THE EFFECT OF SUSPENSION TECHNICAL CONDITION ON MULTI-AXIS VEHICLE DYNAMIC LOADS

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Abstract

The paper describes the operating conditions of multi-axial special vehicles presents the tasks and risks during the so-called peacekeeping and stabilization mission. Given are described risks of travel on the roads and unpaved roads, in towns and hilly terrain. To be able to carry out driving in difficult conditions, the main components of fighting vehicles must have a high reliability. This also applies to the burden of combat.

The paper presents a method to assess the condition of the suspension, consequently, its influence on dynamic loads on the crew and the internal equipment of the vehicle, presents a mathematical model of the vehicle similar to the multi-axis wheeled armoured personnel carrier. Describes the numerical model developed on the basis of it. It concerns on performed research for the most common cases. Are examples of the results of numerical estimates of the impact on the failure of the suspension, including damage to the wheels and suspension components, on the level of dynamic loads acting on the vehicle, its equipment and people stay in it.

The model vehicle is a versatile tool for analyzing the dynamics of different types of vehicles, including tracked combat vehicles and multiaxial vehicles.

Keywords: transport, multi-axial special vehicles, combat vehicles, reliability, dynamic loads,

1. Introduction

Present days are characterized by a change of doctrine, both in purpose and use of ground troops. Modernity is characterized by a change of doctrine, both in purpose and use of ground troops. Increasingly, they are used to perform the tasks in the framework of unconventional stabilization or peacekeeping mission (mission of a police patrol or convoy). Polish accession to NATO Membership in a natural way also determines the obligation to participate Polish troops in such ventures. Regardless of the name, the missions abroad are associated with military activities. For this reason, the task is particularly useful sub-units equipped with special vehicles, including multi-axis wheel armoured personnel carriers. Participation in such activities presents a constant threat in the form of the impact of various enemy munitions. Analysis of available materials and the results of its own studies show that increasing risk is associated with the use of mines, improvised explosive devices (IEDs) and anti-tank hand grenades. They cause damage primarily bottom of the hull and chassis of the vehicle (Fig. 1).

It should be noted that the tactical and technical conditions for imposing the requirement that minor damage to the vehicle (such as damage or a single wheel suspension) did not cause technical unfitness of vehicle. Thus, do not prevent the execution of scheduled task.

One of the most important characteristics of specialized vehicles operated in the army is mobility. Under this term we understand all the features that characterize the ability of driving and manoeuvring on the ground and on public roads, namely:

- linear motion parameters (including the average speed on the ground)
- manoeuvrability,
- the ability to handle the terrain.

Fig. 1. View of armoured personnel carrier BTR-80 damaged by mine explosion [5]

Achieving high mobility depends on many factors, ranging from design of chassis and powertrain systems, through the command system, up to the skills and working conditions of driver.

Dynamic properties of special vehicles, including their speed and acceleration depend primarily on engine power and the type of propulsion system, play a big role for short distances. The value of average speed, significant during long-term driving, the greatest impact is: the type and quality of the powertrain, the mechanisms of control of the vehicle and chassis, in particular the suspension. This is especially important due to the fact that vehicles do most of their special tasks on paved roads and poor quality land or premises without roads (often with limited possibility because of various barriers). For these reasons, at the stage of vehicles construction should provide the most likely operating conditions and the most frequent failures, and assess their impact on the ability to perform further tasks (Fig. 2). To carry out such studies are extremely useful method of computer simulation. Using validated computational models can be performed, among others, assess the impact of changes in vehicle design and different options of loads on selected values characterizing the dynamic properties [1]. The paper presents a proposal for a model with which to conduct this type of analysis.

Fig. 2. Experimental studies of the vehicle with a damaged tire

2. Mathematical model of research object

2.1. Model of the vehicle

Diagram of a discrete model of the vehicle is shown in Fig. 3. The model is distinguished the rigid body of wheels supported on a elastic - damping elements modelling tires, a rigid solid body supported relative to wheels on the elastic - damping elements mapping springs and dampers and a rigid block of the driver's seat. Block of the hall and the chair has three degrees of freedom (vertical displacement and angular displacement relative to the longitudinal and transverse axis of the vehicle). Blocks of wheels have one degree of freedom - vertical displacement.

In addition, the following assumptions were adopted:
- chassis consists of a number of wheels left and right sides of the vehicle, suspended individually in the longitudinal or transverse arms, the number of wheels and their arrangement on the right and left side of the vehicle may be different,
- elasticity and damping characteristics can be linear or nonlinear (in hydro-pneumatic suspension includes a spring element preload),
- ignored clearances in all joints moving,
- constraints imposed on the system, are holonomic and scleronomic, while imposed on the wheels are homogeneous.

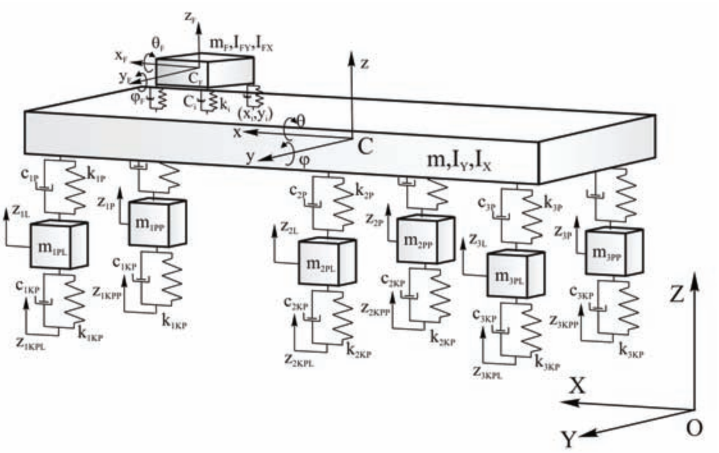

Fig. 3. Diagram of a discrete model

To formulate a mathematical model, the following assumptions were adopted:
- global coordinate system OXYZ in which the equations of motion are formulated,
- local coordinate system Cxyz associated with the model of the hull, which describes a suspension geometry and defines the mass moments of inertia of the body,
- local coordinate system $C_Fx_Fy_Fz_F$ associated with the driver's seat, which defines the coordinates of the elastic-damping suspension elements of seat and the mass moments of inertia.

Used in the model description of elastic and damping elements allows the representation of different types of elements, including coil springs, torsion shafts, hydropneumatic suspension. The latter because of its advantages are seen more frequently.

2.2. Numerical implementation

For car vibration analysis was developed the original computer program. This program allows you to:
- determine the rates and form of vibrations,
- designation timing displacement, velocity and acceleration generalized for different types of disruptions,
- determination of dynamic surface reaction,
- statistical analysis of the calculated waveforms.

The research model can be implemented at a set speed and defined disruptions parameters for the following traffic conditions:
- passage by a single rough roads,
- sinusoidal driving on the track,
- raid on the slope and exit slope,
- ride around the track by a random distribution of rough roads,
- movement of non-zero initial conditions for displacement and speed.

3. Results of model tests

3.1. The frequencies and forms of vibrations

For the developed vehicle model solved the problem of generalized eigenvalues of vibration, so that the designated form and the natural frequency, the first of which four are shown in Tab. 1 [2].

Tab. 1. The frequencies and forms of vibrations

Number of frequency	Frequency f [Hz]	The period of oscillation T [s]
1	0.99	1.01
2	1.11	0.90
3	1.26	0.79
4	2.48	0.40

The first three values are the natural vibration frequencies of hall rigid body, supported on elastic-damping elements of the suspension. The first - the axis transverse vibrations of the vehicle, the second - vibration angular longitudinal axis, the third - the vertical vibrations. The fourth value corresponds to the natural frequency of the driver's seat.

3.2. Failure analysis

The main objective of this study was to assess the impact of some failure of the suspension, on the level of dynamic loads acting on the vehicle and on the people inside the vehicle. For this purpose, simulation studies were performed for different cases. Their choice was dictated by the results of the analysis of occurring suspension failures of multi-axis special vehicles:

a) an efficient vehicle,
b) a vehicle with a damaged of a single front wheel suspension,
c) a vehicle with a damaged front wheel tire (riding on a Run Flat tire),
d) a vehicle with a damaged valve in a single height adjustment suspension or suspensions of one side of the vehicle (heel).

For the calculation assumed the characteristics corresponding to the four axial wheeled vehicles weighing about 20 tons. The vehicle was moving at different speeds. As a forces were adopted the kinematic forces, of quasi - random distribution, acting on the wheels of the vehicle. The characteristics of the road on which the vehicle was moving, corresponded in poor condition unpaved road [3]. As a result of the calculations set characteristics of displacement, velocity and acceleration of generalized degrees of freedom. In addition, were calculated characteristics of impact forces between wheels and the ground.

In Fig. 4 shows the vertical acceleration of centre of mass of the vehicle and the driver's seat for the parameters corresponding efficient vehicle.

Larger values of vertical accelerations of the driver's seat are caused by his considerable remoteness from the centre of mass of the vehicle and the effect of aggregation of linear vibration in the vertical and angular vibrations terms the transverse axis.

In Fig. 5 shows the corresponding waveforms obtained by simulation for a vehicle with damaged suspension. Compared to the efficient vehicle acceleration values have raised - especially the driver's seat. This is due to a much greater activation of the vehicle to the angular vibration.

Table 2 lists the extreme values of vertical acceleration of centre of mass of the vehicle and the driver's seat. It also provides standard deviations of the waveforms obtained for the three pre-defined states. Placed on disability obviously affect the growth of dynamic loads. However, while maintaining an appropriate speed accelerations do not exceed limits.

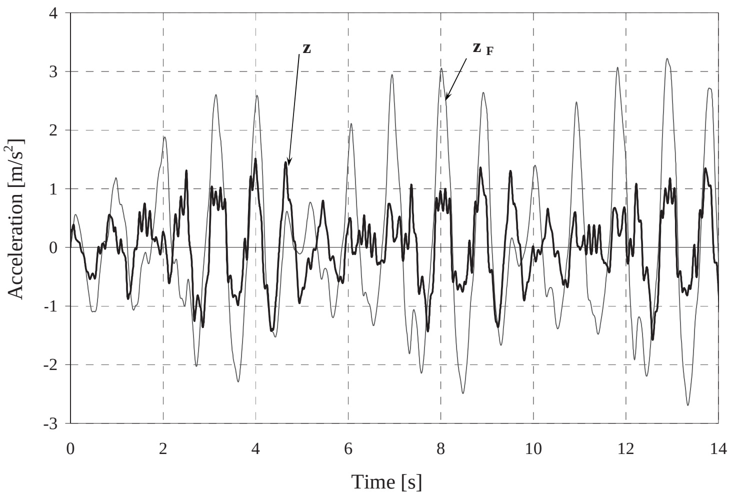

Fig. 4. Vertical acceleration of the vehicle centre of mass (z) and the driver's seat (z_F) for efficient vehicle

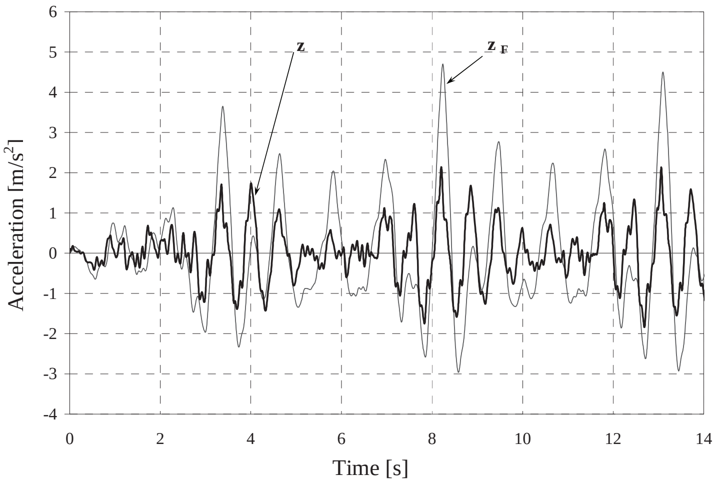

Fig. 5. Vertical acceleration of the vehicle centre of mass (z) and the driver's seat (zF) for a vehicle with damaged suspension

Tab. 2. Extreme values and standard deviations of the acceleration waveforms

Technical condition of the vehicle	**Extreme values of vertical accelerations**		**The standard deviations of vertical accelerations**	
	driver [m/s^2]	**centre of gravity** [m/s^2]	**Driver** [m/s^2]	**centre of gravity** [m/s^2]
efficient	3.16	1.51	1.35	0.62
broken suspension	4.65	2.14	1.41	0.69
flat tire	3.87	3.35	1.31	0.82
lock oil valve	3.43	1.61	1.45	1.01
side inclination	3.38	1.60	1.05	0.84

In Fig. 6 shows the waveforms of dynamic response from the ground on selected wheel of the vehicle. We analyzed two cases - an efficient vehicle and a vehicle with a damaged suspension of the first wheel (elasto-damping element). In the figure, apart from increase in the average strength, there are also much greater changes in this force. Load per first wheel, take the other wheels and especially the second wheel. This is due to decrease in the total stiffness of the suspension of the right side of the vehicle. As a result, this leads to an increase in angular vibrations transverse to the axis. It definitely worsens the working conditions of suspension, and the long drive can lead to damage more wheels suspension or tire.

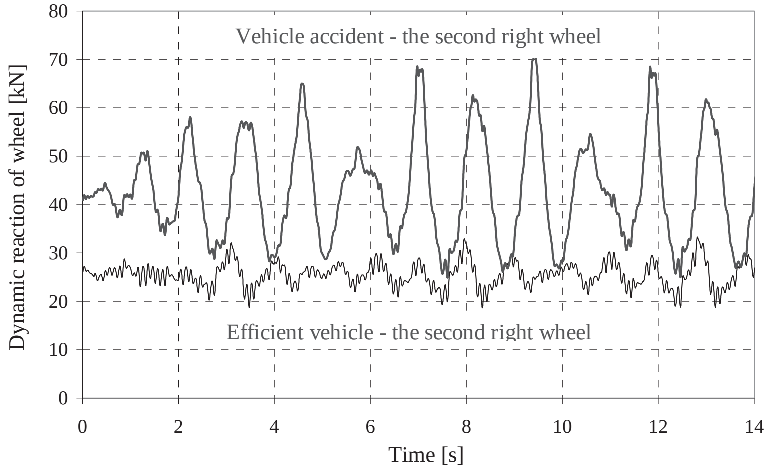

Fig. 6. Dynamic responses of the selected wheels for efficient and damaged vehicle

4. Summary

Presented in the work of a mathematical model of the vehicle and its numerical implementation allows:
- determine the dynamic loads of the analyzed object of study and its components,
- determine the dynamic loads acting on the crew, crew landing or cargo,
- estimate the effects of damage to suspension components on the value of acting loads.

The model vehicle is a versatile tool for analyzing the dynamics of different types of vehicles, including tracked combat vehicles and multiaxial vehicles. When you are able to implement multi-variant testing, taking into account inter alia:
- change the position of centre of mass and mass parameters of vehicle,
- change disruption,
- change the characteristics of elastic and damping elements,
- change the characteristics of the ground,
- impact damage to chassis, and in particular suspension components on the dynamic properties of the vehicle.

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