Path Tracking Control of Tracked Vehicle on Soft Cohesive Soil

Tae-Kyeong Yeu, Sup Hong, Hyung-Woo Kim and Jong-Su Choi
Ocean Engineering Research Department
Korea Institute of Ships and Ocean Engineering, KORDI

ABSTRACT

This paper deals with path tracking control of tracked vehicle on extremely soft cohesive soil. The dynamics of tracked vehicle is very complex and nonlinear because of the slippage of vehicle and the soil shearing. For the purpose of control of tracked vehicle we adopted simplified approaches. The vehicle is modeled as a single-body vehicle. Two kinds of PD (Proportional-Differential) controllers are applied to the single-body vehicle model. First, a simple PD controller is designed for a differential-wheel drive vehicle model disregarding the slippage problem. The designed controller is implemented to the dynamic simulation software of the single-body vehicle model including the vehicle slippage on soft soil. The control error due to the disregard of slippage is investigated. The PD controller is modified to minimize the control error caused by disregard of soil slippage, which control the track velocities for optimum traction force from the soil resistance characteristics, i.e. shear stress vs. shear displacement. Through numerical simulations, it was shown that the control error is reduced by using the enhanced PD controller.

KEY WORDS: Tracked vehicle; Soft cohesive soil; Track slippage; Path tracking; PD controller; Deep-seabed mining system

INTRODUCTION

To develop a mining system for deep-sea mineral resources like manganese nodules is a challenging task in ocean engineering. Mining system is composed of collecting system, lifting system and surface vessel. Self-propelled vehicle aims at proper positioning of the collecting system along the mining tracks on deep seafloor.

Brink et al. (1981) presented a control concept for the combined ship-pipe-buffer system. The buffer position should be controlled close to the miner, both during station-keeping (miner at rest) and during mining operation. To position the combined system, they applied PID controller to the ship system and PD controller to the buffer system, respectively.

Generally, tracked vehicles are used in military, agricultural and recreational applications where terrain conditions are improper or unpredictable. Tracked vehicles are better than wheeled vehicles due to the larger contact area of tracks providing better floatation and traction at various ground conditions. Hence, tracked vehicle has been chosen for the mobility on the soft and cohesive seabed soil.

Since tracked vehicles are steered by skid steering, it is difficult to control. Skid steering is the mostly used steering mechanism for tracked vehicles. Despite of the simple manual operation, the skid steering is based on complicated ground-track interactions. It is a subject of current research topics in terramechanics. Traction forces from the soft soil are produced by the shear stress created by the track slippage relative to the ground. Soil models obtained from experiments provide the relationships between the slippage and the shear stress. The resultant soil resistance of the two track contact surfaces creates the driving or braking force in forward motion and/or the turning moment in steering.

In order to investigate the performance of tracked vehicles, a number of studies have been carried out since Bekker’s pioneering study (1956). For soft ground, the interactions between tracks, road wheels and soil become so complex that the basic theory on pressure-sinkage and shear-traction force is restricted in its application. Wong et al. (1984) developed an analytical method for predicting the normal pressure distribution under a moving tracked vehicle, taking into account the response of the terrain to repetitive shear loading. Kitano and Kuma (1977) developed an analytical method for investigation of the steerability of tracked vehicles in time domain. They used the ground pressures at the road wheels to calculate the traction force of tracks in form of Coulomb friction, and assumed the motion of vehicle is planar. Murakami et al. (1992) derived a mathematical model for 3D dynamics of tracked vehicles on soft ground, which is applicable to the time domain analysis of rigid body vehicles. Tran et al. (2002) investigated the steering performance of tracked vehicle operating over fresh concrete by stationary analysis. Furthermore, Hong and Choi (2001) studied the effects of shape and height of grousers on traction force from cohesive soft soils. Choi et al. (2003) performed an experimental study on the performance of tracked vehicle. Based on the above experimental data, Kim et al. (2004) have developed the numerical simulation model investigating the interaction between single-body tracked vehicle and soft cohesive soil.

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