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Some Aspects of Developing and Improving the Mechanical and Operational Features of Wheelchairs for People with Limited Mobility

E Ph Chubenko¹, O V Grivanova¹

¹Vladivostok State University of Economics and Service,
Russia, Primorsky Krai, Gogolya St., 41

E-mail: elena.chubenko@inbox.ru

Abstract. The present paper presents the field test result softwheel chairs with basic configuration, i.e. self-propelled; motorized with motor-wheels; self-propelled with SOFTWHEELS; and motorized equipped with motor-wheel and SOFTWHEELS at the same time.

Mechanical and operational performance factors are provided for the self-propelled wheel chairs with basic configuration in order to compare them with the ones equipped with supplementary units.

Special attention is paid to the standard design and operation principles of the Bikight hub motor wheel, its mechanical and operational features that allow moving a wheelchair without applying the force of user's hands.

Equipping wheel chairs with SOFTWHEEL. So opens new possibilities for people with limited mobility and allows them to travel not only a long well-paved roads but also along unpaved, gravel, dirt roads and in parks with uneven paths; the vibrations and shocks can be compensated by SOFTWHEELS that greatly improves the quality of motion.

Moving along a bumpy road causes a stiff rim to shrink thus resulting in shock-absorber fluctuations for dampening the vibration and impact for the wheelchair users.

The design of a wheel chair with hub motor wheels and SOFTWHEELS seems to be the most efficient one.

The present paper reviews the mechanical and operational features of the combined use of equipment.

1. Introduction

Improving the life quality of people with limited mobility has remained a challenge since they encounter difficulties while using self-propelled wheelchairs, obtaining services, participating in industrial processes and social life, etc. [1].

When we talk about people with limited mobility we usually mean the disabled people who use wheelchairs [2]. For a long time these people have been using specially-designed wheel chairs that have many downsides. The biggest disadvantage of these devices is that users have to apply manual force to move them [3].

Modern technological advances have brought to the market a new small-size motor-wheel that can propel the wheel chair without having to apply manual force [4]. These wheels have a simple design,



high operational reliability and performance. Easy handling and maintenance as well as high operational reliability make them essential and socially-significant for people with limited mobility.

The engineering solution that includes using SOFTWHEEL in suspension of wheel chairs is of special relevance as it ensures transportation along unpaved roads with many obstacles [5]. This approach to the development of suspension design expands the mobility opportunities of people with limited mobility thus improving their life quality.

The authors applied the Rhinoceros 3D application designed for rendering the NURBS geometry in order to create 3D models [6]. This application is also designed to work with hard-body objects with the help of industrial modelling [7].

2. Methods

The present research involved field studies where specific conditions and road operation facts were recorded during the use of wheelchair throughout 2019. The mechanical and operational features of developed designs were studied with consideration of the space and time parameters of motion. The author s also generalized the most recent experiences of designing wheelchairs, conducted a theoretical analysis and synthesis, system and structural analysis, 3D modelling, specification, as well as collected independent data and statistically processed it.

3. Main part

A hub motor wheel is them a in element of the unit (Fig. 1); it serves as an electric propulsion unit of the whole vehicle [8]. The motor wheel it self is an electric motor in side a conventional wheel that does not use any other additional power transfer unit [9]. High performance and almost zero friction of parts are the important advantages of the motor. This design relies on the Bikight hub motor wheel. The center of the hub has an opening with as haft for connecting with a coupling unit; the hub contains he main element soft he motor wheel: stator, rotor and winding (Fig. 2) [10].

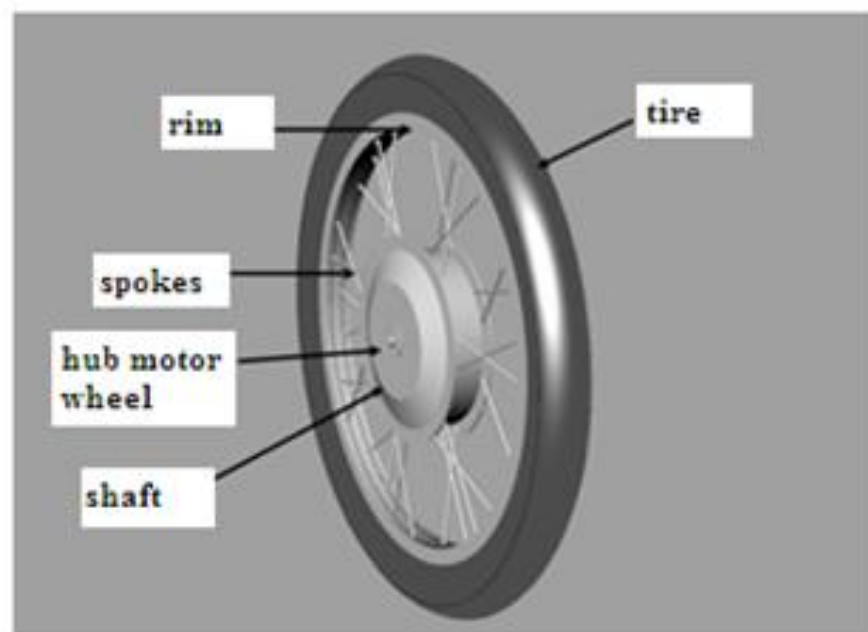


Figure 1. 3D model of hub motor wheel.

The principle of motor wheel operation is as follows: the stator creates a rotating magnetic field that interacts with the rotor magnets that causes the wheel to rotate [11]. The stator has a shape of a multi-beam star with windings on the beams.

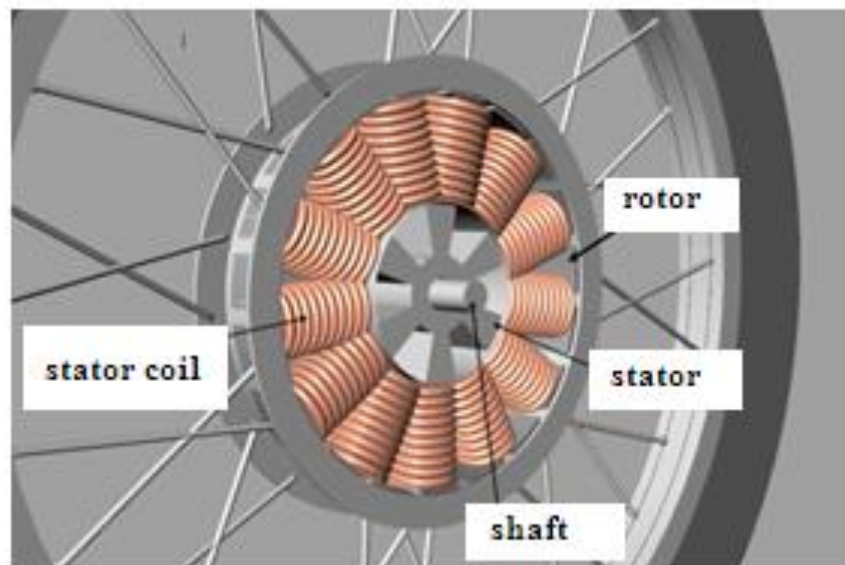


Figure 2. Design of a motor wheel.

When electric current passes through the winding, the beams acquire electromagnetic properties and draw the magnets located on the rotor [12]. There are many winding son the stator – it provides for a smooth rotation and sufficient power [13]. All windings are linked in to three ones that alternate around the circumference.

Continuous rotation of a motor wheel is ensured by the voltage impulses supplied to the winding that active a test heir magnetic properties at the approach to the required magnet. The magnets are located on the rotor at a short range.

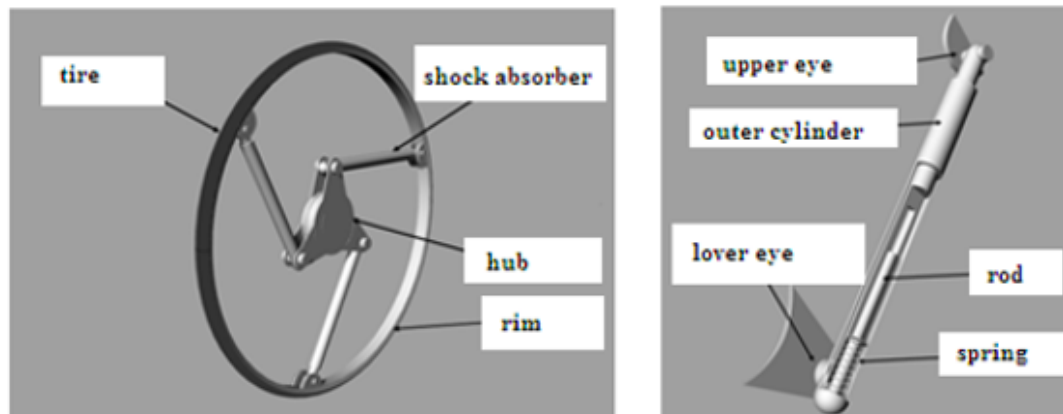
The mechanical properties of a motor wheel used for improvement of the wheelchair suspension are shown below (Table 1).

Table 1. Mechanical properties of Bikight hub motor wheel.

Material	Aluminum alloy, rubber
Power of motor wheel	450W
Size of wheel	10"
Maximum speed under load	45 km/h
Battery capacity	3500 mAh
Capacity and voltage of battery	9 Ah, 45 V

SOFTWHEEL is an innovation suspension system built in to the wheel. The main advantage of this system is that suspension is inside the wheel and is able to absorb impacts and vibrations in several directions thus enhancing the response, handling and efficiency of the suspension.

SOFTWHEEL wheels are designed specifically for bikes and wheelchairs; in the future they may be used in motorbikes as well (Fig. 3). A SOFTWHEEL wheel can absorb up to 50% of energy during moving on bumpy surfaces: curbsides, stairs, etc. Suspension in side the wheel is also activated only in case of contacting with uneven surface: that means that a SOFTWHEEL wheel works as a usual wheel during moving along smooth roads.



\$4\$

a) SOFTWHEEL wheel, b) shock absorber

Figure 3. Design of SOFTWHEEL wheel and shock absorber.

SOFTWHEEL wheels have the following advantages in comparison with conventional wheels:

- absorb vibration and shocks during moving across obstacles and uneven surfaces;
- can be easily removed or installed onto the vehicles thanks to its quick-detachable axis;
- provide for various options of shock absorber stiffness.

In the SOFTWHEEL system three piston shrink to absorb impacts thus ensuring shock absorption.

The rim of a wheel is made stiff and hard while the suspension arms and the hub ensure shock absorption. During motion over obstacles the shock absorber spring shrinks automatically while becoming stiff during motion on smooth surfaces.

Suspension arms are located at equal range around the central hub and are activated only during motion over obstacles or uneven surfaces (Fig. 4).

The system ensures 360° regardless of the angle of the piston location.

These wheels are ideally designed for the wheelchair described in the article that has to operate under the current road conditions. The wheel chair can be controlled with a joystick on the armrest via that transfers electronic signals to the motor wheel [14]. The electronic lines are hidden in the tubular structure of the wheel chair.

The motor wheel is attached to the wheelchair with a coupling unit that consists of two tubular cylinders that are connected with the wheel hub via a special shaft [15].

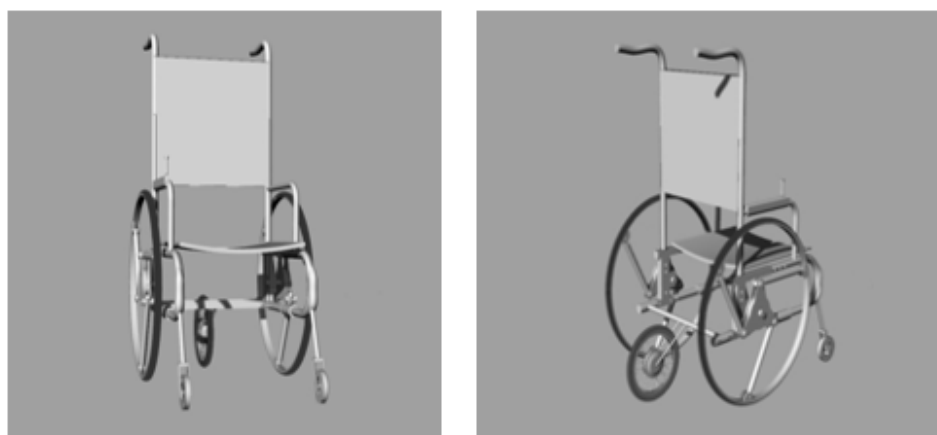


Figure 4. 3D model of suspension of an assembled wheelchair with motor wheel and SOFTWHEEL.

On the other side the plates are connected with a transversal hollow cylinder that is linked to the wheel chair with a number of openings in the rod-shaped suspension.

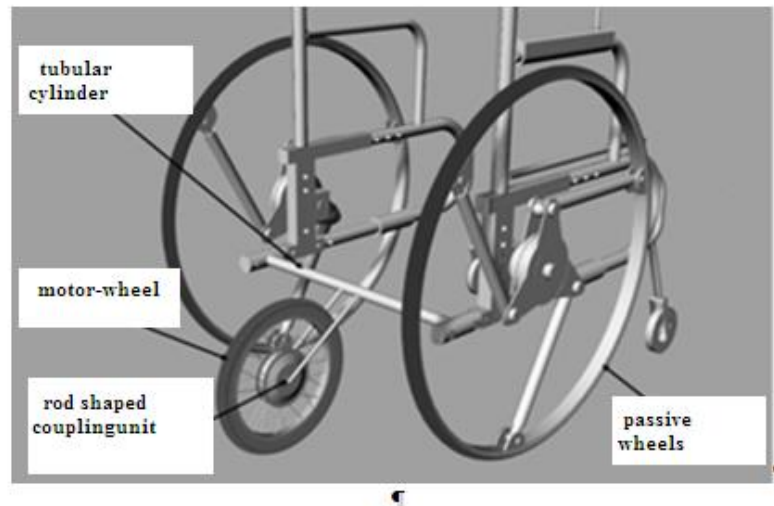


Figure 5. 3D model of wheel chair.

Below (Table 2) there are mechanical features of the four configuration variant soft wheel chairs—basic configuration (no motor wheels or SOFTWHEEL); a wheel chair with motor wheel only; a heel chair with SOFTWHEEL wheels only; a wheelchair with motor wheel as propulsion unit and SOFTWHEEL wheels (combined configuration).

Table 2. Mechanical features of wheelchairs.

No.	Feature	Basic configuration	Wheelchair with motor wheel	Wheelchair with SOFTWHEEL wheels	Combined configuration
1	Empty weight	19 kg	3.5 kg	8 kg	30.5 kg
2	Full weight	169 kg	153.5 kg	158 kg	180.5 kg
3	Road clearance	0.2 m	0.2 m	0.2 m	0.2 m
4	Turning radius	0.75 m	0.95 m	0.75 m	0.95 m
5	Acceleration time	15 – 20 sec.	5 sec	15 – 20 sec	5 sec
6	Breaking distance	3 m	1.5 m	3 m	1.5 m
7	Maximum power	170 W	450 W	170 W	450 W
9	Rotation torque	10 Nm	25 Nm	10 Nm	25 Nm

Table 3 shows operational features of the four configuration variants of wheelchairs, in a similar manner (Table 3).

Table 3. Operational feature of softwheel chairs.

No.	Feature	Basic configuration	Wheelchair with motor wheel	Wheelchair with SOFTWHEEL wheels	Combined configuration
1	Speed	10 km/h	45 km/h	10 km/h	45 km/h
2	Braking	Manual braking	Manual and electrical braking	Manual and electrical braking	Manual and electrical braking
3	Controllability	Loss of controllability	Controllability increased by 20%	Controllability increased by 50%	Substantial increase in controllability
4	Turnability	High short-baseline	Turn ability decreased by 30%	Turn ability increased by 40%	High turnability

5	Maneuverability	turnability High baseline maneuverability	short-	Maneuverability decreased by 30%	Maneuverability increased by 40%	High maneuverability
6	Stability	Propensity for tipping over	for	Propensity for side tipping over	Side tipping over decreased by 50%	Full operational stability at all angles of inclination
7	Passing ability	Low passing ability	passing	Passing ability increased by 15%	Passing ability increased by 40%	Substantial increase in passing ability
8	Smoothness of movement	Absence of smoothness	of	Smoothness increased by 20%	Smoothness increased by 40%	Substantial increase in smoothness
9	Ecological safety	Ecologically safe product	safe	Ecologically safe product	Ecologically safe product	Ecologically safe product
10	Safety of movement	Low safety of movement	of	Safety of movement increased by 40%	Safety of movement increased by 15%	Substantial increase
11	Integrity	Stable integrity		Stable integrity	Increased integrity and stiffness	Increased integrity and stiffness
12	Maintenance requirements	Good		High requirements	High requirements	High requirements

4. Conclusion

Analysis of the field study facts has led to the following results:

- 1) 3D designs of wheelchair suspensions with hub motor wheel, with SOFTWHEEL and with their combined use have been developed and produced;
- 2) designs with combined use of motor wheels and SOFTWHEEL wheels possess the highest mechanical and operational qualities;
- 3) designs with combined use of motor wheels and SOFTWHEEL wheels have a potential for further modernization.

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