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A Review on Design and Manufacturing of Manually Operated Stair Climbing Mechanism

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***Abstract*: In the field of providing mobility for the elderly and disabled the aspect of dealing with stairs continues largely unresolved. The need of automation in stair climbing is on the boost to innovation. This paper focuses on review of various papers and projects related to this topic. The review is mainly based on studying and analyzing reports and conclusions previously conducted in this field.**

***Keywords*: Stair Climbing Mechanism**

1. Introduction

Wheelchair is a device used by disabled people to improve their personal mobility. There are multiple types of wheelchairs present in the market like hand-operated or automatic wheelchair and the selection of wheelchair depends upon the physical and mental condition of the user. Wheelchair has some demerits against architectural difficulties on its way. As per PWD 1995 act it is compulsory to provide a hospitable environment in every public property but many buildings in India are constructed without considering convenience for disabled people and wheel chair users. Many rural as well as urban of India have addressed the problem by providing substitutes for the constructional barriers like building ramps at entrance, wheel chair ramps, lifts etc. yet a wheelchair user had to face few architectural difficulties. In this study we will attempt to design a wheelchair prototype which can reduce the problem faced by a wheelchair user. Stair climbing wheelchairs currently available for sale in market are costly for the users and are not easy to afford an automatic Stair-climbing wheelchair can be a good solution for the user and can enhance the mobility to access most of the buildings. The primary general purpose mobility assistance device to date for the mobility impaired has been the wheelchair. For the outdoor environment the mobility scooter has become increasingly popular. The choice of wheelchair is based on the user's physical and mental ability. A common approach to negotiating stairs is carrying the person in a lightweight wheelchair, one or two persons at each side. An alternative common approach is carrying elderly or disabled persons on one's back. While this represents a very efficient approach it also presents risk of injury for both persons. The choice of a manually propelled wheelchair while providing essential exercise of remaining physical abilities is largely limited to "barrier free environments," that is, environments that do not impede access to such devices as wheelchairs. The inherent high COG (center of gravity) of lightweight wheelchairs combined with reliance on user propulsion makes them unsuitable to steep slopes (~>5°), rough surfaces and of course stairs. Lightweight wheelchairs and users can however be assisted up or down stairs with 2 to 4 assistants. The powered wheelchair in comparison has a much lower COG due to significant battery and motor weight low to the ground making them better suited to slopes and rough surfaced areas. However, the aspect of stairs and entrance to a secondary means of transport, typically a van, represents significant difficulty. So in order to avoid this situation there must be provision of another system which will provide proper assessment for both subject i.e. disable person or accidental person and supporting person.

2. Literature review

K. Paetzold, S. Wartzack, and D. Krause (2014): This Paper states the preserving of the mobility of elderly people is becoming increasingly important, as other factors of quality of life, such as autonomy or participation in social life, are connected with mobility. Paper starts from an analysis of elderly people as users, combined with the analysis of mobility and mobility situations, a catalog of functions is presented in this paper, which provides the basis for a methods platform to develop user adapted modular mobility-supporting systems. Elderly people partly have individual barriers in handling technical systems as well as in the use of public and private spaces. Uncertainty and fear of handling technical systems have to be taken seriously as well as aspects of stigmatization to ensure the acceptability of the product. The user does not want and should not be necessarily confronted with the entire complexity of technical systems. Any forms of barriers in the use of technical aids have to be avoided. Elderly people need a sustainable support by technical systems. The support should be available so far as it is necessary to obtain or to train the performance [1].

Mokara Bharati, V. DeepikaPoornima, S. Jyothrimai

(2015): The optimization of gear design is a challenging problem as the design variables are interrelated to each other through this paper. Various methods have been proposed for solving such problems. This paper aims in developing a methodology for acquiring the desired worm gear design configuration by altering the optimum set of worm gear design parameters which are suitable for the required performance by associating it with SVM (Support Vector Machine). An evolutionary technique like Genetic algorithm (GA) is also used along with it for optimizing the worm and worm wheel with multi objectives, the main object is to attain high wear capacity by considering module, power, velocity ratio, and speed as design parameters. Center distance and strength of worm gear are the constraints taken into consideration. The benefit of such a prediction model is significant reduction of processing time as well as enhanced flexibility in the design performance. If more parameters are considered over a wider range of parameters, it would certainly make the SVM model a lot more robust and thereby greatly enhance the accuracy of the Genetic Algorithm multi objective optimization in obtaining the best gear design model within the defined constraints [2].

M. R. Kushte, O. S. Dalvi, R. R. Date, A. V. Shelar, A. A Kumbhar (2018): This project involves an ergonomically design and fabrication of a stair climbing functionality will be upgraded by changing its structure design and mechanism. The important parts of this product are conveyor belt, frame and driving mechanism climbing wheelchair for regular use by old disabled people. The design of frame will be done by considering various loads, stresses at various positions. The main factor of wheelchair is laid on the angle of stair and center of gravity of whole system. Understanding the different issues regarding the functionality of wheelchair and introducing an advanced design that will be an as help for the medical field and a helping hand for disabled people. A test model was developed by the authors and modifications were made for design for manufacturing and assembly after thorough experimentation on the model. Based on these modifications, the actual prototype was developed. The chair mechanism and the electrical controls were also mounted. The prototype was tested on level surface as well as on staircase. It is seen that the tank mechanism works effectively as it was expected. The actual working prototype is as per figure below [3].

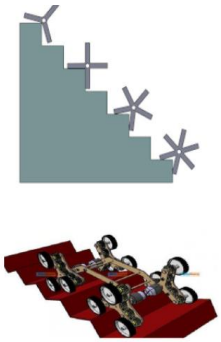

Fig. 1. Working prototype

P. Arulmozhi, M. Chandrasekaran , Ramesh R (2017): This paper describes Gearing is one of the most effective methods for transmitting power and rotary motion from the source to its application with or without change of speed or direction. Gears are mostly used to transmit torque and angular velocity from one shaft to another shaft. The less efficiency of gear box of a machine tool is a serious problem as it increases maintenance cost and also affects the reputation of a firm. Hence its life has to be increased and should be made more reliable. Optimization plays an important role in gear design as reducing the weight or volume of a gear set will increase its service life and improve the bearing capacity. The method of optimum design is effective in the field of gear research to determine the optimum gear parameters for satisfactory design. In gear design, number of parameters were involved. The gear design also requires an iterative approach to optimize the gear parameters. Further work would be directed in the direction of optimization of gear parameters using genetic algorithm producing high quality and cost effective products [4].

Akhilesh Ghogale Gauresh Naik Prince D'silva Devillers Pinto, Sachin Vanjari (2018): The main goal of this paper was to give information about the different wheelchair designed till now. The aim of this paper was to review the state of the art in the technology for stair climbing wheelchair for people with disabilities. They gave review on the research that has been done by difference groups on stair climbing wheelchair. The main goal was to provide the reader that which technology and mechanism can be used to develop the particular wheelchair. By this article we got idea about the environment friendly and by this they can easily compare each type of wheelchair. In this paper, they have mentioned various manually operated as well as automated wheelchairs that can travel on both plane terrains and also in the staircases. They also presented data comparing their capabilities in terms of step climbing and standard wheelchair functions. A number of wheelchairs capable of climbing steps are under current development. These devices represent a variety of approaches to the tasks of climbing a single step or continuous stairs. Control systems range from relying on no sensors at all for detecting features of the environment to closely monitoring the position of each actuated structure and estimating features of the environment. The majority of the identified designs are capable of climbing continuous stairs [5].

Tadakamalla Shanmukh Anirudh Jyoti Pragyan Satpathy (2014): This paper gives us idea that first wheelchair model evolved long back in 18th century, but rapid development in this field initiated since mid of 20th century. Since then, many varieties of models had been designed, extending into broad range of products. This project involves the design of an ergonomically designed electric wheelchair for domestic use by Indian old aged people. Stair climbing functionality is embedded in the design through its structure and mechanism. The product mainly consists of 3 modules viz. seat, links and frame. Anthropometric measures are considered in the

dimensioning of seat. The frame and wheels are designed and developed through the equations generated from the statistical data of dimensions of staircases in Indian houses. Focus is laid on different parameters such as form, functionality, technology and architecture of the product. The design is validated by developing Digital Mockups of individual parts are generated in CATIA and are assembled to form the final product. The mechanism for engagement and disengagement of shaft to the sun gear and the wheel carrier are to be developed further, to accommodate the switching between stair climbing mode and moving on flat ground mode. This could be provided either manually or automatically by setting the maximum limit for torque in flat ground mode [6].

M.J. Lawn (2003): In the field of providing mobility for the elderly and disabled the aspect of dealing with stairs continues largely unresolved. Author focuses on presenting the development of a stair-climbing wheelchair mechanism with high single step capability. The mechanism was based on front and rear wheel clusters connected to the base (chair) via powered linkages so as to permit both autonomous stair ascent and descent in the forward direction, and high single step functionality for such as direct entry to and from a van. Primary considerations were inherent stability, provision of a mechanism that is physically no larger than a standard powered wheelchair, aesthetics and being based on readily available low cost components. The conventional climbing process is shown in figure below. A stair-climbing wheelchair mechanism with high single step capability has been numerically modeled, simulated and a functional scale model built. The scale model mechanism has been equipped with a minimal control system and successfully operated in the negotiation of stairs both up and down in the forward direction. The mechanism had also been successfully operated in boarding and disembarking from a scale model van. The design was based on low cost readily available components. An analysis of actuator output requirements has been provided. Future work is required in the development of the stair-climbing steering mechanism, and the production of a full size prototype mechanism [7].

Fig. 2. Conventional climbing process

Peter Lansleya, Susan Flanagana, Kate Goodacrea, Alan Turner-Smithb, Donna Cowanb (2004): The Author states that a rapidly growing number of older people wish to remain in their existing homes for as long as possible, in many cases leading to the need for adaptations. The extent of the adaptations required is influenced by the nature of the individual's impairments and by the design of their property. An approach to understanding the impact of the needs of older people on adaptation requirements based on the development of standard User Profiles and Mobility Profiles is presented together with an analysis of a varied set of 82 properties selected from across the UK. This paper was presented an embryonic methodology for systematically analyzing the feasibility of the adaptation of properties. As a result, it was possible to draw a number of firm conclusions. The methodology had generated data that is capable of interpretation and accords with expectations from straightforward observation of properties. Whilst the use of User Profiles is valuable, consideration of the adaptability of the properties had been more clearly assessed by Mobility Profiles, which exclude impairments other than locomotion. It should not be forgotten, however, that needs arising from these impairments can add significantly to adaptation costs.[8]

Joe Verghese, Cuiling Wang, Xiaonan Xue, Roee Holtzer (2008): The paper describes the Self-reported difficulty in climbing up or down stairs in non-disabled elderly. With an objective to examine clinical and functional correlates of self-reported difficulty in climbing up or climbing down stairs in older adults. Design included Cross-sectional survey. Setting: Community sample. Participants: Older adults (N310; mean age, 79.7y; 62% women), without disability or dementia. Interventions: Not applicable. Main Outcome Measures were clinical and functional status as well as activity limitations (able to perform activities of daily living [ADLs] with some difficulty). Self-reported difficulty in climbing up and down stairs revealed commonalities as well as differences in related clinical correlates. Difficulty in both climbing up and down stairs should be separately assessed to better capture clinical and functional status in older adults was observed.[9]

J. M. Holden, G. Fernie and K. Lunau (1998), Author states that ageing brings a number of normal physical changes and sometimes is accompanied by diseases that affect physical functions and abilities. Therefore, the elderly requires special consideration in the design of chairs. Requirements for three types of chairs for the elderly are presented. A description of a typical user of each chair provided a reference for the level of ability that must be accommodated. Features of the chairs that promote comfort, safety, ease of ingress and egress and ease of propulsion (where applicable) are discussed in relation to some of the special problems experienced by some of the older members of the population. The comfort, safety and functional independence of our growing elderly population might be dramatically improved with better seating design. This paper had presented a collection of design considerations based on the published literature and our own clinical experiences. The review stated that this review may stimulate the development of

some improved products for the elderly [10].

Michael Hinderer, Petra Friedrich, Bernhard Wolf (2017): This paper gives us idea about Mobility. Author states that demographic change is making more and more elderly people dependent on care. As a result, there are staff shortages at nursing homes, which now require technical aid. Mobility is considered an essential component for ensuring quality of life, social contact, and a self-determined life. With the introduction of the autonomous stair-climbing wheelchair, unlimited and independent mobility was ensured for movement-limited people. Because of dynamic stabilization, the wheelchair moves on only one axis. Thereby, it had highly agile driving behavior and is compact in size. The autonomous climbing system is based on a leg mechanism that consists of two legs with lower and upper leg support. While climbing a stairway, the legs push the wheelchair on the next higher situated step. Afterwards the legs are pulled successively on to the next step as well. While climbing down, the opposite sequence of movements occurs. The autonomous stair-climbing wheelchair based on legs presents a good alternative to the conventional caterpillar-based stair climbers that are commonly afflicted with disadvantages. This leg-based mechanism provides for secure and adaptable climbing. It was also lightweight and very dynamic. There are mostly four, but at least always three, supporting points at sufficient distance from each other, to avoid any chance of falling. This also helps in case of an electrical failure as described by author.[11]

Celso De La Cruz, Wanderley Cardoso Celeste, Teodiano Freire Bastos (2011): A landmark based navigation system for robotic wheelchairs was developed by the author. The proposed navigation system was robust in the localization procedure which was the major problem in robotic navigation systems. Every landmark was composed of a segment of metallic path and a radio-frequency identification (RFID) tag. The odometry information was used for localization, which was corrected on-line every time the robotic wheelchair is over a landmark. A topological map is generated using such landmarks to compute the shortest path. A technique to generate the topological map for this navigation system and an obstacle avoidance strategy are also developed. An effective and efficient landmark based navigation system was developed in this work.[12]

Ruth E. Mayagoitia, John Harding, Sheila Kitchen (2017): The aim of this paper was to develop a quantitative approach to identify three stair-climbing ability levels of older adults: no, somewhat and considerable difficulty. Timed-up-and-go test, six-minute-walk test, and Berg balance scale were used for statistical comparison to a new stair climbing ability classifier based on the geometric mean of stair speeds (GeMSS) in ascent and descent on a flight of eight stairs with a 28 pitch in the housing unit where the participants, 28 (16 women) urban older adults (62e94 years), lived. Ordinal logistic regression revealed the thresholds between the three ability levels for each functional test were more stringent than thresholds found in the literature to classify walking ability levels. Though a small study, the intermediate classifier shows promise of early identification of difficulties with stairs, in order to make timely preventative interventions. Further studies are necessary to obtain scaling factors for stairs with other pitches. The number of volunteers in this study was small and the encouraging results of the GeMSS will need to be put to the test in a larger scale study. Also in order to be able to predict the level of risk of stair-related falling for an individual, based on the use of the three stair climbing ability levels defined here, a future project would need to examine a cohort including known elderly fallers [13].

Giuseppe Quaglia, Walter Franco, Riccardo Oderio (2011): The Author from this paper deals with Wheelchair. A concept for a stair climbing wheelchair capable of moving in structured and unstructured environments, climbing over obstacles and going up and down stairs. The design of the wheelchair, consisting of a frame, a seat and a four-bar linkage mechanism that connects frame and seat, is presented. The four-bar linkage moves and rotates the chair to prevent the wheelchair from overturning and to guarantee a comfortable posture to the passenger during different operations. The kinematic synthesis of the linkage mechanism is discussed using an algebraic method. When the wheelchair faces an obstacle such as a step or a stair, it can passively change locomotion mode, from rolling on wheels to walking on rotating legs, thanks to its self-adaptive locomotion units. The function of the locomotion unit was described and modeled using kinematic equations. The locomotion unit requires only one motor, for both wheeled and legged locomotion. Tests on a scale prototype were conducted in order to evaluate the effectiveness of this locomotion. A concept for a stair climbing wheelchair was presented. Thanks to its auto-adaptive locomotion units, it can move in structured and unstructured environments, climb over obstacles and go up and down stairs. The locomotion unit's mechanical design makes it possible to reduce the number of motors and thus the wheelchair's weight and size. In fact, only one motor is necessary for each locomotion unit. Control algorithm complexity also decreases: changes in locomotion mode, from rolling on wheels to walking on legs, are triggered entirely by local friction and dynamic conditions, with no need for a high level control [14].

Dmitry A. Sinyukov, Karen L. Troy, Matthew P. Bowers, Taskin Padir (2019): Almost every eighth person in the United States has a certain degree of disability. For 130,000 people suffering from paraplegia (severe or complete loss of motor function in the lower extremities and lower portions of the trunk) and almost 120,000 people suffering from quadriplegia (when all four limbs are affected) in the United States, the use of wheelchairs is typically necessary in order to perform activities of daily living (ADLs). When quadriplegia is combined with anarthria (loss of speech), but consciousness is preserved, the condition is known as locked-in syndrome (LIS). Even if the reliable autonomous wheelchair technology is available, are the users ready for it? The short answer is it

depends. It depends on the severity of the disability, and on the individual's overall morale and attitude toward his or her condition. It also depends on how quickly and completely one can put support systems, trained technicians, and services in place. In conclusion, there is a substantial group of early evangelists who are ready to invest in smart wheelchair technologies to improve their mobility and as a result productivity. More work is required to bring this technology to them as described by the author [15].

3. Conclusion

The different mechanisms were reviewed and the most appropriate were studied in detail. Their advantages and limitations were compared. It can be concluded that the manually operated stair case climbing system is best substitute for the electrically powered Chair lift. Taking the high cost of manufacturing the automatic wheel chairs into consideration. This system can be implemented anywhere and it is cost effective.

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