A New Path Tracking Control Algorithm of Deepsea Tracked Miner

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ABSTRACT

Based on the kinematic model of the deep sea tracked miner, a time-optimal control algorithm is proposed. During locomotion, the driving velocity and direction of the vehicle cannot change abruptly, or it will cause excessive slippage of the track. In other words, the vehicle must move smoothly during locomotion. This means that the dynamic constraints of the miner should be taken into account in the control strategy. An intermediate curve is proposed as a temporary tracking trajectory which satisfies the boundary conditions that at the target position the first, second, and third derivative must be zero. Therefore, a cubic spline curve is put forward which could meet the limits. After the analysis of the curve co-efficient, a time-optimal control algorithm is presented and implemented in MATLAB, and a series of computer simulation has been done. By simulation analysis, the curve co-efficient of $\lambda=0.66$ is chosen for it has better validity and accuracy. Through comparison with PID control strategy in previous work, the superiority of this algorithm is confirmed.

KEY WORDS: Deepsea mining; tracked vehicle; path tracking; algorithm

INTRODUCTION

Tracked vehicles are widely used in military, agricultural and mining applications where terrain conditions are difficult or unpredictable. For the deep sea mining task, tracked miner are better suited than wheeled vehicles for the simple reason that they have larger contact area of tracks and can provide better traction. As a method for deep sea mining, mining research using a tracked miner system has been conducted in many countries including Germany, U.S.A., China, India and Korea. For deep sea mining, the miner goes on the extremely cohesive soil. To make sure that the tracked miner moves along the desired mining path, path tracking control is of most importance. Also, skid steering is the most used steering mechanism for tracked vehicles. Path tracking is the process of determining speed and steering settings at the instant of time to follow the desired path. As for all of this, it is difficult to control the tracked miner. To avoid the effect of the slippage, the dynamic constraints of the miner should be considered in the design of path tracking controller.

For path tracking of mobile robots, a number of studies have been carried out since Kanayama’s pioneering work (1990). His work mainly focused on the design of a smooth curve with curvature continuity, and the stability of the system had been proven via Lyapunov function. Since then, various different path planning methods have been addressed (1997). These works consist of backstepping methods (1997, 2002), Lyapunov global methods (2001, 2004, 2010), quadratic curve method [8] and time-optimal trajectory planning (1996), etc. However, these methods are very complicated as they need too much computational effort to be achieved in real time. For tracked vehicles, Schiller (1993) and Ahmadi (2000) have done many studies on the analysis of the longitudinal slippage in the design of the path tracking control system. All these researches mainly focus on the vehicles on the ground without concerning the underwater or deep sea tracked miners. For the deep sea mining tracked miner, Hong (2009) has done the researches on the soil mechanics, and proposed so-called “line of sight” and vector pursuit method to control the vehicle moving along the desired path (2005). By dynamic analysis of the deep sea tracked miner, Han (2011) has put forward a simple PID control strategy to achieve the path tracking task.

KINEMATICS OF THE TRACKED MINER

We consider a deep sea tracked miner moving on a horizontal plane as shown in Fig.1. The miner’s motion is described by kinematic equations written in the miner-fixed coordinate system. In Fig.1, the miner is turning to the right, $(x_C, y_C)$ indicates the position of the miner with respect to the world coordinate system and the triplet $(x_C, y_C, \theta_C)$ defines the miner position. The outside or left track is denoted by a subscript o, and i denotes the inside or right track.

In the presence of the longitudinal slips $i_o$ and $i_i$ of the tracks, the