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Numerical simulation of active track tensioning system for autonomous hybrid vehicle ☆

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ABSTRACT

One of the most important components of a high speed tracked vehicle is an efficient suspension system. The vehicle should be able to operate both in rough terrain for performance of engineering tasks as well as on the road with high speed. This is especially important for an autonomous platform that operates either with or without human supervision, so that the vibration level can rise compared to a manned vehicle. In this case critical electronic and electric parts must be protected to ensure the reliability of the vehicle.

The paper presents a dynamic parameters determination methodology of suspension system for an autonomous high speed tracked platform with total weight of about 5 tonnes and hybrid propulsion system. Common among tracked vehicles suspension solutions and cost-efficient, the torsion-bar system was chosen. One of the most important issues was determining optimal track tensioning - in this case an active hydraulic system was applied. The selection of system parameters was performed with using numerical model based on multi-body dynamic approach. The results of numerical analysis were used to define parameters of active tensioning control system setup. LMS Virtual.Lab Motion was used for multi-body dynamics numerical calculation and Matlab/SIMULINK for control system simulation.

1. Introduction

This paper is an extended version of work published in [1] and expanded by additional description of hydraulic circuit for track tensioning and numerical simulations.

The suspension system of a tracked vehicle is a set of components and mechanisms joining the axis of one or interconnected wheels with a single spring element, the damping element (damper) and a stabiliser (wheel arm) to the chassis. The main purpose of suspension system is transfer the weight force of the vehicle through wheels or tracks to the ground and isolating the vehicles components of terrain in order to increase the safety of users, increase the viability of equipment and provide stability of vehicle construction [2].

From the time of establishment of the first tracked vehicle until this day designers have developed many variants of the suspension. These can be divided into rigid, semi-rigid and flexible. In high speed track vehicles and particularly in military combat machines different types of active or semi-active flexible suspension are used. Electronic control of suspension systems becomes more popular also in wheeled vehicles [3–5].

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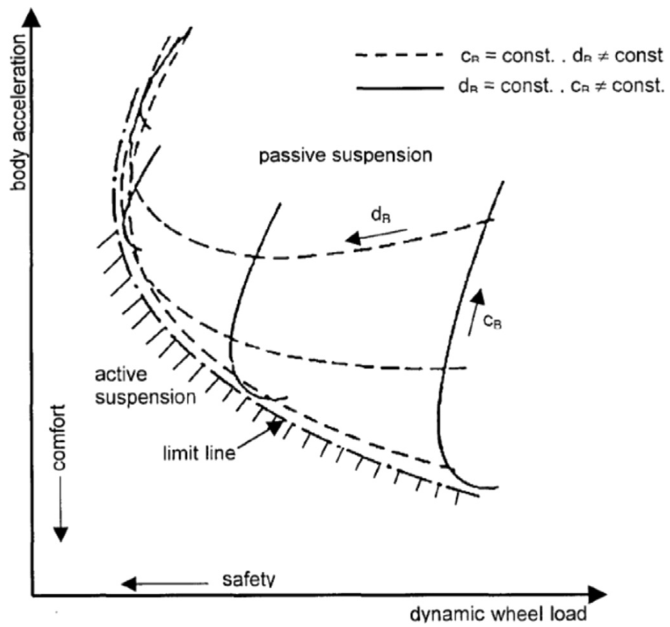

Fig. 1. Design conflict between comfort and safety [6].

Depending on how the wheels are connected to each other and with the chassis, the flexible suspension may be divided into individual, locked and mixed. Most modern combat tracked vehicles incorporate variants of the suspension based on an elastic element in the form of the torsion bar or a coil spring with a hydraulic or friction damper or hydro-pneumatic suspension [2].

In Fig. 1 is presented a curve of comfort in function of safety, which refers to vehicle for transporting human passengers. Since analysed vehicle can operate in unmanned mode it is also important to select correct suspension system to ensure safety of electrical equipment.

To satisfy these requirements, the tracked vehicle suspension system has been developed from passive suspension to intelligent suspension. The intelligent suspension system includes control strategies, sensor and actuator and so on.

Semi-active control suspension system in a tracked vehicle often uses an active damper, which is usually used in parallel with a conventional spring. Moreover semi-active suspension control devices change the damping of the suspension system directly. In recent years, dampers were filled with magneto rheological fluid, which has been one of the most commonly applied materials for semi-active vibration control. It is caused by its good electromechanical coupling characteristics, preferable dynamic performance and higher sensitivity. Moreover, due to the characteristics of low power consumption, high output force and rapid response, the magneto rheological damper seems to be an ideal impact absorber. Although highly nonlinear, the uncertainty and time-varying character hinder research on magneto rheological dampers dynamic character and control technology making it difficult work [7–10]. Whereas the active suspension systems require the use of some actuators.

Another method to develop active suspension is the use of an adjustable idler. The track tension of a tracked vehicle is very important in various dynamic characteristics such as power efficiency, vehicle manoeuvrability, pressure distribution in chassis components and track peel-off from the sprocket. If the track tension is increased to prevent the peel-off of tracks, excessive load is generated on chassis components. On paved roads, the track tension needs to be adjusted to the minimum value so that the power efficiency is maximised by reducing the friction loss. But on the cross-country routes, the track tension should be increased because of the increasing tractive force between tracks, suspension and soil [11]. Alternatively the idler mechanism with a constant force actuator, which acts on the idler wheel, enables one to maintain a constant value of track tension [12]. Moreover the adjustable idler can change stiffness of suspensions system and can affect the mobility of vehicle during passing obstacles.

2. Dynamics of multi-body systems

Analysis of multi-body dynamics system was reduced to solving equations of motion. They are second order ordinary differential equations (ODE), often connected with algebraic equations [4,5,13,14].

From the kinematic constraints and driving components it is possible to prepare a global vector of constraints denoted as, presented below:

$$\Phi(q, t) = 0 \tag{1}$$

where: q is a vector of generalised coordinates and t stands for time.

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