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DESIGN OPTIMIZATION OF WHEEL CHAIR RAMP FOR LOW FLOOR BUS

Tapobrata Dey[1*], Nikhil Mali[1], Vishal Surwade[1], Rameshwar Dokhe, Sharayu Wasu[1], Swati Dhamale[1] and Monica Ugale[1]

[1]Department of Mechanical Engineering, D.Y.Patil College of Engineering, Akurdi, Pune, India

[2]Department of Electrical Engineering, D.Y.Patil College of Engineering, Akurdi, Pune, India

Savitribai Phule Pune University, Pune, India

[*]tdey@dypcoeakurdi.ac.in

***Abstract*—** Use of public transport has been in focus for very long time owing to its obvious benefits. Still around the globe, a large share of urban and inter-urban transport system is out of reach for person with disabilities. Wheelchair users find it difficult to use buses, even low-floor ones. Wheel chair ramps deliver a decorous, identical approach to entering a low-floor bus. Wheel chair ramps are a platform generally constructed in aluminium that can be deployed manually or automatically for wheelchair passenger for on boarding. It is necessary for it to be lightweight yet highly durable ensuring the fuel efficiency for automobile operators. This study discusses a conceptual manually operated foldable design for wheel chair ramp. For this design, a sandwich structure is designed along with use of composite for a designated loading requirement. This will be done to convert the conventional design for light weighting yet durable design. Design evaluation is done using FEA for static structural analysis. Physical testing will be conducted to investigate strength requirement and mechanical behaviour using UTM. FEA results are compared to physical test results under this study.

Keywords— Wheel chair ramps, low floor bus, light weight designs with composites, sandwich panel structures**.**

I. INTRODUCTION

This public transport accessibility has often occupied the media limelight particularly in the past five years the debate regarding priority use off the dedicated wheelchair area on buses and accessibility have received attention from a variety of stakeholders, becoming the rallying point for many disability and elderly charities in the country. Use of public transport has been in focus for a very long time owing to its obvious benefits. Still around the globe, a large share of urban and inter urban transport system is out of reach for person with disabilities. Wheelchair users find it difficult to use buses, even low floor ones. Wheel chair ramps deliver a decorous, identical approach to entering a low floor bus. Wheelchair ramps are a platform generally constructed in aluminium that can be deployed manually or automatically for wheelchair passenger for on boarding. It is necessary for it to be lightweight yet highly durable ensuring the fuel efficiency for automobile operators. Ramps are important because they provide opportunity for the people with locomotor disorders, especially wheelchair users, to overcome differences in grade levels. Fuel efficient and light weighting of automotive vehicles has been focused apart in their designs, automotive makers trying to meet the safety requirements and maintaining goal of light weighting in check. Thus, for all the sub-assemblies however small it is good strength with minimal weight are always preferred. Use of glass fiber composites are finding their use in many automotive parts due to their superior quality of withstanding higher weight with minimum material requirement. This case study explores the use of glass fiber composite for wheelchair ramp design optimization. Around the world, a large proportion of urban and interurban transport systems remain

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inaccessible to persons with disabilities. Bus travel can often cause problems for wheelchair users. Wheel chair users find it difficult to use buses, even low floor ones. Several wheelchair users said that public transport options for them are limited. In recent years all automobile manufacturer moves to increase the efficiency of vehicle. To reduce the weight of automobile, industry is trying to optimize designs of many components using analysis and changing materials. So, we developed the wheelchair ramp which helped to reduce weight as well as increasing strength of the ramp.

Raquel Velho et al explained about transport accessibility for wheelchair. They highlighted the experiences of a marginalized group within infrastructure to investigate how transport impacts their lives and well-being. The barriers faced by wheelchair users in the transit network and largely negative emotions that these barriers bring out in these passengers.[1]

Prof. T Madhusudhan et al described about wheelchair ramp for scooters. There are close to 5.4 million people in India who have disability in movement and majority of them face difficulties in traveling by themselves. A WAV is a car that has been customized to accommodate a wheelchair. One of the main reasons wheelchair bound individuals do not have access to such vehicles is their exorbitant price.[2]

Susan L Deems-Dluhy et al explain about two novel wheelchair anti rollback devices for ram percent in manual wheelchair users with spinal cord injury. Ascending these ramps is often a strenuous and painful experience, and frequently exhibited existing repetitive motion injuries.[3]

Edward D Lemaire et al explains wheelchair ramp navigation challenges in snow and ice conditions. Winter represents the most difficult season for people with mobility deficits. These difficulties include slips, falls, increased walking effort comma and snow ice wheelchair obstructions. Considering the amount of time many wheelchair users spend outdoors in winter, a remarkably small amount of literature exists on non-sporting winter activities.[4]

The review concludes that there has not been much research done on design and development for wheelchair ramp for a low floor bus. This gives us opportunity to explore the conventional designs as scope for further improvement

II. ANALYTICAL METHOD

The design and optimization process is shown schematically. Each design stage is elaborated in details as below in figure 1.

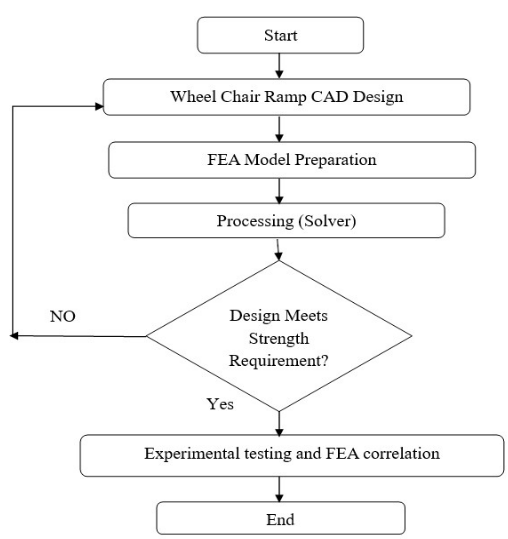

Fig. 1. Wheelchair Ramp Design Process Flow Chart

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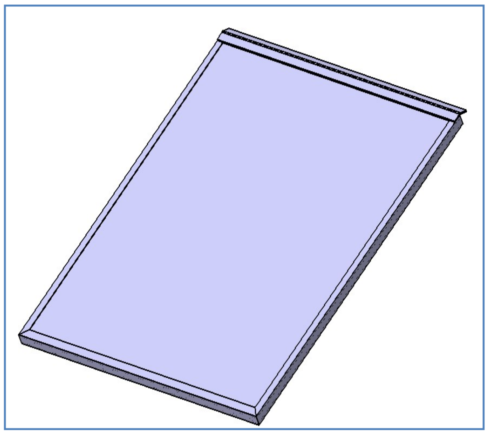
A. *Wheel Chair Ramp CAD Generation*

The baseline wheelchair ramp is generated in CATIA V5 with the help of benchmarking process as shown in below figure 2. The benchmarking process consists of checking the overall dimensions of any parts or components that are used in various competitors' vehicles and figuring out the general dimensions of that specified parts or components.

Fig. 2. Wheelchair Ramp Design Process Flow Chart

B. *Design Requirement*



The design is required to sustain a certain load which is calculated as below.

Total load on ramp= Weight of the wheel chair + weight of human + weight of assisting human= 20Kg+110Kg+110Kg=240Kg .

By the factor of safety of 1.25, the load is of 300Kg weight on ramp. Force applied on ramp is 300*9.81=2943N, so force applied on body is 3000N.

The target is no damage anywhere in the assembly.

C. *Finite Element Model Preparation*

The baseline FE model is prepared in ANSYS 19. The parts are modelled with hexahedron and tetrahedron elements to exactly represent the geometry of wheel chair ramp. The average element size of 10mm is used based on previous experience and convergence. The quality of elements is maintained as per standard criteria. The number of solid elements observed in the model are approximately 21635. The materials and properties are assigned to every individual parts of wheelchair ramp.

D. *Material Details*

The material used for wheel chair ramp is Aluminium alloy with yield of 280Mpa.

E. *Loading and Boundary Conditions*

All degrees of freedom of hinge surface and resting edge are constrained. The load is applied on the surface of flat panel of wheelchair ramp as shown in figure 3.

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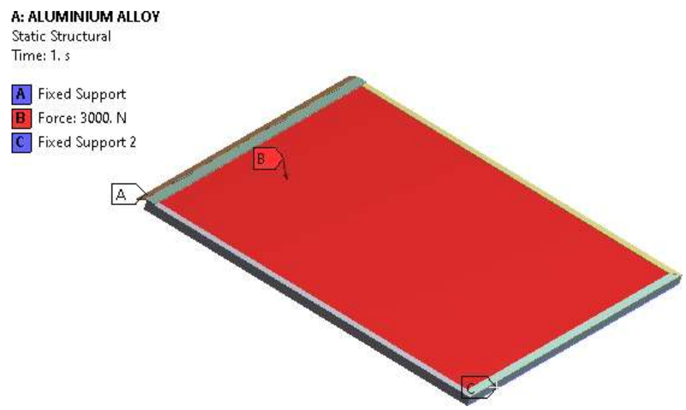

Fig. 3.Boundary Conditions and Loading for Baseline Wheel Chair Ramp

III. FEA RESULTS

A. *Baseline Results*

The Max von Mises stress observed in baseline design is 59.62Mpa as shown in figure 4. The max total deformation observed is 1.69mm. The von Mises stress observed in internal canopy structure is 19.69Mpa as shown in figure 5. The design satisfies the loading requirement criteria and also shows the scope for further improvement.

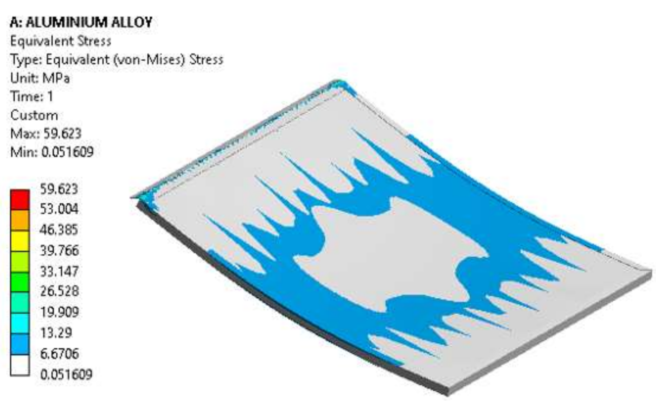

Fig. 4.Von Mises stress for Baseline Wheel Chair Ramp

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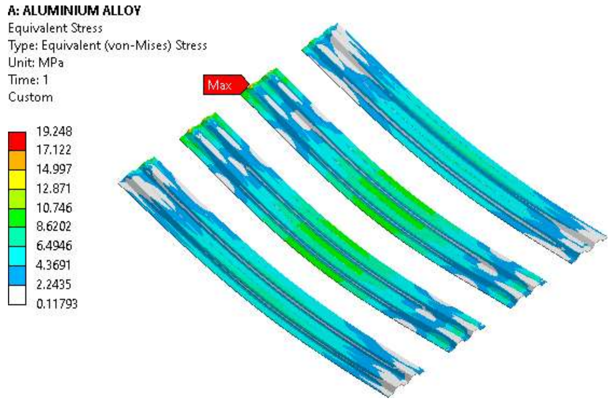

Fig. 5.Von Mises Stress For Internal Canopy Structure

B. Design Modifications

For internal canopy structure sandwich panels, the glass fibre [10] material layer of 2mm is used, thus replacing the aluminium material. The properties are as shown in figure 6.

Properties of Outline Row 4: Epoxy E-Glass UD

	A	B	C
1	Property	Value	Unit
2	Density	2E-09	mm^-3 t
3	Orthotropic Elasticity		
4	Young's Modulus X direction	45000	MPa
5	Young's Modulus Y direction	10000	MPa
6	Young's Modulus Z direction	10000	MPa
7	Poisson's Ratio XY	0.3	
8	Poisson's Ratio YZ	0.4	
9	Poisson's Ratio XZ	0.3	
10	Shear Modulus XY	5000	MPa
11	Shear Modulus YZ	3846.2	MPa
12	Shear Modulus XZ	5000	MPa

Fig. 6.Properties of Glass Fibre Material

Thus, a conventional design is converted into a composite material design making it light weight. The baseline design weight is reduced by 1Kg which is 6.25% weight reduction.

C. Modified Design FEA Results

The max von Mises stress observed in modified design is 33Mpa as shown in Fig. 7. The max von Mises stress observed in internal canopy structure is 2.3Mpa.

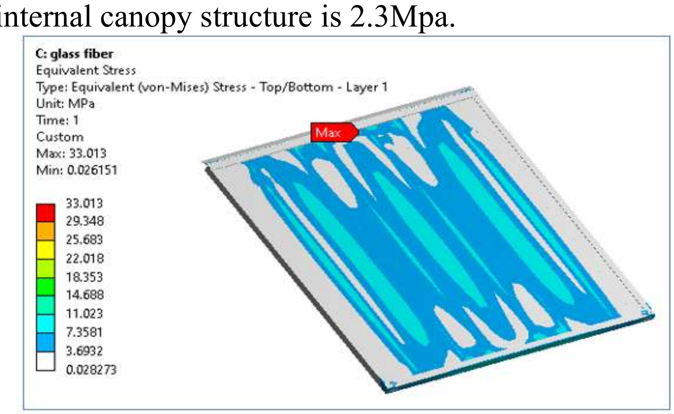

Fig. 7 Von Mises Stress in Composite Wheel Chair Ramp

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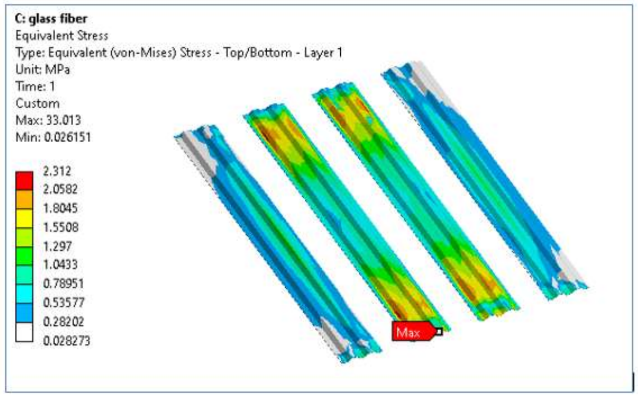

Fig. 8.Von Mises Stress in Internal Canopy Structure

The table 1. shows the comparison between the baseline and modified design.

TABLE I
FEA RESULTS COMPARISON

Sr. No	Parameters	Design	
		Baseline	**Composite Sandwich Panel Design**
1	Total Deformation	1.69mm	0.44mm
2	Von Mises Stress	59.62M pa	33.01Mpa

D. Scale Down Model FEA Results

The composite wheelchair ramp model is scaled down to 1:2 ratio. Again, FEA analysis is conducted with scaled model with respective boundary conditions. The max von Mises stress observed is 117 Mpa. The max total deformation observed is 0.32mm. The equivalent elastic strain observed at max stress area is 141 micron as shown in figure 10.

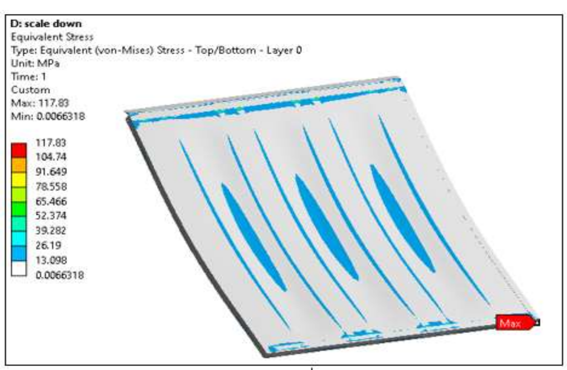

Fig. 9 Von Mises Stress in Scaled Down Model

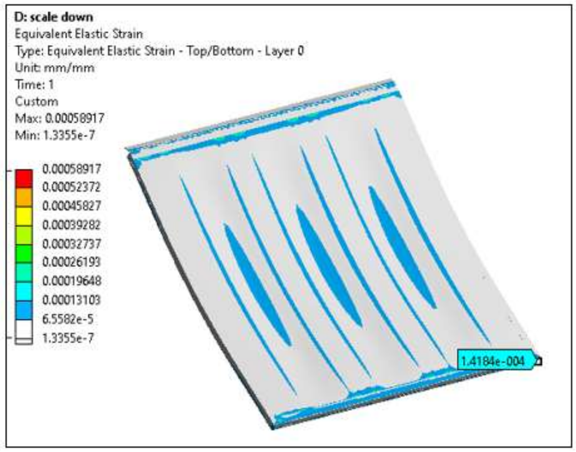

Fig. 10 Equivalent Elastic Strain in Scaled Down Model at Max Von Mises Stress

IV. FEA & TEST VALIDATION

A. Manufacturing of Wheel Chair Ramp

The scaled down model manufactured with modified design dimensions and materials. The internal composite canopy structure prepared with hand lay-up process. The physical model is as shown in figure 11.

Fig. 11 Physical Scaled Down Wheel Chair Ramp Model

B. Physical Test

The model is tested with scaled down model boundary conditions on UTM as shown in figure 12

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Fig. 12 Physical Model Testing on UTM

C. *FEA & Physical Test Co-relation*

The equivalent elastic strain observed in physical test at max stress area is 152 micron. The von mises stress and max total deformation results and comparison with FEA results along with the 92% co-relation percentage is shown in table 2

TABLE III
PHYSICAL VS FEA RESULTS

Sr. No	Parameters	Results	
		FEA	Physical Test
1	Total Deformation	1.69mm	0.44mm
2	Von Mises Stress	59.62Mpa	33.01Mpa

V. CONCLUSIONS & FUTURE SCOPE

A. *Conclusions*

The conclusions for the research study are highlighted as below:

- The FEA analysis of baseline model was performed. The FEA results showed scope for improvement. Hence further study with composite model was conducted
- The FEA results for optimized model with composite material showed improvement in both von mises stress and max total deformation. Total weight reduction of 1Kg in assembly which is 6.25% of total weight
- The 1:2 scaled down model was manufactured and tested on UTM and compared with its FEA results. The max equivalent strain observed was 0.152 micron where FEA results showed 0.141 microns. This gives co relation percentage of 92.2%

B. *Future Scope*

The further research on wheel chair ramp following ways can be adopted:

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- The research can be further extended optimization of other structural parts such as c channels and support panels.
- Automated operation, sliding manual operation and telescopic ramp design are a few design aspects which could be explored in future.

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