User Centric Designed Mechanism For stairs-climbing Wheelchair (manual)

Shanu Sharma, J Ramkumar, Shatrupa Thakurta Roy

Abstract

One of the basic problems of user on manual wheelchair is overcoming architectural barriers (kerbs, stairs etc.) on its way. Even though many research studies have been reported in different fields to increase the independence of wheelchair users, the question of overcoming obstacles by a wheelchair always remains as topic of discussion for many researchers. In this paper, the author has proposed a manual stair climbing wheelchair concept which can overcome the architectural barriers to a considerable extent. Major part of the paper focuses on the proposed creative design concept and concludes by discussing upon the physical working model developed for the proposed design solution.

Keyword: Convertible Wheelchair, Stair Climbing Manual Wheelchair, Design for Barrier, Inclusive design.

1 Introduction

Wheelchair is a device used by disabled people to enhance their personal mobility. There are many types of wheelchairs available in the market like manual or powered wheelchair and the choice of wheelchair depends upon the physical and mental ability of the user [1].

Wheelchair has limitations against architectural barriers on its way. Although as per PWD 1995 act it is mandatory to provide an accessible environment in every public building [2] but numerous buildings in India are designed without considering accessibility for physically challenged and wheel chair users. Many urban cities of India have addressed the problem by providing alternatives for the architectural barriers like providing ramps at the entrance thresholds, lowering kerbs, wheeler chair ramps lifts etc. but still a wheelchair user has to negotiate few architectural barriers [3].In this study the author have attempted to design a stair climbing Wheelchair concept which can address the problem faced by wheelchair users.

The automated stair climbing wheelchairs available in market are more expensive for the target users to afford [4]. Ibot is one such technology which costs around $29000 [5]. A manual Stair-climbing wheelchair can be a low cost solution for the user and can enhance the mobility solution to access most of the buildings. A manual Stair climbing manual wheelchair is necessary to ensure inclusion of the disabled in the mainstream and a major step towards the improved quality of life of a

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user [6]. The paper discuss about the safe and efficient mechanism developed for a manually operated stairs climbing wheelchair concept.

2 Concept Design

2.1 Climbing action of people with disability

Fig 1 Process of climbing up and down on hand

Stair climbing is a challenging task for people with disabilities and hence they manage to work with alternative solutions for their daily activities. Generally people with disability in lower limbs have good upper body strength and manage to do most of the daily activity with hands [7]. Climbing stairs on hand can be one of the alternatives for user to access existing environment without any external support. A person sitting closer to the ground or steps has a low centre of gravity with maximum stability and hence climbing stairs in this position by dragging the body weight on hand is the safest and simplest way of climbing stairs without any support from external devices as shown in Fig. (1). Designing a mechanism for manual stairs climbing wheelchair requires a deep understanding of the user's strengths and limitations. By experiencing stair climbing action from a user's perspective can aid in developing a simple, practical and feasible mechanism.

2.2 Ideation

In this process the various concept was explored by imitating the body posture of disabled people while climbing a staircase manually.

2.1.1 Stair climbing frame

In this concept, a sheet metal structure was to be shaped according to the sitting posture made by a human on a stair case while climbing as shown in fig (2). A disabled person can tie his/her legs on the sheet metal frame using rubber belts so

that the frame gets fixed temporarily while climbing. Seat cushions was also provided on the sheet metal frame so that its initiates smooth and comfortable climbing. The major disadvantage of this particular concept is lifting the physical body as well as the cushioned sheet metal frame by a disabled person using both of his hands. This concept was further refined by providing a lever ratchet attachment along with sheet metal frame.

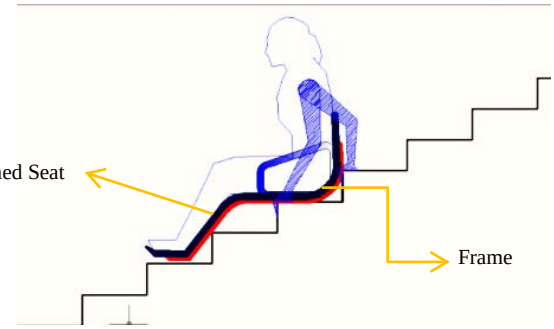

Fig 2 A conceptual representation of climbing stair on a simple frame with cushioned seat

2.1.2 Stair climbing frame with lever ratchet

The initial concept was further improvised by attaching a lever arm and discontinuous wheel for climbing as shown in fig (3). The major drawback in this concept was the stability while operating the lever arm using one hand while climbing the staircase.

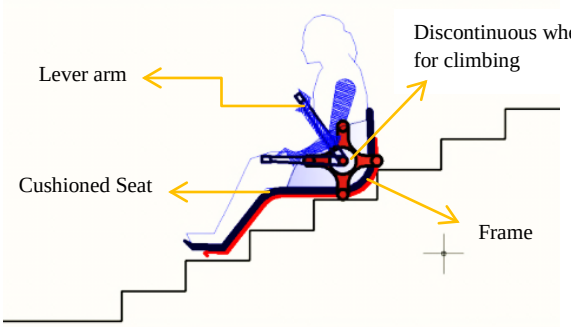

Fig 3 Conceptual representation of stair climbing frame with lever ratchet

2.1.3 Wheelchair and stair climbing frame

The problems associated with the above two concepts was resolved by integrating the concepts and giving rise to a new idea of providing a stair climbing frame on a conventional wheelchair. A conceptual representation of flexible wheelchair design that can shift from conventional wheelchair position to stairs climbing position is shown in fig (4).

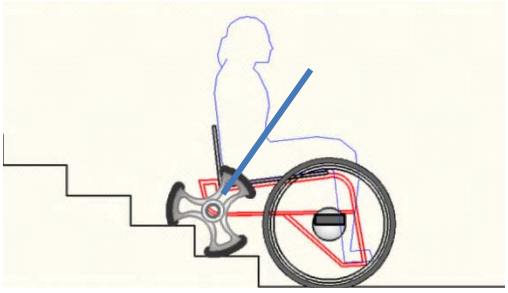

Fig 4 Conceptual representation of a convertible wheelchair

This convertible wheelchair design can help users to access flat surfaces as well as stairs in a convenient way. The concept was further refined by considering the technical parameters like Weight, effort and comfort ability. The below critical parameters were analysed and taken care during the prototype development stage. The lever arm should be designed with an effective gear system to reduce the efforts and enhance the efficiency of the wheelchair [8].

- A provision of resting in the midway while ascending or descending is important, as the user may get tired in the climbing process.
- The size and range of steps in building staircase
- Designing a convenient transition between conventional wheelchair to a stairs climbing position and vice versa.

3 Concept Visualization

The concept of convertible wheelchair was visualized by developing a 3d model using Catia as shown in fig (5).

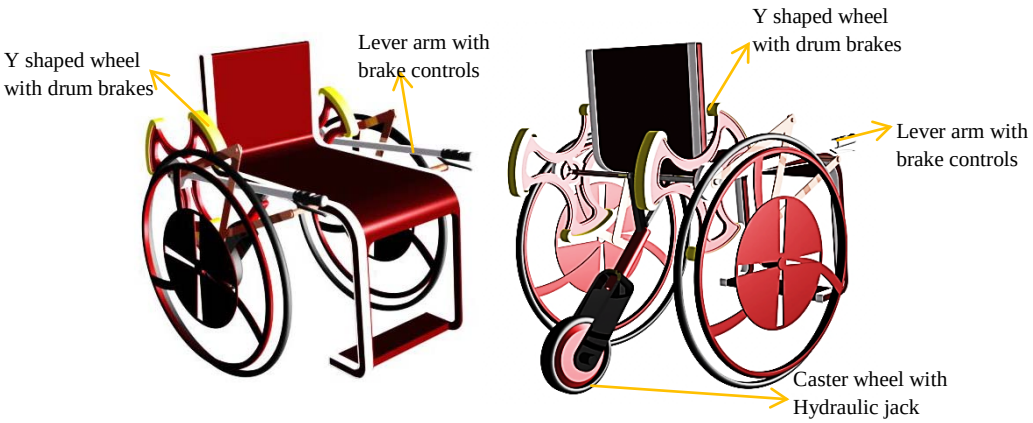

Fig 5 Convertible wheelchair model with Y Shaped Wheel, hydraulic attachment and lever ratchet

All the components of convertible wheelchair like flexible seat, discontinuous wheel, braking system, lever arm was modelled and visualised digitally shown in fig (5)

3.1 Flexible seating position

The convertible wheelchair design needs a smooth, quick and efficient transition from conventional position to stair climbing position and vice versa. A flexible system for changing position can be designed using hydraulic attachment [9]. By designing a four arm linkages with a diagonally placed hydraulic attachment as shown in the fig (6) with the rear caster wheel can make the action more convenient for the user to operate while changing the seating position for climbing stairs or vice versa.

Once the rear caster wheel is locked, hydraulic release will shift the seating position in a guided manner, soon after achieving the stair climbing position Y Shaped wheel will be the active wheels and caster wheel will become inactive.

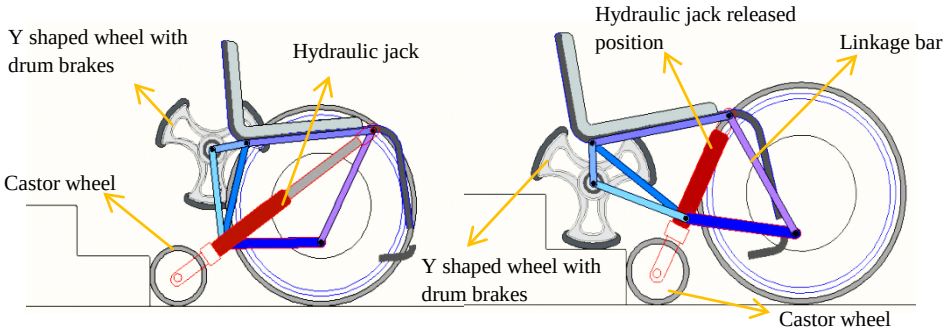

Fig **6** 2d drawing of convertible wheelchair changing position for conventional use on flat surfaces and stair climbing position with the help of hydraulic jack

The distance between the caster wheel and Y shaped wheel is fixed as per the standard public step size. Y shaped wheel is connected with link to seat, which fixes the distance between the wheel and the seat. Aluminium or carbon fibre can be for linkage bar and chassis structure to reduce the weight as well as improve the strength of the wheelchair. These materials will also reduce the efforts made by the user.

3.2 Stair climbing wheel design

The stair climbing Y shaped wheel was designed by imitating the continuous foot movement in a human gait cycle as shown in the given fig (7). The discontinuous wheel or stair climbing Y shaped wheel is designed to produce similar phase cycle as stance and swing phase of human gait cycle [10]. A Conceptual representation of wheel with spokes shoes capable of climbing stairs is shown in fig (7).

The stair climbing Y shaped wheel is designed by considering foot size of human so that each spoke shoe will adjust to the tread size automatically as shown in fig (8). The size between each shoe is designed to negotiate maximum height of the riser in public building. It can negotiate the step riser of range 75 – 185mm and tread width range 230 – 350mm which enables it to access almost all the stairs in public areas [12]. A light weight wheel with drum brakes was also developed to control the movement of the shaft during ascending and descending process.

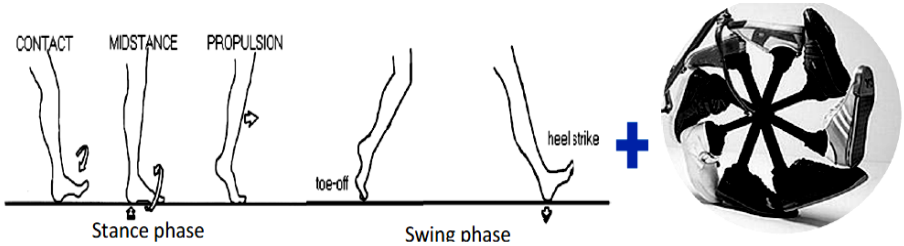

Fig 7 Stance and Swing phases of human gait and Conceptual representation of wheel with flexible foot [11]Photograph from MAINITTE

Aluminium alloy or nylon with rubber grip can be used for the Y Shaped stair climbing wheel to reduce the weight of wheel as well as to provide better strength.

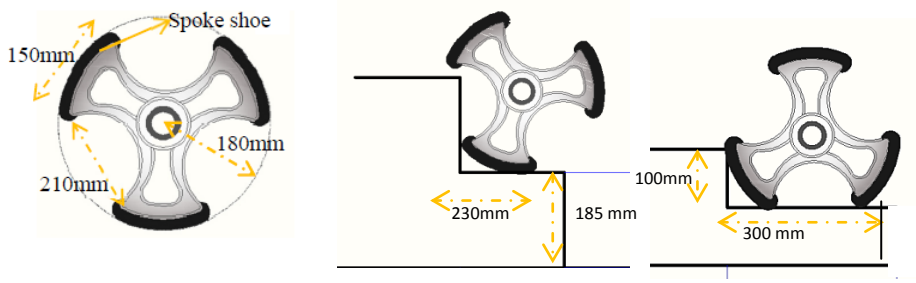

Fig 8 Represent maximum height of riser and maximum depth of tread that can be accessed by stair climbing Y shaped wheel

3.3 Lever mechanism

The two-way ratchet mechanism was developed to attach the shaft connecting both the Y shaped wheel. The mechanism has teeth and a pawl that follows as the wheel turns as per the calculated motion. It can rotate in one direction with the pawl, thereby lifting one pawl and placing the other pawl on the other side makes the shaft go in the other direction. This will control or restrict the motion in one direction either forward or backward and will result stability in motion. With an intuitive action of pushing and pulling the lever ratchet the wheelchair will ascend. A drum brake is connected to each Y shaped wheel to control the speed of motion in both the direction.

4 Prototype

A full-scale prototype was developed to check the feasibility of the proposed concept. For the prototype, an existing wheelchair was modified to a flexible chassis connecting seating and central shaft as shown in the fig (9).

The Y Shaped wooden wheels of 30mm width were made using 25 mm ply wood board which was pasted with rubber grip at the both end as shown in fig (9). A lever ratchet was connected at the end of Y shaped wooden wheel to central shaft of diameter 25 mm

Fig 9 i) central shaft with Y shaped wooden wheel, ii) modified wheelchair chassis

A hydraulic jack having lifting power of two tons was pivoted to the flexible chassis along with the caster wheel on other end. This system can aid in adjusting the seating position while climbing up and down along the staircase. The prototype was tested during every stage of development and necessary modifications were carried out at each stage; prototype was capable of climbing up with sufficient efforts. To achieve an effective speed control mechanism for climbing down, a 180mm diameter disk brake was connected to the central shaft via free wheel.

Fig 10 Prototype climbs up with lever ratchet arrangement and climbs down with disk brake arrangement respectively

The prototype was developed with two separate mechanisms for climbing up by pulling and pushing the lever ratchet as shown in fig (10) and climbing down by controlling the speed by disk brake.

The prototype was tested in almost every building of IIT Kanpur on interior, exterior stairs and has obtained satisfactory results.

- Various step width of the stair that was accessible ranges from 350-230 mm
- Various step height of the stair that was accessible ranges from 110-185 mm
- With various users of weight ranges from 56 - 90 kg

In the final design, disc brakes are then integrated as a part of the stair climbing Y shaped aluminium wheel. The average speed of climbing stairs was 10 steps per minute.

5 Conclusion

The success of initial stage prototype has shown the possibility of exploration of various mechanisms in future. This prototype was an experience based design and can be further iterated considering the technical parameter to develop a successful industrial product for independent stair climbing. The use of appropriate material like aluminium or nylon Y Shaped wheel with drum braking hub, cylindrical aluminium hydraulic jack, geared lever ratchet and light weight frame can also ensures the quality and efficiency of the product.

The proposed concept has proved that there is a possibility to design safe, a low cost, light weight, powered or manual stairs climbing wheelchair.

6 Reference

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