be fabricated using aluminum alloy. The component of the stair lift will be highly durable and will be capable to withstand a high amount of load (200kg) during its usage period. Beginning with the smallest yet the important part of the stair lift, the pulley system is the major components of the stair lift. This pulley system is used to keep the stairlift at the upright position while using the stair lift for transporting the patients to the upper level. All the pulleys will be helpful to keep the stair lift jerk free, these will also be beneficial for the patients while using it. [2,3] The design is based on the use of a high strength aluminum alloy, which has higher bending strength thus providing better load carrying capacity with minimal bending of the platform. The cost of the design is considerably reduced with the use of appropriate design as compared to those in the market, thus enabling it to be used by more public.

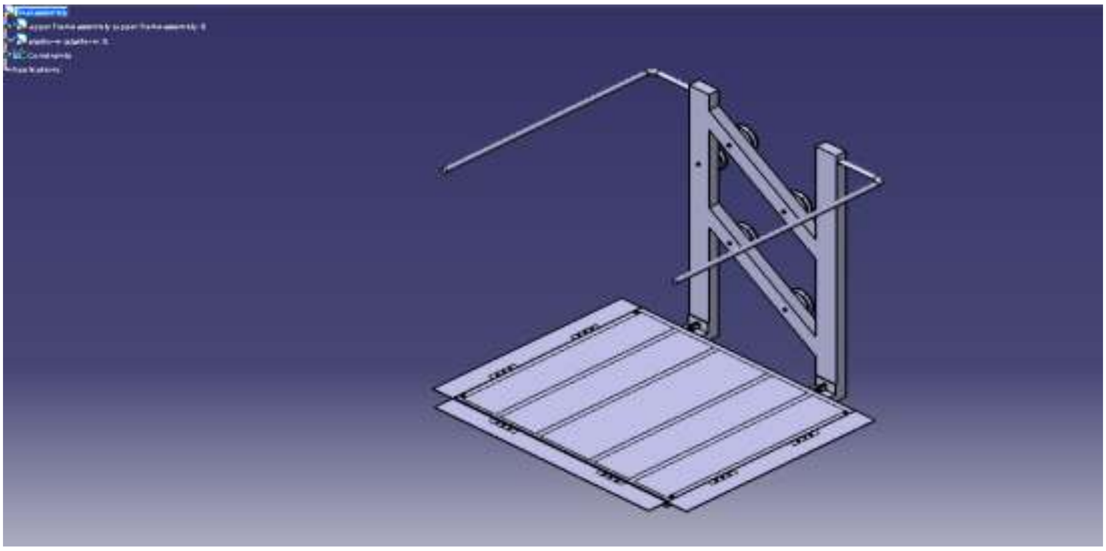

Fig. 7:- Isometric view of Platform Stairlift model

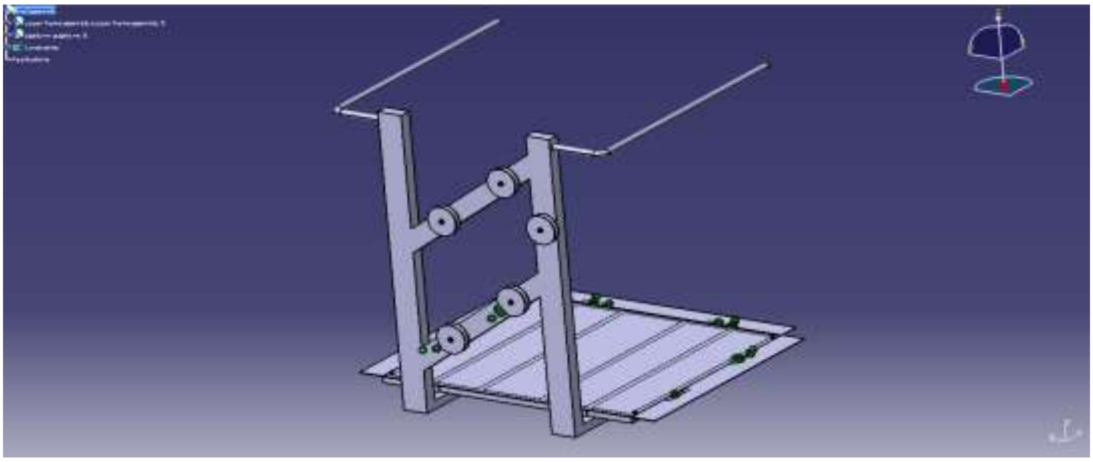

Fig. 8:- Rear View of Platform Stairlift model.

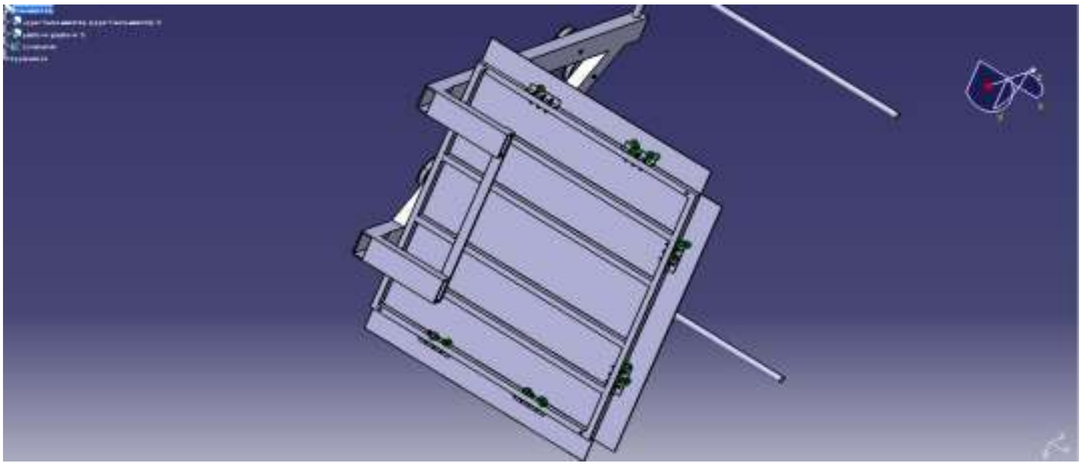

Fig. 9:- Bottom view of Platform Stairlift Model

VI. Displacement and stress Analysis of the platform stair lift

The Finite Element Analysis is the method mostly used to check the stresses and the displacement in the design when the patient is sitting on the frame. All the modeling of the stair lift are done using the CATIA® software and the analysis of the stair lift are done using ANSYS® workbench software. This analysis is used to find out there is not any maximum deflection in the design to avoid the risk of an accident. The links in the following table are prone to structural failure during operation due to maximum stresses generated in them.

Table no 3 - Dimensions of the links with the critical section.

Link	Dimensions (L*B*T) (mm)	Additional features
Beam structure	Overall: 850*750 Each beam: 20*20*2	Rectangular structure of beams with 4 additional support beams in the direction of the breadth.

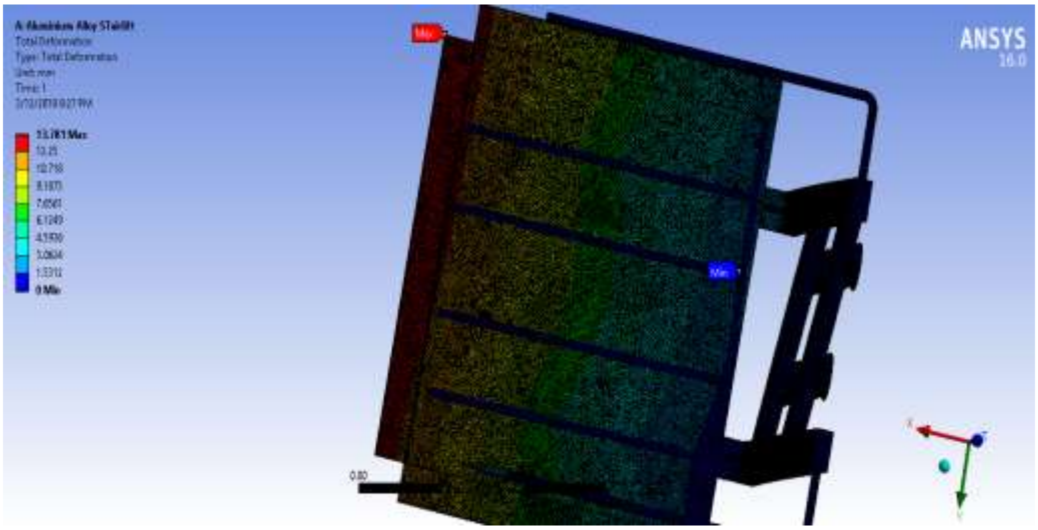

Fig. 10:- Total Deformation analysis.

It can be noticed that at the edge of the beam platform maximum bending occurs. If neglect the rectangular flaps the bending takes place in a very small region of the platform. The maximum bending of the platform is approximately 12 mm max (160 Kg load) and the minimum is 0 mm at the pulley side of the platform.

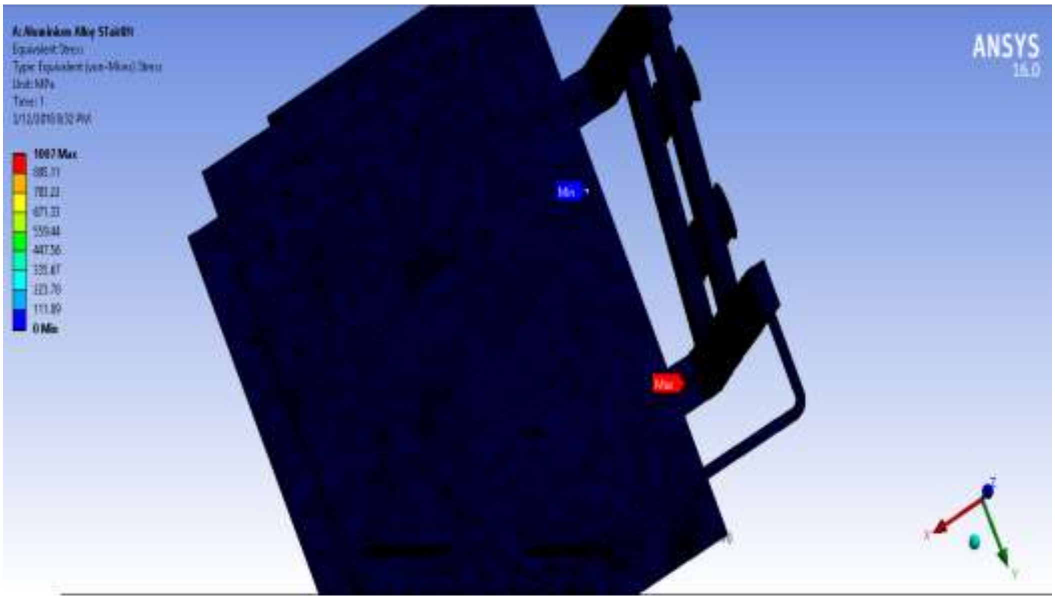

Fig. 11:- Equivalent Stress analysis

The above figure shows the stress analysis of the platform under loaded condition (160 Kg). The platform is secured of any strength concentration so no failure can occur to the platform under loaded condition. The stress concentration occurs at the rotating joint approximately 223 Mpa. The below figure shows the stress concentration on the rotating joints.

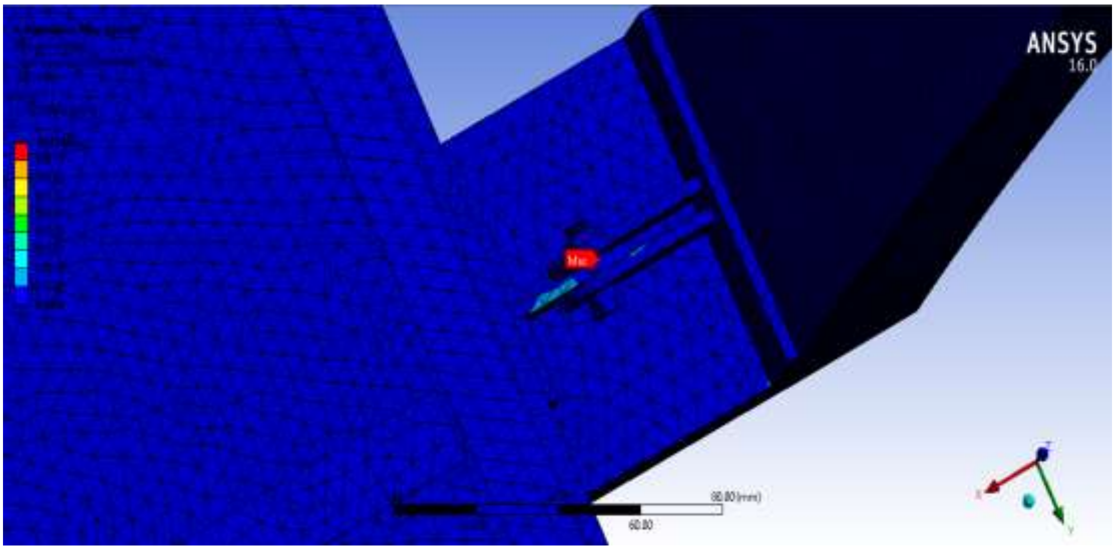

Fig. 12:- Location of maximum Stress Concentration (Hinges)

VII. Conclusion

i. Platform Stairlift mechanism with tackle and block mechanism has been numerically modeled, simulated, and a functional scale model built. The design is based on low-cost readily available components.
ii. The design is cost-effective using the cable drive mechanism and including necessary safety features.
iii. The design developed is strong enough to hold a human with wheelchair up to 160 kg with minimum stresses and deformation produced.
iv. An analysis of platform stairlift requirements has been provided. Future work is required in the development of the Platform stair lift mechanism, and the production of a full-size prototype mechanism.

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