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Conceptual Design of Stair Climbing Wheelchair using Catia

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***Abstract*—Assistive technology is classified as the fastest growing sector among the various technological innovations in today's world. The main focus is to improve the lives of disabled people by providing an independent as well as comfortable living environment. This paper aims to design a wheelchair for the people suffering from disabilities such as motor impairment. The proposed design mainly focuses on enhancing the wheelchair with the low-level stair climbing feature. The wheelchair is designed using CATIA software and the clustered wheel drive mechanism is used. The measurements for the wheelchair are selected according to the standard anthropremetric measurements. This design will help in providing mobility to the disabled persons, independent of the terrain.**

Keywords- Electric Wheelchair, Mobility, CATIA, Assistive Technology

I. INTRODUCTION

Assistive technology has become the part and parcel of present technological advancements. Assistive mobility is defined as a supportive feature for the disabled people to enjoy a life which is rich in human rights and dignity. One of the most commonly used device for the purpose of enhancing mobility of disabled people is a wheelchair. It helps them to overcome their physical barriers and thereby inhibit a feeling of being self-dependent. It can even help them to contribute effectively to the economic productivity of their respective society. A society's prosperity can be analyzed only after estimating the population of disabled people residing in it. According to the World Health Organization (WHO), around 10% of the world population suffers from disability and is alarmingly increasing each year due to factors such as rising calamities, spinal injuries, head injuries, burns, polio, cardio – attacks, vehicular accidents and wars. The report further states that India itself constitutes about 250 million people who are disabled, with a major share of people from the rural background. The rural areas of India are quite economically backward and does not provide stable terrain for wheelchair mobility. Hence the user on a wheelchair will be subject to uneven terrain such as slopes, damps and more importantly stairs. The issue of stairs acting as a mobility barrier does exist more predominantly in the urban areas too. The end-user is thereby restricted to exercise freedom of movement in public places such as malls, workplaces and even homes with more than one floor. The only medium of accessibility in such situations is the usage of specially built pathways or lifts which can help in providing assistance to disabled people. Fig.1 shows the proportion of disabled people by type of disability (in %) in the country according to the National Population Census of 2011. The statistics clearly implies that the disability in terms of movement constitutes the largest proportion (20%) as compared to other disabilities. This is indeed a large amount of people and thereby requires an effective methodology to meet the needs of people by mainly making their lives easy. The main objective to be considered is to make them self-dependent and henceforth motivate them to contribute to the growth of the society.

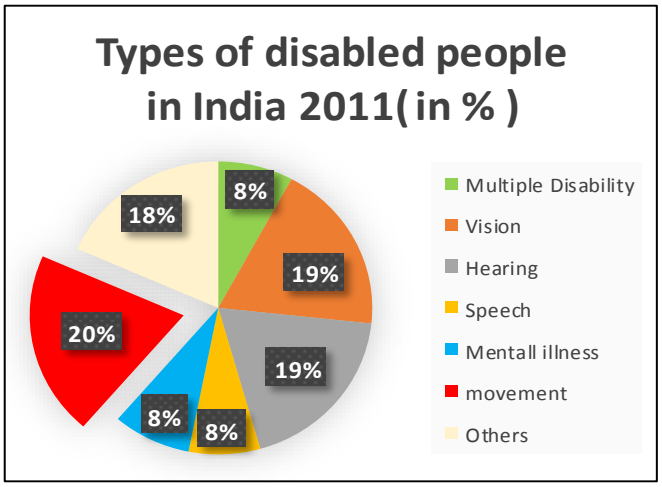

Fig.1. Census data on the types of disabilities in India

This project aims at finding an efficient solution to the problem of stairs or uneven terrains which restrict the mobility of disabled people. Hence in this paper, a stair climbing wheelchair model is designed and simulated using the CATIA design software. The wheelchair is designed as per standard dimensions generally used by manufacturers across the globe. Hence the anthropometry of an average built human is considered for the design process. The stair climbing feature is achieved by using the clustered wheel mechanism which provides additional stability during the ascending and descending operations. Additional design characteristics such as mountable seat-lock as well as accessories carriage shelf add to the aesthetic appeal of the overall wheelchair design. The model is designed to climb a conventional domestic staircase and was found to have effective response. Hence it is believed that the proposed system will help to create mobility among the motor impaired people and thereby sprout a feeling of self-dependency among them. The method is very much effective in terms of a localized environment such as home.

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II. SYSTEM DESIGN

A. Wheelchair Dimensions

The dimensions for the design of wheelchair has been taken with respect to the American Disability Act (ADA) which defines the global standards for wheelchair dimensions. The dimensions of an adult-sized wheelchair as specified by ADA is shown in Fig.2. All the measurements are defined in millimeters (mm) and the accuracy of the dimensions result in stability of the overall system.

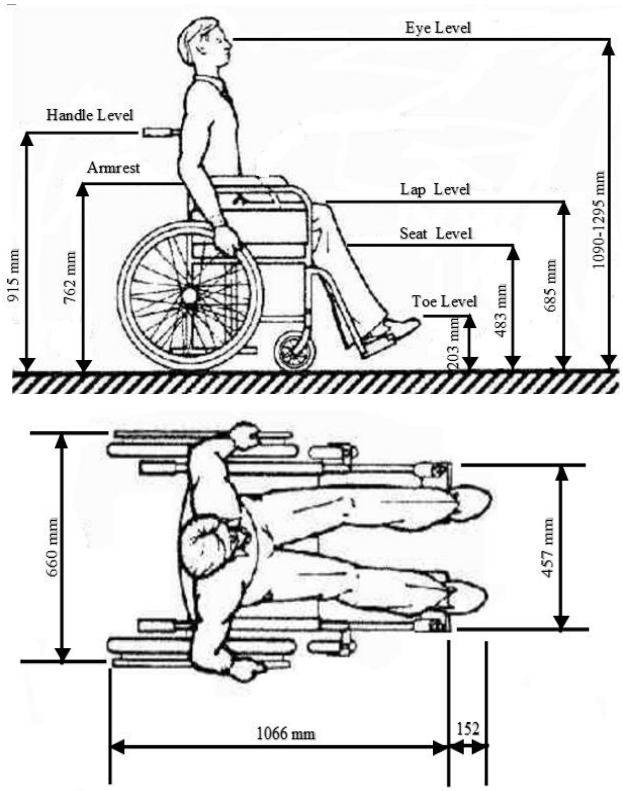

Fig.2. Standard dimensions for adult-sized wheelchair

B. Seat Design

The seating space is one of the most important component to be considered while designing a wheelchair. The seating space is generally referred as a tubular structure capable of carrying the chair as well as pivoting wheels. It must be ensured that the seating space should not be too wide nor too narrow as it results in discomfort for the end-user. The dimensions used for the design of seat are listed out as shown in Table-1.

TABLE 1. Dimensions for seat

	Length (in mm)	Width (in mm)
Armrest	352	75
Backrest	550	460
Base	515	460

The thickness of the seat is considered 50 mm to provide the required stiffness. Fig.3 shows the model of seat designed using CATIA.

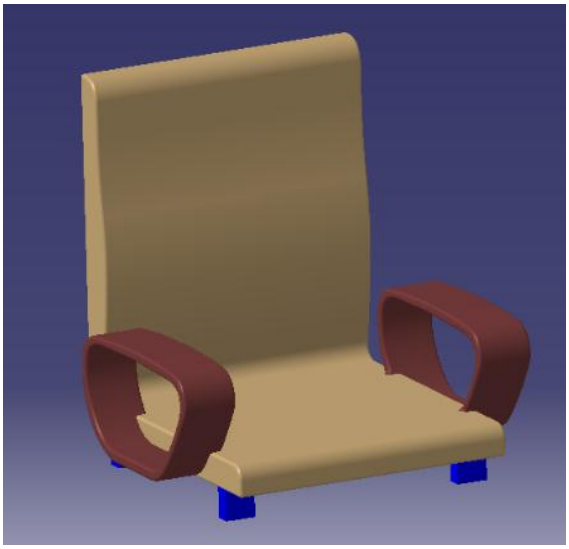

Fig.3. Seat model using CATIA

The seat is designed by keeping in mind the normal inward lordotic curvature of the lumbar and cervical region of the spine so as to provide comfortable seating posture for the user. Since the wheelchair is generally used by people with mobility constraints, an additional unit may be incorporated below the seat which will help the user to answer nature's call without any mobility constraints as shown in Fig.4.

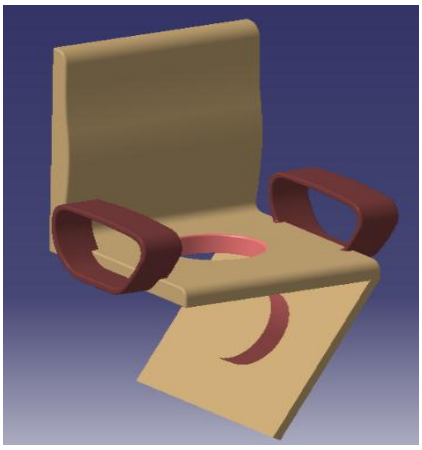

Fig 4. Seat model with detachable block

One of the main issue while climbing the stairs is to maintain the wheelchair stability. This is achieved by moving the seat relative to the frame during ascending and descending operations.

C. Frame Design

The frame of a wheelchair is responsible for its stability. It is very important to ensure that the design is compact and stable. The two motors used for locomotive purpose must be appropriately fixed onto the frame. The space for battery pack, accessories, water bottle as well as wheels should be clearly defined. The frame is ideally two tubular structures which are connected by means of connecting bars. This gives the wheelchair a rigid structure. An appropriate ground clearance must be provided to overcome barriers due to uneven terrain. The seat is fixed on the frame and during the stair climbing feature, the seat is moved relative to the frame using linkage mechanisms. Fig.5 shows the structure of designed frame.

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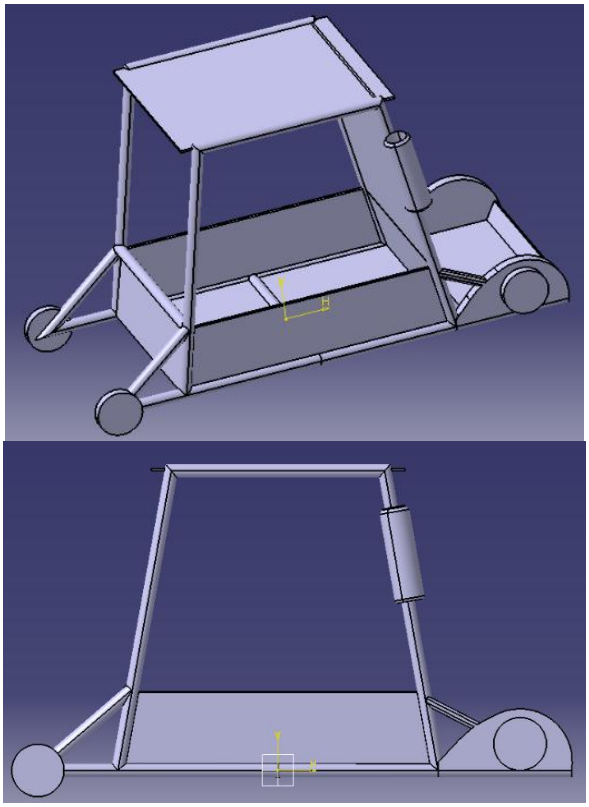

Fig.5. Design of frame using CATIA

Table-2 gives the basic dimensions of the frame calculated according to space constraints.

TABLE 2. Dimensions for frame

Length (in mm)	600 (lower) 400 (upper)
Width (in mm)	440
Height (in mm)	560

D. Wheels

The wheels are the components that enable the mobility functionality of a wheelchair. The wheels may vary in their sizes. The stair climbing feature is attained using the clustered structure of wheels. The wheels in a cluster were spaced in such a way that the centers of three smaller wheels form the three vertices of an equilateral triangle. The equal spacing is one of the most crucial parameter to be considered while designing as it is responsible for the stability and effective operation of stair climbing feature. It is also assumed that these steps are even in shape. It is mandatory that the radius (r) of each wheel must be less than the step height (h). In general, the radius of the wheel was selected as 50 mm. The wheels consists of large as well as small type. The smaller wheels help in reducing the overall dimensions of the wheelchair whereas the large wheels can help in absorbing vibrations during the mobility over uneven terrains. Considering this, the wheels that are often in contact with the ground were selected as large wheels (e.g. locomotive wheels, pivot wheels etc.), while the smaller wheels were used in the triple wheel cluster which comes in contact only during the stair climbing operation of wheelchair. The clustered wheels are structured in such a manner that it consist of a spider connected to a central axis. The three idle wheels are then attached to the vertices of spider to provide rotary movement of the wheels. Fig.6 represents the design of dummy wheels.

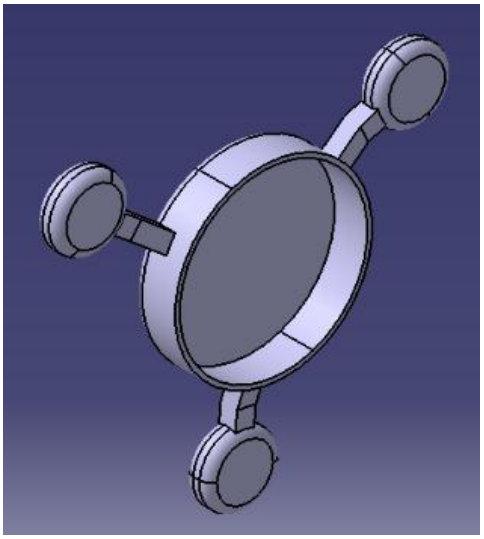

Fig.6. Design of dummy wheel

The motion is transmitted from the motors to the carrier wheels through gear trains. The commercially available gear train specifications used in wheelchairs have been considered to select an appropriate shape and size of the planet carrier. The distance between the centre of wheels was selected to be 200mm. Fig.7 illustrates the design of wheel carrier.

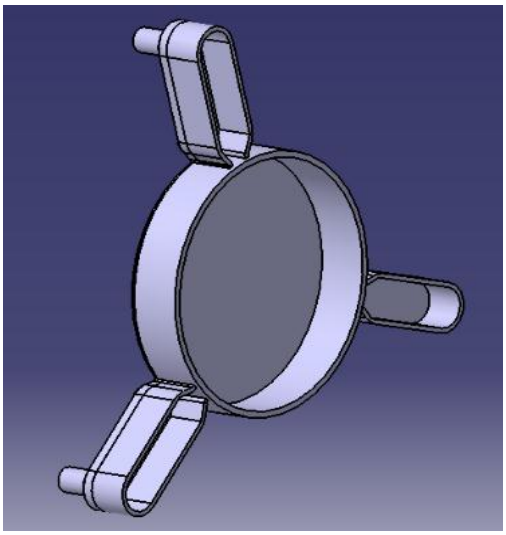

Fig.7. Design of wheel carrier

E. Linkage Mechanism

The linkage mechanism between the frame and the seat is responsible for maintaining the horizontal stable position of the wheelchair during stair ascending and descending operations. The overall working is based on the second inversion principle used in 4-bar linkage mechanisms. This mechanism helps in providing the relative motion between the chair and the frame. This is achieved by moving the seat backwards with respect to the frame during the stair climbing

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operations. The relative movement is provided by a small motor that is connected to the crank of the 4-bar links. This helps in maintain a stable centre of gravity and thereby prevents overturning of the wheelchair unit. Fig.8 shows two different views of the linkage mechanism assembly for maintaining the stability of the seat with respect to the frame.

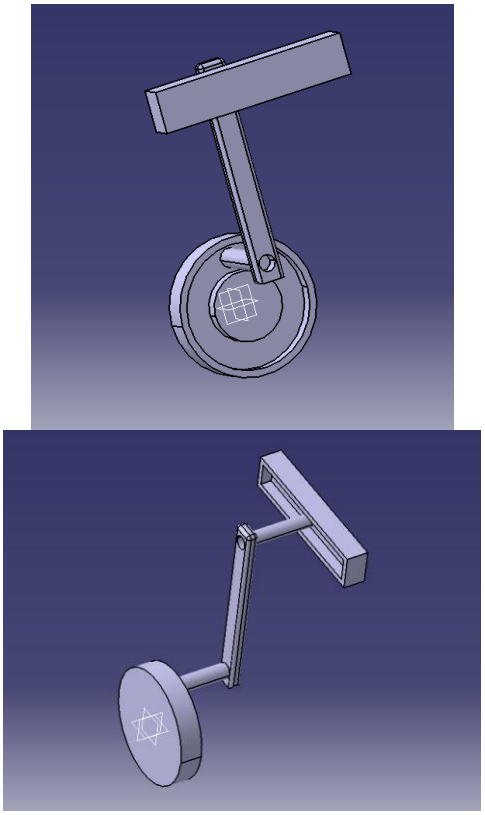

Fig.8. Assembly of linkage mechanism between the seat and frame

F. Materials

The selection of materials for the design of a wheelchair is a crucial step as well. The type of materials used directly affects the weight of the overall system. The lighter the wheelchair, the more energy efficient it will be. It must be noted that the materials used should have high tensile strength to withstand the weight of the user during mobility operations. Table-3 depicts the tabulated information on the types of materials that can be used for the design process.

TABLE 3. Materials used for wheelchair design

Parts	Materials
Seat	Cloth materials, synthetic fabrics, hard plastics, leather, wood, foams etc.
Frame	Aluminum, stainless steel, alloy steel, plastics, titanium, composites, alloys like chrome-moly etc.
Wheels	Solid rubber, plastic, urethane, pneumatic, composite nylons etc.

III. ASSEMBLY AND DISCUSSIONS

The individual parts as explained in section II are assembled together to form a single wheelchair unit. The parts must be designed accurately so as to ensure precision as well as compatibility during the assembly operations. The standard dimensions of a household staircase is considered while determining the size constraints for the frame. Fig.9 represents the assembly diagram of the wheelchair unit during the climbing of first step.

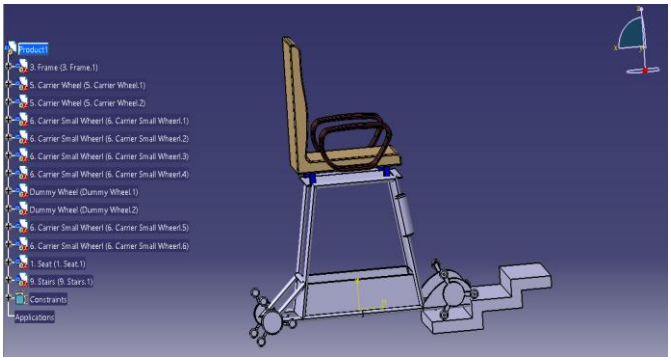

Fig.9. Assembly of wheelchair parts while climbing first step

The stair climbing feature consist of two stages. These stages include detection of step by one of the three wheels on the spider and then rotation of spider to get the other triangular wheel on top of the second step as shown in Fig.10.

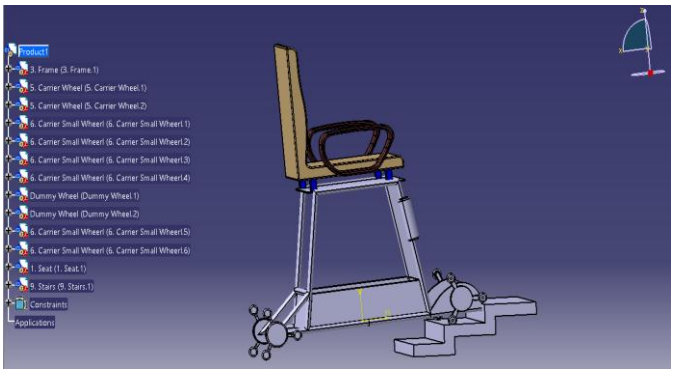

Fig.10. Assembly of wheelchair parts while climbing second step

Fig.11 and Fig.12 depicts the front view and side view drafting of the seat and frame respectively.

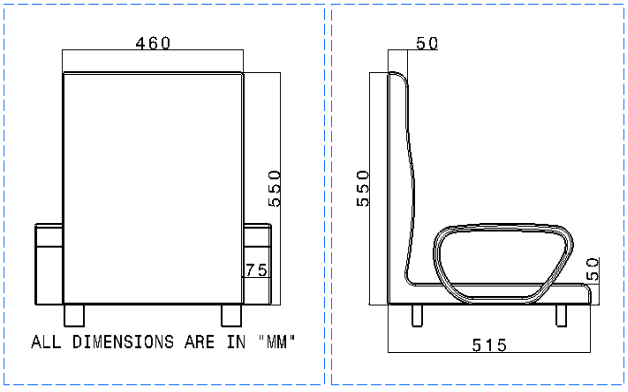

Fig.11. Drafting of the seat

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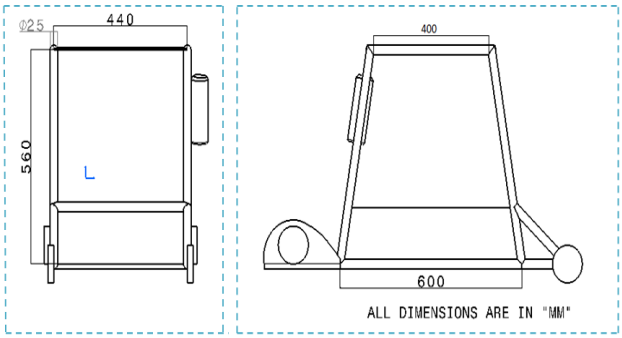

Fig.12. Drafting of the frame

Due to the different values of anthropometric measurements used in the design stage of wheelchair, there may occur slight variations with respect to the overall scaling of system dimensions. It must also be noted that the design of wheels and its carriers vary with respect to the staircase dimensions. Hence, the project is designed with the assumption that the staircases are regular in shape.

IV. CONCLUSIONS

A wheelchair design has been developed using CATIA software which can help in improving the lives of disabled people, by providing them with mobility facilities. The proposed wheelchair has been particularly designed to perform stair climbing operations as well as mobility through uneven terrain. The dimensions of the wheelchair seat has been taken with respect to standard measurements of an adult human being as specified by ADA, whereas the dimensions of the frame and wheels are based on the assumption of conventional stairway at home environment. Each part of the wheelchair such as seat, frame and wheels have been developed using CATIA software and were later assembled to form the final design. CATIA software has been preferred as it helps in the easy development of complex designs, easy assembly and apply materials to the system design according to the requirements of the user. The stair climbing mechanism was simulated using a virtual environment and the wheelchair was observed to give a stable operation. The list of available materials that could be used to enhance the design process have also been listed out.

The future scope of the project involves development of a prototype model of the powered wheelchair using lightweight material by using methods such as additive manufacturing, rapid prototyping or fused deposition modelling. The wheelchair can be made more modular in concept by incorporating spaces for more user functionalities such as advanced safety belt, movable footrest etc. The clustered wheel mechanism can be replaced by a more robust track wheel. This will help in having a better contact with the ground and prevent skidding operations.

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