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DYNAMICS MODEL OF THE THREE-WHEELED MOBILE PLATFORM

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Abstract: *The dynamics model of the 3-wheeled mobile platform has been presented. The proposed model is useful to examine different configurations of the drive wheels and to analyze the relations between causes and effects of the motion parameters. The solution presented in the work allows to study the behavior of the platform also while slippage and in the circumstances to refrain the platform from falling into the skid. The problem of the forced motion and free motion of the platform with the possibility of modification the drive modulus positions has been considered. The formulated initial problem has been solved numerically and sample results are presented.*

Keywords: mobile platform, dynamics, motion parameters.

1. Introduction

Considerations about various issues, both theoretical and experimental, in mechanical systems such as mobile platforms and mobile robots are widely described in literature. The kinematic and the dynamic analysis including the trajectory tracking and path generation for nonholonomic systems are a continually common matter. In previous studies the kinematics of wheeled mobile robots have been the main subject in planning the control of nonholonomic systems. The analysis of motion planning with consideration of the dynamics equations of the three wheeled mobile robot is proposed among others in (Zohar et. al., 2011). Proposition of the trajectory planning problem for multi-objective is widely described in (Khoukhi, 2015). The formulation of tracking control of a group of mobile robots with guaranty of no collisions between robots is proposed and described in (Do, 2009). The analysis of the internal dynamics, specifically the system stability is presented in (Eghtesad & Necsulescu, 2006). Approach of the kinematic and dynamic solutions for the possible positions of the wheeled platforms are proposed in (Campion et. al., 1996). Simple or inverse task of the dynamics can be solved by establishing the differential equations of motion. Some approaches are described by using the Langrange method (Staicu, 2009). Knowing the differential equations of motion the motion parameters can be determined. The effect of this is generating and implementing the trajectory of the platforms motion.

In this paper the description of the dynamics for three-wheeled mobile platform is described. The main purpose is to know the platforms work conditionings. The proposed model is necessary for an analysis of the planar motion, including a progressive and rotational motion of the platform. Description of the dynamics of the platform in the classical approach ultimately is a base to provide the fundamental parameters, which are velocity and acceleration, taking into account the cause of the motion and allow to know the position of the platform at a particular point in time.

2. Model of 3-wheeled mobile platform

The modular construction of the design solution of the mobile platform has been adopted. The prototype model enable to creating any different configurations of selected positioning of the platform wheels by the using the drive member with electric drive. The realization of the preset trajectories of vehicular

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transporter is possible. The assumption that chassis of the platform is constructed from a rigid frame and the provision of possibility to separate the selected wheel drives have been made.

Description of dynamics of 3-wheeled mobile platform has been made on the basis of the model according to the geometrical scheme presented in Figure 1.

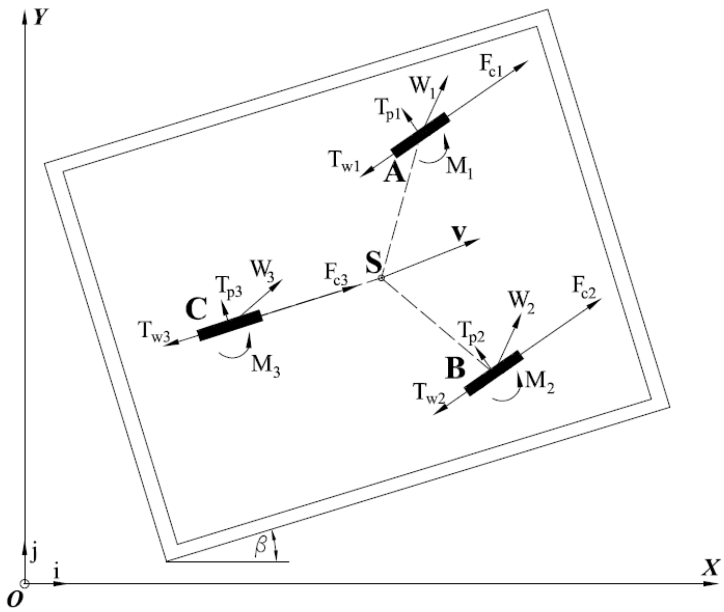

Fig. 1: The geometric scheme with distribution of forces in the platform wheels

In order to draw up a description of the mobile platforms dynamics, the motion parameters are determined with respect to the global reference frame *OXY*.

To establish the important quantities of the dynamics is an obligation. First, the form of functions, equations of motion for global coordinate system to designate the path of motion the mobile robot, and for the local coordinate systems. The analysis of platforms motion during rotational movement as well as during linear movement occurs in a planar surface. Instantaneous motion is composed of the progressive motion with the velocity of the center of the mass and the rotational motion with the velocity around the center of mass of the mobile platform.

In Fig. 2 the forces occurring in the wheels of platform during the movement are presented. The force N_i, as a reaction on the weight of the platform wheels are considered. In the figure the driving torque M_i which later is the base to determine the active force $\mathbf{F}_{ci}$ is also shown.

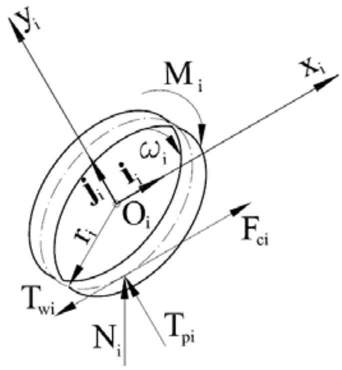

Fig. 2. Distribution of forces acting on each wheel of the platform

In Fig. 2 the following forces are presented: $\mathbf{M}_i$ – the drive torque, $\mathbf{F}_{ci}$ – the active driving force, $\mathbf{T}_{wi}$ – the friction force in the longitudinal direction, $\mathbf{T}_{pi}$ – the friction force in the transverse direction, $\mathbf{N}_i$ – the reaction force of the *i*-th wheel, ω_i – the angular velocity of the *i*-th wheel.

3. Dynamics description of 3-wheeled mobile platform

In determining the forces occurring during the motion there is a need to take into account the drive torque and the friction, which is consequent from the contact of the wheel with the raceway. It is necessary to determine the values of wheel loads on the roadway. The values of the resultant forces $\mathbf{W}_i$ have been calculated as follows:

$$\mathbf{W}_1 = \mathbf{F}_{c1} + \mathbf{T}_{w1} + \mathbf{T}_{p1}, \qquad (1)$$

$$\mathbf{W}_2 = \mathbf{F}_{c2} + \mathbf{T}_{w2} + \mathbf{T}_{p2}, \qquad (2)$$

$$\mathbf{W}_3 = \mathbf{F}_{c3} + \mathbf{T}_{w3} + \mathbf{T}_{p3} \qquad (3)$$

The active forces acting on each wheel were calculated by the formula:

$$\mathbf{F}_{ci} = \frac{M_i}{r} \cdot \mathbf{i}_i \qquad (4)$$

where: M_i – the drive torque of the i-th wheel, r – the radius of the driver wheel.

The passive forces should be determined, in addition to the active forces which cause motion of the system. The resistance forces such as friction forces $\mathbf{T}_{wi}$ in the longitudinal direction, and the friction forces $\mathbf{T}_{pi}$ in the transverse direction are considered according to the motion parameters. Because the active force $\mathbf{F}_{ci}$ is different from zero, the friction force values are also different from zero during the platform motion. The values of those forces are described below:

$$\mathbf{T}_{wi} = -\mu_w \cdot N_i \cdot sign(v_{wi}) \cdot \mathbf{i}_i \qquad (5)$$

$$\mathbf{T}_{pi} = -\mu_p \cdot N_i \cdot sign(v_{pi}) \cdot \mathbf{j}_i \qquad (6)$$

where: μ_w, μ_p are the coefficients of friction for the longitudinal and transverse directions and the v_{wi} and v_{pi} are the velocity components for the longitudinal and transverse directions.

Considering the formulated formulas (1-6) representing the active and passive forces the translational motion equation can be formulated in the form:

$$m\mathbf{a} = \sum_{i=1}^{3} \mathbf{W}_i \qquad (7)$$

where: m – the mass of the whole object, $\mathbf{a}$ – the acceleration of the platform center of mass, $\mathbf{W}_i$ – the i-th resultant force.

By using those equations the determining of the motion parameters of the mass center under the influence of known external forces is possible. The progressive motion of the center of mass is described by Eq. (7).

The equation of the rotational motion around the center of mass for the platform can be written in the form:

$$\frac{d\mathbf{K}}{dt} = \sum_{i=1}^{3} \mathbf{s}_i \times \mathbf{W}_i + \sum_{i=1}^{3} \mathbf{M}_i \qquad (8)$$

where: $\mathbf{K}$ – the angular momentum vector of the whole platform, $\mathbf{s}_i$ (i=1,2,3) – the location vectors of points: A, B, C in the global coordinate system.

By using the derived equations of motion, written in the form of differential equations, the rate of change certain physical quantities (ex. velocity, positioning) can be defined. For the local coordinate system the parameters of motion for the center of mass platform are: $\dot{x}_i$ - longitudinal velocity, $\dot{y}_i$ - transverse velocity, $\dot{\beta}_i$ - angular velocity.

The dynamic equations of motion in the global coordinate system can be written in case of the planar motion in the form:

$$\ddot{X} = \sum_{i=1}^{3} \frac{W_{ix}}{m} \qquad (9)$$

$$\ddot{Y} = \sum_{i=1}^{3} \frac{W_{iy}}{m} \qquad (10)$$

$$\ddot{\beta} = \frac{\sum_{i=1}^{3} (s_{ix} \cdot W_{iy} - s_{iy} \cdot W_{ix})}{I_z} \qquad (11)$$

To formulate the initial problem by adding the initial conditions according to the starting values of the motion parameters the set of equations (9-11) can be used.

4. Sample simulation results

The dynamics of the mobile platform generally can be develop in two ways. First, to solve the forces acting on the system based on a motion description. Second, the so-called inverse dynamics, where the forces are well known but the motion parameters need to be determined. This work contains the inverse dynamics description. The sample simulation results has been obtain with the following assumptions. The assumed values are: drive torque M_1=0,1 kNm, coefficients of friction in the longitudinal direction μ_w=0,1 and in the transverse direction μ_p=0,1, mass of the platform m=150 kg, and the acceleration of gravity g=9,81 m/s^2.

Analysis of the dynamics of mobile platform was made by using the described formulas. The results in form of graphs of motion parameters and the sample trajectory are presented in Fig. 3.

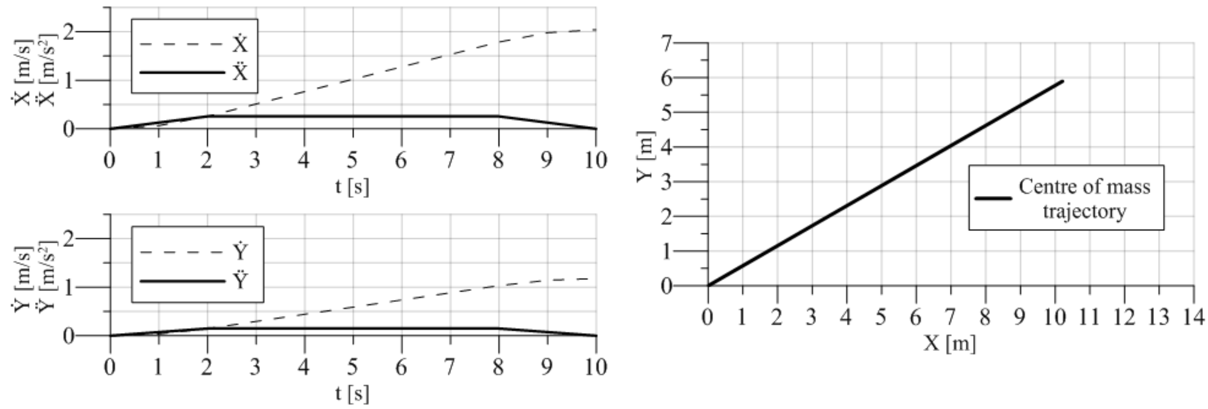

Fig. 3. Obtained motion parameters $\dot{X}$ [m/s], $\dot{Y}$[m/s], $\ddot{X}$ [m/s^2], $\ddot{Y}$ [m/s^2], and trajectory of the center of the mass for β=Pi/6.

5. Conclusions

The dynamics model of the 3-wheeled mobile platform has been presented. The model enables to know the determinants of platforms work, which in consequence allow to determine the parameters affecting to the movement of both the platform and its components. The proposed model is useful to examine different configurations of the drive wheels and to analyze the relations between causes and effects of the motion parameters. The problem of the forced motion and free motion of the platform with the possibility of modification the drive modulus positions has been considered. The formulated initial problem has been solved numerically and sample results are presented.

The solution presented in the work allows to study the behavior of the platform also while slippage and in the circumstances to refrain the platform from falling into the skid. The model can also be developed by introducing to the mathematical description other elements of the real object.

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