Methods for road microprofile statistical data transformation

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Abstract. In the paper presents methods for road microprofile statistical data transformation. These methods can be used to solve suspension theory problems related to rapidity functions determination using velocity characteristics and transport vehicle movement imitational modeling via microprofile random function trajectory.

Analysis of the transport vehicle (TV) comfort problems arising at the design stage leads to the conclusion that the research into the TV body vibrations should be based on the mathematical simulation modeling [1, 2].

This approach implies description of the external inputs on the vehicle in the form of the functional dependencies of the road disturbance parameters along the roadway. Therefore, in order to describe inputs from the roadway, methods for modeling random functions trajectories based on available statistic data are needed. This paper is dedicated to roadway microprofile modeling.

Any bearing surface real profile can be represented as a dependence (z=z(x)), where z and x are respectively the vertical and the horizontal co-ordinates of the fixed Cartesian co-ordinate system associated with the bearing surface.

Different terrains, that vehicle crosses along the way, and driving directions are random. Therefore, it is necessary to consider the roadway profile function as a random function trajectory [3].

Terrain microprofile can be determined in various ways: it can be directly measured via a roulette or a ruler; determined by the wheel position pattern obtained for a vehicle driven on the measured terrain; scanned using Doppler sensors and laser rangefinders.

There are two ways of using probability characteristics of a roadway microprofile. According to one of them, the microprofile is represented as a continuous vertical coordinates changing random process which has known variances distribution spectral density and correlation function (CF) (fig. 1). It is considered that this random process is Gaussian, static, ergodic and centric [4]. The other one is representing tracks statistics as an irregularities lengths and heights distribution function (ILDF and IHDF) (fig. 2). The first one is more convenient to substitute in a mathematical model. But the bottom value of TV mean speed can be determined by using the ILDF and IHDF. Therefore, these two methods correlation is analyzed in this paper.

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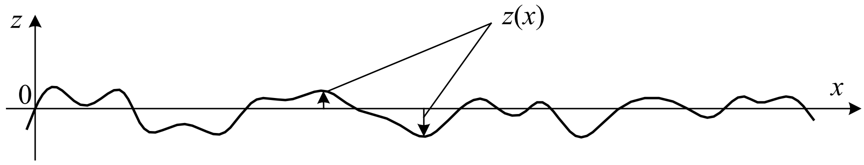

Fig. 1. Representation of microprofile as a continuous vertical coordinates changing random process

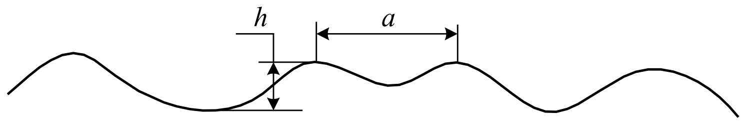

Fig. 2. Representation of microprofile as an irregularities lengths and heights distribution function

Thus, it is necessary to develop the applied methods of transforming roadway microprofile statistic data to solve suspension theory problems related to rapidity function determination via speed characteristics and imitational modeling of TV movement using microprofile random function trajectory.

To solve the suspension theory problems microprofile random function should be considered as a static, centric one with Gaussian irregularities vertical co-ordinates (z) distribution. The distribution density [4]:

$$\varphi_x(z)=\frac{1}{\sqrt{2\pi D_z}}\cdot e^{-\frac{z^2}{2D_z}}, \quad (1)$$

where D_z is random values (z) variance.

Simultaneously, TV tracks profile irregularities heights distribution density (IHDD) can be presented as a Rayleigh distribution [4]:

$$\varphi_x(h)=\frac{h}{D_h}\cdot e^{-\frac{h^2}{2D_h}},\ h\geq 0, \quad (2)$$

where D_h is random values (h) variance.

$$D_h=\frac{4D_z}{k^2}, \quad (3)$$

where k is a quotient resembling the ratio between extrema amount expected value and random function zeros amount expected value per roadway unit.

Knowing the random function (z(x)) trajectory, the total amount of zeros (n_0) and extrema (n_e) can be calculated. Thus, the zeros amount mean value and extrema amount mean value are [4]:

$$\overline{n_0} \approx \frac{n_0}{S_0};\ \overline{n_e} \approx \frac{n_e}{S_0}, \quad (4)$$

where S_0 is function (z(x)) trajectory length.

Then using the following equation it is possible to calculate k:

$$k=\frac{n_e}{n_0} \approx \frac{\overline{n_e}}{\overline{n_0}}. \quad (5)$$

Therefore, using the ergodicity property, variance (D_h) can be determined via random function extensional trajectory and as a result obtain IHDF is obtained:

$$\Phi_x(h)=1-e^{-\frac{h^2}{2D_h}}. \qquad (6)$$

This equation can be used for random functions which are similar to harmonic functions ($k\approx1$) [4]. In this case, using the known IHDF, it is possible to calculate (D_z) and then irregularities vertical co-ordinates CF can be determined.

Dependence between ILDF ($\Phi_x(A)$) and irregularities vertical co-ordinates CF ($R_z(x)$) for random function ($z(x)$) trajectory is represented as [5]:

$$r_z(\chi)=\int_{-\infty}^{\infty}\varphi_x(\omega)\cdot e^{i\omega\chi}d\omega, \qquad (7)$$

$$\varphi_x(\omega)=\frac{1}{2\pi}\int_{-\infty}^{\infty}r_z(\chi)\cdot e^{-i\omega\chi}d\chi, \qquad (8)$$

where $r_z(\chi)$ is normed CF ($r_z(\chi)=\frac{R_z(\chi)}{D_z}$),

$\varphi_x(\omega)$ is spatial frequency (ω) distribution density (SFDD).

$$\varphi_x(\omega)=\frac{d\Phi_x(\omega)}{d\omega}. \qquad (9)$$

Also dependence between spectral density ($S_z(\omega)$) and SFDD can be determined using the equation [5]:

$$2\pi\varphi_x(\omega)=\frac{S_{z(\omega)}}{D_z}. \qquad (10)$$

If $\omega=\frac{2\pi}{A}$, sought-for ILDD ($\varphi_x(A)$) can be calculated. Using it ILDF ($\Phi_x(A)$) can be determined as well.

As a result, roadway microprofile statistic data transformation methods algorithms are the following:

<u>Method №1:</u>

1) Determine variance and CF using the microprofile trajectory defined in z and x coordinates and known approximate dependencies [2]:

$$D_z\approx\frac{1}{S_0}\cdot\int_0^{S_0}\dot z(x)^2dx$$

$$R_z(\chi)\approx\frac{1}{S_0-\chi}\int_0^{S_0-\chi}\dot z(x)\dot z(x-\chi)dx,$$

where $\dot z(x)$ is a centered value and S_0 is a function ($z(x)$) trajectory length.

2) Determine SFDD ($\varphi_x(\omega)$) using (8).

3) Determine spectral density ($S_z(\omega)$) using (10). It can be used later for microprofile random function trajectory determination via noncanonical representations method [6, 7].

4) Determine variance distribution density ($\varphi_x(z)$) using (1). Using integral of $\varphi_x(z)$ distribution function $\Phi_x(z)$ is determined, which is used later to determine microprofile random function trajectory via canonical representations method [5, 8].

<u>Method №2:</u>

1) Determine variance (D_z) and CF ($R_z(\chi)$) using the microprofile trajectory defined in z and x co-ordinates.

2) Determine irregularities heights variance (D_h) using (3) where k is calculated via equations (4) and (5).

3) Determine IHDF ($\Phi_x(h)$) using (6).

4) Determine ILDD ($\varphi_x(A)$) using $\varphi_x(\omega)$ (where $\omega=\frac{2\pi}{A}$). Using integral of $\varphi_x(A)$ ILDF ($\Phi_x(A)$) can be determined.

Method №3:

1) Determine irregularities heights variance using the known IHDF ($\Phi_x(h)$).

2) Determine variance (D_z) using (3) while assuming that $k\approx1$ for random functions which are similar to harmonic functions.

3) Determine variance distribution density ($\varphi_x(z)$) using (1). Determine distribution function ($\Phi_x(z)$) using integral of $\varphi_x(z)$.

4) Determine spatial frequency distribution function ($\Phi_x(\omega)$) using the known ILDF ($\Phi_x(A)$), assuming that $\omega=\frac{2\pi}{A}$. Then determine SFDD ($\varphi_x(\omega)$) using (9).

5) Determine spectral density ($S_z(\omega)$) using (10) and known (D_z) and ($\varphi_x(\omega)$).

6) Determine CF ($R_z(\chi)$) using (7) and known (D_z) and ($\varphi_x(\omega)$).

Method №4:

1) Determine variance (D_z) using the known z co-ordinate distribution function ($\Phi_x(z)$).

2) Determine irregularities heights variance (D_h) using (3) and assuming that $k\approx1$ for randon functions similar to harmonic functions.

3) Determine IHDF ($\Phi_x(h)$) using (6).

4) Determine SFDD ($\varphi_x(\omega)$) using (8), D_z and $R_z(\chi)$.

5) Determine irregularities lengths distribution density ($\varphi_x(A)$) using $\varphi_x(\omega)$ and assuming that $\omega=\frac{2\pi}{A}$. Using integral of $\varphi_x(A)$ ILDF ($\Phi_x(A)$) can be determined.

Conclusions

These roadway microprofile statistic data transformation methods can be used to solve suspension theory problems related to rapidity functions determination using velocity characteristics and TV movement imitational modeling via microprofile random function trajectory.

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