MECHATRONIC SYSTEM FOR INCREASING MOBILITY OF PEOPLE WITH LOCOMOTOR DISABILITY

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Abstract. This article presents research results on the concept and design of a mechatronic system for assistive mobility of people with locomotor disability. Component elements of the system have been designed and kinematic analysis of the parallelogram mechanism has been done, so that to have estimation of the end effector trajectory as Cartesian motion. Further development of research is envisaged to be on mechanism synthesis, system's components optimization and prototyping.

Key words: mechatronic system, parallelogram mechanism, kinematic analysis, motion trajectory, design, 3D model.

1. INTRODUCTION

There are many people who have health problems that preserve them form conveniently moving from one place to another. Basically, locomotor disability is defined as restriction in limbs movements [1], either the upper or the lower limbs. Still, this article is focused on the meaning of locomotor disability as the loss of ability of moving from one place to another, caused by the impossibility of coordinating joints, muscles, bones and nerves of the lower limbs. The idea of improving life of people with locomotor disability by helping them to use a car for getting to various remote places (hospital, market, recovery center) is not new, and basically arises from the need of helping them, their family and the persons involved in their assistance.

The mechatronic system studied is based on the concept of an elevator that lifts the person with locomotor disability from the wheel chair and transfers him / her into the car. Its basic working principle is that of the parallelogram mechanism [2–5]. The main issue is to enable comfortable positioning onto the chair,

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considering the limited space of the chassis, therefore the door frame, and the obstacle avoidance problem, so that not to do any harms the person.

There are similar products available onto the market, with advantages and disadvantages regarding their ease of use, as mentioned below (Fig. 1).

– the transfer device is fixed onto the door lock system of the car;
– the device does not enable any vertical motion and it is the risk of injury person's legs while transferring onto the car chair [6],

– the transfer device is a car component, including the car (driver / passenger) seat;
– the device is customized for one car;
– the device is expensive [7];

Fig. 1 – Transfer devices available on the market.

Based on the needs of the people with locomotor disability for having an active and better life, the authors have developed research on mechatronic system's concept and design that would be versatile and adjustable to various car types, should prevent any injuries of the person when transferred onto the car seat, would be convenient to store and, not the least cost affordable.

2. CONCEPT AND 3D MODEL OF THE MECHATRONIC SYSTEM

There are considered some basic hypotheses for the concept and design of the mechatronic system for increasing mobility of disabled people, mentioned next:

– maximum weight of the person with locomotor disability not to exceed 120 kg;

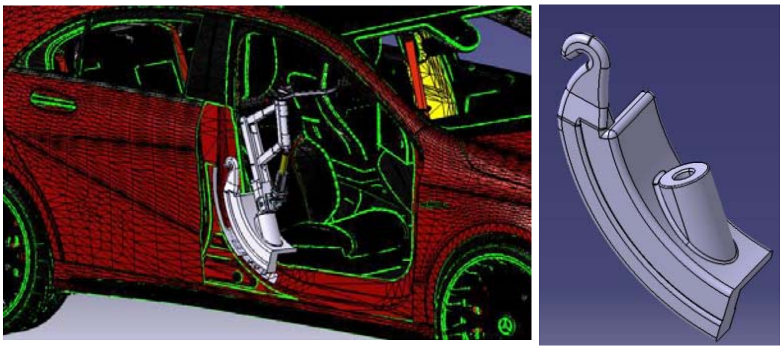
– fixture subassembly (orientation on the car chassis and fixing it) should be versatile and not to intrude car components;

– trajectory of the end effector (the one with the "basket" for holding the person) should consider the available space for the car door frame and, consequently, the seat positions;

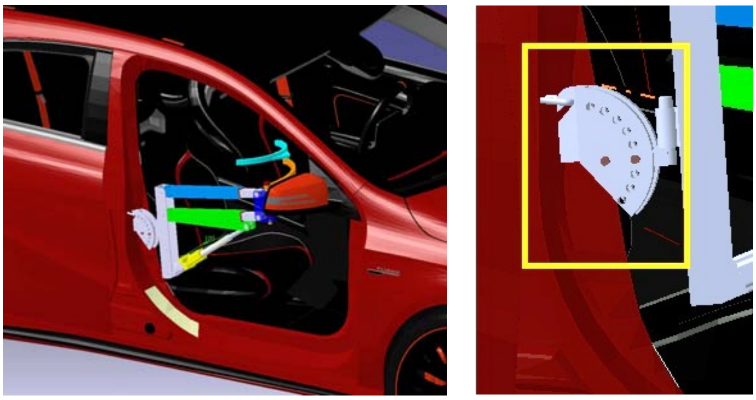
– mechanical components would be light weighted, with good strength resistance and high rigidity;

– mechatronic system should be reliable and user friendly.

Considering all the above mentioned, the first concept for fixing the device onto the car was that on the door hinge and with a hook for ensuring its contact with the frame. The second concept for fixing, considered a higher versatility and ease of maneuverability, still using the door hinge (Fig. 2). The primary purpose of the design was to reduce the fixing components number and to have as few as possible parts customized for the car type considered.



a. fixing system using the door hinge and a special hook



b. fixing system using the door hinge

Fig. 2 – Fixing the mechatronic system onto the car frame.

The main concept of the mechatronic system is based on a parallelogram mechanism that is driven by an electric servomotor (12 V power supply) and controlled by processing the signals related to speed and distances (speed of moving the person toward the car chair and distance of the person body up to the car door frame and car seat). The block scheme of mechatronic system's components is shown in Fig. 3 and the system's 3D model is presented in Fig. 4.

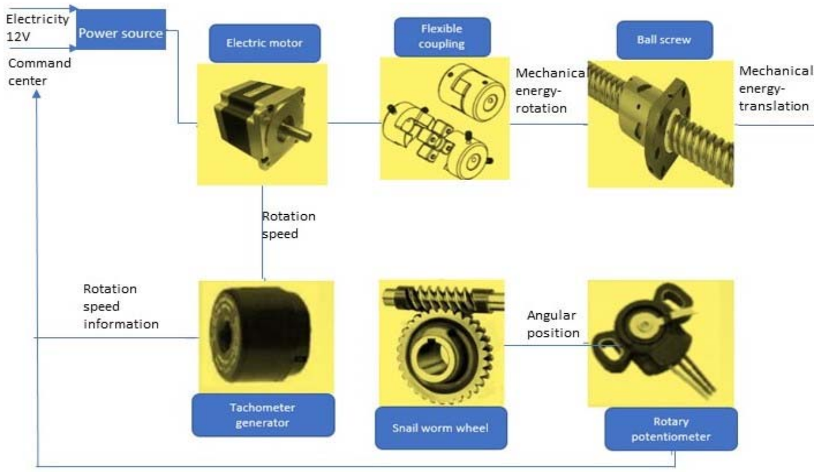


Fig. 3 – Block scheme of the mechatronic system.

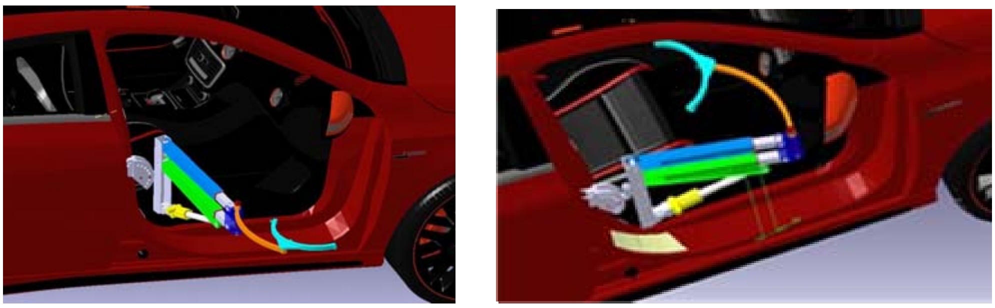


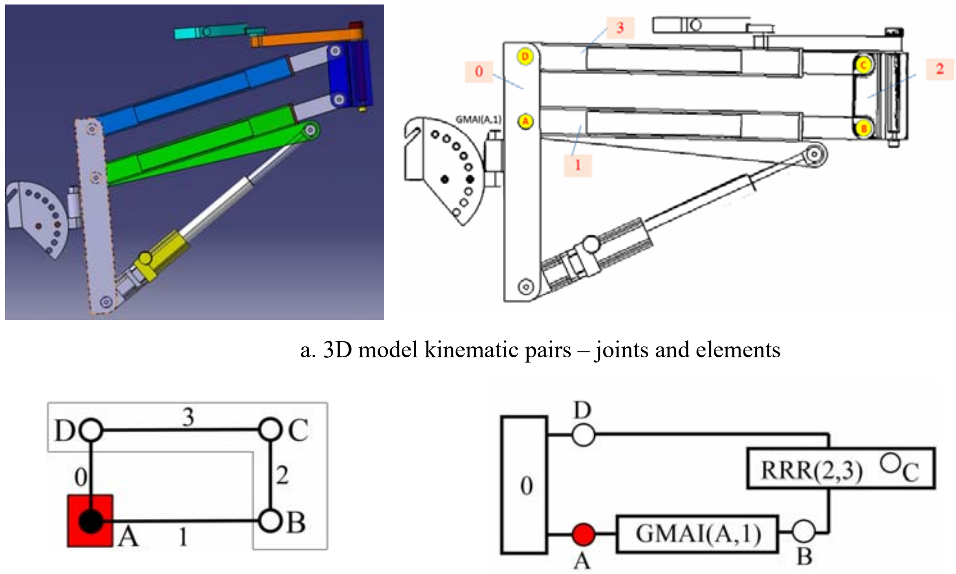
Fig. 4 – The 3D model of the mechatronic system.

3. KINEMATIC ANALYSIS OF PARALELLOGRAM MECHANISM

The parallelogram mechanism enables complete motion required for transferring the person with locomotor disability from the wheel chair onto the seat of the car. The trajectory of each joint, as well as their speeds and accelerations are to be determined by kinematic analysis [5, 8] of the mechanism, as follows next.

Structurally, the studied mechanism is made of two modular groups, the driving (rotation) and the passive one dyad with zero mobility. Its structural model and the associated connection scheme are presented in Fig. 5.

For determining coordination values of each joint there is used Mathcad software and the notation refer both to the first (by index, k1) and the fourth (by index, k2) trigonometric dials. Basically, the rotational angle varies from 0° up to 45° and, respectively, from 305° up to 360°.



a. 3D model kinematic pairs – joints and elements

b. structural model

c. connection scheme

Fig. 5 – The parallelogram mechanism kinematics.

The joints kinematics (position coordinates) are determined by the equations mentioned in Table 1.

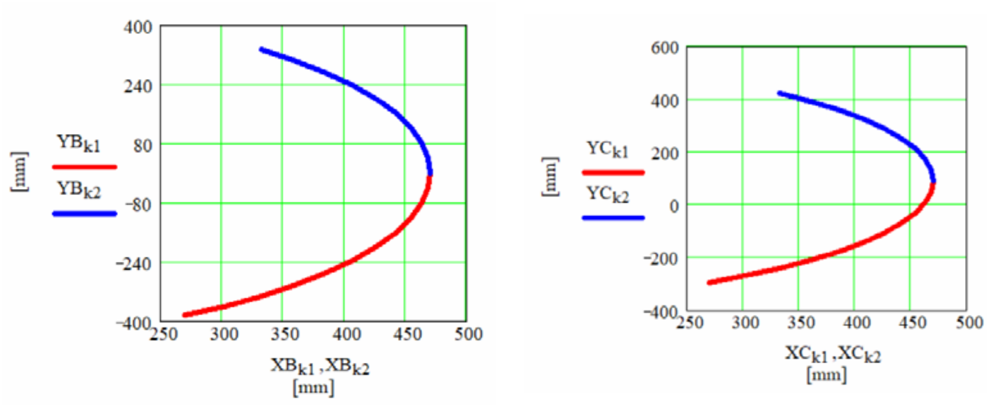
Table 1

Joint points coordinates equations

Joint	Coordinates	
B point (cinematic element, 1)	$XB_{k1} := AB \cdot \cos(\phi 11_{k1})$ $YB_{k1} := AB \cdot \sin(\phi 11_{k1})$	$XB_{k2} := AB \cdot \cos(\phi 12_{k2})$ $YB_{k2} := AB \cdot \sin(\phi 12_{k2})$
Dyade (RRR) (cinematic elements, 2 and 3)	$XB_{k1} - XD + BC \cdot \cos(\phi 21) - DC \cdot \cos(\phi 31) = 0$ $YB_{k1} - YD + BC \cdot \sin(\phi 21) - DC \cdot \sin(\phi 31) = 0$ $XB_{k2} - XD + BC \cdot \cos(\phi 22) - DC \cdot \cos(\phi 32) = 0$ $YB_{k2} - YD + BC \cdot \sin(\phi 22) - DC \cdot \sin(\phi 32) = 0$	
C point (end effector)	$XC_{k1} := XB_{k1} + BC \cdot \cos(\phi 21_{k1})$ $YC_{k1} := YB_{k1} + BC \cdot \sin(\phi 21_{k1})$	$XC_{k2} := XB_{k2} + BC \cdot \cos(\phi 22_{k2})$ $YC_{k2} := YB_{k2} + BC \cdot \sin(\phi 22_{k2})$

The calculation (using Mathcad) results in the coordinate values for each of the mobile joints, meaning B and C points (Fig. 6). One can notice the same motion amplitude (717 mm) for both point B [Y coordinates: 332– (–385)] and point

C [Y coordinates: 422– (–295)], that in fact is specific feature for the parallelogram mechanism. The plotted graphs are shown in Fig. 6.



B point trajectory C point trajectory

Fig. 6 – Parallelogram mechanism points' trajectories.

4. CONCLUSIONS

Research results on the concept and model of a mechatronic system for people with locomotor disability are presented by this paper. This system is aimed to be versatile and adjustable to various car types, should prevent any injuries of the person when transferred onto the car seat, would be convenient to store and, not the least cost affordable. Component elements of the system have been designed and kinematic analysis of the parallelogram mechanism has been done, so that estimation of the end effector trajectory to be possible.

Further development of research would consider mechanism synthesis, system's components optimization followed by other complementary modules to be integrated, such as AI for the recognition and vocal warning of the distances and obstacles. Prototyping and validation, in different customized environments and, therefore, requirements are also envisaged.

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