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Investigation of geometric characteristics of the micro landform of the cutting area as a source of perturbing oscillations of logging machines

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Abstract. The article presents the results of experimental studies of the micro landform of the cutting area surface as a source of perturbing continuous oscillations of the sprung and unsprung masses of the logging machine. The substantiation of the expediency of studying the microprofile of forest support surfaces in the framework of this work is presented. The characteristic of the objects of the experimental study of the micro landform is given. A new measuring complex and the procedure for measuring geometric parameters of irregularities and slopes of the forest support surface of vehicles were proposed. The justification of the number of measurements in the planning of the experiment is given. As a result of data processing after approximation, normalized correlation functions and their approximation coefficients for the studied types of forest growing conditions were obtained. The obtained curves of normalized correlation functions have a decreasing character, which indicates the presence of a strong correlation on a small section of the length and differ in the steepness of the decline and the distance of the correlation, which varies from 1.8 to 11.6 m for different sections. The obtained approximation coefficients quantitatively characterize the perturbing effect of the irregularities of the natural surfaces of cutting areas of various types of forest growing conditions on the movement of logging machines.

1 The state of the issue in the field of research of the micro landform of the cutting area surface

During transportation and other logging operations, the movement of wheeled forest vehicles along the cutting area proceeds under the influence of numerous and diverse factors, among which the irregularities of the supporting surface can be distinguished. This is especially important during removing a tree from under the canopy of the forest in an upright position by the movement of a vehicle.

The irregularity of the support surfaces of forest machines is the main source of continuous oscillations of sprung and unsprung masses, whose amplitudes and accelerations sometimes reach significant values. During designing and conducting finishing tests of

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springing systems of wheeled forest machines, it is necessary to have stable characteristics of forest support surfaces or their known changes.

The geometric parameters of the irregularities and slopes of the supporting surface of vehicles are depicted in the form of a longitudinal profile of the road. The profile of the road, and, consequently, of the path, is considered to be the cut of the landform in the direction of movement of the transport system. Each cut of the surface of a particular plot is an implementation of a profile, and the totality of such implementations is a random function or a random process [1].

Researchers of vehicle dynamics divide the road profile into macro profile, micro profile and roughness, which is caused by their various effects on the vehicle. The macro profile includes smoothly changing irregularities with a length of 100 m or more, which do not cause oscillations in the sprung mass, but have an impact on the operating modes of the engine and the dynamics of the machine. The micro profile consists of irregularities from 10 cm to 100 m long that excite oscillations of the sprung mass. Irregularities less than 10 cm are considered roughness, which are smoothed by tires and do not have a noticeable effect on the oscillations of the sprung mass [1].

The influence of the geometry of the macro profile on the oscillation of the machine should be taken into account only in the case of high speeds of movement, which are not found in the practice of operating forest machines. Therefore, in the future it is expediently to consider only the microprofile of forest support surfaces.

Two methods are used to obtain information about the microprofile. A direct method of measuring the ordinates of surface irregularities with subsequent mathematical processing to obtain statistical characteristics of the microprofile - correlation function and spectral density. The indirect method is reduced to measuring and recording the oscillations of a dynamic system when moving over irregularities and transforming these oscillations into microprofile indicators [1, 2].

The analysis of the works [3-5] showed that when obtaining statistical characteristics by the indirect method, the dispersion of the country road micro-dimensions is 15 times greater than with the direct method. With the direct method of measuring surface roughness, various technical solutions are used from leveling to complex systems using probes, pendulums, etc. Simplified methods and tools have low productivity, and complex ones are not suitable for use in forest cutting conditions. Therefore, it is necessary to search for new technical solutions and measuring instruments in order to obtain statistical characteristics of the microprofile of the routes of probable forest skidding and the support surface of forest cutting areas.

A number of sources of perturbation and types of perturbing forces and their characteristics have been studied by many authors [1 - 3, 6 - 10]. However, despite the large number of information about the irregularities of forest skidding routes, there is practically no information about the geometric characteristics of the micro landform of the cutting area itself.

In this regard, the experimental study of the geometric characteristics of the micro landform of the forest cutting area in various types of forest growing conditions is an important task.

2 Experimental studies of geometric characteristics of the micro landform of the forest cutting area

2.1. Characteristics of research objects

Experimental studies of the micro landform were carried out on the territories of the Educational and Experimental, Suburban and Zvenigov forestries of the Republic of Mari El, Russia.

To study the irregularities of the support surfaces, 15 plots with different types of forest growing conditions were selected, which are the most common on the territory of the Republic of Mari El.

The selection of plots was made by preliminary study of the plans of forest planta-tions of the studied forestries. According to the cartographic image of the territories of plantings with the indication of the quarterly and sighting network, the quarters and allotments with the closest location to each other and to the main roads were select-ed.

Test areas were laid on each selected plot, where the irregularities of the support surfaces were studied by direct measurement method using a special measuring com-plex. The irregularities of the micro landform of the cutting area were studied only during the snowless period.

The objective of the experimental studies was to determine the empirical depend-ence of the indicators of the micro landform of the cutting area on the type of forest growing conditions.

2.2. Description of the measuring complex and the procedure for conducting the experiment

The measuring complex for evaluating the micro landform of the cutting area surface (see Fig. 1) consists of: a steel cable – 1, a jack – 2 pulling device – 3 in the form of a winch, a laptop computer – 4 and a laser rangefinder – 5 with a special suspension device. The recording equipment of the measuring complex was a laser rangefinder with wireless data transmission with a measurement error of ± 1.5 mm per 30m.

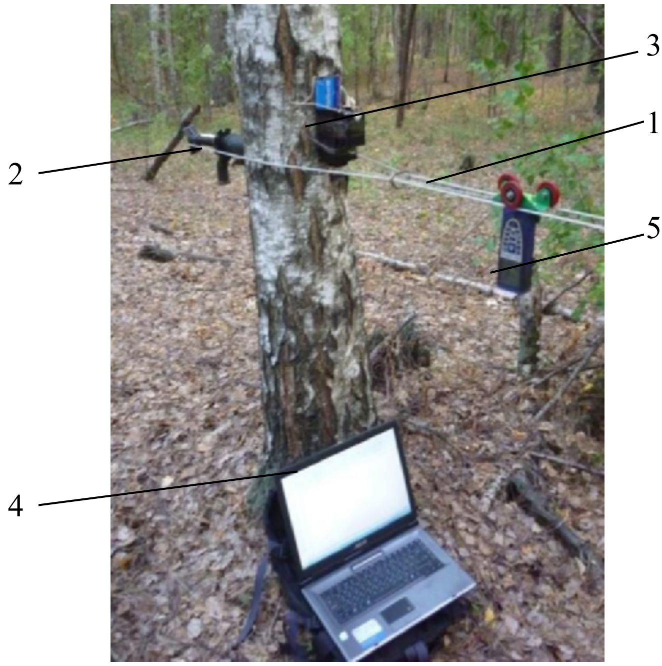

Fig. 1. Measuring complex for recording the micro landform of the cutting area surface

The suspension device is a carriage with a mount for a laser rangefinder, on which two levels are located to control the horizontality during measurement.

The measurements were carried out on test areas with different types of forest growing conditions, the total measurement length for some conditions was at least 1000 m, which is necessary to preserve the stability and reliability of statistical char-acteristics of the microprofile. With the help of a laser rangefinder, deviations of the micro landform of the natural surface of the forest cutting area in height from the conditional horizontal plane were measured and recorded. This method is called the intersection method in mathematical statistics, and in measurement theory - the method of random ordinates.

The order of the experiment is as follows. On the test area, two trees were selected, standing at a distance of 10-15 meters from each other, a double cable was stretched between them at a height of 1 meter (for convenient visual control) from the origin. The cable was pulled using a screw jack, the horizontal control was checked using a level (with error of 0.1 mm per 1 m). The deflection of the cable under the weight of the laser rangefinder did not exceed 3 mm by 10 m in length.

The carriage with a laser rangefinder was moved by a portable winch consisting of batteries, a constant-speed electric motor and a drum with a thread. After the carriage was withdrawn to the opposite tree, the winch was turned on and dragged the carriage along the cables at a constant speed of 0.1 m/s. Data from the laser rangefinder was transmitted via Bluetooth wireless communication directly to a laptop computer in the MS Excel program.

2.3. Experiment planning and number of measurements

It is expediently to determine the length of the studied plot using the methodology for determining the length of the measuring plot of the skidding route [11].

The method is based on the value of the coefficient of variation (degree of varia-bility) of the process (V), which is determined by the formula [12]:

$$V = \frac{\sigma}{M} \cdot 100, \tag{1}$$

where: σ is the mean square deviation; M is the mathematical expectation.

To determine the coefficient of variation, it is necessary to carry out preliminary measurements and find the distribution law of the process. In addition, the necessary probability and acceptable error are accepted. After obtaining the values of the coefficient of variation, reliability and permissible error, the "Nomogram of sufficiently large numbers" or "Table of sufficiently large numbers"[12]. The experience of research on skidding tractors [13], agricultural machines [14] and the technique of statistical calculations [12] allow us to assert that with values of the coefficient of variation of more than 10, the number of counts can be determined by the “Table of sufficiently large numbers“ [12].

Preliminary measurements of the micro landform of the cutting area showed that the values of the coefficients of variation are significantly greater than 10.

With reliability of 0.95, acceptable error value of 0.03 and coefficient of variation of more than 10 according to the "Table of sufficiently large numbers", the number of counts should be 1067, and with reliability of 0.90 and acceptable error of 0.03, the number of counts can be 751.

In view of the fact that an automated measuring unit with a quantization step of 2 cm is used in the study, the reliability of the results can be maximized, and the value of the permissible error is minimal.

In addition to the height, the oscillatory system of the forest machine will be affected by the length of the irregularity, which in the conditions of the forest cutting area can reach 100 m. Therefore, to analyze its value, the length of the measured plot of the surface under study must be entered using an additional quantization step of 0.5 – 1.0 m.

Knowing the number of samples and the quantization step, it is possible to determine the length of the measuring plot of the surface under study. Therefore, the length of the measuring plot of the cutting area at the maximum quantization step of 0.5 – 1 m should be from 534 to 1067 m.

2.4. Research results and their analysis

As a result of experimental measurements of the irregularities of forest support surfaces, more than 40 thousand values were obtained for one type of forest growing conditions.

The result processing of micro irregularities measurements of the cutting area measuring plot (Table 1) was carried out on a computer by the "intersection method", as a result, graphs of normalized correlation functions of micro irregularities were obtained. Due to the fact that the correlation functions of a random process are non-random functions, they are usually approximated by a known functional dependence [15, 16].

Table 1. A fragment of the initial data for mathematical modeling of the micro landform of the cutting area surface (Non-stationary process).

	1	2	3	4	5
SV, PP on [0;1], F	0.502971137	0.049811549	0.095987922	0.118260131	0.726343082
Average value, Tsr	0				

Standard deviation,	1				
Random variable, T(F)	0.007447605	-1.646683596	-1.304756298	-1.183729237	0.601790145
Discrete white Gaussian noise	-0.988331197	-0.477803965	0.464154124	0.652001503	-1.028824235
The first value	-4.077212	35	15	12	0.35
Time, t	0.01	0.05	0.09	0.13	0.17
Mathematical expectation of the process, Xsr	35.1499975	35.74968754	36.34817824	36.94451214	37.53773524
Process variance, D	12.04207359	12.21184827	12.38401651	12.55861206	12.73566913
Normalized correlation coefficient, k2	0.98				
Coefficient k1	0.690554932	0.695405775	0.700290692	0.705209924	0.710163712
Implementation of a random process, Xn	-3.847296936	-3.572204533	-3.137866819	-3.723109327	-3.774973919
Implementation of a random process, X	31.30270056	32.17748301	33.21031142	33.22140281	33.76276132

As a result of processing after approximation, normalized correlation functions were obtained (see Fig. 2-4) for the studied types of forest growing conditions (FGC).

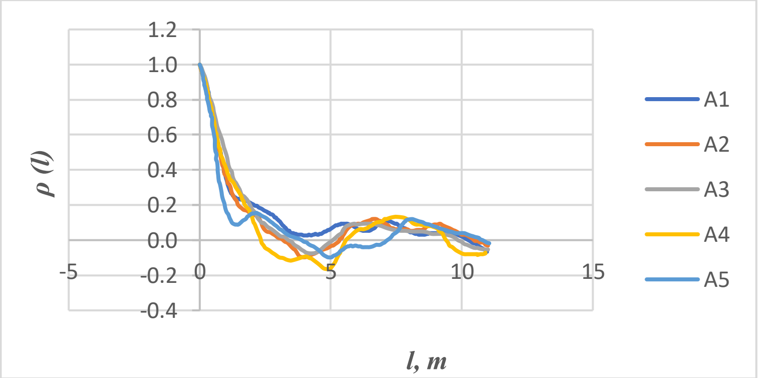

Fig. 2. Normalized correlation function of the micro landform of the cutting area for (FGC) A1-A5

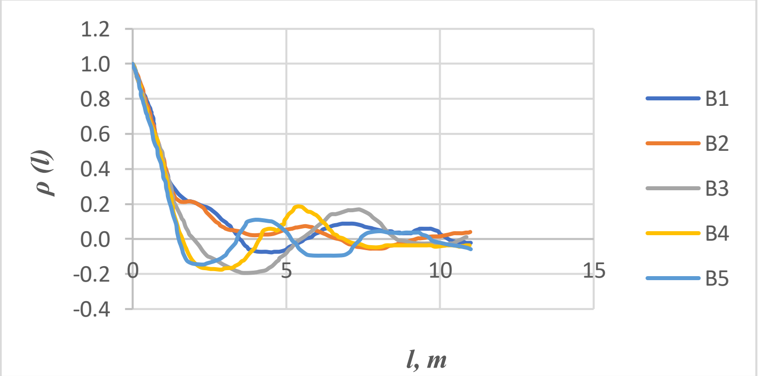

Fig. 3. Normalized correlation function of the micro landform of the cutting area for (FGC): B1-B5

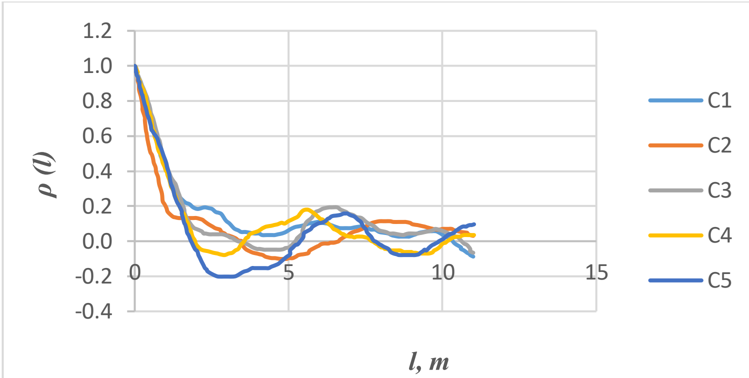

Fig. 4. Normalized correlation function of the micro landform of the cutting area for (FGC): and C1-C5

Table 2 shows the approximation coefficients values of normalized correlation functions, where: α – characterizes the rate of decrease of the function, β – characterizes the average frequency of periodic components of a random process.

Table 2. Approximation coefficients values of normalized correlation functions.

Coefficient	Type of forest growing conditions														
	A_1	A_2	A_3	A_4	A_5	B_1	B_2	B_3	B_4	B_5	C_1	C_2	C_3	C_4	C_5
α	0.71	0.77	0.69	0.56	0.79	0.64	0.37	0.65	0.72	0.80	0.65	0.71	0.55	0.56	0.68
β	1.3	1.5	1.8	1.03	1.25	1.19	1.75	1.6	1.4	1.15	1.55	1.35	1.1	1.05	1.4

The curves of the normalized correlation functions of the micro irregularities impact have a decreasing character, which indicates the presence of a strong correlation in a small area of length, with an increase in which the functions intersect the abscissa axis, and the correlation relationships are equal to - 0. However, with a further increase in length, they cross the abscissa axis again, gradually fading. This important property of the correlation function indicates the periodicity in the studied irregularity structure and that the random process is ergodic, that is, a specific implementation represents the entire general set.

The curves of the normalized correlation functions differ in the steepness of the decline and the distance of the correlation, which varies from 1.8 to 11.6 m for different plots.

The conducted experimental studies of the micro landform of the cutting area surface made it possible to obtain approximation coefficients of normalized correlation functions that quantitatively characterize the perturbing effect of the cutting areas natural surfaces irregularities of various types of forest growing conditions on the movement of forest logging equipment.

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