COMPARISON A RUNNING SMOOTHNESS OF A WHEELED TRACTOR WITH A SEMITRAILER TANK OR UNIT WHILE DRIVING ON ASPHALT-CONCRETE SURFACE

Andrii Kozhushko
PhD, Associate Professor
Department of Car and Tractor Industry[1]
Andreykozhushko7@gmail.com

Kseniia Riezva
PhD, Associate Professor
Department of Hydraulic Machines[1]
rezvayaks@gmail.com

[1]*National Technical University "Kharkiv Polytechnic Institute"*
2 Kyrpychova str., Kharkiv, Ukraine, 61002

Abstract: The problem of providing functional stability while moving vehicles arises during research of the types of transport works used in agriculture. A wheeled tractor with trailer or semitrailer units is used as a vehicle in the agricultural sector. These days most manufacturers of tractor technology increase the performance of transport work, such as increasing of engines power and cargo transportation. This trend is dangerous, especially when transporting units with variable mass (tanks), because the transportation of liquid cargo leads to significant self-oscillations, which effects on the movement dynamics. One of the studies that characterizes the dynamics of the vehicle movement is running smoothness. This research can provide information about the driver's comfort and vibration occurrence in a vehicle. The materials in this article are basic in the study of running smoothness of a tractor with a variable mass unit and also provide prerequisites for the coverage of the recommendations for reducing driver seat and tractor frame vertical acceleration.

Keywords: wheeled tractor, semitrailer tank, unit, oscillations, smoothness, redistribution weight, dynamics, partial oscillator, amplitude-frequency characteristics, acceleration.

1. Introduction

The investigation of the running smoothness of the vehicle assumes the definition of resonant zones in terms of values of the body acceleration (frame) and the driver's seat at the construction of amplitude-frequency characteristics. This study is based on the calculation of dynamic mathematical model of the oscillatory motion of the investigated system under the action of irregularities of the road. Running smoothness of the vehicle allows to advance arguments for the influence oscillations to the comfort of the driver and provide prerequisites for vibration investigation.

That kind of the vehicle can be presented not only as a car, but also as a wheeled tractor that performs transport work (cargo transportation). Special attention should be given to the transport work, which provides for the transportation of liquid cargoes. This is due to the absence of internal partitions in the tractor tank, which, as a consequence, causes additional oscillatory movement of fluid in the container, which ultimately affects the movement of the tractor. The stimulating character, which arises during redistribution of the liquid mass in the tank can make for the deterioration of the driver's health, the additional energy consumption and, in some cases, to the accidents (for example, during performing maneuver, etc.). Therefore, the study of the running smoothness of a wheeled tractor while carrying out transport work with a semitrailer tank is relevant.

2. Materials and Methods

The study of oscillatory motion of the system "environment – tractor with the unit – driver", which covers the change of technical, economic and ergonomic (comfort ability) characteristics, was published in the works [1–6]. But the effect of oscillations in the fluid movement of the tractor with the tank is not investigated in these works. So the effect of variable mass on the running smoothness of the vehicle as a whole is not investigated. A number of scientific papers [7, 8] are devoted to the study of free and forced liquid oscillations in a tank with a free surface. The problem of influence on the object of fluid oscillation by modeling process of mass flow in a tank (in particular, in fuel tanks) of launch vehicles is solved there. But it is not entirely correct to use these methods in the field of transport machine building. Therefore, papers [9, 10] were chosen as the basic. Simulation of fluid oscillations due to the introduction of partial oscillators, which have their size and weight, is performed in these works by mathematical modeling of Rayleigh surface waves.

Based on the above mentioned, it is possible to define the purpose of this paper, which consists in the study of the impact on the characteristics of running smoothness of the wheeled tractor while transportation work of solid and liquid cargo.

3. Results

The imitation concept of fluid oscillations in the horizontal container (tractor tank) is in determination of the redistribution of the liquid weight. This simulation is become possible by the introduction of partial oscillators which will be compliant with the individual basic form of low-frequency liquid oscillations relative to the tank shell. Consequently, according to the methods described in the works [9, 10], its eigenfrequencies, the coefficient of stiffness c_k^p and coefficients of damping f_k^p of the oscillations of the k partial oscillator are determined.

$$c_k^p = m_k^p \cdot \left(g + \frac{\mathrm{d}^2 y_{str}}{\mathrm{d}t^2} \right) \times \times \left(\pi \cdot \frac{k-0{,}5}{L} \right) \times \times th\left(h \cdot \left(\pi \cdot \frac{k-0{,}5}{L} \right) \right); \qquad (1)$$

$$f_k^p = \frac{2d_p \cdot m_k^p}{2\pi} \sqrt{\left(g + \frac{\mathrm{d}^2 y_{str}}{\mathrm{d}t^2} \right) \cdot \left(\pi \cdot \frac{k-0{,}5}{L} \right) \cdot th\left(h \cdot \left(\pi \cdot \frac{k-0{,}5}{L} \right) \right)}, \qquad (2)$$

where g – free fall acceleration; y_{str} – vertical movement of the semitrailer tank frame; k – partial oscillator number; L – distance from the center to the edge of the tank; d_p – logarithmic decrement of the damping; m_k^p – mass of the k partial oscillator.

The next step is the discretization of the calculation model (the total strength $P_{\text{B}\Sigma}$ and the force moment $M_{\text{B}\Sigma}$, which effect on the frame, are calculated).

$$m_k^p \cdot \frac{\mathrm{d}^2 x_k^p}{\mathrm{d}t^2} + f_k^p \cdot \left(\frac{\mathrm{d}x_k^p}{\mathrm{d}t} - \frac{\mathrm{d}x_{str}}{\mathrm{d}t} \right) + +c_k^p \cdot \left(x_k^p - x_{str} \right) = m_k^p \cdot \left(g + \frac{\mathrm{d}^2 y_{str}}{\mathrm{d}t^2} \right) \cdot \varphi_{str}; \qquad (3)$$

$$P_{\text{B}\Sigma} = \sum_{k=1}^{n} \left[\begin{array}{l} f_k^p \cdot \left(\frac{\mathrm{d}x_{str}}{\mathrm{d}t} - \frac{\mathrm{d}x_k^p}{\mathrm{d}t} \right) + c_k^p \cdot \left(x_{str} - x_k^p \right) + \\ + m_k^p \cdot \left(g + \frac{\mathrm{d}^2 y_{str}}{Yt^2} \right) \cdot \varphi_{str} \end{array} \right]; \qquad (4)$$

$$M_{B\Sigma}=\sum_{k=1}^{n}\begin{bmatrix} f_k^p\cdot\left(\dfrac{dx_{str}}{dt}-\dfrac{dx_k^p}{dt}\right)+c_k^p\cdot\left(x_{str}-x_k^p\right)+ \\ +m_k^p\cdot\left(g+\dfrac{d^2y_{str}}{dt^2}\right)\cdot\varphi_{str}\end{bmatrix}\cdot h_k^p, \qquad (5)$$

where x_{str}, y_{str}, φ_{str} – horizontal, vertical, angular movement of the tank frame; h_k^p – the distance between mass centers of k partial oscillators.

The obtained dependencies (1)–(5) are inserted into the total mathematical model. The calculation scheme is presented in **Fig. 1.**

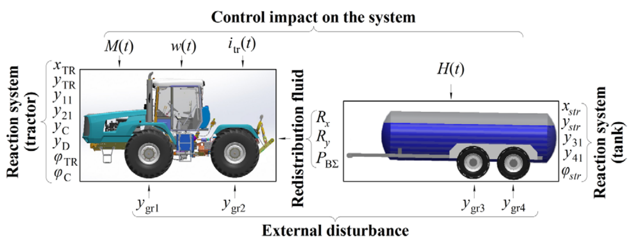

Fig. 1. Calculation scheme of the model in the longitudinal plane: y_{11}, y_{21}, y_C, y_D, y_{TR} – vertical movement of the tractor axles, cabins, driver's seat and tractor frame; y_{31}, y_{41}, y_{str} – vertical movement of axles frames of the tank; φ_{TR}, φ_C, φ_{str} – tilt angle of tractor frame, cab and tank; x_{TR}, x_{str} – longitudinal movement of the tractor and tank; $M(t)$ – torque of the engine; i_{tr} – transmission gear ratio; y_{gri} – function that describes the roughness change; $P_{B\Sigma}$ – nonlinear characteristic of force generated by fluid oscillations in the tank; R_x, R_y – longitudinal and vertical part of the force applied to the funnel from the tractor hook; $H(t)$ – liquid level in the tank

The investigation of the running smoothness of a vehicle is based on the construction of amplitude-frequency characteristics of the vertical accelerations of the seat and vehicle frame, respectively, from the frequency of external perturbation. The function describing the road microprofile changes has to obey a sinusoidal law for a more illustrative comparison

$$y_{grj}=A_\lambda\cdot\sin\left(\frac{2\pi}{ar}\cdot(x_T-\Delta L_j)\right), \qquad (6)$$

where A_λ – amplitude of the soil microoscillations; ar – inequality wavelength; ΔL_j – phase shifts, which are determined by the distance between axles.

4. Discussion and conclusions

Let's consider the straightforward movement of the vehicle on asphalt-concrete surface. There are graphs of the amplitude-frequency characteristics of the driver's seat and frame accelerations in **Fig. 2.**

The following phenomena are traced in frequency ranges (from 0.5 to 3 Hz):

– from 1 to 1.5 Hz – the resonance zone of the tractor front axle;

– from 1.5 to 1.7 Hz– clear observed the resonance zone of the unit influence on the vertical tractor accelerations;

– from 1.7 to 2.5 Hz – the resonance zone of the tractor frame accelerations.

Estimating the dependence of vertical accelerations from frequency of the external perturbation, it is determined that with in the low frequencies when comparing liquid to hard cargoes the vertical accelerations of the tractor frame (**Fig. 2**) increases. In resonance zones are observed: the front tractor axle by 9.8 %; influence of semitrailer unit by 23.1 %; tractor frames by 15.9 %.

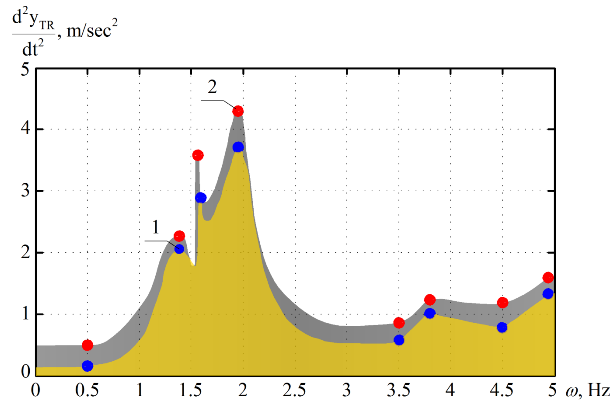

Fig. 2. Amplitude-frequency characteristics of vertical accelerations tractor frame: 1 – liquid cargo; 2 – solid cargo

The following variations of the impact of resonant zones are observed during an exploration of the seat accelerations change (**Fig. 3**) in the low frequency range:

– the front tractor axle by 8.5 %;

– influence of semitrailer unit by 15.4 %;

– tractor frame by 7.8 %.

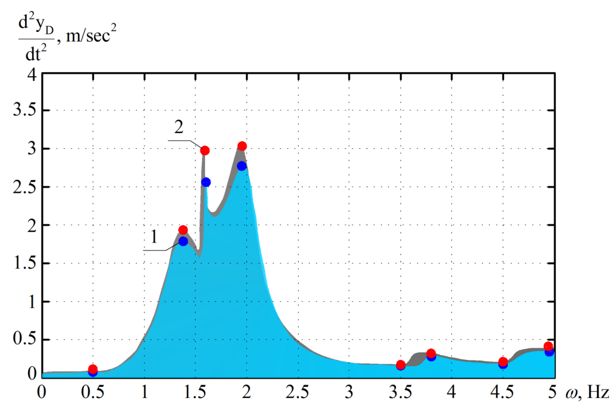

Fig. 3. Amplitude-frequency characteristics of vertical accelerations driver's seat: 1 – liquid cargo; 2 – solid cargo

At the average frequencies (from 3 to 16 Hz) the change of tractor frame accelerations (**Fig. 2**) varies between 20 % and 50 %, and for the vertical accelerations of the driver's seat (**Fig. 3**) it is from 7 % to 20 %.

The established theoretical dependencies predetermine to further researches of the movement dynamics of a wheeled tractor with the unit of variable mass (tractor tank) in the performance of transportation work. The problems of providing functional stability of tractors movement with redistribution center mass in trailer (or semitrailer) devices can be solved in this way.

Choose of rational parameters of the running system, i. e. optimization of the characteristics of unsprung and sprung tractor masses and the coupling unit can become one of the possible recommendations for stabilization of such complex movement. The analysis of the vibration protection wheeled tractor is the prospect of further research. Because those prerequisites, which describe the process of running smoothness research, indicates the increase of vertical accelerations. This will provide a more qualitative assessment of the impact on the driver's health during vibration study. In addition, it is impossible to ignore the influence of vibration in the context of reliability of units and assemblies, because it is relevant as well.

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Received date 12.09.2019
Accepted date 07.10.2019
Published date 23.11.2019