CONCEPTUAL DESIGN AND ANALYSIS OF EASY LIFT STAIRS FOR ELDERLY AND PHYSICALLY CHALLENGED PASSENGERS

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Abstract — *Transportation is an extremely important policy issue for those with disabilities. People with disabilities have consistently described how transportation barriers affect their lives in important ways. So there is a need to focus technology on providing an optimum quality of life for the disabled/elderly to provide a high level of artificial or "barrier free" environment and an easy and smooth means of transportation. This research investigates the inaccessibility of the elderly and the physically challenged community into the public transportation vehicles in our country and the challenges faced by them while using the steps in high floor buses. The problems faced by them can be eradicated by designing an easy lift stair which can be implied in the buses which will provide easy accessibility to the physically challenged and the elderly.*

Keywords — disabled/elderly, inaccessibility, high floor buses, easy lift stairs, barrier free environment

I. INTRODUCTION

Stairs play a very important role in our daily lives and they are unavoidable due to the factors like affordability, simplicity, flexibility, ease of construction and also a good health exercise. But steps are not "accessible" to persons with a wide variety of disabilities and the elderly.One specific area of need is that of providing increased freedom in terms of mobility for the elderly or disabled. The reasons being to provide an optimum quality of life for the disabled or elderly, and to reduce the load on care workers, the two aspects being closely linked by the conscious sense of being a "burden"[1].

The demographic trends common to both developed and developing countries are a cause of major concern in many countries. United Nations data on demographic trends show that Currently 11 per cent of the global population is more than 60 years old; By 2050, this figure is expected to be 22 per cent; rising from 700 million people in 2009 to 2 billion; The number of people over 80 is growing at 4 per cent per annum; the population as a whole is growing at 1 per cent per annum;The pace of population ageing is faster in developing than in developed countries; Currently 64 per cent of older people live in developing countries, by 2050 this figure will rise to 80 per cent; 3.5 million people will be over 100 years old by 2050: over half will live in Asia. It is also clear that there is a strong correlation between age and disability. There is evidence that about 10 per cent of the world's population has a disability; About one third of older people have a disability and in some countries as many as two thirds of disabled people are also elderly; 80 per cent of the world's 500 million disabled people live in developing countries; Disability and poverty are closely linked [2].

Environmental factors restrict the extent to which people with disabilities can participate in society. The reduction of environmental barriers will increase their participation in the social, educational and vocational spheres of life. Analysis of the Accessibility issue among wheelchair users revealed that the maximum percentage (52%) perceived barriers in transportation on a daily basis, and felt it was a big problem. Similar findings reported by Venter et al (2002) suggested that vehicle design of the public transportation system such as high-floor buses, and surfaces like uneven roads and steep slopes, created barriers for persons with disabilities [3].

Excessive bus-to-platform gaps at BRT stations can make boarding and alighting more difficult for all passengers and especially for children, elderly or frail persons, blind persons, and passengers using wheelchairs. Complaints have been received from users in many countries. Excessive gaps require passengers to carefully watch the gap when they board or alight, causing delays and creating the risk of injuries as well as line delays [4].

Various aids have been invented to assist the elderly and disabled community and those have been discussed here. A lift using a step-shaped shaft for raising and lowering a person or goods on a platform over one or more steps from one elevation to another elevation. The lift is especially suited for

use over porches and raised thresholds of buildings and in and out of vehicles. The lift is suitable for use by persons with or without a wheelchair. This is mainly used for domestic purposes and if it is to be implied in a vehicle, it is difficult to attach and detach when needed [5].

A device was invented for helping a physically challenged person move up and down a flight of stairs. The user must lift or lower the device from step to step which is bulky and the person using must have the full ability of balance. So, there is a delay of safely moving and orienting the step set [6].

Passive rotary wheelchair lift that is retrotable in transit vehicles on either the forward or rearward edge of a side double-door step well is implemented for assisting the disabled but it is large in size and adds weight to the vehicle.Also,it cannot be easily attached and detached [7].

A stairway climbing aid was invented having a plurality of individual adjustable half-step members fixedly connected to a rigid elongated channel member at spaced locations along the length of the latter to comprise a rigid assembly. The user still raises each foot one full rise of step,but the rise between feet is only a half step, so this method is not feasible [8].

Then, a portable banister was invented, for use by a person in climbing or descending a staircase having a plurality of Steps are separated by risers, comprising a foot portion, a handgrip portion, and mast members extending between the foot portion and handgrip portion. The foot portion is stepped to match the contours of the staircase. In particular, the foot portion includes a pair of horizontal slabs Which rest against a vertical member Which extends between the horizontal slabs and rests against the riser there between. The horizontal slabs extend parallel to each other. The distance between the horizontal slabs is adjustable to match the staircase. The mast members each extend between one of the horizontal slabs and the handgrip portion, and are each adjustable in length to vary the height and angle of the handgrip portion for the comfort and safety of the user but the problem with this device is that once the person gets to the upper step, the device also has to be carried along in order to move to the next step which causes a delay in the movement [9].

An improved automotive lift device for vehicles which consists of a lift carriage having movable upper step and riser elements so as to selectively form normal upper and lower entrance steps in their retracted normal use position. The upper step and riser pivotally connected thereto are selectively extendable outwardly and downwardly by self-contained actuating device so as to form a continuous horizontal loading platform in association with the fixed lower step formed by the base of the lift carriage. Thus formed, the horizontal loading platform can be selectively lowered to the ground or curb level, but this device cannot be implemented in all of the vehicles. It is limited to certain vehicles [10].So, all these mechanisms are not feasible for the modern society.

The modern technologies which are now in existence in our country to assist the elderly and disabled community are the low floor buses and the kneeling buses. A **low-floor bus** is a bus that has no steps between one or more entrances and part or all of the passenger cabin. Being low floor improves the accessibility of the bus for the public, particularly the elderly and people with disabilities, including those in wheelchairs and walkers. In the modern context, "low floor bus" refers to a bus that is accessible from a certain minimum height of step from ground level, to distinguish it from some historical bus designs that did feature a level interior floor throughout but with a relatively high-floor height [11].

Fig.1 Low floor bus

A kneeling bus is a bus that not only has no steps between the door and the bus floor, but also has an air-adjustable suspension. This feature allows the driver to actually lower the bus to the curb to make entering and exiting the bus much easier. By lowering the bus, the handicapped and elderly are given much easier access to the bus, and even wheelchair access is made easier. The kneeling bus takes its name from the kneeling-like manner in which it lowers itself at the bus stop.By using an on-board air compressor and air bag suspension, this kind of bus can drop to a much lower position when loading and off-loading passengers. By depressing a button inside of the bus, the operator is able to release air from the front air bag suspension. This allows the kneeling bus to slowly drop down from its normal ride height. Once the passengers have made their way on or off the bus, the switch is released, and the suspension once again fills with air. This brings the bus back to its normal operating height.Along with the air-lift system, the kneeling bus has no stairs or steps on the interior of the bus to impede traffic. Passengers who use wheelchairs as well as any passenger who may have an impediment which makes climbing steps on a conventional bus difficult can navigate the entrance of a kneeling bus much easier than a traditional bus. Typically, the doors and aisles of a kneeling bus are also wider than the same areas in a standard bus, making access much easier for the physically challenged [12].

Fig.2 Kneeling bus

Even though, the low floor buses and the kneeling buses have so many advantages, these type of buses cannot be used in rural areas and hilly areas due to the bad road conditions and there has to be some ground clearance maintained for a comfortable ride but the low floor buses and the kneeling buses are fit for use in only in urban areas because they have only a minimum amount of ground clearance. So, in rural areas, only high floor buses can be operated and if anything has to be done, modifications should be done only in high floor buses to make them accessible to the elderly and the physically challenged community.

II. DESIGN OF EASY LIFT STAIRS

In Tamil Nadu, India most of the buses in rural areas are operated by TNSTC (Tamil Nadu State Transport Corporation)

Fig 3. The physically challenged and the elderly find it difficult to enter with their aids

and so the system which is designed is also based on the structure of a TNSTC bus. Generally, in a TNSTC bus, the number of doors will be either one or two based on the size of the bus. Mostly, the number of steps on the doors will be three. Here, the model is designed for one door with the help of Catia v5.0.

Methodology of lifting the stairs :

The lifting system consists of three specially designed steps (Fig 1). The whole system consists of two movable steps and a fixed step and the specially designed steps have sliders in them in order for the steps to move up and down (only vertical movement) in a smooth manner. The steps have movement restrictor (fig 3) in them to restrict the motion of the steps from falling down. The steps are actuated by two linear actuators (fig 2). Two linear actuators are kept at either sides of the base step and they are powered by a 24V DC motor. The total stroke length of the actuator is 600mm and each steps are divided equally according to the total stroke length of the actuator.

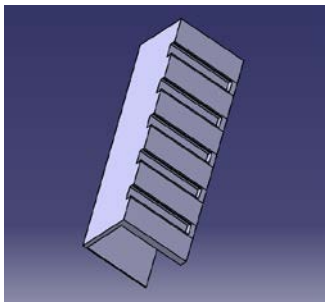

Fig 4.Specially designed steps

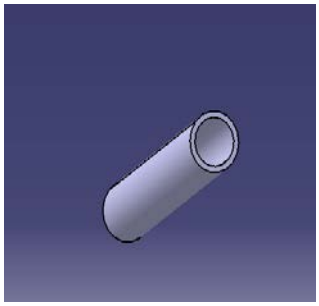

Fig.5 Linear actuator

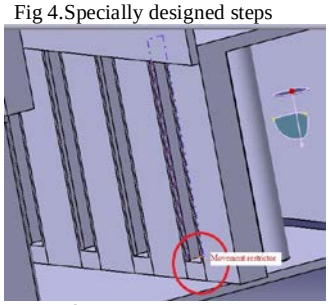

Fig 6. Movement restrictor

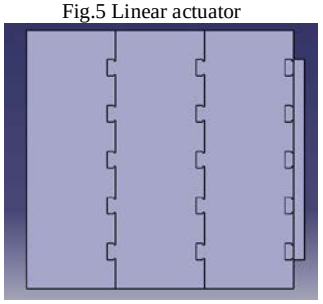

Fig 7. Top view

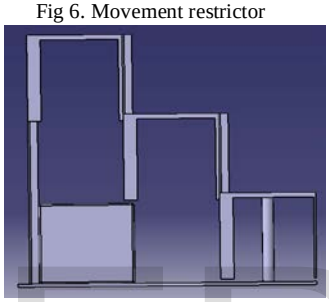

Fig 8. Side view

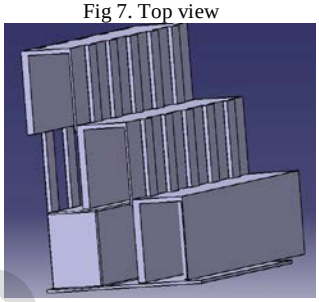

Fig 9. Full assembly

The working of the model is that when an elderly or a physically challenged passenger has to get into the bus, he has to step into the base step(Fig.6). Underneath the whole model is a load sensor and when the passenger steps into the base step, the load sensor detects it, and the microcontroller attached to it actuates the linear actuator under the base step extends according to the stroke length of the actuator and it lifts the base step and moves to the middle step. As soon as it reaches the middle step, due to the sliders and the movement restrictors in it, it lifts the middle step and after it reaches the last step, it forms a platform (fig 4) for the passenger to easily get into the bus without any difficulties. Also, when the platform is formed at the top step, the micro controller signals the actuator to stop to form a platform in order to restrict minor accidents and the whole system is programmed by Arduino.

TABLE 1 MATERIAL APPLICATIONS

Material	Applications
Mild Steel	Steps in the system
Stainless steel	Sliders, movement restrictor

Aluminium	Covering the steps with sheets

Terminologies used in description:

Easily accessible:

This term refers the ability to access the buses as per demand. This system can be used whenever a disabled or an elderly person wants to enter into the bus. For an average bodied human being, it will remain an ordinary step as it is in the public buses and that's why this design is proposed and is to be implemented inthe buses to help the disabled persons.

Easy lift system:

In this system, the steps are able to move only vertically. The vertically movable step system means all the three steps are movable linearly. The vertically movable step is attached to the actuators which can move vertically at a range of 600mm than the normal lower step of the bus. All the steps are moved by the linear actuator, controlled by a microcontroller and programmed by Arduino to ensure smooth linear movement.

Linear Actuator:

An actuator is something that converts energy into motion. It also can be used to apply a force. An actuator typically is a mechanical device that takes energy usually energy that is created by air, electricity or liquid and converts it into some kind of motion. That motion can be in virtually any form, such as blocking, clamping or ejecting. Actuators typically are used in manufacturing or industrial applications and might be used in devices such as motors, pumps, switches and valves. In this research, linear electric actuator actuator operated by 24V DC is used.

FIG.9 LINEAR ACTUATOR

III.COMPUTATIONAL ANALYSIS

Easy lift stairs along with the linear actuators was modelled and analysed using Catia software to determine the dynamic characteristics.

A. Geometric Model

Using CATIA V5R20, easy lift stairs was modelled in a logical manner. Starting from steps, then the sliders in the steps, movement restrictors which controls the movement of the steps, linear actuators, battery were built and finally assembled together.

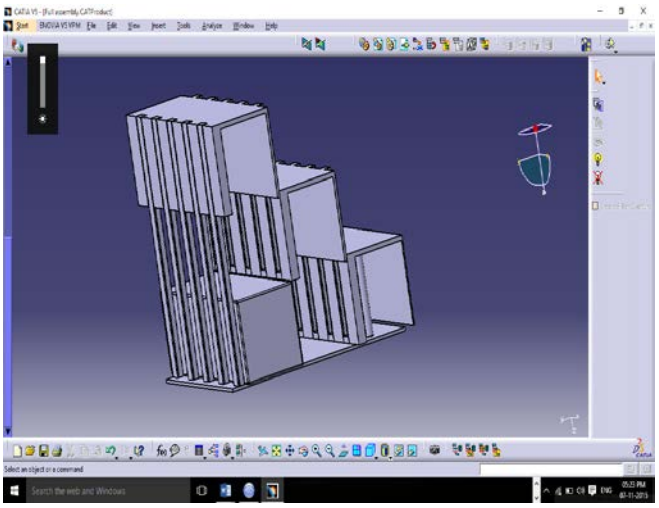

Fig. 9 Geometric model of easy lift stairs

B. Simulated Output

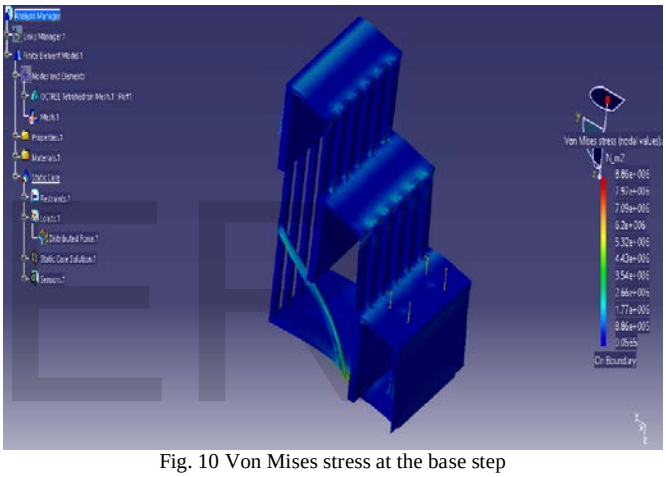

Fig. 10 Von Mises stress at the base step

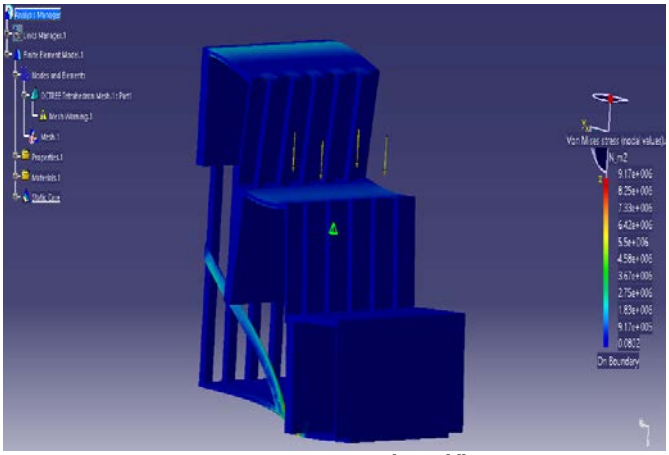

Fig. 11 Von Mises stress at the middle step

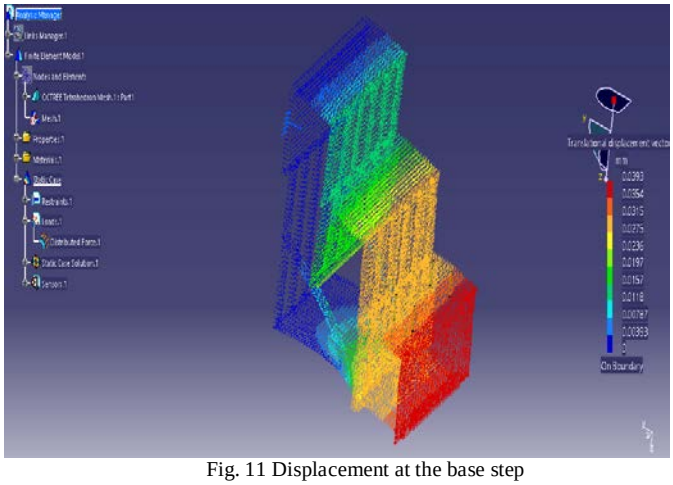

Fig. 11 Displacement at the base step

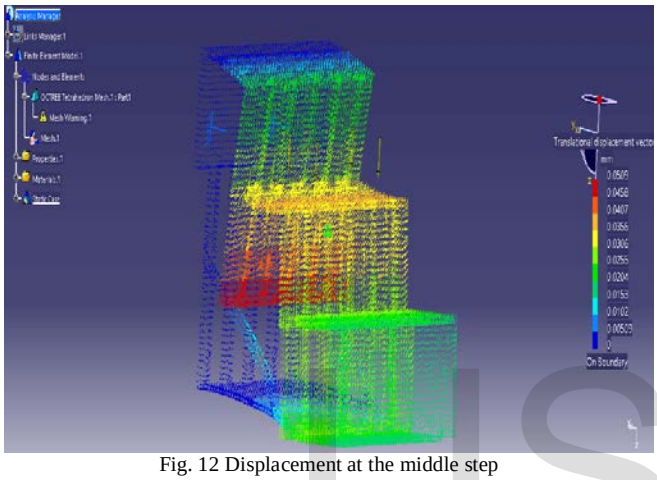

Fig. 12 Displacement at the middle step

Terminologies used in simulation :

Meshing:

The partial differential equations that governs fluid flow and heat transfer are not usually amenable to analytical solutions, except for very simple cases. Therefore, in order to analyze fluid flows, flow domains are split into smaller subdomains (made up of geometric primitives like hexahedra and tetrahedral in 3D and quadrilaterals and triangles in 2D). The governing equations are then discretized and solved inside each of these subdomains.Typically, one of three methods is used to solve the approximate version of the system of equations: finite volumes, finite elements, or finite differences. Care must be taken to ensure proper continuity of solution across the common interfaces between two subdomains, so that the approximate solutions inside various portions can be put together to give a complete picture of fluid flow in the entire domain. The subdomains are often called elements or cells, and the collection of all elements or cells is called a mesh or grid. The origin of the term mesh (or grid) goes back to early days of CFD when most analyses were 2D in nature. For 2D analyses, a domain split into elements resembles a wire mesh, hence the name.

Von Mises Stress:

The von Mises yield criterion suggests that the yielding of materials begins when the second deviatory stress invariant J2 reaches a critical value. For this reason, it is sometimes called the J2-*plasticity* or J2 flow theory. It is part of a plasticity theory that applies best to ductile materials, such as metals. Prior to yield, material response is assumed to be elastic.

Equivalent Strain:

A scalar quantity called the equivalent strain, or the von Mises equivalent strain, is often used to describe the state of strain in solids.Several definitions of equivalent strain can be found in the literature. A definition that is commonly used is change in length divided by the original length.

Factor of Safety (FOS):

For structural applications,FOS is the ratio of the allowable working unit stress, allowable stress or working stress (1). The term was originated for determining allowable stress. The ultimate strength of a given material divided by an arbitrary factor of safety, dependent on material and the use to which it is to be put, gives the allowable stress.

$$FS = \frac{S_{al}}{\sigma_{ap}} \quad (1)$$

Where,
Sal = Allowable strength
σ ap = Applied stress (Allowable stress)
FS = Factor of Safety

IV.COST ANALYSIS

S.No	Name of parts	Price/piece	Number needed	Price
1	Linear actuators	5000	2	10000
2	Ball bearing sliders	310	4	1240
3	24V battery	1500	1	1500
4	Relay switch	200	1	200
5	Miscellaneous	2000	-	2000
				Total: 14,940

V. RESULTS AND DISCUSSION

Through mesh analysis the stability of the model is readily understood as the maximum displacement for the stairs due to the loading of a passenger is less than a millimeter and the maximum stress is developed at the positions where passenger is stepping in the vertically movable stair and the stress is not

acting at any alarming magnitude. The strain analysis developed is also less than a mm. The cost that is obtained is very reasonable and if government takes this project into concern for the sake of the elderly and the physically disabled community of Tamil Nadu, the cost can be further reduced. Here, in this research work, we integrated the mechanical design, static analysis and program algorithm of the system which allows the passenger to get comfortably into the high floor bus. There are still scopes of developing this system, the lifting mechanism and materials can be modified by further research in this field.

VI. Conclusions

In this paper, the problems faced by the elderly and the physically challenged community were discussed. Accessibility is the first need of a person to communicate and to interact with the world. But in our country, due to certain problems, we are still unable to provide a barrier free environment to the elderly and the physically challenged. This research has showed the current situation of bus system in our country and stated a cheap way to come out from this situation by modifying the stair system in buses. It also created scopes of further research for developing this system for the noble sake of the physically challenged and the elderly community in our country.

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