Transposed Wheelchair with Stair Climbing Mechanism

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Abstract

Wheelchairs are one of the only means by which disabled people get to go around places. Developed countries are almost well equipped with the infrastructure to accommodate them, as in ramps and lifts, which accompany stairs. But for developing and under developed countries in Asia and Africa, such facilities are far from reality. In our own country, there are a large percentage of buildings in urban and semi urban areas, built without consideration for accessibility. A normal wheelchair user need to be lifted and carried manually by two more helpers to get to different floors of a multi-storied public building or even their own flats and apartments. One solution for this would be to modify civil structures, but that would neither be economical nor practical. So, the other solution would be to engineer a wheelchair that can ascend stairs. These are available in the market, like SCALEVO, but being the products of Japanese and American research labs, they are aimed at people who can afford such technology; not for the less fortunate majority. What made stair climbing costly for a powered wheelchair, was the complicated wheel motion, and the electronic control systems. So to simplify this we propose a Star Wheel, taking inspiration from the rack and pinion mechanism, and the cluster wheel mechanism. Also, the complex and expensive control systems can be replaced by an even more sophisticated, but freely available human brain, that of the assistant or any helper. The effort for the motion is taken by a 250W permanent magnet DC motor powered by two 12V battery, with high torque (reduction using chain) and the helper need to take care of only maneuvering the device, during the climb up or down the stairs. This same motor can provide powered motion in the forward direction, by reversing polarity, and attaching an auxiliary circular wheel. People with considerable upper body strength would be able to hold the handle, lift themselves and mount on to it. Assistance is required for the old and weak. To solve this, we considered different ideas and found that, by removing the backrest and placing the seat slightly below the average height of a bed, chair or toilet-seat (450mm), with a slight outward slope, the user can simply slide on to it from the back! If he is a very weak person, then he can be helped by an assistant to do so, still reducing the assistant's effort considerably; earlier, the person needed to be lifted manually and placed by him. Thus there is transposed entry to the wheelchair, along with conventional entry. The backrest is locked in place after entering. A two wheel plus one caster-wheel design ensures 3-point ground contact at all time and has a lower tipping angle, also it makes the frame design simple and light. So, three high traction wheels, vibration isolation using suspension and a high torque drive makes it suitable for rough terrain. The frame and drive is made minimal enough to reduce cost, using standard parts as far as possible, and the ability to be assembled, modified and reassembled.

Keywords: Star Wheel, Stair Climber, Transposed Entry

I. INTRODUCTION

Since the second millennium there is an increasing mindfulness of the need to focus technology on helping people. This has been in part on account of many countries currently experiencing what is referred to as an aging population that is the number of children born has continued to reduce over a long period of time. The result of this along with many other factors has caused the need for a reducing number of care workers to care for an increasing number of persons. 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'. Autonomy in the area of mobility has always been highly valued, but is sometimes impaired by some form of disability. In many cases this results in reliance on some form of external transport mechanism. In this regard traditional wheelchairs and

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powered wheelchairs continue to play a vital role. However wheelchairs to date provide a high level of mobility only inartificial or 'barrier free' environments. That is there remains a significant gap between the obstacle negotiating ability of a wheelchair and that of the average able bodied person. This aspect is perhaps most apparent when considering stair-climbing. While modern architecture and new policies continue to make newly built areas as "accessible" as possible to persons with a wide variety of disabilities steps will always be a reality in the 'real world'.

The main focus of this project revolves around providing a personal means of negotiating stairs, the first question that must be considered is why stairs are used. Stairs provided means of ascent or descent. What alternatives are there to stairs? In terms of passive means slopes are the primary alternative. When considering powered assistive mechanisms such as escalators or lifts the range of alternatives is greater. The advantage of a slope (4.8 degrees max. for manual wheelchair) is that it does not significantly impede access to wheeled vehicles or most walking assistive devices. However the two inherent disadvantages of a slope are the space used compared to a set of stairs and the requirement that sufficient traction is present.

II. OBJECTIVE

- Help old and disabled by reducing their dependence on helpers for mounting and getting off a wheelchair.
- Reducing the helper's effort.
- Assistance for the aging middle-aged population living in flats or apartments.
- Develop a wheelchair design, simple to reproduce/modify and manufacture.

III. EXPERIMENTAL / ANALYTICAL PROCEDURES

A. Components selected

The major components that are effectively involved in the manufacture of Transpose Wheel Chair with stair climbing mechanism are as follows.

- Motor
- Star Wheel
- Battery
- Circlip
- Motor Controller
- Chain
- Free Wheel
- Locking Mechanism

IV. DESIGN CONCEPT

A. CAD/CAE

Computer aided design or CAD has very broad meaning and can be defined as the use of computers in creation, modification, analysis and optimization of a design. CAE (Computer Aided Engineering) is referred to computers in engineering analysis like stress/strain, heat transfer, and flow analysis. CAD/CAE is said to have more potential to radically increase productivity than any development since electricity. CAD/CAE builds quality form concept to final product. Instead of bringing in quality control during the final inspection it helps to develop a process in which quality is there through the life cycle of the product. CAD/CAE can eliminate the need for prototypes. But it required prototypes can be used to confirm rather predict performance and other characteristics. CAD/CAE is employed in numerous industries like manufacturing, automotive, aerospace, casting, molding making, plastic, electronics and other general-purpose industries. CAD/CAE systems can be broadly divided into low end, mid end and high-end systems. Low-end systems are those systems which do only 2D modeling and with only little 3D modeling capabilities. According to industry static's 70-80% of all mechanical designers still uses 2D CAD applications. This may be mainly due to the high cost of high-end systems and a lack of expertise. Mid-end systems are actually similar high-end systems with all their design capabilities with the difference that they are offered at much lower prices. 3D sold modeling on the PC is burgeoning because of many reasons like affordable and powerful hardware, strong sound software that offers windows case of use shortened design and production cycles and smooth integration with downstream application. More and more designers and engineers are shifting to mid end system. High-end CAD/CAE software's are for the complete modeling, analysis and manufacturing of products. High-end systems can be visualized as the brain of concurrent engineering. The design and development of products, which took years in the past to complete, is now made in days with the help of high-end CAD/CAE systems and concurrent engineering

V. MODELING

Model is a Representation of an object, a system, or an idea in some form other than that of the entity itself. Modeling is the process of producing a model; a model is a representation of the construction and working of some system of interest. A model is similar to but simpler than the system it represents. One purpose of a model is to enable the analyst to predict the effect of changes to the system. On the one hand, a model should be a close approximation to the real system and incorporate most of its salient features. On the other hand,

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it should not be so complex that it is impossible to understand and experiment with it. A good model is a judicious tradeoff between realism and simplicity. Simulation practitioners recommend increasing the complexity of a model iteratively. An important issue in modeling is model validity. Model validation techniques include simulating the model under known input conditions and comparing model output with system output. Generally, a model intended for a simulation study is a mathematical model developed with the help of simulation software.

Software for modeling:

- Solid works,
- Creo,
- CATIA,
- Unigraphics, etc.

VI. ENGINEERING DESIGN (SOLID WORKS)

Solid works offers a range of tools to enable the generation of a complete digital representation of the product being designed. In addition to the general geometry tools there is also the ability to generate geometry of other integrated design disciplines such as industrial and standard pipe work and complete wiring definitions. Tools are also available to support collaborative development. A number of concept design tools that provide up-front Industrial Design concepts can then be used in the downstream process of engineering the product. These range from conceptual Industrial design sketches, reverse engineering with point cloud data and comprehensive free-form surface tools.

The figures represents CAD model in SolidWorks.



Fig. 1: Final Model



Fig. 2: Stair Climbing Mode



Fig 3: Frame



Fig. 4: Shaft

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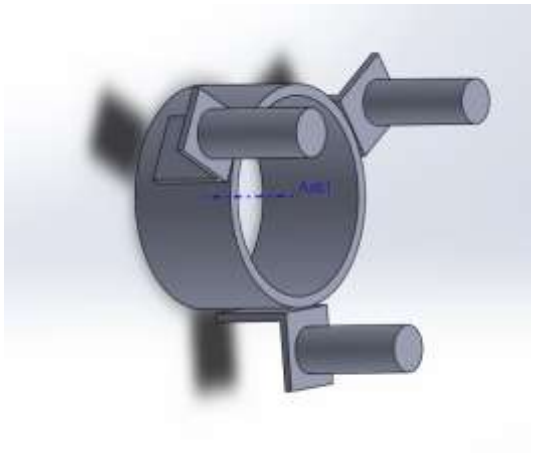


Fig. 5: Locking Mechanism

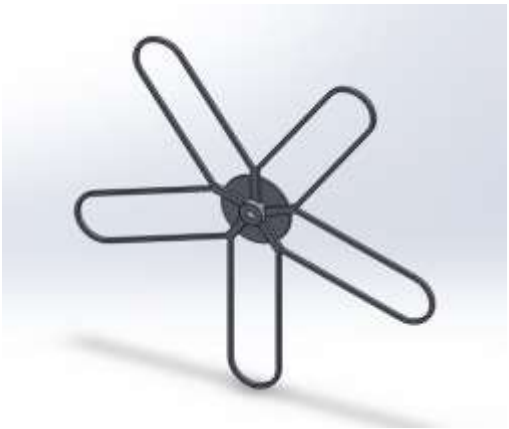


Fig. 6: Star Wheel Cad design

VII. DESIGN CALCULATIONS

Resolving the force components in the Fig.3.5,
$F \sin \Phi + R = W$
But we Know that, $T = R \times p \Rightarrow R = T/p$.
Substituting for R,
$F \sin \Phi + T/p = W$
By design requirements, Assistance effort is 30% of the load, i.e.
$F = (T/p) \times 0.3$
Substituting for F,
$0.3(T/p) \times \sin \Phi + (T/p) = W$
$T/p\ (0.3 \sin \Phi + 1) = W$
$T = W p / (0.3 \sin \Phi + 1)$
Now, Maximum torque required is when, $\sin \Phi = 1$.
Therefore, $T = W p / (0.3+1)$
Assuming, W=140kgf, i.e., $W = 140 \times 9.81$ N
$T = (140 \times 9.81 \times p)/1.3$
We know that, p = 0.28m and on substituting we get,
$T = (140 \times 9.81 \times 0.28)/1.3$
T= 295.80 Nm
Now, we know that, $P = T \theta$,
And in the design we take $\theta = 72°$.
On substituting values for T & θ,
$P = 295.80 \times 72 \times \Pi / 180$
P= 371.72 Watt
Taking upper limit of power requirement as 600 Watts, and using a suitable reduction mechanism with 1:5 reduction,
$P/600 = 1/5 \Rightarrow P = 600/5 = 120$ Watts
Therefore, 120 Watt is required at the motor end.
So, using a 250 Watt motor at 1/2 load we get the motor requirement as a 0.33 hp (250 Watt).
Further reduction in amplitude of jerks is obtained using a suspension system between the axle and the frame.
The system was reduced to a simple kinematic one and the torque requirement was found out (for a person of weight 80kg and system's weight 40kg). Suitable motor is a 1/2hp permanent magnet DC motor.
Travel for normal terrain is obtained by a wheel, which can be easily attached to the axle (without removing Starwheel). Also the DC motor will now be working in reverse direction, to provide forward motion. Steering is done by manipulating the castor wheel using brake cables (from bikes).
A safety locking mechanism (using a freewheel hub) is engaged during stair climb. This prevents any downward motion during the climb.

VIII. RESULTS AND DISCUSSION

A. Analysis and Results

ANSYS is the usually preferred analysis software package because of its functionality. In this interface, you can apply forces, pressures, torques, etc on models and see how the stresses develop. The ANSYS Workbench platform is the framework upon which the industry's broadest and deepest suite of advanced engineering simulation technology is built. An innovative project schematic

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view ties together the entire simulation process, guiding the user through even complex multi physics analyses with drag-and-drop simplicity. With bi-directional CAD connectivity, an automated project level update mechanism, pervasive parameter management and integrated optimization tools, the ANSYS Workbench Platform delivers unprecedented productivity, enabling simulation driven product development.

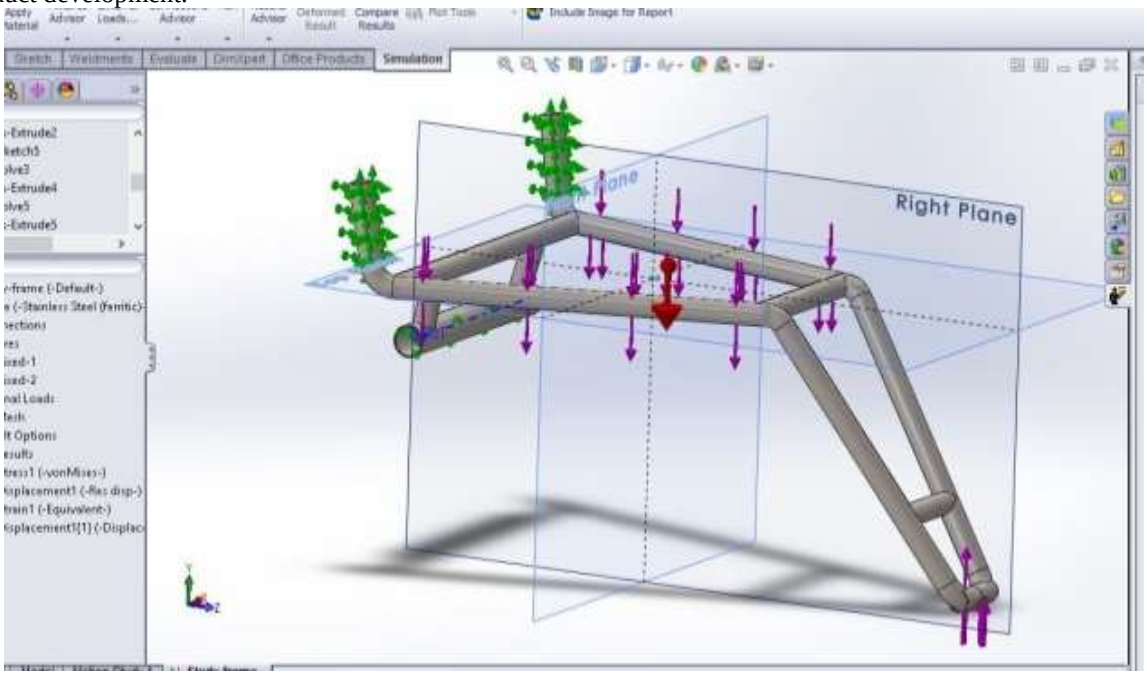


Fig. 7: Frame analysis

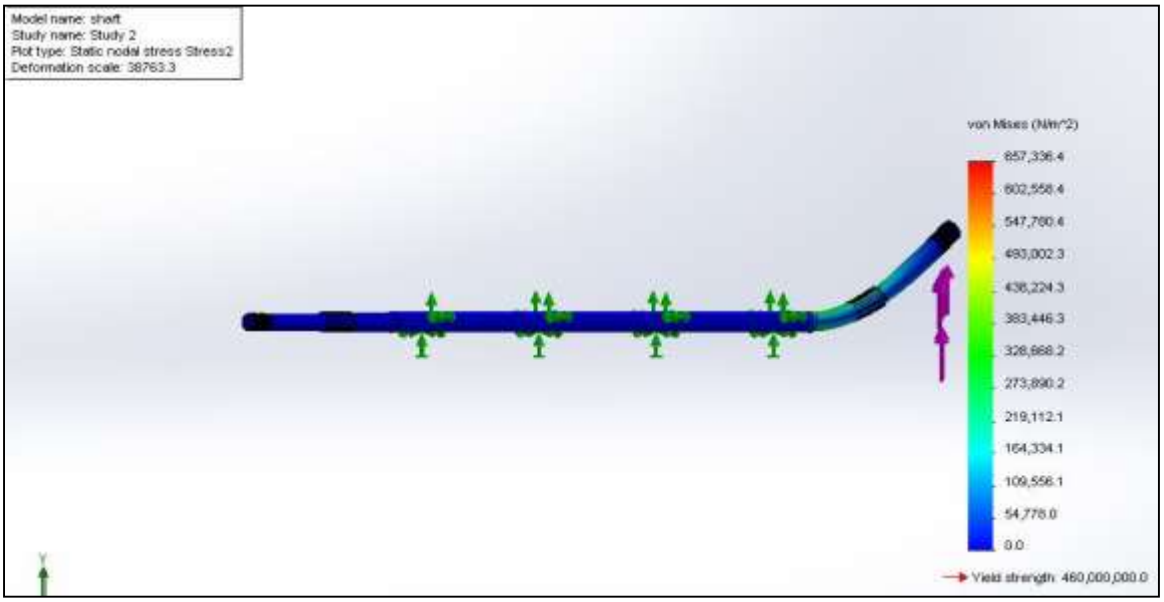


Fig. 8: Shaft analysis

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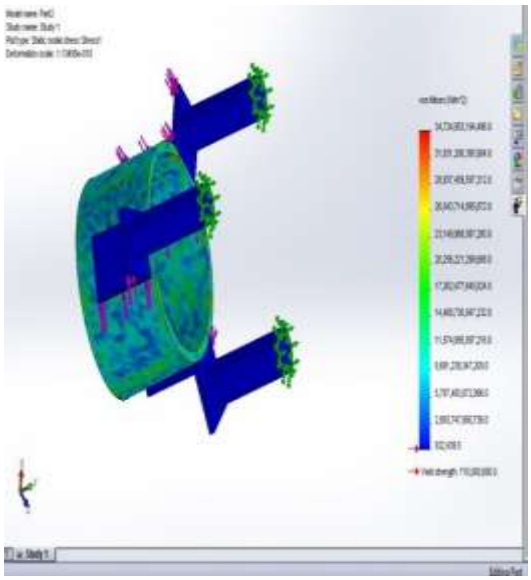


Fig. 9: Locking Mechanism

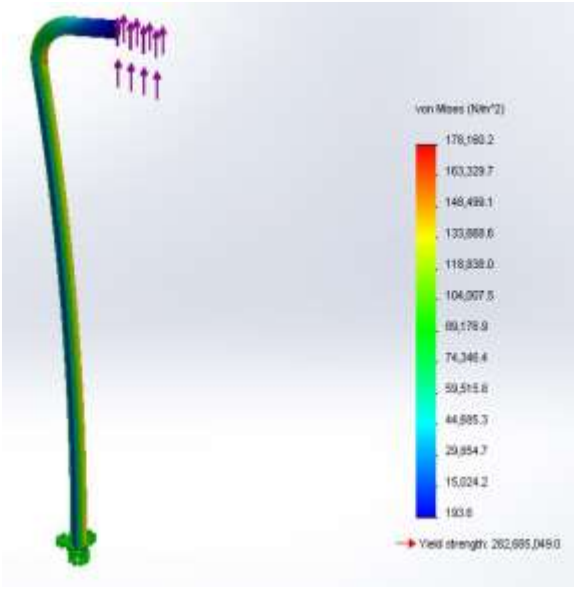


Fig. 10: Handle

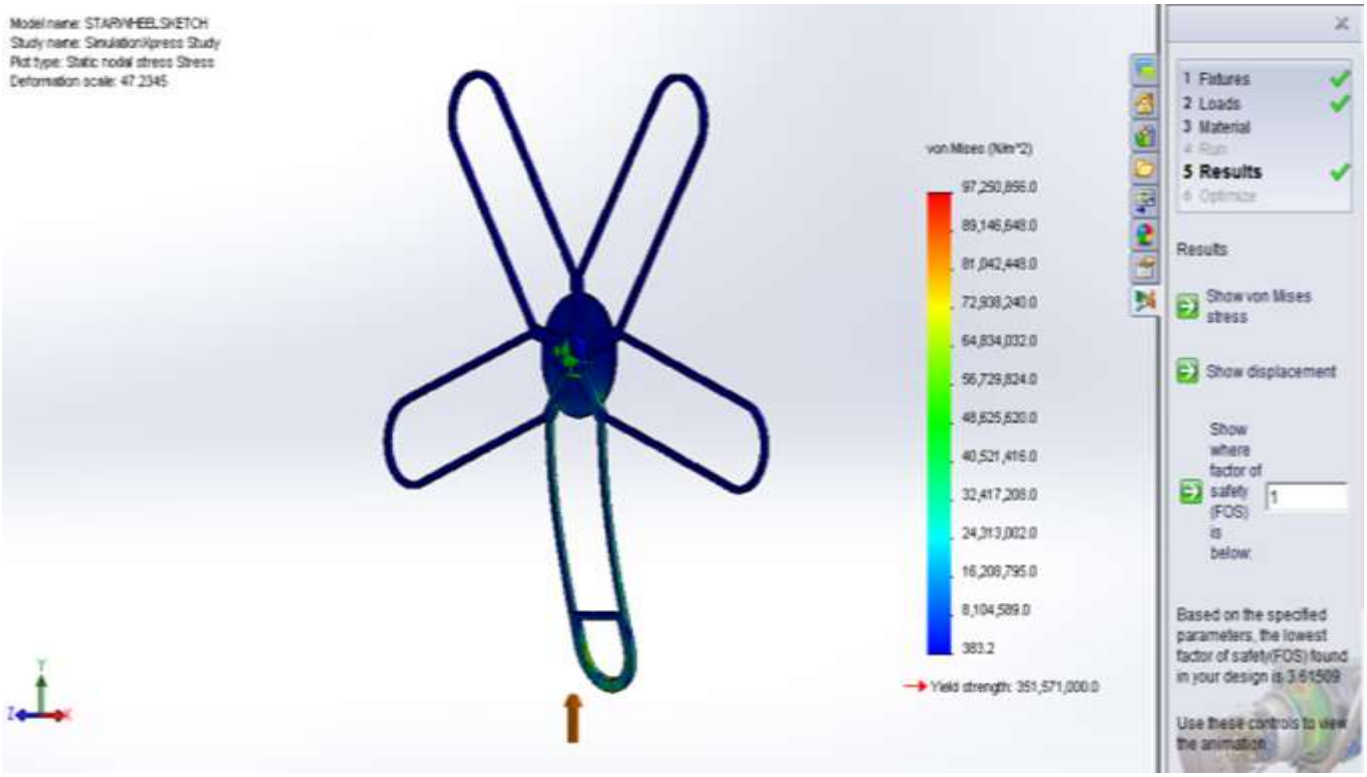


Fig. 11: Star Wheel

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IX. FABRICATION DETAILS



Fig. 12: Final Model

A. Details of Fabrication

So we are designing a wheelchair that can climb stairs, and is affordable. What made stair climbing costly for a powered wheelchair, we found, was the complicated wheel motion, and the electronic control systems. So to simplify this we propose a Star Wheel, taking inspiration from the rack and pinion mechanism, and the cluster wheel mechanism (working explained in figure). Also, the complex and expensive control systems can be replaced by an even more sophisticated, but freely available human brain!, that of the assistant or any helper. The effort for the motion is taken by a permanent magnet DC motor powered by a 24V battery and the helper need to take care of only maneuvering the device, during the climb up or down the stairs. This same motor can provide powered motion in the forward direction, by reversing polarity, and attaching an auxiliary circular wheel.

Our team, on analyzing the design of a wheelchair from the user's perspective, came across a major setback of every conventional wheelchair's design. How a disabled, say, hemiplegic person is supposed to climb on to something set perpendicular to him without using his legs? People with considerable upper body strength would be able to hold the handle, lift themselves and mount on to it. Assistance is required for the old and weak. To solve this, we considered different ideas and found that, by removing the backrest and placing the seat slightly below the average height of a bed, chair or toilet-seat (45cm), with a slight outward slope, the user can simply slide on to it from the back! If he is a very weak person, then he can be helped by an assistant to do so, still reducing the assistant's effort considerably; earlier, the person needed to be lifted manually and placed by him. Thus there is transposed entry to the wheelchair, along with conventional entry. The backrest is locked in place after entering.

The Star wheel has 5 spokes, with internal angle of 72˚. This was synthesized with the help of drawings, and practical testing. The spoke length being 280mm, set higher than the average step's rise, will facilitate smooth motion during climb or descend.

X. CONCLUSION

The project was aimed at developing and manufacturing a wheelchair that can overcome the shortcomings of a conventional wheelchair, with focus on cost effectiveness and utility. Areas of focus for designing process was:

- Stair climbing wheelchair, with power assist.
- Affordable powered mobility, with suspensions for comfortable travel.
- Innovative method for mounting.
- Help old and disabled by reducing their dependence on helpers for mounting and getting off the wheelchair.
- Reducing the helper's effort (for the very weak).
- Assistance for the aging middle-aged population living in flats or apartments.

These goals were achieved by the use of engineering tools such as CADD/Analysis softwares and knowledge of subjects such as Design of Machine Elements, Strength of Materials and Engineering Mechanics.

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Shortcomings of the current project were the jerk experienced during the climb, even after reduction of shocks using suspension seats. This could be solved by using more cushioning on the seats and a softer suspension.

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