COMPUTATIONAL MODELING AND SIMULATION OF WALKING MECHANISM

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Abstract

This paper explains the basic principles on which the walker mechanism for the rehabilitation of injured people is functioning. This paper presents the mechanism geometry, kinematics of its work as well as the appropriate model and simulation obtained by the software package SolidWorks. This work can be applied to the design of medical devices for the rehabilitation of persons with injured spine, paraplegics or those who have difficulties in walking due to cerebral apoplexy.

Keywords: *mechanism, walker, simulation, medical aid*

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1. INTRODUCTION

Consideration, analysis and synthesis of various types of walking mechanisms can be important at least in two different fields of science. First, this study offers the contribution to the theory of kinematics, mechanisms, machines and similar fields of science and techniques. And secondly, but not of less importance, this research can be applied to the design and practical construction of walking and standing mechanisms by which the walking rehabilitation and training in the treatment of spinal cord injured (SCI) patients can be obtained. Moreover, various types of mechanical walkers and walker systems can be applied for establishing the standing and walking assistance functions for elderly and temporarily or permanently disabled people.

The problem of synthesis and design of different categories of mechanical walking mechanisms represent the respectable subject of research in modern science and technique. Modern methods are CAD with the special software for analysis processing, which can simulate not only the motion of the mechanism, but can define the position, velocity, acceleration, forces, moments and other parameters at every moment of time, but verification and mechanics laws understanding are necessary. The exposed methods are significant for the motion simulation, and analysis of kinematical characteristics of the mechanical walker model accomplished in this paper by CAD application. Authors emphasized that main features for the proposed biped machine are low-cost design and easy-operation in terms of compactness, light weight, and reduced number of degrees of freedom (DOFs). During a pilot clinical test, a hemiplegics patient could use the suggested gait rehabilitation robot with a slow walking speed. The rehabilitation plan was also suggested for the patient and the possible therapeutic effects of the suggested rehabilitation robot system are discussed. The implementation of mechanism for the reconfigurable quadruped/biped walking robot is described and its application is discussed. In [2], Takeshi et al proposed a new mechanical gravity compensation mechanism suitable for the wearable lower limb rehabilitation system. The gravity compensation ability of the proposed mechanism and the effectiveness of the proposed system as a lower limb rehabilitation system are examined by some computer simulations and experiment using the actual equipment. Authors claimed that the proposed gravity compensation systems are safer than previous ones since the proposed mechanisms which generate gravity compensation torques are totally embedded to the body link. In [4], Yong et al generated a conceptual design for a prosthetic ankle-foot mechanism that can automatically adapt to the slope of the walking surface. The mechanism simulates the behavior of the physiologic foot and ankle complex by having low impedance in the early stance phase and then switching to higher impedance once foot-flat is reached.

In [5], Veg et al presented an improved planar biomechanical model of a human leg which comprises three body segments and two joints. Model was developed to investigate automatic control for functional electrical stimulation.

This paper describes the synthesis and principal kinematical analysis of mechanically established walking and standing mechanism. Moreover, design and motion simulation of mechanical walker 3D model is shown, elaborated and documented by various kinematical diagrams.

2. THE MECHANICAL WALKER MECHANISM

The curved sliding mechanism OABC, with special parameters, extended with dyad CC' and DC' is the fundamental mechanism of the model of the mechanical walker (Fig. 1)

Since the point A of a crank OA of the leading link has a circular trajectory SA, the point C of the link AC, of the leaded member moves over the trajectory SC,, the symmetrical 6th order curve (1) with special characteristic are of interest for application.

By transforming of the curved sliding mechanism on the equivalent four bar linkage [6] it is possible to synthesize the six member joint mechanism. One of the members has the curve translation law of motion, which can be described by the law of motion of the point C of link of the curved sliding mechanism [7], [8]. Because the link and the moving link of the equivalent four bar linkage are infinite, its practical application is inconvenient. This fact improves the use of the quasi equivalent joint four bar linkage with the members of infinite length. The law of motion of the point C of the quasi equivalent mechanism is close to the law of motion of the point C of the link of the curved sliding mechanism [8].

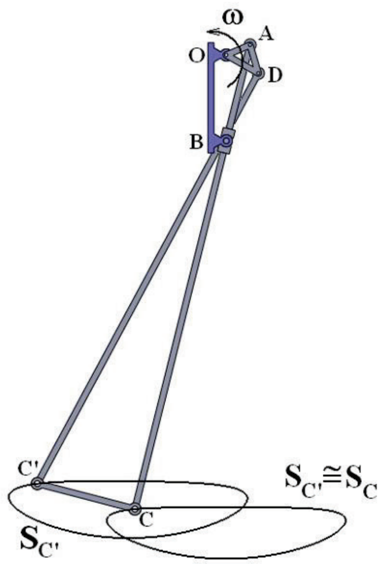

Figure 1*. The fundamental mechanism of mechanical walker model*

By applying the Robert-Chebyshev theorem on the quasi equivalent joint four bar linkage it is possible to obtain the parameters of the added dyad, in which one of the members does the curve translation [7], [8].

By the invention of curves sliding mechanism extended with the dyad, whose one member do the close to translation, it is possible to treat it as an four bar linkage CADC' with the added link OB and slider B (Fig. 2).

Two of such identical six member mechanisms, placed in two parallel planes, with the common crank phasic shifted for 1800, able to rotate around the point C, forms the fundamental structure of the mechanical walker (Fig. 3). The members CC', the feet, has the floor contacts with the unmoving ground, one after the other. The trajectory SOb of the translatory moving couple of the walker is to be obtained by assembling of the upper parts of the trajectory SB, from a to b (Fig. 2), that is from a1 to b1 in a continual curve in the sagittal plane (Fig. 4). Details of the walker mechanism are shown in Fig. 5.

The mechanical walker, synthesized by the use of mentioned method, does not imitate the human pattern of walking. The conditions necessary for motion stability are based on the explained mechanical structure. Because of the low walking speed of the walker, the static stability is of the main interest, the dynamical influence of the stability is of the second order [3].

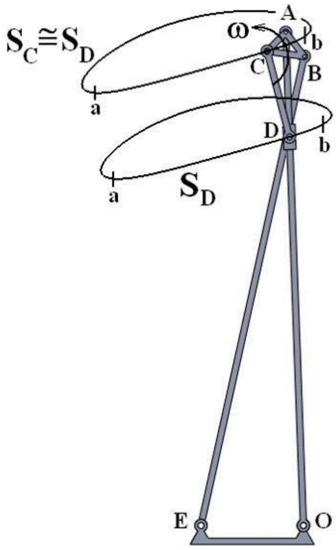

Figure 2. *Four bar linkage CADC' with the added link OB and slider B*

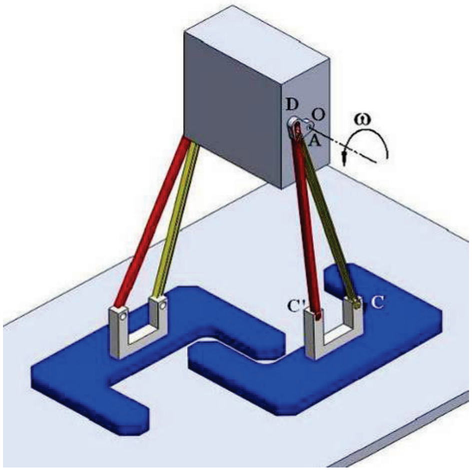

Figure 3. *The fundamental structure of the mechanical walker*

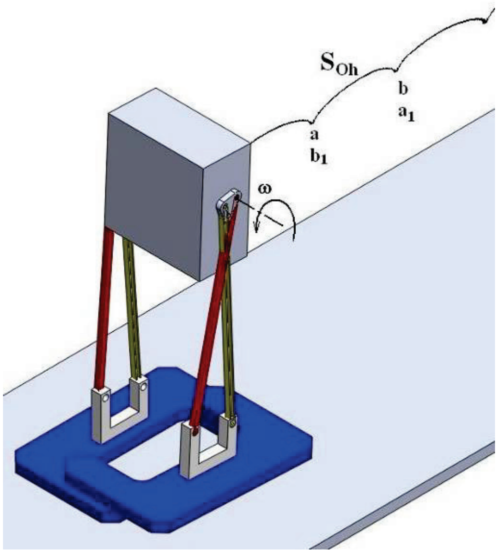

Figure 4. *The trajectory of the translator moving couple of the walker*

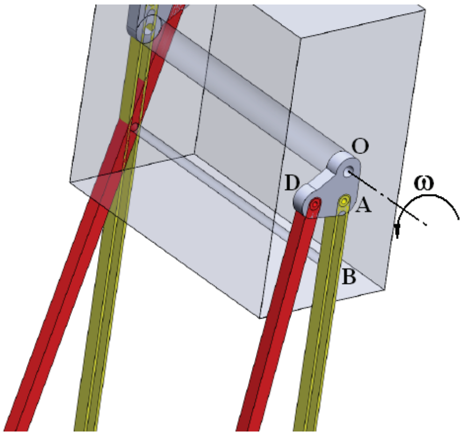

Figure 5. *Details of the walker mechanism*

By analyzing of the human walk [2] it could be concluded that the head and shoulders are moving approximately uniform, with a constant velocity during walk cycle. Comparing the trajectories of the mechanical walker (Fig. 2) and man's head it is to be pointed out that it is necessary in first approximation to build in the horizontal moving component to the point of the seat (predicted for the handicapped person) OB, for obtaining close to constant velocity during walking.

This is possible to realize by harmonic mechanism, with the initiating angular velocity $\omega 1$, doubled to the angular rate of the fundamental mechanism $\omega 2 = -2\omega$. Superposition of the motion laws of the fundamental mechanism and the harmonic one result that the moving of the seat of the walker is obtained with the close to constant velocity.

3. EVALUATION AND VERIFICATION OF THE SOLUTION

Since the mechanical walker, proposed in this paper, is expected to be used for walking rehabilitation and training in the treatment of spinal cord injured patients, its kinematical characteristics should be compared with the kinematical characteristics of human walk. That comparative evaluation can offer the verification of mechanical walker as a useful medical tool for the purpose of walking rehabilitation.

The positions set of the mass center of the walking man is obtained by corresponding anthropometric measurements and are graphically exposed on Fig. 6 by the series of dots. The trajectory of one chosen point on the 3D model of mechanical walker is shown on the same Fig. 6 by the continuous red curve. This 3D model is created by the using of CAD [7] (SolidWorks) application and the trajectory is generated by the motion simulation tools of the same CAD application. The comparative consideration of this trajectory and the positions of the walking man center of mass represented by the series of dots shows significant fitting, i.e. almost trivial differences. Thus, it can be regarded that designed mechanical walker is a practical and beneficial medical device for walking rehabilitation

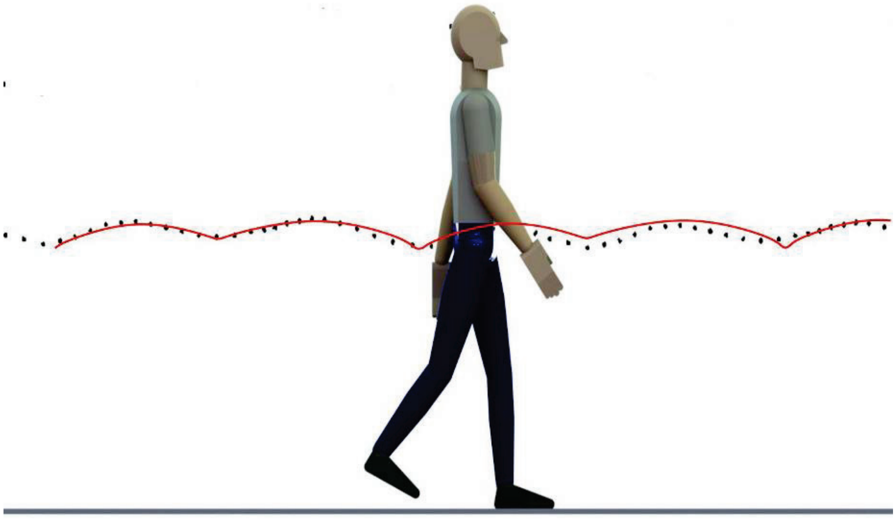

Figure 6. *The mechanical walker trajectory (red curve) and the positions of the walking man's center of mass (black dots)*

4. CONCLUSIONS

This paper describes a novel walker with mechanically established walking and standing mechanism. Described synthesis of mechanism of the mechanical walker can be compared with the similar solution, the tripod walking robot, based on mechanism composed of 8 linkages, [8], whereas our mechanical walker comprises just 6 elements. Moreover, the fulcrum of the walker described in this paper, is the structural member of the mechanism, while the tripod walking robot rests upon the surface in singular points. Finally, tripod walker has larger overall dimensions than mechanism proposed here. Since both mechanisms generates similar walking path, it can be concluded that the design exposed in this work is more practical and reliable, as well as less expensive.

In further establishment, it is possible to develop new mechanisms, function generators, which will take into account horizontal component, as well as the vertical one. It is of interest to correct the vertical component of the velocity of the seat of the mechanical walker. The goal for the correction is to obtain better coincidence of the motion laws of the walker to the walking patterns described in gate analysis [4].

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