Handwheelchair.q: Innovative Manual Wheelchair for Sport

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Abstract. In this paper the development of an innovative system of propulsion for manual wheelchair is described. It can be applied to sports wheelchairs and to wheelchair employed in everyday life. Regarding sports wheelchair, the use of this system of propulsion for racing wheelchair and hand bike is shown. The innovative system of propulsion tries to solve the injuries on the upper limb, caused by the other manual system of propulsion: push-rim system and levers system, employing traction movement applied on a cable transmission and ratchet device. The paper describes the functional design of different solutions, identifying the main involved parameters. In addition, the first prototype of wheelchair for everyday life is described and tested.

Keywords: Disabled sports, Paralympic games, Manual wheelchair

1 Introduction

According to [1], wheelchair users suffer from upper limb injuries, particularly in the shoulder, in higher percentage than the rest of population, the percentage increases in wheelchair athletes. As shown in [2], wheelchair sports are an important tool in rehabilitation from a physical and psychological point of view. It is important and necessary to develop medical and technological knowledge to decrease and to prevent injuries derived from wheelchair sports. The authors of this paper have many prior experiences about aid to overcome architectural barriers [3, 4] and prototyping manual wheelchair with innovative system of propulsion [5].

In wheelchair racing [6], athletes compete in four categories based on the types of disability: T51, T52, T53 and T54. The distance involved in wheelchair racing include sprint distances of 100 m, 200 m, and 400 m, middle distances of 800 m and 1500 m, long distances of 5000 m and 10000 m in field and the marathon in road. As shown in figure 1, racing wheelchairs have two-rear traction wheel with the push-rim that the users use to transmit power, a front steering wheel that is controlled by the users through the steering. On the steering, there is the brake lever that works on the front wheel. Each athlete has a customized sitting. An ultra-light frame connects the two-rear wheel, the sitting and the steering with the front wheel.

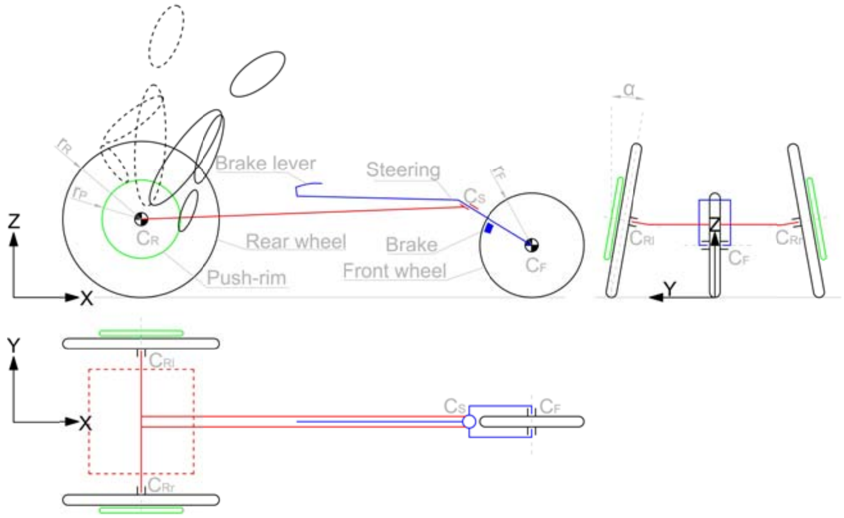
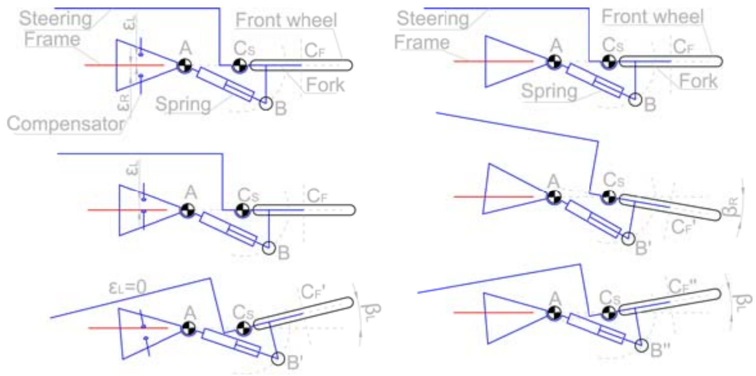


Figure 1: Functional scheme of racing wheelchair

In figure 2, the steering system of the wheelchair racing is shown. The athlete moves the steering and the front wheel rotates around the joints CS. The fork is connected to the frame through a gas spring that allows to keep the fork in the desired position. During the race field, the wheelchair racing is equipped with the compensator steering, as shown in figure 2 a). The compensator steering allows to set a defined angle to achieve the turn with a specific radius, as in athletics tracks. The angle is defined by the distance ε and it depends on the physical characteristics of the athletics track, the wheelchair and the speed. During the race field ε_L is set to achieve the desired β_L to follow the trajectory of the athletics track, while $\varepsilon_R = 0$, avoiding to turn on right. During the road event the compensator steering is removed, with this configuration the steering angle is adapted for different radius of curvature, as shown in figure 2 b).

In hand bike racing [6], athletes compete in five categories based on the types of disability: H1, H2, H3, H4 and H5. The races involved in hand bike racing include road race and individual time trial. There are two types of hand bike: hand bike employed by H1, H2, H3 and H4 categories and hand bike employed by H5 category. The athletes with spinal injuries compete in category H1, H2, H3 and H4. These athletes use the recumbent hand bike as shown in figure 3. The amputated athletes compete in categories H5, and they use a hand bike shown in figure 4. The position of athletes is different in these two types of hand bike, while the rest of the Hand bike has the same configuration. There are two rear wheels and a front traction steering wheel. The athletes execute a synchronous pedal with the arms and the power is transmitted to the front wheel through a chain. The transmission system is connected directly with the fork, that is used by athletes to control the steer.



(a) (b)

Figure 2: Steering mechanism for race field (a) and for road race (b)

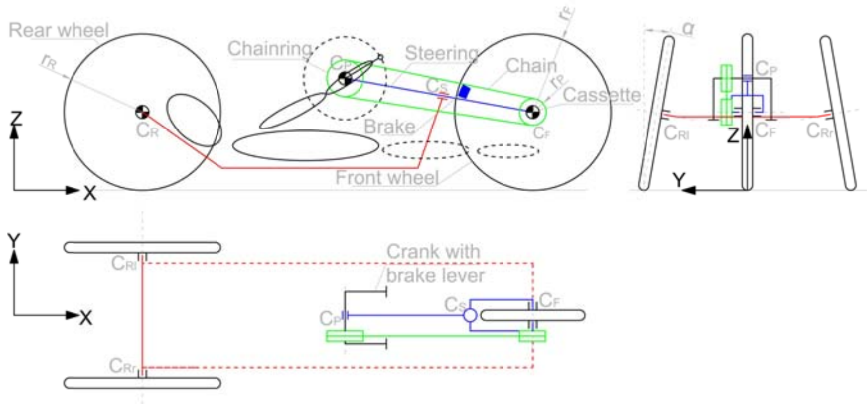


Figure 3: Hand bike for categories H1-H4

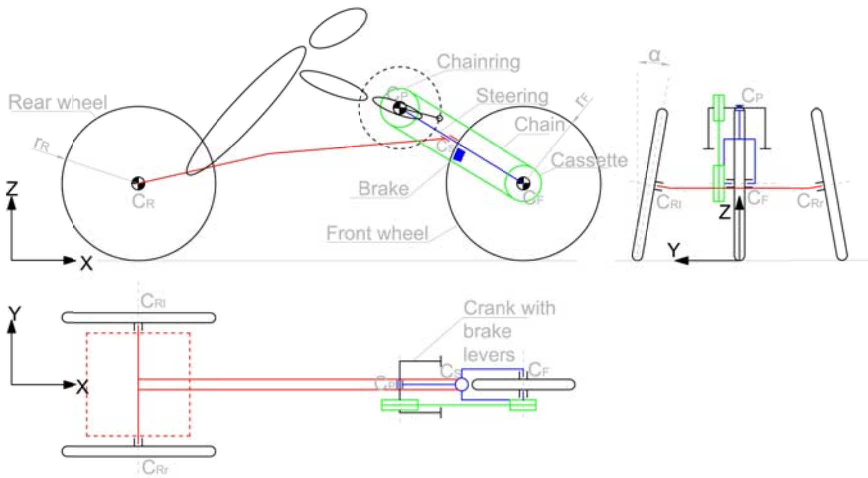


Figure 4: Hand bike for categories H5

All these described systems are representative of the state of the art of the racing wheelchair and hand bike categories. In the next paragraph, an innovative principle is presented and compared to them.

2 Functional design

The characteristics of the innovative system of propulsion concentrate on the generation and the transmission of power. The user's gesture to generate power is inspired by the rowing motion without employment of the lower limbs, to solve the shoulders injuries. In addition, the power is transmitted by two handles, connected with a pair of pulleys by cables, that are wrapped on pulleys to transmit the motion unidirectionally. The pulleys are connected to the frame by a power spring. This allows the system to be adapted to individual user's physical characteristics. The gesture is divided into two different phases: the traction phase and the recovery phase. During the traction phase, Tp, the user pulls towards him the handles. Through a cable system, the power is transmitted to the wheels. During the recovery phase, Tr, a power spring, loaded during the pushing phase, brings the system in the initial condition. The figure 5 shows the gesture during the traction phase and the recovery phase, while the figure 6 shows the angular position and the angular speed of the pulley and the wheel. In this figure, the hypotheses are that the speed of the wheel is constant and the time of traction phase, Tp, is longer than the time of the recovery phase, Tr.

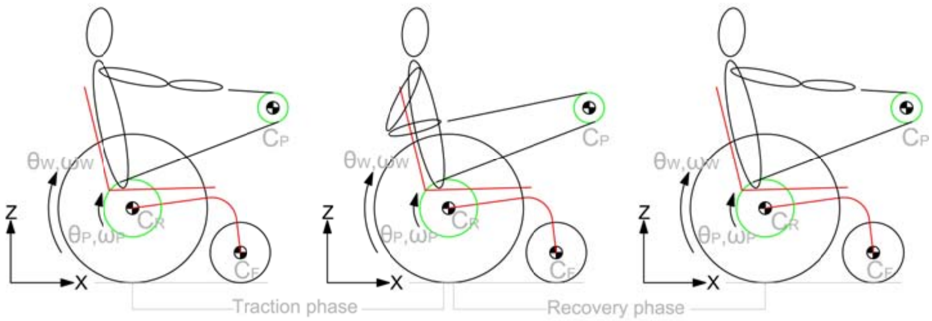


Figure 5: Innovative cable transmission system

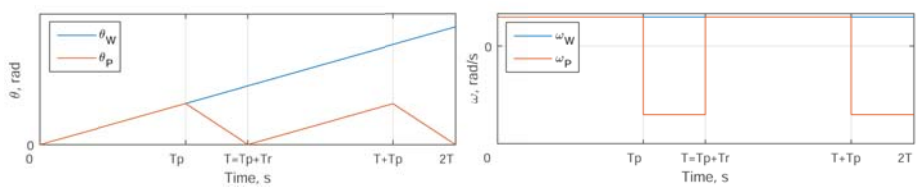
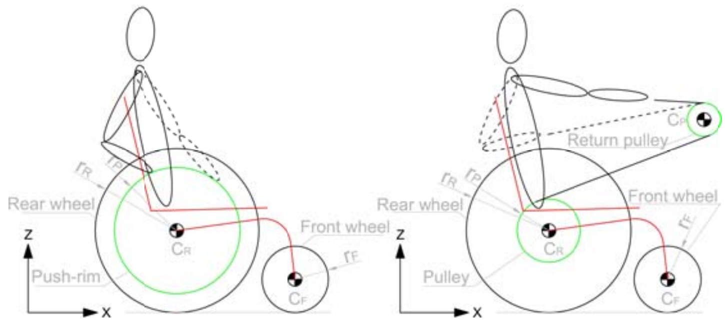


Figure 6: Angular position and angular speed respectively of wheel (W) and pulley (P)

2.1 Handwheelchair.q

The innovative system of propulsion has been employed and added to the standard wheelchair for everyday life and this prototype is named Handwheelchair.q. Figure 7 shows the modifications made on a pre-existing wheelchair sketch to adapt it for the new configuration. A pair of pulleys have been seated in the joint C_R and a pair of return pulleys have been located in C_P through specific support rods. The handles have been designed in order to transmit power with a cable system and to brake on the rear wheels with the brake levers integrated with the handles.



(a) (b)

Figure 7: User movement: Push-rim (a), Innovative (b)

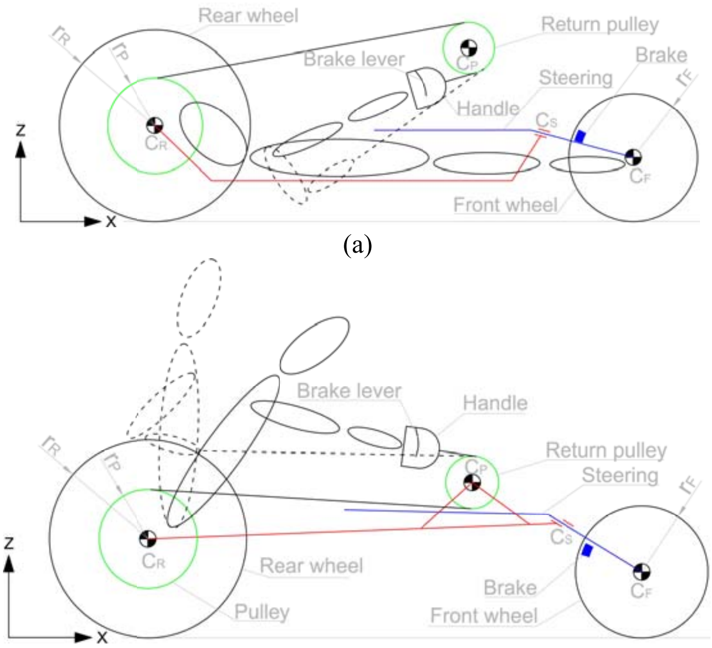
This innovative system of propulsion could be advantageous if it is employed and added to the standard push-rim system. The innovative system can be employed for outdoor journeys, thus achieving an increment in mobility and a reduction in fatigue; the push-rim system can be employed indoor, exploiting its compactness and achieving excellent manoeuvrability in small spaces. It is mandatory to enable quick switching from the innovative system, figure 8a, to push-rim system, figure 8b, so a folding system of the cable traction system was designed and implemented.
Finally the first functional prototype is shown in figure 8c during the first preliminary experimental tests.

(a) (b) (c)

Figure 8: Folding system of the cable traction system (a) and (b), Handwheelchair.q testing (c)

2.2 Handwheelchair.q racing

The innovative system can be installed on the racing wheelchair, as shown in figure 10a, with few modifications of a standard racing wheelchairs. The push-rims have been removed, a pair of pulleys have been placed on the joint C_R and a pair of return pulleys have been located on C_P joint. In figure 9 a) a recumbent configuration of racing wheelchair is shown, inspired by hand bike employed from categories H1, H2, H3 and H4. This configuration allows to optimise the aerodynamic. In figure 9 b), the usual racing wheelchair with the innovative system of propulsion is shown.



(a)

(b)

Figure 9: Racing Handweelchair.q for H1-H4 (a) and for H5 (b)

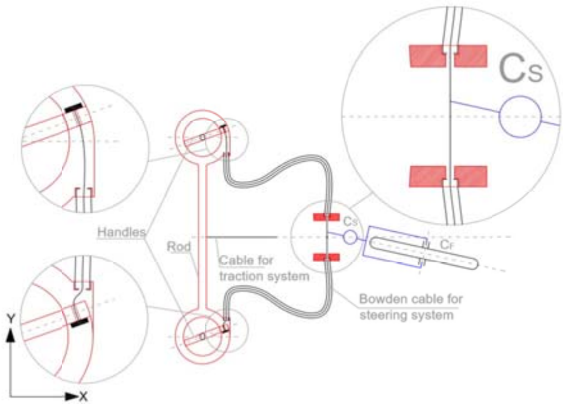


Figure 10: Steering system

Two different handle solutions are designed. In the first system the user has a pair of handles and each handle transmits power to a corresponding wheel, left or right. In this configuration the trajectory is determined as in racing wheelchair presented in the previous paragraph.
The second system is shown in figure 10. The user has a pair of handles connected by a rod. The rod is connected to a couple of traction cables. The rotation of the two handles, by means of a bowden cable system, defines the rotation of the fork around the joint C_S and so the steering of the wheelchair.

2.3 Handbike.q

Finally, the innovative system can be employed on the hand bike. Figure 11 shows the functional design of Handbike.q with the innovative system of propulsion for categories H1, H2, H3 and H4. A pair of pulleys have been seated on the joint C_F, one of each side in order to balance the fork transversely. A return pulley has been located in C_P in order to optimise the athlete's gesture.

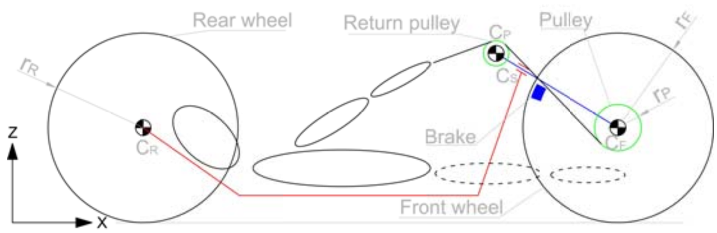


Figure 11: Handbike.q for categories H1-H4

The cables to transmit power connects the return pulley with the rod, as shown in figure 12. In the Handbike.q, the same steering system used in racing Handwheelchair.q (fig. 10) is implemented.
Figure 13 shows the configuration of Handbike.q for user categories H5.

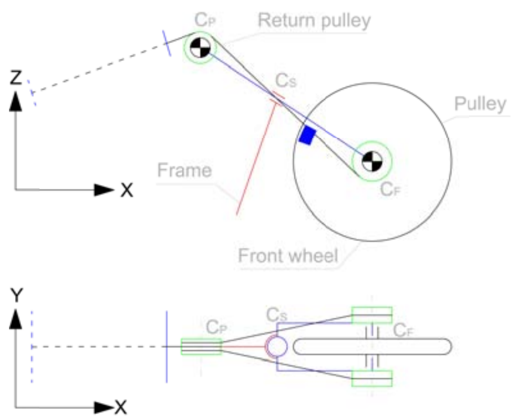


Figure 12: Traction cable setup for Handbike.q

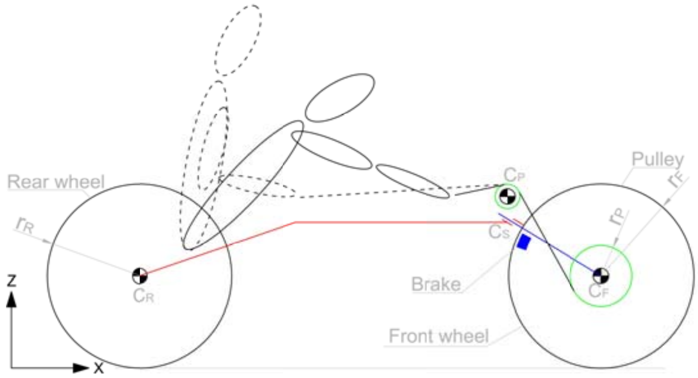


Figure 13: Handbike.q for categories H5

3 Conclusions

The development of an innovative system of propulsion for manual wheelchair is described in different possible sketches, in order to be implemented in sports wheelchairs and for wheelchair employed in everyday life. The innovative system of propulsion is a robust idea to solve the injuries on the upper limb, caused by the other manual system of propulsion. By means of a first prototyping and testing phase, the improvements of athletes gesture is currently under evaluation.

4 References

1. Lewis A. R., Phillips E. J., Robertson W. S. P., Grimshaw P. N., Portus M.: Injury prevention of elite wheelchair racing athletes using simulation approaches. 12th Conference of the International Sports Engineering Association, Brisbane, Queensland, Australia, 2018, 2, 255.
2. Cooper R. A., De Luigi A. J.: Adaptive sports technology and biomechanics: wheelchairs. Paralympic Sports Medicine and Science, 2014, Vol. 6, pp. 31-39.
3. Quaglia G., Nisi M.: Design of a self-leveling cam mechanism for a stair climbing wheelchair. Mechanism and machine theory, 2017, 112, pp. 84-104.
4. Quaglia G., Franco W., Nisi M.: Design of a reconfiguration mechanism for an electric stair-climbing wheelchair. ASME IMECE2014 International Mechanical Engineering Congress and Exposition, 2014, Volume 4A, pp. V04AT04A022.
5. Quaglia G., Bonisoli E., Cavallone P.: A proposal of alternative propulsion system for manual wheelchair. International Journal of Mechanics and Control, 2018, Vol. 19, No. 01, pp. 33-38.
6. International Paralympic Committee: Explanatory guide to Paralympic classification, Paralympic summer sports, www.paralympic.org/sites/default/files/document/150915170806821_2015_09_15%2BExplanatory%2Bguide%2BClassification_summer%2BFINAL%2B_5.pdf available in 24/05/2018.