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Studies of dynamics of a lightweight wheeled mobile robot during longitudinal motion on soft ground

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Highlights

1. Influence of desired velocity on selected robot motion parameters is investigated.
2. Empirical studies are conducted in the container with dry sand.
3. Simulations are based on multi-body method and classical terramechanics models.
4. Formula for front-to-back contact angle ratio dependency on velocity is proposed.

Abstract

The paper is concerned with the study of longitudinal motion of a lightweight wheeled mobile robot on soft ground. The study is focused on the influence of the desired longitudinal velocity of a robot on both the longitudinal slip of the wheels and the ratio of wheel-terrain contact angles. Design of the four-wheeled skid-steered robot and research environment are described. Experimental investigations were conducted on a dedicated test stand with dry sand. A dynamics model of the robot-ground system taking into account properties of soft ground is presented. The classical terramechanics models of Bekker and Janosi-Hanamoto are used. Results of simulation research of robot motion and of the analogous experimental investigations are presented. Actual motion parameters of the robot and the values of longitudinal slip ratio of the wheels are determined. The results of simulation and experimental investigations are compared and discussed. A formula to describe front-to-back wheel-terrain contact angle ratio dependency on the desired velocity is proposed.

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Keywords: wheeled mobile robot, soft ground, tire-ground model, longitudinal velocity, wheel slip

1. Introduction

Wheeled mobile robots are unmanned vehicles whose motion is primarily a result of interaction of the wheels with the ground. In the case of robot motion on the soft ground, wheel slip phenomena and ground deformability should be considered in the model of robot dynamics. The dynamics model can be used, among other applications, as a tool in the process of robot mechatronic design.

The problems of modeling of the tire-ground system were considered so far mainly from the point of view of requirements of automotive vehicles, which over the years resulted in the development of multiple tire models with diverse capabilities, both on-road [1] and off-road [2,3]. However, it turns out that the wheeled mobile robots, especially lightweight robots, differ significantly from automotive vehicles in terms of applications, maneuvers performed, types of ground on which they move, vehicle design and properties of tires [4]. It seems that there is much less work done so far in the field of modeling of tire-road interaction for medium-weight and lightweight wheeled robots. Most studies are concerned with wheel-terrain interaction of planetary rovers, for instance [5–8].

One of the questions, important from the point of view of robot mobility and efficiency of motion, is the influence of the robot desired velocity. Some studies focus on the influence of wheel slip on vehicle mobility [8] and efficiency [9], but not many on the influence of desired vehicle velocity on wheel slip.

The aim of the present work is a numerical and experimental study of the dynamics of a lightweight skid-steered wheeled mobile robot on deformable ground with a focus on the desired velocity influence on robot motion parameters, especially on wheel slip. An important feature of the study is that the robot is equipped with non-pneumatic tires of small diameter. Results of

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