Dynamic Analysis and Path Tracking Control of Tracked Underwater Miner in Working Condition

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ABSTRACT

In this paper, dynamic analysis of underwater tracked miner in working condition is done during both straight driving and steering. First, based on the relationship between maximum shear displacement and shear stress, required shear displacement during working of the tracked miner is obtained. Considering the bulldozing resistance, compaction resistance, water resistance and force from flexible hose, the dynamic and kinetic model of tracked underwater miner is established. By simulation, the shear displacement of both left and right track of the miner are obtained. By using PD control strategy, the tracked underwater miner can move along the desired path, and the shear displacement of both left and right track are successfully controlled and therefore the miner can get optimum tractive force. The work in this paper offers a theoretical base for further research.

KEY WORDS: Tracked underwater miner; slip; path tracking; PD control

INTRODUCTION

Tracked vehicles are currently used in military, agricultural and mining applications where terrain conditions are difficult or unpredictable. They are better suited for such tasks than wheeled vehicles due to the larger contact area of tracks which provides floatation and better traction at various ground conditions. As a method for deep underwater mining, mining research using a tracked vehicle system has been conducted in many countries including Germany, U.S.A, China, and Korea.

Due to complex working conditions, it is necessary to do the dynamic analysis of the tracked underwater miner. First, because the miner goes on the extremely cohesive soil, the traction force is provided by shear stress caused by the shear displacement of the track. Second, during working, the miner can inevitably experience compaction resistance, bulldozing resistance from soil, as well as hydrodynamic force from current and transient forces from the piping system attached to the miner. All of these influences should be taken into account for dynamic analysis of the miner.

Further, to make sure the miner move along the desired path with a optimum traction ability, the slip of the tracks should be controlled.

In order to investigate the performance of tracked vehicles, a number of studies have been carried out since Bekker’s pioneering study (1956). Bekker formulated a relationship between sinkage pressure and shear stress of a wheeled vehicle on soft ground; Wong (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; Schiller (1993) developed a path tracking method; Ahmadi (2000) derived a dynamic model of tracked vehicles and a path tracking algorithm. But all of these research works focus only on the ground. Yeu(2005) has developed a numerical simulation model to track the desired path by using enhanced PD control method, without taking the effect of compaction force and hydrodynamic force into account; Kim (2005) developed dynamic analysis of an underwater tracked vehicle with considering the currents effects by using the Euler parameter method, but did not give detailed information about the maximum shear displacement of the track during steering.

In order to study the various effects on the tracked underwater miner during working, for better control of shear displacement and slip rate, in this paper, all the resistance forces, including compaction force, bulldozing force, hydrodynamic force and force form flexible hose, are taken into account. After the theoretical analysis, a simulation work has been done to show the proper shear displacement values to make sure that the miner has optimum traction ability. Using PD control strategy, the miner can move along the desired path with small error.

SOIL MECHANICS

The load applied to the soil consists of normal stress and shear stress. Normal stress is caused by vertical pressure from the weight of the vehicle, and can be obtained according to a relationship between sinkage and pressure. Shear stress comes from tractive and braking forces for the vehicle, and can be obtained by using a relationship between shear displacement and shear stress.

For homogeneous soil, Bekker formulated a relation of sinkage and pressure (Bekker, 1956):

\[ P = \left( \frac{k_s}{b} + k_p \right) z^n \]  

Here, \( P \) is normal stress, \( k_s \) is cohesive deformation module, \( k_p \) is...