Design and Fabrication of Wheelchair Accessing Mechanism for Scooter

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Abstract - *A wheelchair model evolved long back in 18th century, but rapid development in this field initiated since mid of 20th century. Since then, many varieties of models had been designed, extending into broad range of products.*

This project involves the production of an economically designed, wheel chair accessing mechanism for scooter, for use by handicapped and old aged people. The person on the wheelchair can drive himself into the scooter, and thereby the wheelchair functions as the driver seat. To achieve this, a motor controlled rear ramp and a wheel chair arrester is embedded in the design.

For the loading of the wheelchair, a rear ramp is lowered. The actuation of the ramp is achieved using a rope and pulley mechanism. After it is loaded, the wheelchair is arrested to the body of the vehicle, to ensure safety. The ramp is now moved back to its initial position.

A 3D model of mechanism is generated in solidworks and analysis is taken by Finite Element Method.

The mechanism is installed in a continuously variable transmission scooter. This new design helps make the disabled self-sufficient to use a vehicle and thus lead a better life.

Key Words: **Ramp, rope and pulley, solidworks continuously variable transmission, Finite Element Method.**

1.INTRODUCTION

Mobility is an important requirement especially for the motor disabled individuals who likes to live and work without the help of others.

This project outlines a self mobility option for physically disabled individuals (with healthy uppertorso but pelvic to foot restraint) who rely on wheelchair.

The mechanism described in this work when installed in an ordinary scooter can accommodate a wheelchair, thus providing an option to self commute.

2.LITERATURE REVIEW

Hassan et al.(2012) : This journal proposes a tricycle that is for the wheel chair users, which has an engine mounted to a frame and a platform for the movement in and out the frame. The anthropometrics data like sitting height, handle length, foot rest position etc have been taken into consideration at the design stage of the tricycle. It is inferred that to design mobility options for physically disabled persons relevant anthropometrics data should be considered.

Tim Storr et al.(2004) : This study evaluated a range of portable wheelchair ramps to highlight the effect of different product features on ease of use when wheelchair users climb curbs or access vehicles.Generally wheelchair users preferred the wide platform ramps because they were able to drive up these with ease and little preparation.

A.Hari Kumar et al.(2016): In this journal design and analysis of an automobile chassis is carried out to understand the criteria of selecting chassis frames of different cross section. The chassis frame chosen was a ladder type. The boxed cross section frame produced least deflection and minimum von mises stress among 'C' and 'I' sections.It is understood that the Rectangular Box section is having more strength than *C* and *I* Cross-section type of Ladder Chassis under similar loading conditions.

Madhusudhan et al.(2017) : This project was aimed at building a scooter that a wheelchair bound individual can access independently. Safety features as per the ANSI (American National Standards Institute) were followed and a WTORS (Wheelchair Tie down Occupant Restraint System) is also placed) We Inferred that proper wheelchair arresting mechanism is necessary and it is also notable that currently existing wheel chair accessible vehicles are unaffordable and non popular.

3. OBJECTIVE

In short, Literature study outlines wheelchair vehicles with limited concern regarding affordability. In addition to this, it shows various anthropometric data that should not be compromised.

Our main objectives include:

- Economically Design, analyse and fabricate an extra fitting for a scooter that includes all mechanisms for wheelchair access and comfort commute.
- Develop and install a method for wheel chair tie down system
- Installation of parking brake

4. METHODOLOGY

4.1 Literature study and recognition of scope
4.2 Design
4.3 CAD Modelling
4.4 Simulation and Analysis
4.5 Failure study
4.6 Fabrication
4.7 Implementation and Testing

5. STUDY

5.1 The Wheelchair Tiedown and Occupant Restraint System(WTORS)

It is important to use a complete WTORS to secure the wheelchair and provide the wheelchair occupant with a properly designed and tested seatbelt system. WTORS has been crash tested and labelled as complying with SAE J2249, a voluntary standard developed by safety and rehabilitation experts.

WTORS: Four point Tie Downs: Wheelchairs have four designated points for attaching the four tie-down straps, with two in front and two in the back. Rear attachment point may be at the intersection of the seatframe and backrest frame and Forward attachment points, around the main frame and as close to the top of the caster as possible.

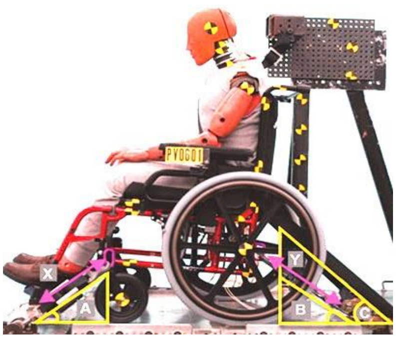

Fig -1: Side view of Wheelchair Tie down

It is to be ensured that the rear tie down must have a side view angle of 30-45 degree relative to the horizontal and the front tie down must have a side view angle of 40-60 deg relative to the horizontal.

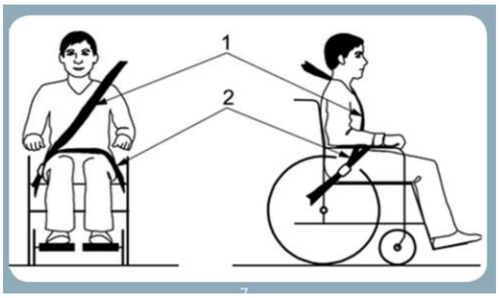

Fig -2: Pelvic and Uppertorso belts

To protect the wheelchair user during a crash or sudden braking, both pelvic and upper torso belts should be used. The lap belt (2) should be placed low across the front of the pelvis near the upper thighs, not high over the abdomen and the diagonal shoulder belt (1) should cross the middle of the shoulder and the centre of the chest, and should connect to the lap belt near the hip of the wheelchair user.

Slope of Ramp: The inclined platform that acts as pathway for wheelchair to get in and out is called ramp of wheelchair accessible vehicle. Americans with Disabilities Act (ADA) recommends a maximum slope of 1:12 for self propelled and 1:8 with motorized wheelchairs without assistance.

6. DESCRIPTION

The main parts of *wheelchair accessing mechanism* includes chassis frame with motor housing, rope and pulley, a control unit and the Ramp that attaches main frame through hinge.

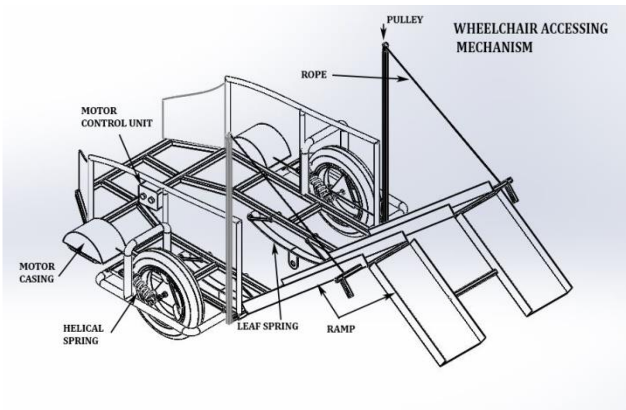

Fig -3: Wheelchair Accessing Mechanism sketch

The lifting and lowering action of ramp is achieved by winding and unwinding of rope about motor shaft respectively. The pulley system guides the rope through the desired path and the electrical unit controls clockwise and anticlockwise rotation of motor shaft. A separate second rope from rear ramp is tied to a vertical support of mainframe. The tension in this rope is determined by the rotational position of fore ramp. During the lowering of fore ramp when it reaches at an angle of about 46 degrees with horizontal, the tension in second rope begins to rise up preventing the direct vertical hit of rear ramp on the ground.

A hinge joint is provided at the front portion of chassis frame and a leaf spring attachment provision in the middle of its longitudinal member. The mechanism is attached to scooter through these hinge joint and leaf spring. Two side wheels are present in mechanism and is connected to its chassis frame through a helical spring equipped suspension. Power to operate ramp motor is taken from a separate 12 V battery (placed inside motor housing). Its charging is done from scooter alternator through a voltage regulator.

Separate provision for arresting wheelchair to chassis frame is provided inaddition to pelvic and uppertorso safety belts.

7. DESIGN

7.1 Design of chassis frame

Chassis is of ladder type with 4 longitudinal members of 1000 mm length for each, simply supported at 3 points as shown in figure.

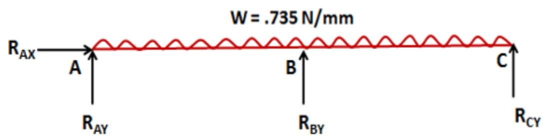

Fig -4: FBD of chassis longitudinal member

The above shown reaction forces can be determined by applying method of superposition in which the problem is equivalent to superposition of FBDs shown below.

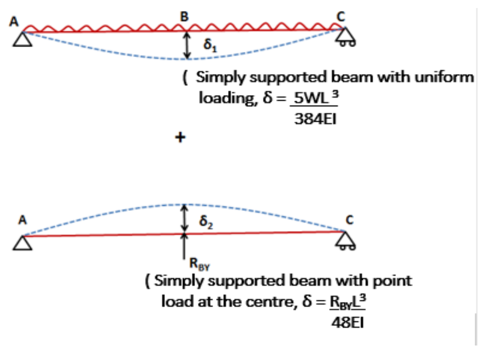

Fig- 5 : Superposition diagram

The Frame material is mild steel having an allowable bending stress of 165 Mpa (max).

Total load considered to be acting on the chassis =300 Kg

Thus, load on each member = 75 Kg

With the load assumed to be uniformly distributed,

load on each member , W = (75*9.81)/1000

= .735 N/mm

Now the total deflection at B,

$$\delta_B = -\delta_1 + \delta_2 = 0$$

» $(-5W(L*L*L)/48EI) + (RBY*(L*L*L)/384EI) = 0$

i.e $R_{BY} = 459.84$ N

Taking net moment about A, $\sum M_A = 0$

» $(459.84*500) + (R_{CY}*1000) = (0.736*1000)*500$

» $R_{CY} = 137.953$ N

Sum of all vertical forces is zero, i.e $\sum FY = 0$

» $R_{AY} + R_{BY} + R_{CY} - W = 0$

» $R_{AY} = 735.75 - (459.844+137.953)$

$= 137.853$ N

With above obtained values Shear Force Diagram and Bending Moment diagrams are drawn, maximum bending moment is obtained as 22992.22 N mm

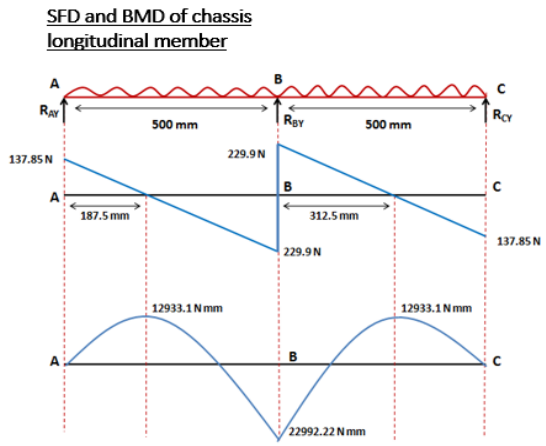

Fig -6 : Shear Force and Bending Moment Diagram

Considering the member cross section,

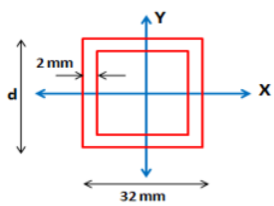

Fig -7 : Member crosssection

Moment of Inertia , I = (32*d*d*d/12)-(28*(d-4)^3/12)

= 1/12 * ($32d^3-28d^3+336d^2-1344d+1729$)

= 1/12 * ($4d^3+336d^2-1344d+1729$)

Bending moment equation,

$$\frac{M}{I} = \frac{f}{y}$$

where, M_{max} = 22992.22 N mm, $f_{permissible}$ = 165 Mpa

solving, we get d = 25.76 mm.

From standard , a cross section of 32*32*2 mm is adopted.

With, 32*32*2 section,

bending stress y = (M/I)*y

= (22992.22*16/36514.75)

= 10.173 N/mm ^{2} < 165 Mpa.

Hence the design is considered safe.

7.2 Design of Ramp

7.2.1 Ramp length (l)

We have from figure,

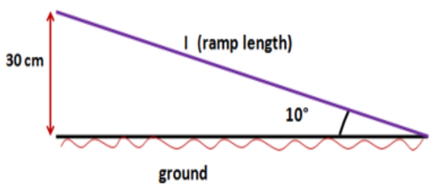

Fig -8 : Ramp slope

l = 30/sin(10) cm

= 173 cm

The breadth b of each ramp is conveniently taken as 24 cm.

7.2.2 Ramp thickness (d)

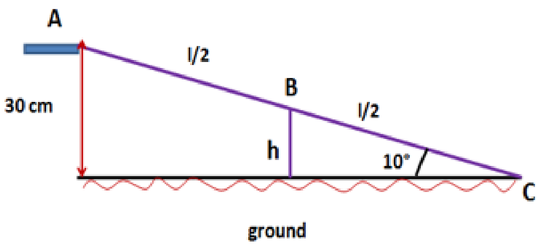

Fig -9 : Ramp with three supports

The extended ramp is considered as simply supported at 3 points namely A,B and C as shown.

We have 30/l = h/.5l

» h = 15 cm.

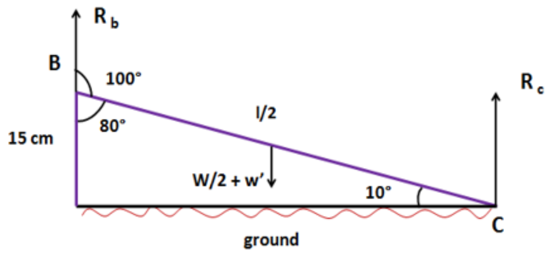

Fig -10 : FBD of beam ramp portion BC

Since the ramp is symmetrical , considering the loading at portion BC

From the deflection formula ,

deflection δ = ((W/2+w')*(L/2)^3)/(E*I)

Where W/2 = weight of half length of ramp in Kg

= ρ*b*(l/2)*d Kg

The material chosen is Wrought Aluminium , which is a commonly used ramp material having its density ρ = 2710 kg/m ^{3}.

Thus W/2 = 2710*24*173/2 *10^{-4} *d Kg

= 562.596*d Kg.

w'= Half the combined weight of the wheel chair and user considered = 80 Kg

I = moment of inertia

= $bd^3/12$

= .24*d^3 /12

= .02 d^3

E = Young's modulus of the material

= 70*10^9 N/m

Now by assuming a permissible bending of 1 mm ,we have

$$.001 = \frac{(150 + 562.596\ \mathrm{d}) * 9.81 * .865^3}{48 * 70 * 10^9 \ * .02\ d^3}$$

» d = 2 cm (approx)

Thus the weight of a ramp W is obtained as 22.5 Kg= 220.7N.

7.2.3 Tension on rope at different positions and to find maximum tension

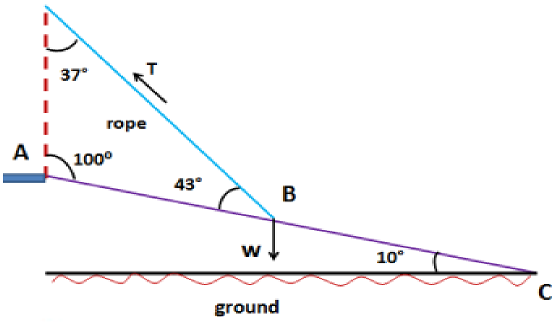

Fig -11 : Ramp at beginning of lift

A) Beginning of lift ($\alpha = 43^0$)

Considering ∑ M at hinge point A to be zero , we get

T Sin(43)* l/2 = W Cos(10)*l/2

» T= W Cos(10) / Sin(43)

= 220.7*Cos(10) / Sin(43)

= 318.69 N

B) When ramp is just lifted ($\alpha = 46^0$)

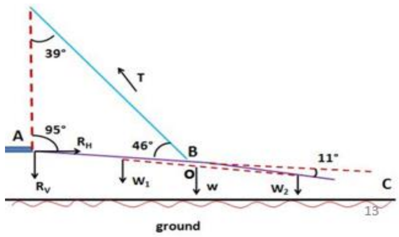

Fig -12: Ramp when just lifted

The position of the new centre of mass of the ramp, O is obtained as:

x = ((m1x1+m2x2)/(m1+m2))

m_1 = mass of 100 cm ramp portion = 13Kg

m_2 = mass of 73 cm ramp portion =9.5 Kg

x_1 = position (horizontal) of w_1 from A = 49.8 cm

x_2 = position (horizontal) of w2 from A = 135.4 cm

Proceeding , we obtain x = 85.94 cm

Similarly y = ((m1y1+m2y2)/(m1+m2))

y_1 = position (vertical) of w_1 from ground level = 29cm

y_2= position (vertical) of w_2 from ground level = 12cm

Proceeding , we obtain y = 21.82cm

Now , considering ∑ M at hinge point A to be zero , we get

T Sin(46)* l/2 = W * 85.94* 10^{-2}

» T = (220.7*85.94*10^-2)/(Sin46 *86.5*10^-2)

i.e T = 304.82 N

C) Ramp in horizontal position ($\alpha = 49^0$)

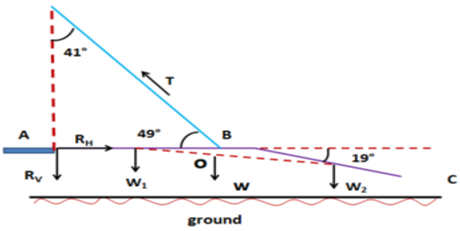

Fig -13 : Fore ramp in horizontal position

The position of the new centre of mass of the ramp, O is obtained as:

x = ((m1x1+m2x2)/(m1+m2))

m_1 = mass of 100 cm ramp portion = 13 Kg

m_2 = mass of 73 cm ramp portion =9.5 Kg

x_1 = position (horizontal) of w_1 from A = 50 cm

x_2 = position (horizontal) of w2 from A = 134 cm

Proceeding , we obtain x = 85.46 cm

Similarly y = ((m1y1+m2y2)/(m1+m2))

y_1 = position (vertical) of w_1 from ground level

= 30 cm

Y_2 = position (vertical) of w_2 from ground level

= 18 cm

Proceeding , we obtain y = 24.92 cm

Now , considering ∑ M at hinge point A to be zero , we get

T Sin(49)* l/2 = W * 85.46* 10^{-2}

» T = = (220.7*85.94*10^-2)/(Sin49 *86.5*10^-2)

i.e T = 288.91 N

Similarly Tension is obtained for

D) Ramp 45^0 with vertical and $\alpha = 77^0$

E) Position above horizontal (Ramp 22^0 from vertical and $\alpha = 100^0$)

F) Position above horizontal (Ramp 22^0 from vertical and $\alpha = 100^0$) where tension is negligible.

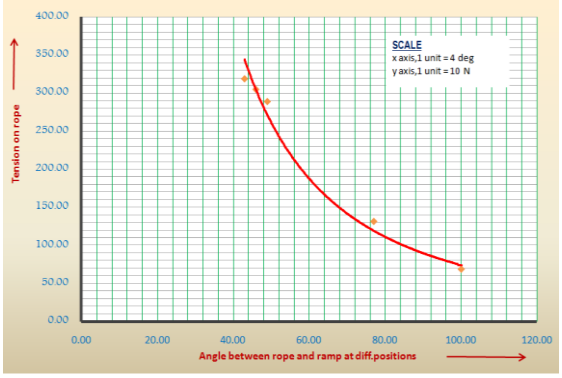

Fig -14: Graph of rope tension vs position

From the calculations it is obtained that the maximum tension in each rope is close to 318.7 N , encountered during the beginning of the lift. Thus the minimum torque requirement of each motor is obtained as,

T = F * r ,where, F = 318.7 N

r = motor shaft radius

= .01 m

Thus T = 318.7* .01

= 3.18 Nm

= 32.48 Kg cm

Motor adopted : worm gear motor Z01530 , having a working torque of 100 Kg cm.

Rope selected : 5 mm diameter Nylon rope .

It possess a minimum breaking strength of 3.91 KN. Allowing a Factor of safety of 10, the maximum load capacity is 391N.

8. CAD MODELLING

With the values obtained from design, a 3D CAD model is drawn using professional CAD design software SOLIDWORKS.

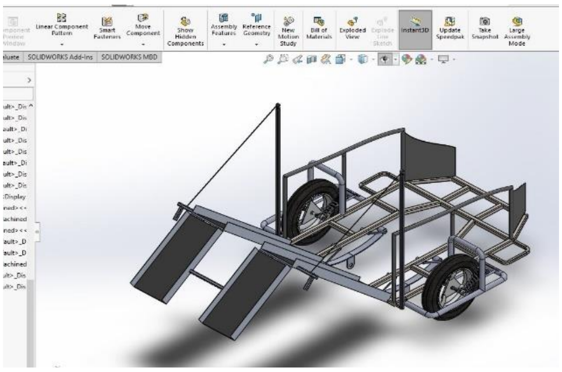

Fig -15 : 3D CAD model generated in Solidworks

The part files are saved in igs format and imported in ANSYS for analysis.

9. ANALYSIS

9.1 Analysis of chassis frame

Static structural analysis was done using Finite element method. Material is selected as mild steel.

9.1.1 Meshing

The model has been meshed with method of meshing as automatic.

Number of nodes : 143605
Number of elements: 64060

9.1.2 Boundary conditions

Boundary conditions for the model were eight area of fixed point applied on model (at the ends of each longitudinal members).

9.1.3 Loading

75 Kg uniform loading is applied along each longitudinal member and the problem is solved for finding maximum deflection, von mises stress and strain.

9.1.4 Results

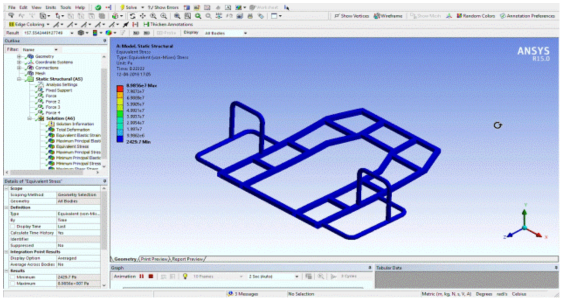

Fig -16 : Von mises stress in chassis frame

Table -1: Solution results of chassis frame analysis

Maximum von mises stress	8.9856*10^7 Pa
Equivalent Elastic Strain	.00049746
Maximum shear stress	4.731*10^7 Pa
Maximum principle stress	1.1441*10^8 Pa
Minimum principle stress	3.2248*10^7 Pa

The maximum von mises stress developed is about 89.856 MPa which is less than 250Mpa (Yieldstrength of mild steel).

9.2: Analysis of ramp

9.2.1 Meshing

Tetrahedral elements with 4736 number of elements and 8983 number of nodes.

9.2.2 Boundary conditions

Fixed supports are given at two ends of both fore and rear ramp.

9.2.3: Loading

110 kg point load is applied at the mid point of ramp.

9.2.4: Results

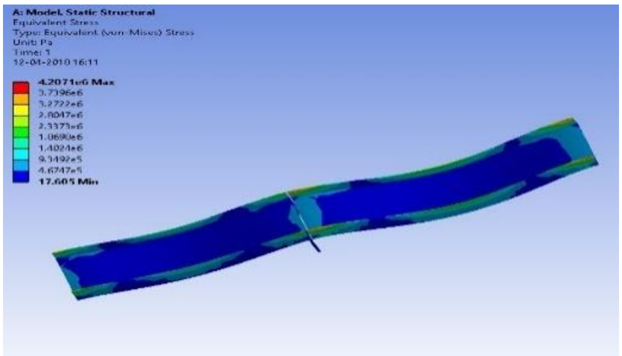

Fig -17 : Von mises stress in Ramp

Table -2: Solution results of ramp analysis

Maximum von mises stress	4.2*10^6 Pa
Total maximum deformation	.018 mm
Equivalent Elastic strain	2.13*10^-5
Maximum shear stress	2.22*10^6 Pa

The maximum von mises stress developed is about 4.2 Mpa which is less than yield strength of Aluminium (Ramp material).

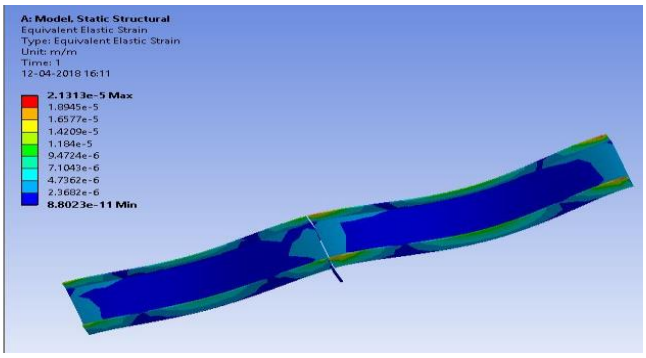

Fig -18 : Equivalent Elastic strain in ramp

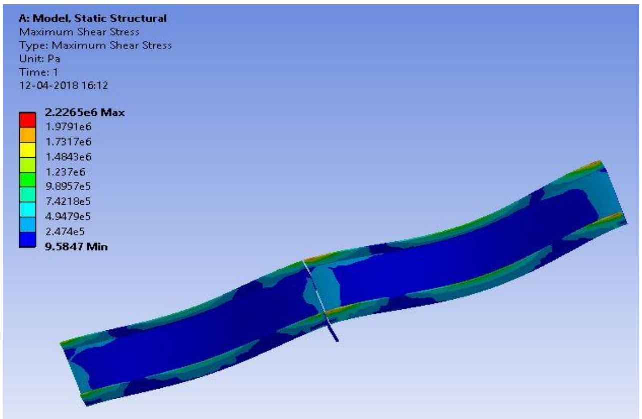

Fig -19 : Maximum Shear stress in ramp

10. ELECTRICAL CIRCUIT DIAGRAM OF MOTOR CONTROL UNIT

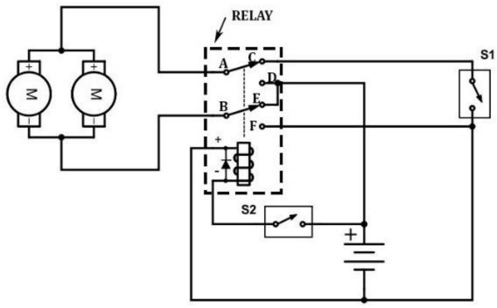

Fig -20 : Circuit diagram of motor control

Clockwise rotation and anticlockwise rotation of motor is achieved by reversing the polarity at terminals A and B. For this a DPDT Relay is used. The normal connection is between;

1.Terminals A and C
2.Terminals B and F

Upon excitation of realy coil, changeover occurs and hence connection re establishes between

1. Terminals A and D
2. Terminals B and F

When switch S1 is ON, terminal A gets connected to negative potential through C. Similarly B receives positive potential through E. This completes the circuit and rotates motor. The opposite rotation is achieved when switch S1 is open and S2 is closed. When S2 is closed, coil gets excited and hence changeover takesplace. Terminal A receives positive potential through D and B receives negative potential through F. Polarity is now reversed resulting in opposite motor rotation.

11. FABRICATION AND IMPLEMENTATION

Wheelchair accessible mechanism is fabricated with the designed values and dimensions. Machining processes undertaken include grinding, metal cutting, Electric arc welding etc. Polishing and painting is done as the final processes.

Fig21: Wheel chair Accessing mechanism for scooter

The fabricated mechanism is installed and tested. For installation, body cover of scooter is removed. The attachment to scooter chassis is through hinge joint at front and through leafspring at midspan of mechanism's frame**.**

Fig -22 : Implementation in HONDA ACTIVA (2003 Model)

12. CONCLUSION

The design, analysis and fabrication of wheelchair accessible mechanism for scooter is successfully completed and the proposed mechanism has been installed in HONDA ACTIVA (model 2003). It is fabricated economically, at a production cost of Rs.18,500.

The design and installation has been done considering the anthropometric data required and stability was ensured with analysis and redesigning. We hope this approach helps unwind the restricted freedom of wheelchair users in mobility**.**

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