Design of a Vehicle for Disabled People Motion

Nicolae Dumitru, Ionuț Geonea, Cristian Copiluși, Mihnea Cătăneanu

University of Craiova, Craiova, Romania
`nicolae_dtru@yahoo.com,igeonea@yahoo.com,`
`cristache03@yahoo.co.uk, cataneanu@yahoo.com`

Abstract. In this paper is proposed a new design solution for a motorized wheelchair intended for motion of disabled people. Vehicle transmission uses two motors, one for traction and another with less power for steering. The front wheels of the vehicle are self directionally. In order to achieve the steering motion, is used the principle of differential steering. The steering transmission uses a central bevel gear and two differential mechanisms. For straight line displacement the motion is transmitted from the traction motor, equipped with a worm gear to final transmission with spur gears, coupled to the back traction wheels shafts. The purpose of this paper is to study the dynamic behavior of the vehicle in different motion conditions. A CAD model of the transmission is designed assembled with the vehicle body. Dynamic simulation in ADAMS was made, in order to calculate wheelchair dynamic parameters and demonstrate the functionality of this transmission. The obtained results are satisfactory, and demonstrate the proper design of wheelchair transmission, and allow development of this solution to an experimental model.

Keywords: vehicle, design, disabled people, dynamic study.

1 Introduction

In the literature, are presented several research projects, focused on the design of robotic wheelchairs [1,2,3,4], and upon the improvement of human interfaces for wheelchair guidance, such as voice recognition, eye movement or face movement [3,4,5,6].

In [4] is described a special approach, in which a special attention is given to equip the robotic wheelchair with a comprehensive sensorial system managed by a robotic architecture [4] that provides human-friendly interaction. Developed robotic wheelchair, improves a commercial powered wheelchair, equipped with sensors (ultrasonic rotating sensors, a CCD camera, radial laser scanner, infrared sensors) which allows the wheelchair to perform tasks in indoor environments.

The most important evaluation factors for robotic wheelchairs are safety and easy operation. The autonomy provided by batteries improves both factors.

The avoidance of obstacles using infrared or ultrasonic vision is another development direction. And not at least, is studied the goal that a wheelchair will take sub-

International Congress of Automotive and Transport Engineering, CONAT 2016
Transilvania University of Brasov, 2016
ISSN 2069-0401

jects automatically to specified destination [6]. Some researchers have developed wheelchairs that instead of a joystick use for navigation voice to give command [7].

The American National Standards Institute/Rehabilitation Engineering and Assistive Technology Society of North America (ANSI/RESNA) have developed wheelchair standards based on different tests: braking distances, energy consumption, and obstacle climbing, to provide authorized information about the performance and safety characteristics of wheelchairs [8]. Electric powered wheelchairs test methods concerning control system performance are presented in ISO 7176-14 and ISO 7176-21 standards [9].

The attention given today for people with locomotors disabilities is high and disabled people integration into society represents one of the European Commission priorities. Article 26 from ”EU Charter of Fundamental Rights”, recognizes the right of disabled people to ”benefit by measures intended to assure their autonomy, social and professional integration, as well as participation to the community life” [11]. According to the Direction for Protection of Disabled People from Work, Family and Social Protection Minister, at 31 June 2014 in Romania are living a total number of 700736 persons with disabilities (about 3,5 % from Romanian population) [12]. These numbers highlights the dimension of this important community of disabled people, with special needs, for each every initiative of live conditions improvement is very important. Disabled people experience barriers when they want to work, go to school or other situation. For lower legs disabled people, using a motorized wheelchair represents their chance for motion independence and soul wellness. The purpose of this research paper is the development of a design and experimental solution for a wheelchair with electric motors used for disabled people motion.

2 Wheelchair proposed design solution

2.1 Structure and kinematics of wheelchair transmission

The kinematic scheme of the wheelchair transmission is presented in fig. 1. For the wheelchair motion in straight line is used the motor with worm gear reducer, placed on shaft II. The steering motion is given from the motor placed on shaft V. Combining those two motions, steering and straight line motion, the wheelchair can be driven on any desired trajectory. The motors are operated by means of a joystick and controllers. For straight line motion, is active only the motor M_1 placed on shaft II. From shaft II, the motion is transmitted to propulsion wheels, by final transmission with spur gears (2, 4), and (2’, 4’). To achieve the steering motion, is started the steering motor M_2, placed on shaft V, and the steering motion is transmitted to back wheels. The steering transmission chain is achieved by shafts IV and IV’, which rotate in opposite direction, because the motion is transmitted from the motor, with the bevel gears (8, 9), and (8, 9’). Shafts IV and IV’ actuates the planetary gears (10), and (10’) of each wheel differential mechanism. The satellites bevel gears (11, 13), and (11’, 13’), engages the planetary wheels (12) and (12’), connected to the wheel shafts III and III’. In this case the wheelchair right and left propulsion wheel rotate with the same angular speed but in opposite directions, and the wheelchair achieved trajectory is a circle.

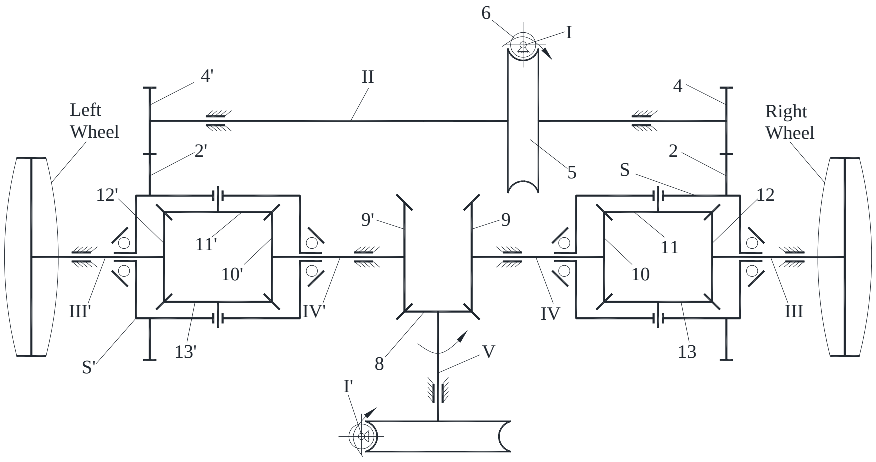

Fig. 1. The wheelchair transmission kinematic structure.

The wheelchair transmission gears geometric parameters: number of teeth, gears ratio and division diameters are presented in Table 1.

Table 1. Gears ratios and dimensions

Gear pair	**Z_2=80** **Z_4=18**	**Z_8=9** **Z_9=34**	**Z_6=1** **Z_5=17**	**Z_{10}=16** **Z_{11}=10**	**Z_{12}=16** **Z_{13}=10**
Gears ratio[-]	**1,88**	**3.77**	**17**	**1,6**	**1,6**
Gears module [mm]	**2.25**	**5**	**5**	**5**	**5**
Gears division diameter [mm]	d_2=180 d_4=40.5	d_8=45 d_9=170	d_6=20 d_5=85	d_{10}=80 d_{w11}=50	d_{w12}=80 d_{w13}=50

For straight line motion displacement, the transmission ratio from the traction motor to the wheels is given by equation (1):

$$w_{wheel} = \frac{w_{M_1}}{i_{65}^{w} \times i_{42}^{c}} \left[rad / s \right] \tag{1}$$

where: ω_{M1}- is traction motor angular velocity; i_{65}^{w} -is worm gear ratio; i_{42}^{c} -is final transmission with spur gears ratio;

Taking into account the basic principle of gearing, the tangential velocities are equal in the gearing point. So we have the equation (2):

$$W_{wheel} = \frac{W_{10}^{\ c} + W_{12}^{\ c}}{2} \tag{2}$$

For the case of wheelchair steering, the angular velocities of steering shafts are:

$$W_{10}^{\ c} = \frac{W_{M_2}}{i_{89}^{k}} \ ; \ W_{10}^{\ 'c} = \frac{W_{M_2}}{i_{89'}^{k}} \tag{3}$$

Where, $W_{M\,2}$ is the steering motor angular velocity; i_{89}^{k} -is the bevel gear ratio.

2.2 Development of wheelchair design solution

A virtual model of the wheelchair assembly is developed in Autodesk Inventor. The gears design is made also in Autodesk Inventor software. The CAD model is used for the dynamic simulation of the wheelchair motion in ADAMS and also to elaborate the manufacture documentation of components. A detail of designed differential transmissions and final transmission with spur gears is shown in fig. 2.

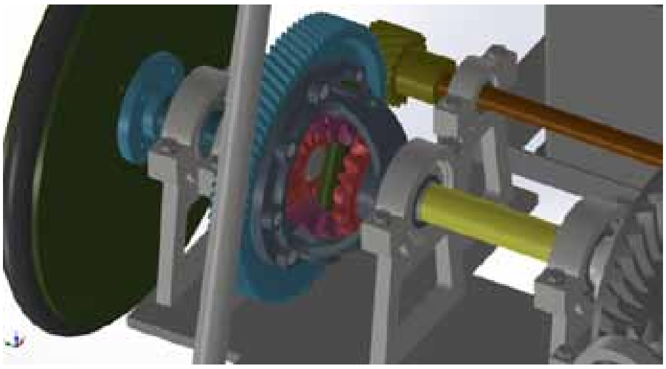

Fig. 2. Detail of differential transmission

Steering bevel gear detail is shown in fig. 3. The final assembly of the wheelchair is shown in fig. 4. To the wheelchair frame are attached the batteries for motors.

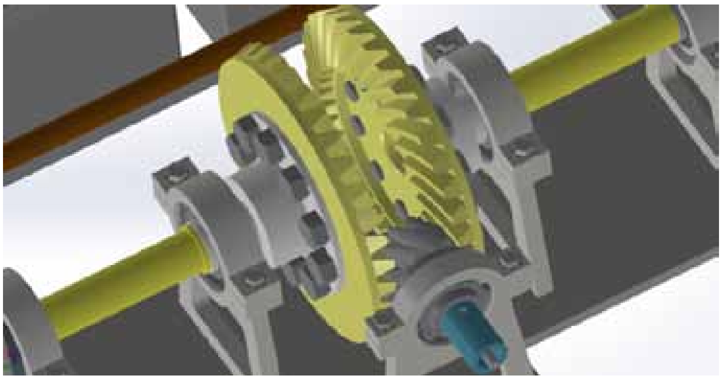

Fig. 3. Detail of steering bevel gears.

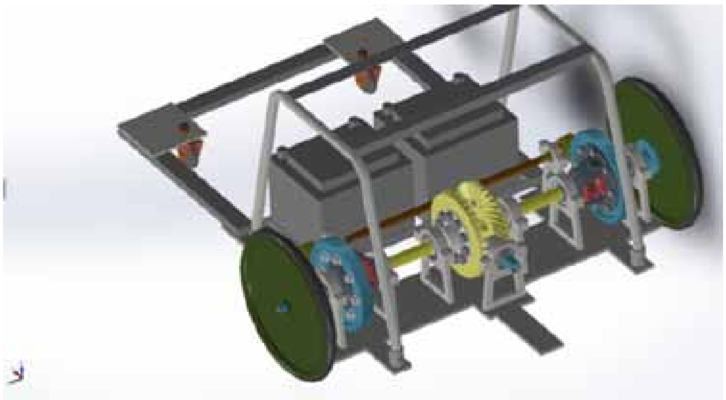

Fig. 4. Detail of final assembly of the wheelchair.

The experimental model of the wheelchair is finalized from mechanical structure point of view, as is presented in fig. 5.

Fig. 5. Experimental model of the wheelchair.

3 Dynamic simulation in ADAMS of the wheelchair

The virtual prototype of the wheelchair, as modeled in Fig. 4, is used in ADAMS to develop a multi-body dynamic model. The main stages to complete the ADAMS model are: define of elements mass properties, define of kinematic joints of mechanical structure, and specify the friction models (wheels to ground and gears friction). As load is considered a 75 kg human subject, defined in ADAMS as a force load. The most important stage of the multi-body model development are gear type connections definition. These connections are defined by gears solid bodies contact. ADAMS necessary parameters for gear contact are explained in next subchapter.

3.1 Contact parameters

For modeling the contact of gears, is used the ADAMS impact method, taking into account the computation efficiency and accuracy of results. Necessary parameters used to define contact model of gears tooth are presented below. The contact force in ADAMS computed with impact method is composed of two components: the elastic force produced by the solids bodies' deformations and the damping force caused by the relative deforming velocity of gears body's [12, 13, 14].

1. Stiffness **K**. Considering the Hertzian elastic contact theory [12, 14], the stiffness of two bodies in contact is described by two ideal cylindrical bodies, with the equivalent radius calculated from the engaged spur gear pair. The materials for the wheelchair gears are alloy steel, so the values for the Young's modulus and Poisson ratio values are: $u = 0.3$, $E = 2.1 \times 10^5 N / mm^2$. Based on calculations the stiffness values for the gear pairs are completed in ADAMS contact model.
2. Force exponent. Taking into account the numerical convergence, a force exponent ***e***=1.8 is used for this wheelchair simulation model [12, 13, 14].
3. The damping coefficient **C**, takes values of 0.1%~1% from the stiffness **K**. For this wheelchair simulation model the damping coefficient is set to **C**=1200Ns/mm.
4. Penetration depth. In this model is used *d*=0.1, for the penetration depth value.

It is performed the wheelchair motion analysis in ADAMS, in the case when is active the traction motion and steering motion, defined by (7). Angular velocities, in [radians/sec] of traction and steering motors, used in ADAMS to define motions are:

IF (time-2 : 4, 0, I F (time-4:0, 4,4))–used for traction motion (shaft I)

IF (time-2 : 0,0 , 4) – used for steering motion (shaft I') (7)

The results of simulation with those parameters, respectively the wheelchair computed trajectory is presented in fig. 6. The right wheel angular velocity (respectively, planetary gear 12) is computed in ADAMS simulation, and is presented in fig. 7. The obtained torque variation, for the steering motor is presented in fig. 8, and for traction motor the torque variation is shown in fig. 9.

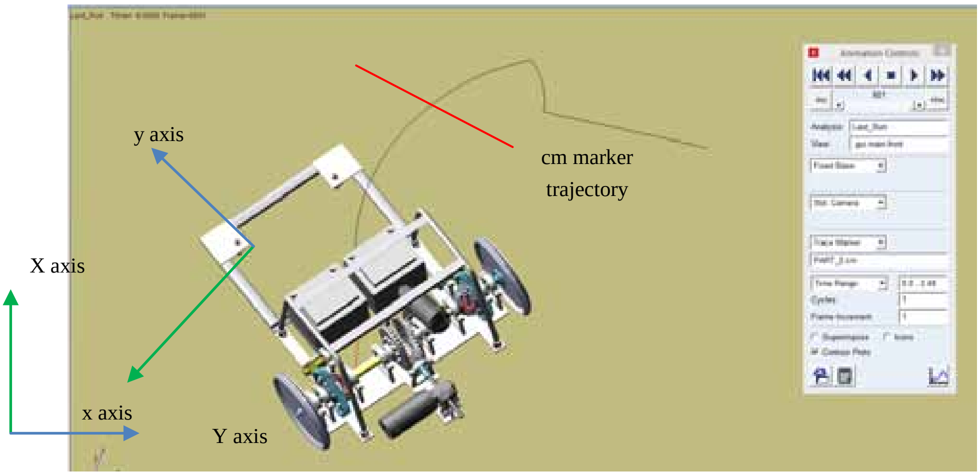

Fig. 6. Wheelchair trajectory computed in ADAMS dynamic simulation.

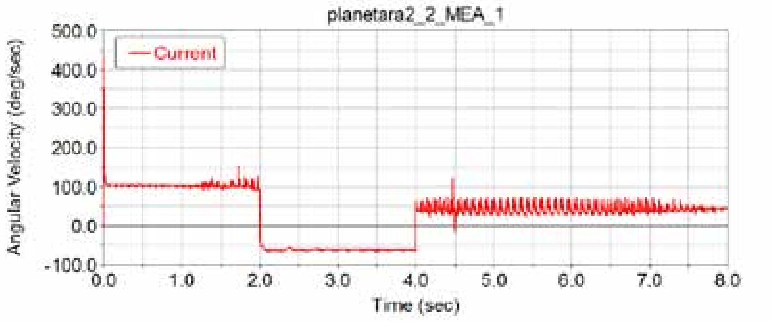

Fig. 7. Right wheel angular velocity, computed in ADAMS dynamic simulation.

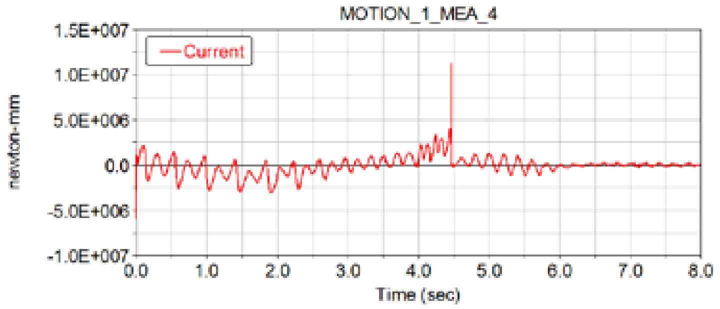

Fig. 8. Steering torque variation, computed in ADAMS dynamic simulation.

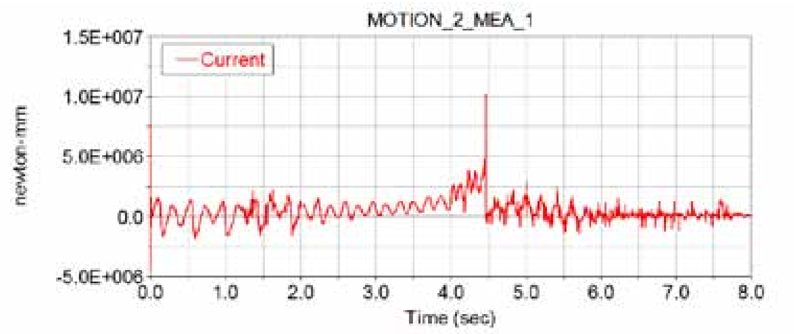

Fig. 9. Traction torque variation, computed in ADAMS dynamic simulation.

4 Conclusion

In this research paper is presented the design solution of a robotic wheelchair. In order to travel the wheelchair use two motors, for steering and traction. For straight line motion the wheelchair use one motor with worm gearbox and a final transmission with spur gears. For steering motion the wheelchair uses a transmission chain with bevel gears and differential gearboxes. Is designed in Autodesk Inventor a CAD model, based on that it is developed a dynamic simulation in ADAMS, in order to validate the wheelchair model. The simulation in ADAMS is performed in the case of a combined straight line and steering motion. Is computed the wheelchair motion trajectory, gears angular velocity, wheelchair traction and steering motors torque. Dynamic simulation performed in ADAMS is useful for computation of wheelchair kinematic and dynamic characteristics.

Irregularities form angular speed variation (fig. 7), are from the wheels contact modeling, from ground and traction wheels. The torque variation, recorded for the steering and traction kinematics chains, appear at moments of motors coupling and decoupling.

References

1. Balcells A. C., Abascal J.: TetraNauta: A Wheelchair Controller for Users with Very Severe Mobility Restrictions, 3rd European Conf. on Tech. for Inclusive Design and Equality, Helsinki, Finland (1998)
2. Levine S. P., Bell D. A., Jaros L. A, Simpson R. C., Koren Y., Borenstein J.: The NavChair assistive wheelchair navigation system IEEE Trans. Rehab. Eng., vol. 7, (1999)
3. Prassler E., Scholz J., Fiorini P.: A Robotic Wheelchair for Crowded Public Environments. IEEE Robotics and Automation Magazine, vol. 7, (2001)
4. Gonzalez J., Muaeoz A.J., Galindo C., Fernandez-Madrigal J.A., Blanco J.L.: A Description of the SENA Robotic Wheelchair, IEEE MELECON 2006, May 16-19, Benalmádena (Málaga), Spain (2006).

5. Hoyer H., Hoelper R.: The OMNI Wheelchair with High Manoeuvrability and Navigational Intelligence, in Rehabilitation Technology, Proc. of the 2nd TIDE Congress, Brussels, IOS Press (1995)
6. Kuno Y., Shimada N., Shira Y.: A Robotic Wheelchair Based on the Integration of Human and Environmental Observations, IEEE Robotics & Automation Magazine, (2003)
7. Simpson R.C., Levine S.P.: Adaptive shared control of a smart wheelchair operated by voice control, in Proc. 1997 IEEE/RSJ Int. Conf. Intelligent Robots and Systems, vol. 2, pp. 622-626 (1997)
8. Fass M.V., Cooper R.A.: Durability, value, and reliability of selected electric powered wheelchairs, Arch. Phys. Med. Rehab., vol. 85, no. 5, pp. 805–814, (2004)
9. Wheelchairs-Part 14: Power and Control Systems for Electric Wheelchairs—Requirements and Test Methods, ISO 7176-14 (1997)
10. http://www.europarl.europa.eu/charter/
11. http://www.anph.ro/admin/doc/
12. Kong D.: Nonlinear Contact Analysis of Gear Teeth for Malfunction Diagnostics, Conference and Exposition on Structural Dynamics, Orlando Florida (2008)
13. Geonea I., Dumitru N., Margine A.: Design and Motion Study of a Wheelchair for Disabled People, In Proceedings of the World Congress on Engineering 2015 Vol. II, pp.1028-1033, London (2015)
14. Geonea I., Dumitru N.: Motion Analysis of a Robotic Wheelchair, In Advances in Intelligent Systems and Computing 371, pp.471-479, Springer International Publishing Switzerland (2016).