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Research on the Dynamics of an Omnidirectional Platform Taking into Account Real Design of Mecanum Wheels (as Exemplified by KUKA youBot)

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The subject of this study is an omnidirectional mobile platform equipped with four Mecanum wheels. The movement of the system on a horizontal plane is considered. The aim of this research is to study the dynamics of the omnidirectional platform, taking into account the design of Mecanum wheels: the shape of the rollers and their finite number. The equations of motion of the onmidirectional mobile platform are derived taking into account the real design of the Mecanum wheels and their slippage. A comparative analysis of the results of numerical modeling for different models of contact friction forces is presented. It has been established that switching of contact rollers and displacement of contact points lead to the occurrence of high-frequency components of wheel rotation speeds, as well as an offset of their average values (in comparison with the modeling results without taking into account the design features of the chassis).

Keywords: omniplatform, Mecanum platform, Mecanum wheel, youBot, omniwheel

1. Introduction

The subject of this study is a mobile platform for omnidirectional movement, equipped with Mecanum wheels (Swedish wheels or Ilon wheels [1]). On the periphery of each of them several rollers are mounted, the axes of which skew with the axis of the wheel at an angle of 45°. The design of the Mecanum wheels allows the vehicle to make omnidirectional movement (i.e., in any direction with an arbitrary orientation), for example, to make translation motion along an arbitrary trajectory or to make a turn in place.

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Due to their mobility and ease of parking, omnidirectional platforms are used to work under the cramped conditions of storage, production and similar premises, and to create vehicles for disabled persons and for other purposes [2].

Mecanum wheels are used to drive spherical wheels [3] and outer shells of spherical robots [4, 5].

Mobile omni and Mecanum wheeled platforms are actively studied.

Most theoretical studies of the mechanics of omnidirectional platforms use simplified models of omni and Mecanum wheels. They are modeled by disks, slipping at the contact points with the floor in the direction of the axis of the roller [6–9], or it is assumed that the position of the contact point on the roller does not depend on the angle of rotation of the wheel [10, 11]. These simplifications allow a description of the dynamics of the system in the framework of nonholonomic mechanics and reduce the dimension of the system of differential equations of motion.

However, it should be noted that some design features of the Mecanum wheels lead to negative effects: the occurrence of vibrations when moving at high speeds and a decrease in the energy efficiency of the control forces (see the review in [12]), which can be studied with an increase in the level of detail of the description of the models of wheels and contact forces.

The results of an experimental study of the dynamics of the controlled movement of the four-wheeled Mecanum platform are given in [13]. It has been established that with sufficiently accurate speed control of wheel speeds, the actual trajectories are significantly different from those required. Also, experiments showed that, with the same initial state of the platform, the same desired motion is tracked with different accuracy. These phenomena are explained by the use of the model, which does not take into account the actual size and number of rollers, their slippage, the dependence of the system's movement on the initial location of the contacting rollers.

In a series of works [14–17], the influence of the real omniwheel design and inertia of the rollers is studied: stability of such systems [15], their computer modeling [16] are considered; tangent impacts occuring due to switching contacting rollers are studied in [17].

A mathematically rigorous description of the geometry of the Mecanum wheels and their kinematics is given in [18]. The influence of the real design of the Mecanum wheels on the accuracy of the odometric navigation of an omnidirectional platform was studied in [19].

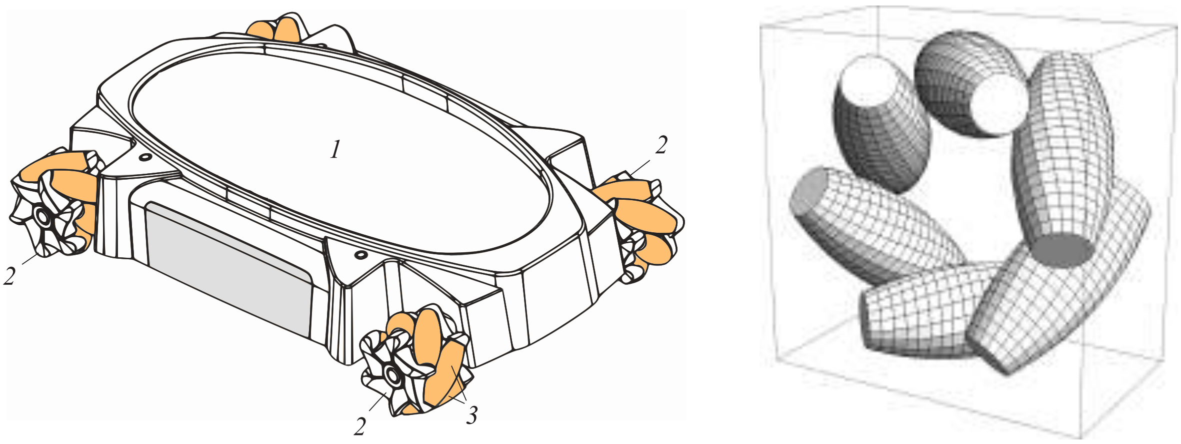
In the present paper, the *KUKA* mobile robotic platform *youBot* is chosen as a specific object of study [20] (see Fig. 1). The open and free software of this robot allows it to be used for educational and scientific purposes.

To increase the loading ability of the Mecanum wheels of the *youBot* robot, each of them is equipped with six rather large rollers, the axes of which are equipped with bearings (see Fig. 1). It is expected that the relatively large size of the rollers and their small number will significantly affect the dynamics of the investigated system.

In the present paper, the movement of the *youBot* Mecanum platform on the horizontal plane (the floor) is investigated taking into account the real geometry of the rollers, linear friction in the joints of the bodies, and wheel slippage.

2. Description of the Mecanum platform

In order to describe the kinematics of a mobile robot, we introduce a fixed coordinate frame xyz with a horizontal plane xy, and a moving coordinate frame $OXYZ$ with origin at the geometric center of the platform O. The axis OX is a longitudinal symmetry axis of the



(a) General view (b) Rollers of one wheel

Fig. 1. Mobile omnidirectional platform of the youBot robot (1 — platform; 2 — Mecanum wheels; 3 — rollers)

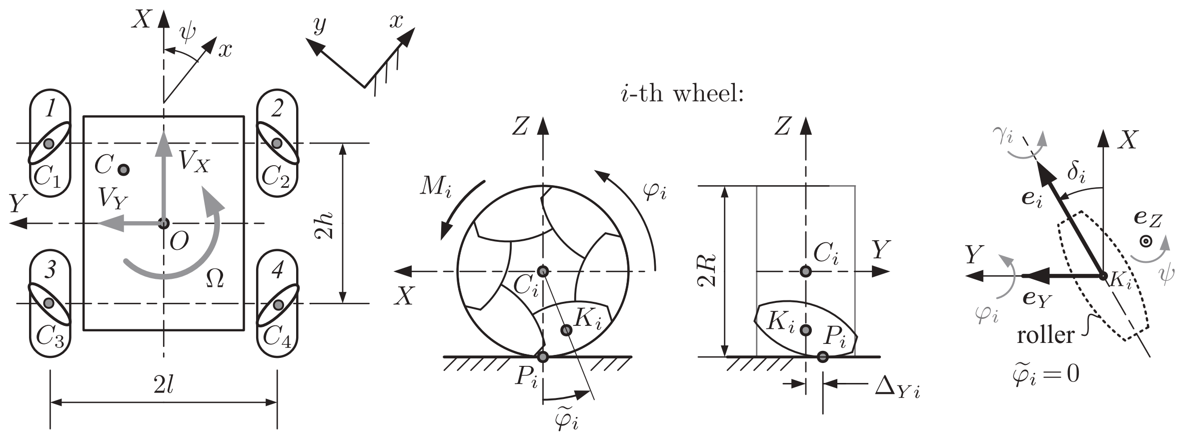


Fig. 2. Kinematic scheme of the mobile platform.

platform, and the OY axis is a transverse axis. The coordinate axes z and OZ are vertical and aligned with each other. The kinematic scheme of the Mecanum wheeled platform is shown in Fig. 2.

The position of the platform is defined by the Cartesian coordinates x_O and y_O of its geometric center O in the fixed frame xyz and by the angle $\psi = \angle(x, OX)$.

The platform's center of mass C is displaced relative to the point O. Its Cartesian coordinates in the moving plane OXY are denoted by a_X and a_Y, respectively (see Fig. 2).

The *youBot* mobile robot is equipped by four pairwise coaxial Mecanum wheels with six peripheral rollers. In the kinematic scheme of the platform, the rollers in contact with the floor are shown as ovals on wheels *1*, *2*, *3*, *4*.

The centers of the wheels C_i, $i = \overline{1,\,4}$, and the platform's center of mass C lie in the OXY plane. The axes of rotation of the wheels pass through points C_i parallel to the Y axis.

The angles of rotation of the ith wheel ($i = \overline{1, 4}$) relative the robot base are denoted by φ_i, and the angle of rotation of the contacting roller, by γ_i (see Fig. 2).