Dynamic Analysis of a Tracked Vehicle Based on a Subsystem Synthesis Method

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ABSTRACT

This paper concerns about subsystem synthesis method for dynamic analysis of complex multi-body tracked vehicle systems which can be divided into several subsystems. Using subsystem synthesis method, subsystems in the complex model can be independently analyzed with virtual massless reference bodies. The virtual massless reference body has information of position, velocity and acceleration for base body. In the subsystem synthesis method, analyses of position, velocity and acceleration of the subsystems are carried out in a forward recursive fashion. For overall multi-body tracked vehicle system analysis, subsystems can be synthesized to the base body with effective matrix and vector from the virtual massless reference body of each subsystem. Using these effective matrix and vector of subsystems, equations of motion with base body can be solved independently. After then equations of motion of each subsystem can be solved using results of base body. Advantages of the proposed method are investigated in terms of computational efficiency and solution accuracy. In order to show the effectiveness of the proposed method, a multi-body tracked vehicle of seafloor massive sulfide has been analyzed.

KEY WORDS: Tracked vehicle, Subsystem synthesis method, effective matrix, effective vector, virtual massless body

INTRODUCTION

Many kinds of multi-body dynamic analysis programs have been developed for the mechanical system design of vehicle, tracked vehicle, robot, and etc. This simulation based design (SBD) technology has contributed to the reduction of production costs by reducing frequency of experiment and production of prototype. The SBD technology is applied in the field of development of deep-sea mining system. As a result, there are a number of related studies into the dynamic analysis of tracked vehicle(Bode, 1991; Murakami et al., 1992; Zhang, 1995; Tran et al., 2002; Hong et al., 2002; Kim et al, 2003, 2004). Numerical simulations of tracked vehicle have been developed in two main directions: multi-body and single body tracked vehicle dynamic analyses.

An efficient dynamic analysis method of multi-body models based on recursive formulation was proposed by Bae et al.(1999). Ryu et al.(2002) developed an efficient method on multi-body dynamic simulation of high speed tracked vehicles. In multi-body dynamic analysis model, because modeling of each element is possible as the actual system, simulation results can be used effectively to determine detailed design parameters of a mechanical system. However because number of equation of system is increased, i.e. the large size of system equations, it will take a lot of time to solve equations.

Several program have been developed in field of single body tracked vehicle dynamic analysis(Bode, 1991; Murakami et al., 1992; Zhang, 1995; Tran et al., 2002; Hong et al., 2002; Kim et al, 2003, 2004). Especially Hong et al.(2002) and Kim et al.(2003, 2004) developed an analysis program of tracked vehicle on extremely cohesive soft soil. The size of systems equations to be solved is small in a single-body model. Single-body models allow real time analysis and are frequently used for selection of principal dimensions. Real time simulation can be applied for development of control algorithms of mechanical systems as well. In this special application, a single-body model of a tracked vehicle can be applied for the development of the dynamic simulation of a complete integrated mining operation system. However, the analysis of a single-body model is not applicable for the evaluation of detailed design specification of a vehicle prototype(Kim et al, 2003).

Unlike tracked vehicle for manganese nodules of deep-sea, tracked vehicles of SMS(Seafloor Massive Sulfide) have a several suspension excavations. Therefore the motion tool of boom type at front of vehicle. Multi-body dynamic analysis model must be used to describe the motion of system for this vehicle model. The method of describing motion for multi-body model is split into two methods, method using Cartesian coordinates and method using relative coordinates. In the Cartesian coordinate-based method, equations of motion are described as differential-algebraic equations (DAE). Generally, DAE are more difficult to solve than ordinary differential equations (ODE) (Löstedt and Petzold, 1986). On the other hand, recursive multi-body formulation using relative coordinates has been studied since the late 80’s. It has been utilized for real-time numerical analysis. However this method is ineffective for creation of numerical analysis model, which is consisted of several subsystems with a number of different kinematic characteristics as a tracked vehicle of SMS. In order to analyze the SMS tracked vehicle model, total system analysis is required through the formulation which