REVIEW OF TRACTION SYSTEMS AVAILABLE FOR A CONVENTIONAL WHEELCHAIR

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ABSTRACT

Motorized wheelchairs use mechanical and electronic devices, having a high cost to purchase these assistive equipment. Nowadays it is possible to find on the market various types of drive systems to transform a conventional wheelchair in a motorized chair. This study aims to perform a literature review of the models of traction kits that can be coupled to conventional wheelchairs, turning it into an electric tricycle, in order to facilitate the movement of wheelchair users. These traction systems provides the wheelchair user a new option for daily use of the wheelchair getting more comfort in their day to day. The adaptive KITs can be used in a wide variety of models of wheelchairs and for internal or external environments. This KITs enables the adaptive wheelchair travel greater distances in less time, making more quality of life.

Key Words: Wheelchair, Motorization, Electric tricycle, Assistive technology.

1 - INTRODUCTION

It is important and necessary to ensure to persons with disabilities the right to locomotion with autonomy and independence, allowing strengthening their social, political and economic as citizens. One of assistive technology equipment most used for moving people with inability to move (temporarily or permanently), using the lower limbs, is the wheelchair(Becker, 2000).

The World Report on Disability (2011) reports that 15% of the population has some form of disability. This number is increasing due to various factors such as an aging population (due to increased life expectancy), environmental degradation or malnutrition leading to the onset of chronic diseases, traffic accidents, work accidents, wars and birth defects, contribute to escalation of the number of people with movement difficulties (Cook, 1995).

It is important and necessary to ensure to persons with disabilities the right to locomotion with autonomy and independence, allowing strengthening their social, political and economic as citizens. One of assistive technology equipment most used for moving people with inability to move (temporarily or permanently), using the lower limbs, is the wheelchair(Ferrada, 2007; Souza, 2011).

Since the invention of the wheelchair, according to historians in the sixteenth century, is considered the most practical means of locomotion for people who have difficulty in walking. Besides the mobility of utility, the wheelchair has the function of socializing the poor. Currently, a special focus is placed on mobility, since for people with disabilities, the physical and/or mental level, the wheelchair can be the only means of mobility. For this reason, it is essential to have wheelchairs that allow a better quality of life (Bazzo et al, 2009).

The wheelchair is present in the lives of these people as the primary means of locomotion, therefore, for several years it has been developed and there are several types of this product on the market. Prices are varied depending on the value added, because this technology in the chair (Cook, 1995).

Wheelchairs are available for different purposes, with different modes of cooking. In general, one can classify the wheelchair as to propel: manual or motorized. Within this classification, there are other categories related to the environmental context and individual needs(Silva, 2010; Rodrigues, 2000; Bromley, 2006).

In the current market is a very large range of wheelchair, namely: folding wheelchair with manual propulsion, semi-reclining chair, standing position chair, wheelchair for use in sports and scooters, among others (Bromley, 2006).

Motorized wheelchairs are technologically complex equipment, which use mechanical and electronic devices, having a high cost to purchase these assistive equipment. Research on development of assistive technology are constantly held to promote social inclusion (Mason et al, 2013). Currently, some other forms of motorization for wheelchairs are found in the market.

For the last years we have been experiencing a constant evolution in the field of electric wheelchairs which allows more flexibility of use for disabled people. Wheelchairs have passed from roller or belt drive to back-geared motor drive, from electric to electronic control with all the advantages it can offer in programming. The construction of electronic wheelchairs requires many elements to be taken into account. As a matter of fact a wheelchair design must integrate various parameters such as speed, acceleration, braking, dynamic stability, dimensions and adjustments to comply with the impairment (Attali, 2001).
Nowadays you can find on the market various types of drive systems to transform a conventional wheelchair in a motorized chair. This study aims to present a history of the development of wheelchairs and research on the main models of traction kits that can be coupled to conventional wheelchairs, turning it into an electric tricycle, in order to facilitate the movement of wheelchair users.

2- CONFIGURATIONS OF THE WHEELCHAIR COMPONENTS

There are wheelchairs for different purposes. In general, one can classify the wheelchair as to propulsion: manual or motorized. Within this classification, there are other categories related to the environmental context and individual needs. The prescription of the wheelchair starts with the choice of the mechanical construction of the wheelchair. Especially for patients with impaired mobility of the upper limbs, weight is an important factor and should be considered in the selection of the wheelchair frame(Bertoncelo, 2002; Sudheesh, 2012).
In turn, the wheelchair can have a fixed or folding structure. In the fixed structure, also called monobloc, the closing is front with the back going against the seat, which provides a difficulty in transportation. The foldable structure has a constitution equivalent to an X, which causes its name, "X" or "double X". By being a fold structure, it has better handling and transport, a fact that should be considered when prescribing wheelchair. The structure "double X" has a greater strength and resistance, recommended for obese patients.
The goal of accessibility is to allow a gain of autonomy and mobility to a broader range of people, even those who have their reduced mobility or difficulty communicating, so they can use the spaces and the advantages that the environments can provide (Das, 1999).
There are basically two groups of wheelchairs when referring to the form of propulsion: manual and electric, and there are several subgroups within each type. Some models of wheelchairs found in the market are presented below(Souza, 2011). Folding wheelchair with manual propulsion (Figure 1A), standard type chair (Figure 1B), semi-reclining chair (Figure 1C), wheelchair for sports and scooters (Figure 2).

A B C

Figure 1 - (A) Folding wheelchair with manual propulsion, (B) standard type chair, (C) semi-reclining chair.

Figure 2 - Wheelchair for sports and scooters.

2.1- Motorized Wheelchair

Electro mechanical and electro electronic wheelchairs, called motorized wheelchairs, despite having the higher cost, have numerous advantages over the manual chairs(Mark et al, 1998; Zagol, 2010). Due the fact of work by self-propelled, their movement is totally independent of physics wheelchair force, as well as providing other devices, such as lifting system "stand-up", speed variation, differentiated gravity center for amputees, directional control for driving by third parties command for driving the jaw for quadriplegics, backrest cushion, basket for shopping, umbrella, table, backpack, fanny pack with urine collector, ankle tab, support for cane, crutch, bags, oxygen and serum among other facilitators devices (Alves, 2011; Mazo, 1995).

Currently the market has a competitiveness among manufacturers who actively seek continuous improvement of its products and technological innovation in its many electromechanical wheelchairs. This equipment provides comfort, pleasant visual and reliable system structure and motorization(Figure 3) (Freedom, 2016).

Figure 3 - Freedom electromechanical wheelchair models.

3- TRACTION SYSTEMS FOR CONVENTIONAL WHEELCHAIR

One way to power train wheelchair is to obtain independent accessories that enable the transformation of a manual wheelchair in an electromechanical wheelchair. Generally, the installation of such devices is feasible in most models available on the market (Alves, 2011; Cunha, 2015).

This motorized equipment model aims multifunctionality of a wheelchair. It makes possible the use of the chair in motorized form which provides greater autonomy to the user, while maintaining the integrity and functionality of the manual equipment.

The traction systems to be embedded in the wheelchair turning it into an electric tricycle must be functional, safe, reliable and economically viable. The basic premises of the project were: (a) The product must provide performance that meets user needs; (b) The product must not endanger the users; (c) The product should be a strong competitor in the market; (d) The product shall provide a user-friendly interface, meeting the specifications such as size, strength, posture, reach, power and control; (e) The product should be kept to a minimum number of components, suitable for large scale production.

These traction systems can be used for internal, external or both environments. There is a wide variation in the components found in these motorized accessories. There are those who keep the traditional "joystick" as a means of control and the other controlled by a steering wheel. Some of these drive systems are presented below.

Alves (2011) presents a mechanical structure divided into two parts, the independent automotive equipment (Figure 4a) and the universal support for the wheelchair (Figure 4b). The support consists of a simplified structure capable of installation on many wheelchair and the next part is coupled to the first quickly and safely. The basic safety system consists of a pair of mirrors, front and rear light. The steering column is adjustable to the driver's size. It is coupled to a universal support, also with adjustments that adapt to the chair. The fixing is made by means of a support fixed with clamps on the underside of the seat. The user can make the coupling if it has power in his hands.

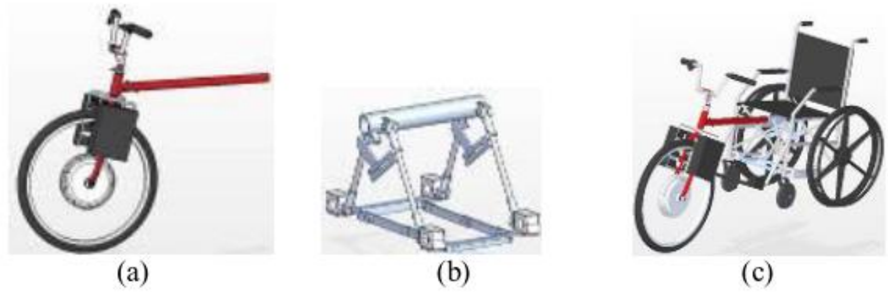

Figure 4 - (a) Independent automotive equipment; (b) Universal support for wheelchair; (c) Motor traction system for wheelchairs.

The device (Figure 4c) must be detachable and easy to install in any wheelchair model, and can be used in different types of ground. The engine is made by a brushless motor and according to the weight of the wheelchair, can be used with an engine power of 250W, 350W or 500W, directly coupled to the hub of the front wheel. The power electronics is performed by a set of batteries. The equipment consists of some electronic devices, such as, potentiometer accelerator, brake sensors, control module and control panel with battery charge indicator and speedometer (Figure 5).

The speed can reach 35km/h, but is limited to 20km/h for safety reasons. The tire varies from the standard size of 20 inches or can be used a 16-inch size, to facilitate entry into tight spaces. The battery allows autonomy of 20 km.

Figure 5 - Adaptable wheelchair kit.

The coupling and uncoupling of the motor equipment on the wheelchair is accomplished by a joint system on the main bar to enable the user to perform the installation of the self-propelled equipment securely. This linkage allows raising the small front wheels of the wheelchair, allowing the self-propelled drive the rear wheels(Alves, 2011).

Cunha et al (2015), present an adaptive KIT that was divided in 4 sets, called: (a) Fixed set: It is fixed to the lower part of the chair; (b) Coupling set: Part that is embedded in the fixed set; (c) Panel set: Components that control the direction, such as the handlebars and adjustments KIT components; (d) Power set: Components that provide the mobility of the chair as the motor, batteries and the wheel.

In the full KIT (Figure 6), the Coupling set and the Fixed set are responsible for KIT engagement in the chair. The Coupling set consists of two bars that are connected to the Fixed set through pins. The Panel set is composed of the handlebars and other mechanisms that allow the user to adjust the operation of the KIT, such as the brake system, speedometer and drive key. The Power set consist of items that promote traction as the motor coupled to the wheel, batteries and the wheel.

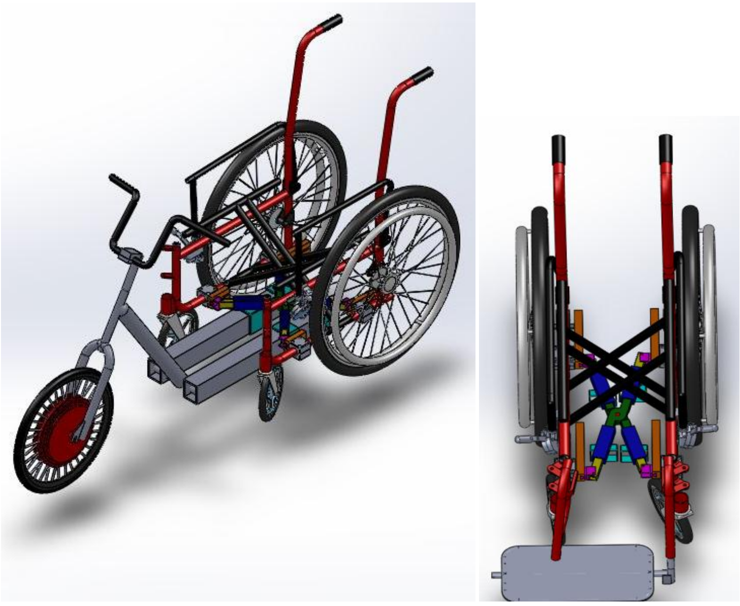

Figure 6 – Adaptive KIT assembled on the wheelchair.

The fixed set is permanently attached in the chair (Figure 6). This structure is fixed to the lower part of the chair and has four cube-shaped pieces that allow coupling KIT. The assembly has a "X" format that permits rotation around the center pin allowing the closing of the folding chairs without the removal of KIT(Cunha, 2015).

Some models of commercially available kits, which can be adaptable to the wheelchair, are presented below.

3.*1 –"Power-trike" Kit*

The model "Power-trike" (Figure 7) consists of a trailer electrical system, moved by a tensioned front wheel able to be installed in about 80% of models of manual wheelchairs. The maximum speed is 17 km/h for users up to 90 kg (PDG Mobility, 2016).

Figure 7 - Model "Power-trike".

The device features a dual mechanical brake system with brake pads and electronic control system with two speeds which offers great efficiency and drivability. Its structure in aeronautical aluminum ensures a low weight equipment. The model has autonomy of 30 km during use with batteries at full charge. Suitable for use in various common areas, this assistive equipment ensures great freedom of movement to the user in their daily activities.

3.2 – "Firefly" Kit

The Firefly model can be designated as a kit to attach to a manual wheelchair, turns into an electric wheelchair. As can be seen from Figure 8, the kit is adapted on both sides of the chair by a fixing system which uses clamps which are easily adjusted (Rollick, 2016).

Figure 8 - Firefly - Adaptable kit in the wheelchair turning it into a tricycle.

The Firefly is designed to be used in most conventional market wheelchairs due to its simplified mounting system and allows a maximum speed of 30 km/h. The system is powered by an electric brushless motor, compact and quiet. All controls are within easy reach. It has display to select the power level, speedometer, battery level indicator and brake system.

4 - Research and development for electric wheelchairs

The recent wheelchairs with traction system have motorized wheels driven by the controller, which needs to detect propelling force and continuously determines the amount of assisting force exerted by the motorized wheels. Suzuki et al (2006) proposed a model for designing of safe motorized wheelchair. The model evaluates the movement of the wheelchair and the effect of the drive system to provide wheel torque.

During the design of this type of device is necessary to conduct an analysis of the structural integrity of the wheelchair and components that will be adapted to it. Generally it uses finite element programs for performing the simulations in the conditions of use (Dsouza, 2010; Liu et al, 2014; Cowan, 2009; Chenier, 2014; Yilmazcoban, 2012).

Gorce and Louis (2012), presented a study to examine the influence of the wheelchair settings on kinematics during wheelchair propulsion. Recordings were made under various wheelchair configuration conditions to understand the effect of wheelchair settings on kinematics parameters.

Wanga et al (2009), purposed to evaluate the effects of three different control methods on driving speed variation and wheel slip of an electric-powered wheelchair. A kinematic model as well as 3D dynamic model was developed to control the velocity and traction of the wheelchair. A smart wheelchair platform was designed and built with a computerized controller and encoders to record wheel speeds and to detect the slip. The speed errors, variation, rise time, settling time and slip coefficient were calculated and compared for a speed step-response input. Experimental results showed that model based control performed best on all surfaces across the speeds.

Dicianno et al (2010) discuss the current state of control interface technology and the devices available clinically for power wheelchair control. In addition, a novel hardware and software approaches that are revolutionizing joystick interface technology is presented, that allow more customizability for individual users with special needs and abilities.

Assistant robots like robotic wheelchairs can perform an effective and valuable work in the user's daily lives. However, they eventually may need external help from humans in the robot environment to accomplish safely and efficiently some tricky tasks for the current technology, i.e. opening a locked door. Galindo et al (2006), have proposed a control architecture for assistant robots, that can be applied to eletrocnic wheelchair, designed under a multi-agent perspective that facilitates the participation of humans into the robotic system and improves the overall performance of the robot as well as its dependability. The proposed architecture is illustrated with a real assistant robot: a robotic wheelchair that provides mobility to impaired people.

Wang and Chiang (2012) proposed the design and control of a powered wheelchair. It was designed a fuel-cell powered electric wheelchair that can be continuously operated, thereby extending the moving range. The system consisted of three subsystems: a commercial electric wheelchair, a proton exchange membrane fuel cell (PEMFC), and two secondary battery sets.

Cruz et al, (2011) present a landmark based navigation system for robotic wheelchairs. The system is robust in the localization procedure which is the major problem in robotic navigation systems. Every landmark is composed of a segment of metallic path and a radio-frequency identification tag. The odometer information is used for localization, which is 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.

5 - DISCUSSIONS

Currently there are an infinity of models of wheelchairs available. Motorized systems adaptable to conventional wheelchair has been gaining attention as more accessible products as regards cost, compared with a motorized wheelchair. This type of assembly provides the wheelchair user a new option for daily use of the wheelchair getting more comfort in their day to day. The adaptive KITs presented in this work can be used in a wide variety of models of wheelchairs. This KITs enables the adaptive wheelchair travel greater distances in less time, making more quality of life.

However, existing kits on the market need to be uncoupled from the wheelchair frame when the user wishes to use it as a conventional wheelchair. The main challenge to evolve existing models is to develop a system that does not need to be uncoupled from the wheelchair so that it can be used as a conventional wheelchair.

Therefore, it is necessary to reduce the total weight device and to develop a articulated system for collecting kit components in any part of the wheelchair frame.

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