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OPERATIONAL EFFECTIVENESS OF MULTIPURPOSE LOGGING MACHINERY CONSIDERING LIMITING FACTORS

The work is devoted to the study of the effectiveness multioperational harvesting machines. A comprehensive evaluation of the effectiveness criterion forwarders and harvesters. The efficiency of the forwarder MLPT-354 and harvester MLH-414 in various operating conditions. The analysis of the effective methods of operation limbing harvester. The recommendations for the effective use of combining operations.

Introduction. Parameters effectiveness of design and drive of multipurpose logging machines is determined by their efficiency, effectivity and reliability in desired conditions. To choose the parameters there have been used fragmented techniques of power estimation, efficiency and loading of machines when performing operations. However, operation conditions, methods of performance and parameters theirselves render different, quite often opposite effect on the mentioned parameters. It makes inconvenient their both separate and combined usage as estimation criteria.

Main part. The criterion of energy potential of efficiency (EPE) is developed for the evaluation of multioperational logging machines effectiveness. This criterion is determined as the ratio of useful power N to the duration of engineering cycle operations T.

Similar criterion has been used before for the evaluation of unioperational transport road-building machines [3]. It was determined by the expression of the useful work performed by the tractor per unit of time considering portion of working operations during the total time of the cycle.

It should be noted that harvesters and forwarders are multioperational machines. On moving operations they don't perform useful work. Energy efforts on their engineering operations vary within a wide range. That's why the value of useful power should be included in the original expression for EPE determination as the product of mathematical expectation of its constituents. In the case of forwarder performance function EPE will become:

$$EPE = \left(\begin{array}{l} \left(\begin{array}{l} M_1^f \omega_1^f t_1^f + M_2^f \omega_2^f t_2^f + \\ + M_3^f \omega_3^f t_3^f + M_4^f \omega_4^f t_4^f \end{array} \right) \dfrac{V_f}{V_p} \\ + P_k v_l t_1^f \end{array} \right) \frac{1}{T_c^f} \qquad (1)$$

Where t_1^f – time needed for lifting a pack of assortments; t_2^f – time for manipulator turning when pack loading; t_3^f – time for manipulator turning when pack unloading; t_4^f – time for piling; V_f – a volume of assortments transported by a forwarder; V_f – a volume of lifted pack of assortments; $M_1^f - M_4^f$ – lifting and pivotal times made by manipulator when performing; $\omega_1^f - \omega_1^f$ – correspondent angular rates; T_c^f – total time of forwarder working cycle [2] correspondently; P_k – tangential tractive effort developed by loaded forwarder propeller in desired conditions; v_l – travelling speed of loaded forwarder.

Value of tangential force of traction bar R_k for various types of propellers and traveling conditions is determined using technique [4], and lifting and pivotal times of manipulator is determined by the mathematical model of forwarder performance.

The overall performance of forwarder MLPT-354 at production association "MTZ" in different operating conditions is shown in Fig. 1.

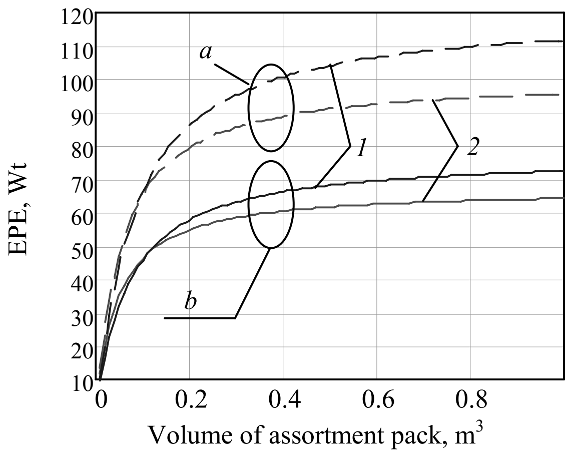

Fig. 1. Parameter effectiveness of forwarder MLPT-354 for different operating conditions:
a – 3rd type of soils; *b* – type of soils;
1 – load capacity of 7 tonne forwarder;
2 – load capacity of 5 tonne forwarder

According to the strength of bearing structure the speed of loaded forwarder in the given conditions is limited to 1.2m/s, and idle speed – 2 m/s. Therefore, a forwarder underutilizes the production capacity of engine (88 kWt) in conditions of the 1st type soils.

Degradation of travelling conditions from the 1st type to the 3rd type results in increase of engineering cycle capacity and in decrease of efficiency. Due to this fact, EPE rises and therefore forwarder design and drive parameters are realized in more complicated operating conditions.

A volume rise of lifted assortment pack leads to EPE rise owing to full power consumption of manipulator drive and smaller number of idle operations when loading and unloading. In examined operating conditions the performance efficiency of forwarder with s=s assortment packs of 0.4m^3 and 1 m^3 differs not more than by 7%. A little difference in efficiency is stipulated by a slight influence of loading time on the total duration of engineering cycle, which greatly depends on limited forwarder speeds.

EPE also allows to estimate performance efficiency of harvesters. In this case EPE is determined as follows:

$$EPE = \begin{pmatrix} M_1^h \cdot \omega_1^h \cdot t_1^h + M_2^h \cdot \omega_2^h \cdot t_2^h + \\ +F \cdot v \cdot t_4^h + M_3^x \cdot \omega_3^x \cdot t_3^h \cdot n_1 \end{pmatrix} \frac{n_2}{T_c^h} \qquad (2)$$

where t_1^h – time needed for cutting a tree, t_2^h – time needed for logging a tree to the place of bucking, t_4^h – time needed for limbing, t_3^h – time needed for bucking, M_1^h, ω_1^h – rotary moment of saw tire thrust on a tree and its angular velocity while felling a tree; M_2^h, ω_2^h – rotary moment of manipulator and its angular velocity; F, v – strength and velocity of grabbing a tree through the harvester head; M_3^h, ω_3^h – rotary moment of saw tire thrust on a tree and its angular velocity while bucking a tree; T_c^h – the total time of harvester working cycle; n_1 – a number of kerfs for bucking of one tree trunk; n_2 – a number of trees being treated from the one side of engineering stand which is dependant from the type of cutting and the density of crop.

The strength F, needed for grabbing a tree feeding it by the mills of harvester head, is determined as the sum of engineering resistance forces to drag a tree [5], dragging resistance F and tree inertial force F_{in}. Due regard for tree inertial force is essential for large tree trunk volume, where it influences much on the value of the maximum of dragging velocity.

$$F = \frac{P_l + (q + Q_w) \cdot \mu + F_c}{2} + F_r + F_{in}$$

where P_l – resistance force to limbing in harvester head; q – total pressure of rolls on the tree being treated; Q_w – weight of the tree; μ – friction factor of trunk rolling along feeding rolls of the head; F_r – resistance force in the roll journals.

The ability to perform the engineering operations of various styles depends on operator's skills. Thus, experienced harvester operators apply oncoming feeding of a tree to harvester head during limbing.

In case of dragging a tree with work mix, forces F_r and F_{in} do not affect the total dragging force because the tree is in rest. Determining the power used for limbing in work mix it is much more efficient to calculate rotary moment of manipulator and the angle velocity of its turn.

Comparative efficiency of such work mix for harvester MLH – 414 is shown on the Fig. 1(the comparison is given with the arm of crane of 5 m).

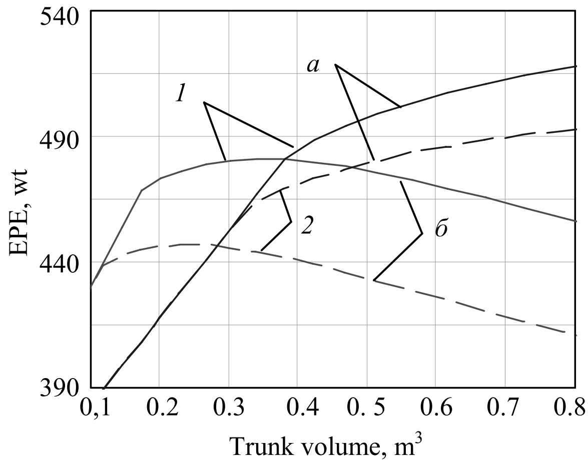

Fig. 2. The effectiveness of various styles of limbing in different operational conditions:
a – with the work mix; *b* – without the work mix
1 – power of harvester head drive is 50 kWt
2 – power of harvester head drive is 40 kWt

For EPE function describing the harvester functioning with the combination of operations , it is taken into account that after oncoming feeding of harvester head to a tree it is necessary to skid the tree to the place of bucking and this operation cannot be regarded as useful work but only increases the time of the cycle.

The change in working efficiency in pine forest stand with the estimated productivity of the 2nd class (where the trunk volume from 0.1 to 0.8 m^3) varies greatly. So, when the tree trunk is less then 0.17 m^3, the effectiveness of harvester exploitation falls greatly. The intensive efficiency decline is stipulated be the limits in maximum speed of dragging trees (5m/s for harvester head Kesla 20 RH installed on the described harvester). Using the work mix we can also observe a sharp decrease in effectiveness but this time the trunk volume is less than 0.4m³. This is the result of velocity limits in the rotation of manipulator Kesla 1,395 H.

EPE function indicates the efficiency of the work mix application while working in the forest stands with tree trunks more than 0.38 m^3. The work in this area is characterized by the maximum acceptable speeds of limbing. In this case resistance force to tree dragging and inertial force of a tree are significant at full speed. On the contrary, the moment of rotary inertia is small and resistance force to tree dragging with work mix doesn't affect the power being used here.

It should be noted that if the trunk volumes are more than 0.75 m^3, the exploitation of such a harvester is awkward because of the limits in the force of dragging rolls of the harvester head (18 kN).

The decline in efficiency of the harvester head drive power affects greatly the effectiveness of its performance in common engineering operations. So, while working in the forest stand with the volume of long-tailed timber of 0.3 m^3, the fall in the harvester head drive power from 50 to 40 kWt results in the decline in the effectiveness of harvester operation to 13%. In case of working with work mix, harvester head drive power has no influence on the work in the forest stand with trunk volume up to 0, 32 m^3. The limit of effective exploitation of the work mix decreases in this case to the volumes of 0.28–0.3 m^3.

Diverse effects of the harvester head drive power on the effectiveness of various styles of limbing are explained by the dependence of the maximum speed of tree cleaning not only from the power and speed of the harvester head operation, but from rotation characteristics of manipulator drive.

The examined EPE function doesn't consider random character of the stress appearance in the process of engineering cycle as well as the distribution of operational conditions. Considering of such distribution will enable to use EPE criterion more accurately for determination of effective parameters of multioperational machinery for the certain logging enterprises. It should be marked that EPE function is intended for estimation of machine parameters effectiveness in the given circumstances, but doesn't allow to compare logging efficiency when these parameters are changed.

In order to rise the efficiency of harvester operation in forest stands with trunk volume more than 0.17 m^3, it is possible to increase maximum power of the harvester head and acceptable dragging force of the rolls. But such an approach is interfaced with the overloading of the bearing structure of the harvester and its drive.

The examined functions of EPE (1) and (2) don't take into account both possible occurrence of forces in the process of each operation performing in engineering cycle and operating conditions distribution. Considering such a distribution will make possible to use EPE criterion more accurately in order to fix effective parameters of multipurpose machinery for the certain logging enterprises. It should be noted that EPE function is intended for effectiveness estimation of machines parameters in the desired conditions, but doesn't allow to compare logging efficiency when changing them.

Conclusion. The examined criterion of energy potential efficiency enables to make the complex estimation of harvesters' drive and their structure parameters in various natural and operational conditions.

Its peculiarity is the combined regard for energetic and time constituents of harvester operation efficiency and the possibility of introduction of engineering and structural limiting factors.

The research proved that exploiting the harvester MLH – 414 for limbing in pine forest stands with the estimated productivity of the 2nd class it is very efficient to use the oncoming feeding of harvester head by the manipulator to the tree with a trunk volume more than 0.38 m^3. With less trunk volumes the common style of limbing is more reasonable.

The decline in harvester head power from 50 to 40 kWt leads (in the given case) to the decrease in harvester efficiency by 13%. While working with work mix such decline has an impact only on operation effectiveness in forest stands with trunk volume more than 0.32 m^3. The performance of harvester MLH – 414 without work mix in the forest stands with long-tailed tree volume more than 0.78 m^3 is awkward because of the limits in the dragging force of rolls.

The use of the given harvester in forest stands with trunk volume less than 0.17 m^3 is also irrational. A significant decline in effectiveness is stipulated by delimbing speed limited to 5m/s.

Efficiency growth of forwarders examined in operating conditions is limited by traveling speeds acceptable for given strength of structure.

Degradation of traveling conditions (for forwarder MLPT-354) from the 1st to 3rd type of soils leads to EPE rise that means better correspondence of its design parameters and drive to these conditions. However in more complicated operating conditions the given forwarder performance is difficult due to limits in possibility of tangential tractive effort application.

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