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Typology of means of technical control of physiological and ergonomic indicators of machines for forestry works

Abstract. Nowadays, during logging and timber transportation operations, most of the equipment that is used was put into mass production at the beginning of the millennium. Due to the lack of own funds at the enterprises of the forest complex in recent years, there is no renewal of machines for forestry works, and the worn-out equipment is re-introduced into the same devices as replaceable parts and other fragile elements. In the structure of the existing machinery fleet, 80% is occupied by fully amortised equipment that needs to be upgraded or written off, and the disposal rate is 10 times higher than the renewal rate. The existing repair policy was developed in pre-market conditions with appropriate ratios of prices for raw materials and machinery. At that time, the concept of technical control of machines for forestry operations, which is still in force today, was created: admissions, regulations, standards, etc. In the current economic conditions, new approaches to the development of a methodology for technical control and repair of machinery for forestry operations are needed. Technical support for the operation of machines for forestry operations can be considered as a tool for managing the stock of their potential capabilities laid down during manufacturing and restored during technical control and repair. Determining the time to carry out work to restore the technical condition of the machine depends on various factors, which often contradict each other. The goal is to perform analytical and experimental studies to confirm the existence of typological means of technical control of physiological and ergonomic indicators of machines for forestry operations by modelling the processes of their functioning. Methodology – to test the means of a systematic approach and a systematic analysis of the typology of technical control tools for physiological and ergonomic indicators of machines for forestry operations. The paper presents the generated result in the form of a recording algorithm of the module for technical control of machines for forestry operations. Based on the results of experimental studies, the authors present a graphical interpretation of Integral noise levels at the workplace of a forward driver in a loaded state, in an empty state. Conclusion – the conducted research allows suggesting the optimal placement of elements on the vehicle's instrument panel in terms of information perception and reading time. Scientific significance – it is confirmed that when analysing the impact of the frequency of performing technical control operations of forestry equipment on the listed indicators, it is advisable to use a pair correlation analysis, which consists in determining the relationship between the frequency of performing technical control operations and the amount of total unit costs, reliability indicators, and functional properties indicators

Keywords: ergonomics of timber road trains, typology of technical control tools, reliability indicator, forestry equipment, technical control and repair

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INTRODUCTION

The issue of improving the use of the suitability of machines for forestry operations is multifaceted [1]. This multiplicity is a direct consequence of the close connection of the advantages and disadvantages of machines as objects of managing their technical condition and reliability with the economic processes of using them for their intended purpose [2].

The content of the scientific foundations of the organisation, technology of technical control and repair

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of machines for forestry works is mainly aimed at studying the dynamics and identifying the causes of changes in their condition [3], assessing and predicting further changes in the technical condition of parts, components, and the machine as a whole to develop optimal methods [4] and ways to manage the technical condition of machines [5].

In accordance with this, the main research areas were formulated, dictated by the need to improve the organisation, technology of maintenance and repair of machines for forestry operations.

Adjustment of technical control modes of machines for forestry operations consists in clarifying the list of maintenance operations [6] and the frequency of their implementation to achieve modes that are optimal for these operating conditions of machines for forestry operations [7].

In this regard, when adjusting the modes, both specific costs for technical control and repair of machinery for forestry operations, and reliability indicators were considered [8]. Thus, the task under consideration is to determine the numerical values of the list of technical control operations and the frequency of their maintenance [9], which ensure not only the necessary reliability of the forestry equipment in operation [10], but also the minimum costs for maintenance and repair of the forestry equipment [11], which fall on a unit of mileage or transport work [12].

MATERIALS AND METHODS

For each group and homogeneous elements, the task of adjusting the frequency of technical control of the forestry equipment to find l_{oi} – the optimal frequency of technical control operations of one group of elements [13] is formulated in the form of an objective function as follows:

$$C_{un_i}=f(l_{oi})\rightarrow min,$$

provided that:

$$P_{i_1}=\varphi_1(l_{oi})=\overline{P_{i_1}}, Z_{i_1}=\psi_1(l_{oi})=\overline{Z_{i_1}},$$
$$P_{i_m}=\varphi_m(l_{oi})=\overline{P_{i_m}}, Z_{i_k}=\psi_k(l_{oi})=\overline{Z_{i_k}}, \quad (1)$$

where: l_{oi} – optimal frequency of technical control operations of one group of forestry equipment elements, years [14]; C_{un_i} – total specific reduced costs for technical control of a homogeneous group of forestry equipment elements, UAH/1,000 km [15]; $P_{i_1},\ldots,P_{i_m}$ – indicators of reliability of forestry equipment elements, to be taken into account when determining the frequency [16]; $\overline{P_{i_1}},\ldots,\overline{P_{i_m}}$ – standard values of reliability indicators of forestry equipment elements to be taken into account [17]; $Z_{i_1},\ldots,Z_{i_k}$ – indicators of functional properties of forestry equipment elements forestry equipment, which must be taken into account when determining the frequency [18]; $\overline{Z_{i_1}},\ldots,\overline{Z_{i_k}}$ – normative values of indicators of functional properties of forestry equipment elements [19]; $\varphi_1(l_{oi}),\ldots,\varphi_m(l_{oi})$ – dependence of reliability indicators of forestry equipment elements on the frequency of technical control [20]; $\psi_1(l_{oi}),\ldots,\psi_m(l_{oi})$ – dependence of indicators of functional properties of forestry equipment on the frequency of technical control [21].

A second-degree polynomial was used to approximate these dependencies (1) [14]. Therefore, the considered dependency models have a form:

$$P_i=a_o+a_1l+a_2l^2, |Z_i=b_o+b_1l+b_2l^2. \quad (2)$$

where: a_o, a_1, a_2, b_o, b_1, b_2 – coefficients of the polynomial.

Then the objective function:

$$C_{un}=C_o+C_1l+C_2l^2\rightarrow min, P_l=a_{01}+a_{11}l+a_{21}l^2=\overline{P_l}; \quad (3)$$
$$P_2=a_{0m}+a_{lm}l+a_2ml^2=\overline{P_m};$$
$$Z_1=b_{01}+b_{11}l+b_{21}l^2=\overline{Z_1};$$
$$Z_K=b_{0K}+b_{1K}l+b_{2K}l^2=\overline{Z_K}. \quad (4)$$

To obtain sufficiently objective data when adjusting the technical control modes, the number of controlled vehicles for forestry operations was 15...20, and the duration of follow-up was 3...6 months [22].

When analysing the influence of the frequency of performing technical control operations of forestry equipment on the listed indicators, a pair correlation analysis was used, which consists in determining the relationship between the frequency of performing technical control operations (X) of the amount of total unit costs, reliability indicators, and indicators of functional properties (Y) [23].

The correlation ratio is used as an indicator of the tightness of the connection:

$$\rho=\sqrt{\frac{S_x^2(Y)}{S_n^2(Y)}}, \quad (5)$$

where:

$$S_x^2(Y)=\frac{1}{N-1}\Sigma_1^N(y_c-\overline{y})^2, \quad (6)$$

$$S_n^2(Y)=\frac{1}{N-1}\Sigma_1^N(y_j-\overline{y})^2, \quad (7)$$

where: $S_x^2(y)$ – variance of the regression line deviation from the overall average; $S_n^2(y)$ – total variance of the dependent variable specific costs, reliability indicator, functional indicator; N – scope of observation.

Variable costs are the cost of paying staff C_{rs}, for spare parts and materials C_{sp}:

$$C_{ver}=C_{rs}+C_{sp}+E_NK_o \quad (8)$$

Determining the cost of spare parts and materials:

$$C_{sp}=\Sigma_{j=1}^{k}P_i, \quad (9)$$

where: P_i – cost of j-th detail or materials, UAH; j – the number of materials and parts that are replaced at the considered mileage interval of forestry equipment.

Staff labour costs are determined by:

$$C_{rs}=C_{tar}\Sigma t, \quad (10)$$

where: C_{tar} – average staff rate, UAH.; $\sum t$ – total labour intensity of maintenance and repair of forestry equipment at the mileage interval, person-hour.

Determination of capital investments for technical control and repair of forestry equipment:

$$K=mN, \quad (11)$$

where: N – rate of capital investment per production worker, UAH; m – the number of workers required for technical control and repair of the controlled forestry equipment at the mileage interval.

Value m is calculated using the equation:

$$m=\frac{\sum t_i}{T_F}, \quad (12)$$

where: $\sum t_i$ – total labour intensity of technical control and repair in a given mileage interval, person-hour; T_F – time fund of repair workers for this period, h.

To get unit costs, the resulting value C_{ver} is divided by the mileage interval of forestry equipment [24].

After determining the values of functional indicators [25], reliability indicators, and unit costs for each controlled unit of forestry equipment, the information obtained can be provided in the form of a matrix:

$$\begin{vmatrix} x_1, P_{11}, P_{21}, \ldots, P_{m1}, & Z_{11}, Z_{21}, \ldots, Z_{k1} \\ \ldots \quad \ldots & \ldots \quad \ldots \\ x_n, P_{1n}, P_{2n}, \ldots, P_{mn}, & Z_{1n}, Z_{2n}, \ldots, Z_{kn} \end{vmatrix} \quad (13)$$

where: $x_1, x_2, \ldots, x_n$ – the value of periodicity in controlled forestry equipment, h; $P_{i1}, P_{i2}, \ldots, P_{in}$ – values of reliability indicators of controlled forestry equipment; $Z_{j1}, Z_{j2}, \ldots, Z_{jn}$ – the value of functional indicators of controlled forestry equipment.

The output data matrix (13) is used to find the regression coefficients of models included in the objective function (4). The task is to determine the regression coefficients of the equation:

$$y=b_o+b_1x+b_2x^2. \quad (14)$$

In this case, the task of b_i evaluation is to find a curved regression using the least squares method. Using Chebyshev system of orthogonal polynomials, equation (14) can be represented as follows:

$$y=c_0+c_1\varphi(x)+c_2\varphi_2(x). \quad (15)$$

For this equation, the formulas for calculating Chebyshev polynomials will have the form:

$$\varphi_1(x) = x - \frac{1}{N}\sum_{j=1}^{N} x_j,$$

$$\varphi_2(x) = x^2 - \frac{\sum x^3 - \frac{1}{N}\sum x^2 \sum x}{\sum x^2 - \frac{1}{N}(\sum x^2)}\left(x - \frac{1}{N}\sum x\right) - \frac{\sum x^2}{N} \quad (16)$$

The values of the coefficients included in equation (15) are determined by:

$$C_o = \frac{1}{N}\sum_{j=1}^{S} m_j \overline{y_j}, \quad (17)$$

$$C_o = \frac{\sum_{j=1}^{S} \varphi_1(\overline{x_j}) m_j \overline{y_j}}{\sum_{j=1}^{S} \varphi_1^2(\overline{x_j}) m_j}, \quad (18)$$

$$C_1 = \frac{\sum_{j=1}^{S} \varphi_2(\overline{x_j}) m_j \overline{y_j}}{\sum_{j=1}^{S} \varphi_2^2(\overline{x_j}) m_j}, \quad (19)$$

where: S – the number of intervals for changing the frequency of performing operations of technical control of forestry equipment; $\overline{xj}, \overline{yj}$ – average value of values x and y in j interval; m_j - the number of machines for forestry operations, in which the frequency is in the j interval.

Checking the adequacy of the constructed equation is performed using the F-criterion:

$$F = \frac{S_f^2(y)}{S_{res}^2(y)} > F_\alpha(f_m, f_{res}) \quad (20)$$

where: $S^2_{res}(y)$ – residual variance, which characterises the scattering of experimental points relative to the regression line; $S_f^2(y)$ – total variance, which characterises the scattering of points near the general average.

The adequacy hypothesis is accepted.

Value $S^2_{res}(y)$ (y) is final and $S_f^2(y)$ is determined by the equations:

$$S_{res}^2(y) = \frac{1}{N-k-1}\sum_{j=1}^{N}(y_i - y_c)^2, \quad (21)$$

$$S_f^2(y = S_p^2(y) + S_{res}^2(y) = \frac{1}{f_p}\sum_{j=1}^{N}(y_j - \overline{y}) + S_{res}^2(y) \quad (22)$$

where: k – the number of parameters of machines for forestry operations when y; f_p – number of degrees of freedom, f_p=k-1.

Value f_f and f_{res} are calculated using the formula f_f=N-1, f_{res}=N-k-1. If the equations are adequate, the constructed objective function is used to calculate the optimal frequency of technical control of forestry equipment [26-28]. If the adequacy condition is not met, then additional terms are introduced into the polynomials, after which regres-sion coefficients are calculated again and the adequacy of the refined model is determined. This process is repeated sequentially until models that satisfy the adequacy condition are obtained.

When adjusting the list of technical control operations for mechanisms that ensure traffic safety, the condition for including the operation in the corresponding type of technical control is determined at the value of the repeatability coefficient that satisfies the following ratios:

a) for TC-1 – $1\geqslant k_1\geqslant 0.26$;

b) for TC-2 – $0.26\geqslant k_2\geqslant 0.12$.

The operation remains under current repair if k<0.12.

For other mechanisms, the condition for including troubleshooting operations of forestry equipment during a particular period of technical control is determined from the ratio:

a) for TC-1 – $1\geqslant k_1\geqslant 0.30$;

b) for TC-2 – $0.30\geqslant k_2\geqslant 0.13$.

The operation remains in the current process of technical control of forestry equipment if k<0.13.

The purpose of the study is to perform analytical and experimental investigation to confirm the existence of typological means of technical control of physiological and ergonomic indicators of forestry equipment by modelling the processes of their functioning.

RESULTS AND DISCUSSION

The study presents a methodology for assessing the reliability of drivers of forestry equipment vehicles of the forwarder type.

To assess the driver's level of reliability, it is suggested to use the reliability criterion:

$$K=K_S \cdot K_Q \cdot K_E \cdot K_{EC} \cdot K_{BM}, \quad (23)$$

where: K_S – criterion of safety for performing forestry operations by machine; K_Q – criterion of productivity of timber transportation by car; K_E – criterion of cost-effectiveness of performing forestry operations by machine; K_{EC} – criterion of extreme conditions for performing forestry operations by machine; K_{BM} – criterion of knowledge of the basic mechanics by the driver of forestry equipment.

It is proposed to determine the safety criterion for performing forestry operations by a machine:

$$K_S = \frac{K_{DB} + K_{un.m\,X} + K_{un.m\,Y}}{3}, \quad (24)$$

where: K_{DB} – criteria for evaluating driver behaviour,

$$K_{DB} = \frac{3}{\left(1+\frac{H_{er(o.b)}}{S}\right)\frac{H_{er(o.b)}}{T^2_{er(o.b)} \cdot j_{adm(o.b)}} + \left(1+\frac{H_{er(M)}}{S}\right)} \cdot$$
$$\cdot \frac{3}{\frac{H_{er(M)}}{T^2_{er(M)} \cdot j_{adm(M)}} + \left(1+\frac{H_{er}}{S}\right)\frac{H_{er}}{T_{er} \cdot v_{razr}}},$$

where: $H_{er(o.b)}$ – number of errors during acceleration and braking; $H_{er(M)}$ – number of errors when performing transverse manoeuvres; $T_{er(o.b)}$ – time of movement of the forwarder with longitudinal acceleration, s; $j_{adm(o.b)}$ – permissible value of longitudinal accelerations, m/s²; $K_{un.mX}$, $K_{un.mY}$ – criteria for the degree of uniformity of movement along the longitudinal and transverse axes of forestry equipment.

Transportation productivity criterion:

$$K_Q = \frac{v_{av}}{v_{av_b}} \tag{25}$$

where: v_{av} – average movement speed by the test driver, km/h; v_{av_b} – the basic speed of forestry equipment, km/h.

Cost-effectiveness criterion:

$$K_E = \frac{\frac{L_{Qb}}{L_Q} + 1 - \frac{|N_{En} - N_{En_b}|}{N_{En_b}} + \frac{Q_F}{Q}}{3}, \tag{26}$$

where: E_{n_b} – standard value of the number of rotations of the engine crankshaft; Q_F – standard value of fuel consumption, cm³; Q – actual fuel consumption when traveling along the route, cm³.

Indicators that characterise the assessment of driver behaviour in extreme conditions K_{EC} and the driver's knowledge of basic mechanics K_{BM}, were determined using the simulator programme.

On-board recording equipment (Figure 1) was equipped with: fuel consumption sensor, motion sensor, transverse acceleration sensor, crankshaft speed sensor, driving speed sensor, longitudinal acceleration and deceleration sensor.

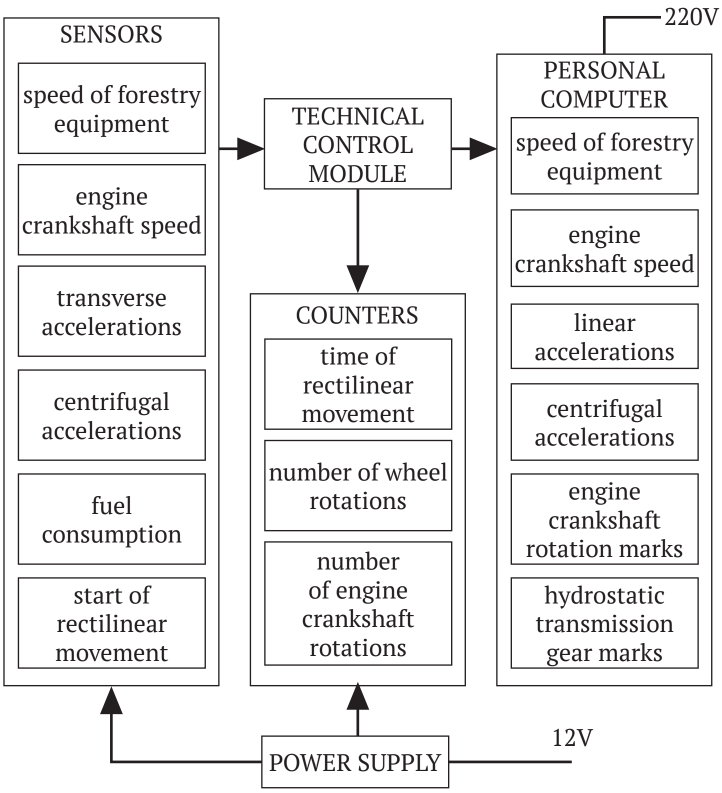

Figure 1. Correlation between gas (a) and electricity (b) consumption and external temperature

Test algorithm:

1. Checking the serviceability and technical condition of indicators and control and measuring devices of forestry equipment.

2. Determination of the test route with a length of one hour drive at a speed of 40...80 km/h.

3. Synchronisation of data acquisition, calibration of channels of measuring and recording equipment.

4. Determination of standard speed values v_{av_b}, fuel consumption on the route Q_b, the weighted average value of the gearbox gear ratio i'_{tr}.

5. Performing 39 runs by 20 test drivers along a given route on forestry equipment machines, equipped with a complex of the module of technical control of forestry equipment with measurement of the duration of movement of forestry equipment D_M, the number of rotations of the crankshaft N_{En_b}.

6. Processing of results and conclusion about the level of reliability of the driver of a timber road train.

Based on the criteria K_Q, K_E, K_S, K_{EC}, and K_{BM} an integral driver reliability criterion is defined K. Moreover, if the driver's reliability is high, then K_Q, K_E, K_S, K_{EC}, K_{BM}, $K_{ECc} \geq 1.0$. If the driver's skill is not sufficient, the values of the indicators K_Q, K_E, K_S, K_{EC}, K_{BM}, and $K_{EC} < 1.0$. The developed technique improves the handling of forestry equipment. The position of the model of the oscillating system of a forestry machine with two controlled axles and independent wheel suspension is determined by generalised coordinates: the angle of rotation of the wheels of the first axle around the pivot axis – Q_1, deg.; the angle of rotation of the wheels of the second axle around the pin axis – Q_2, deg.; the angle of rotation of the wheels (body) in the transverse vertical plane Ψ, deg.

Equation of motion by coordinates q_k=Q_1, Q_2, Ψ is compiled in the form of the second order Lagrange equations:

$$L(q_k, \dot{q}_k, t)\frac{d}{dt}\cdot\frac{\partial E_k}{\partial \dot{q}_k} - \frac{\partial E_k}{\partial q_k} + \frac{\partial E_p}{\partial q_k}, \quad (28)$$

where: E_k – kinetic energy of the system, J; E_p – potential energy of the system, J; R_k – generalised reactions of elastic wheel connections with the road.

After the transformations, the equation of motion of the two-bridge model is obtained. When solving the system of equations (27) on a PC, the physical parameters were represented by their electrical counterpart –voltage. Physical differential equations were transformed into machine equations. Where: Q_t – real-time variable; Q_τ – variable in machine time τ and M_t=5:

$$\theta_t = \theta_\tau;\ \frac{d\theta_t}{dt} = 5\frac{d\theta}{d\tau};\ \frac{d^2\theta_t}{dt^2} = 25\frac{d^2\theta_t}{d^2\tau}. \quad (29)$$

Value of scale coefficients: M_Θ=1,000 r/rad; M_φ=1,000 r/rad; M_Ψ=1,000 r/rad; M_λ=2,000 r/rad. Physical variables expressed in terms of machine and time scales:

$$X_t = \frac{1}{M_X}X_\tau;\ \frac{dX_t}{dt} = \frac{M_t}{M_X}\cdot\frac{dX_\tau}{d\tau};\ \frac{d^2X_t}{dt^2} = \frac{M_t^2}{M_x}\cdot\frac{d^2X_\tau}{d\tau^2}, \quad (30)$$

where: t – index of physical quantities; τ – index of machine variables.

Then a system of machine equations is obtained describing the motion of a two-bridge model with three basic degrees of freedom (Q_1, Q_2, Ψ). For testing, a machine for forestry operations was allocated, which has a factory setting of the parameters of steerable wheels. The technical condition of forestry equipment met the requirements of the factory instructions. Recording and measurement of oscillation parameters was carried out using a measuring complex, which was developed considering the specifics of the experiment and the conditions of its conduct.

Operational tests of the timber road train were carried out to determine reliability, operability, compliance with safety and ergonomics requirements in the general technological cycle in two shifts in LLC "European timber processing group" of Zhytomyr Oblast. Export of forest products was carried out on three types of haul roads: forest tracks, roadways, highways in the amount of 20 thous. km of mileage. The actual load ranged from ±10% of the rated load. Timekeeping observations were carried out during 15 control runs in each season (winter and off-road).

Studies to determine the effect of wheel convergence on self-oscillation have shown little effect. In general, there is a tendency to slightly decrease the intensity of self-oscillations with a change in convergence towards negative values. At small values of the angle γ, the effect of convergence is greater than at large positive values.

Self-oscillations for forestry equipment exist when γ<-1.9°, that is, the stability of movement of the steered wheels is ensured when setting the angle γ within the range of -1,5° to -9°. At angles γ less than -9° aperiodic instability occurs. Stability of the steered wheels is also possible at other values of angle γ – with large positive results. The movement will be stable even when γ>13°. The greatest intensity of fluctuations is observed at γ=3°...5° and v=45 km/h.

If there are no gaps in the power steering mounting hinges (δ=0) the movement of the steered wheels is stable when setting the angle of the longitudinal pin γ<-1.5°. Considering the operational gaps, the pins must be installed with a slope of γ=2°...3°. If there are gaps in the system of the order δ⩾6 mm, the movement of the steered wheels becomes unstable at any negative angle values γ. The intensity of vibrations is the lowest at γ=-4°, that is, the lowest required damping energy of reservations at γ=-4°.

When considering the working conditions of drivers, the study used a noise-vibration measuring equipment, a luxmeter, and a thermometer. The external noise spectra are shown in Figure 2.

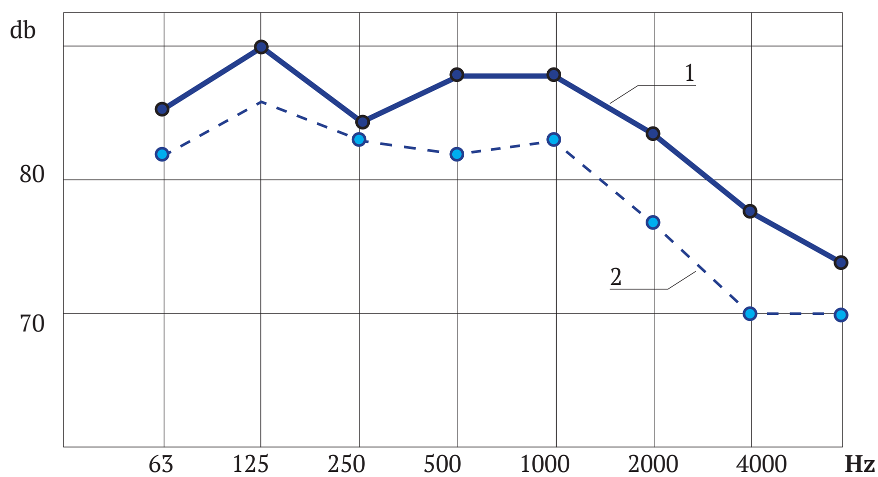

Figure 2. External noise spectra of the forwarder: 1 – on the left; 2 – on the right

The noise spectrum in the cabin is shown in Figure 3. The forwarder does not meet the ISO requirements for external noise, and it meets the ISO requirements for noise at the driver's workplace.

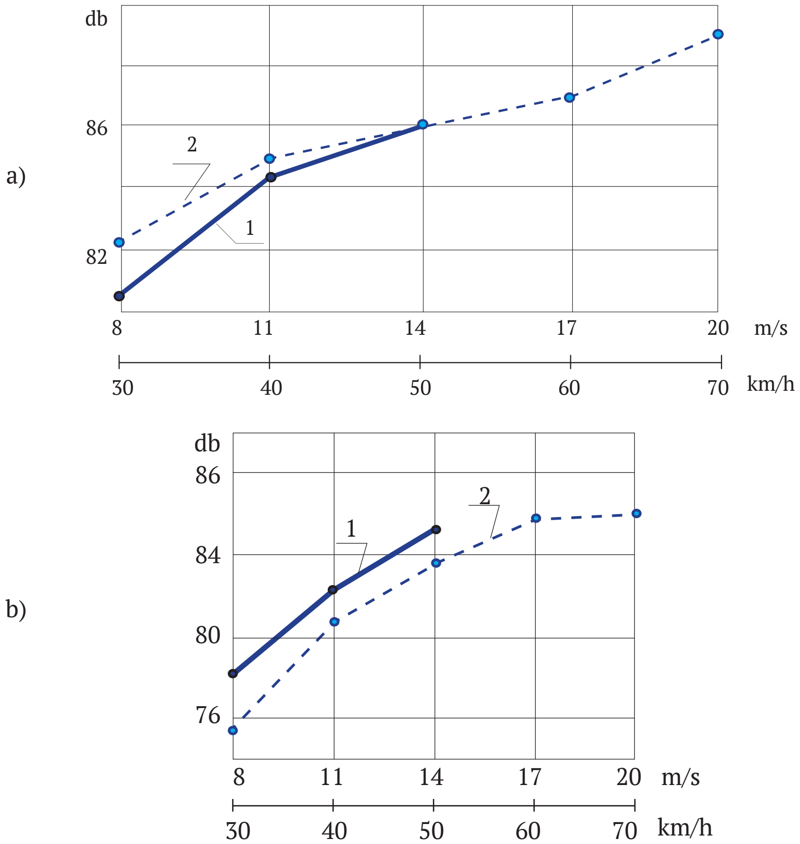

Figure 3. Integral noise levels at the forwarder driver's workplace: a) in the loaded state; b) in the empty state. 1, 2 – speed in 7-th gear

The average operating fuel consumption per shift was carried out by refilling the fuel tank during daily refuelling. The regular load of each road train was checked by control weighing using a dynamometer. Identification of the reliability and operability of the road train during operational tests was carried out by registering failures. At the same time, the average time to failure separately for the tractor and semi-trailer and the complexity of eliminating failures were determined. Tests were carried out to determine the speed characteristics (Fig. 4).

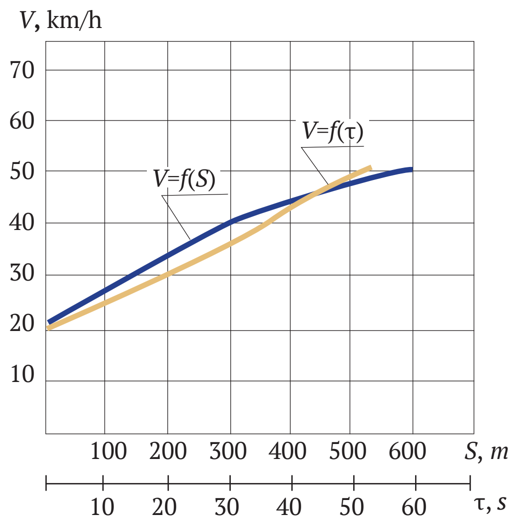

Figure 4. Speed characteristic of acceleration in direct transmission

To improve the ergonomics of timber road trains, a different layout of display elements on the instrument panel is offered. The best layout option was determined based on consideration of the load of the driver's visual analyser. There are 4 options for placing indicators, from which the best option was selected. When modelling the information display elements of the instrument panel of a timber road train, indicators of various car brands were used.

When processing the findings, an assessment scale of psychophysiological indicators of drivers was used. The conducted research offers the optimal placement of elements on the vehicle instrument panel from the standpoint of information perception and reading time: place the speed sensor in the centre of the driver's field of view; place the water temperature and oil pressure indicator to the left of the speedometer; place the fuel level sensor and ammeter vertically to the right of the speedometer; place the tachometer to the left of the temperature indicator; place the indicator system at the top of the field.

A set of measures has been developed to improve the organisation and technology of maintenance of machinery for forestry operations, which reduces downtime in routine repairs and improves the quality of maintenance. Savings from the implementation of the proposed measures amount to 523,572 UAH/year in December 2021 prices.

CONCLUSIONS

1. A methodology for assessing the reliability of drivers and operators has been developed, which allows determining measures to improve traffic safety on forest roads. The effectiveness of implementing measures is determined by reducing traffic violations, reducing physical and psychological injuries from road accidents, reducing the degree of danger to the driver's profession, and improving the reliability of timber removal. Reduction of accidents occurs by increasing the professional skills of drivers and reducing fuel consumption.

2. The developed analytical dependencies allow calculating an integral criterion that characterises the reliability of the driver of forestry equipment based on the data of recording equipment.

3. The developed method of improving the handling of forestry equipment allows determining the permissible value of wheel imbalance for any model of forestry equipment. Self-oscillations for forestry equipment exist when $\gamma<-1,9°$, that is, the stability of movement of the steered wheels is ensured when setting the angle γ within the range of -1,5° to -9°. At angles γ less than -9° aperiodic instability occurs. The movement will be stable even when $\gamma>13°$. The greatest intensity of fluctuations is observed at $\gamma=3°...5°$ and v = 45 km/h.

4. Different placement of control and measuring sensors on the instrument panel of a forestry machine affects the speed and accuracy of information perception. The compact pairwise-symmetrical vertical arrangement of control and measuring sensors on the instrument panel reduces the time of reading information and the number of errors.

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Типологічність засобів технічного контролю фізіологічних і ергономічних показників машин для лісотехнічних робіт

Анотація. На сьогоднішній день під час лісосічних, лісотранспортних роботах, в більшості, експлуатується техніка, яку здали на серійне виробництво на початку тисячоліття. Через відсутність власних коштів у підприємств лісового комплексу в останні роки не проводиться оновлення машин для лісотехнічних робіт і устаткування, в яких за термін їх служби зношуються не тільки вихідні зразки, а й цілий комплекс повторно вводиться у ті ж машини змінюваних деталей і інших нетривких елементів. У структурі діючого парку техніки 80 % займає повністю амортизована техніка, яка повинна бути модернізована або списана, а коефіцієнт вибуття в 10 разів перевищує коефіцієнт оновлення. Існуюча ремонтна політика сформувалася в доринкових умовах при відповідних співвідношеннях цін на сировинні ресурси і машини. У той період і була створена діюча до сьогоднішнього дня концепція технічного контролю машин для лісотехнічних робіт: допуски, регламенти, нормативи і т. д. У нинішніх економічних умовах потрібні нові підходи до формування методології технічного контролю і ремонту машин для лісотехнічних робіт. Технічний супровід експлуатації машин для лісотехнічних робіт можна розглядати як інструмент управління запасом їх потенційних можливостей, закладених при виготовленні і поновлених (відновлюваних) при технічному контролі та ремонті. Визначення моменту для проведення робіт по відновленню технічного стану машини залежить від різних чинників, часто суперечать один одному. Мета – виконати аналітичні та експериментальні дослідження з підтвердження існування типологічності засобів технічного контролю фізіологічних і ергономічних показників машин для лісотехнічних робіт шляхом моделювання процесів їх функціонування. Методологія – апробувати засоби системного підходу та системного аналізу типологічності засобів технічного контролю фізіологічних і ергономічних показників машин для лісотехнічних робіт. В статті представлено згенерований результат у вигляді реєструючого алгоритму модуля технічного контроля машин для лісотехнічних робіт. Авторами за результатами експериментальних досліджень представлена графічна інтерпретація інтегральних рівнів шуму на робочому місці водія форвардера в навантаженому стані, в порожньому стані. Висновок – проведені дослідження дають можливість запропонувати оптимальне, з точки зору сприйняття інформації і часу зчитування, розміщення елементів на панелі приладів транспортного засобу. Наукова значимість – підтверджено, що при аналізі впливу періодичності виконання операцій технічного контролю машини для лісотехнічних робіт на перераховані показники доцільно використовувати парний кореляційний аналіз, який полягає у визначенні зв'язку між періодичністю виконання операцій технічного контролю і величиною сумарних питомих витрат, показниками надійності і показниками функціональних властивостей

Ключові слова: ергономіка лісовозних автопоїздів, типологічність засобів технічного контролю, показник надійності, машина для лісотехнічних робіт, технічний контроль та ремонт