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S. E. Ariko, assistant lecturer (BSTU)

FORESTRY MACHINERY TIRES: TEST RESULTS

In this paper, MLH-414 harvester is used as an example to analyze how the tire rate influences the distribution of responses between the wheels of logging machinery, stability of the process module, the power module and the multiple-function machine as a whole. The nominal tire rates are determined for harvesters to be used for various types of intermediate fellings.

Introduction. Many machines, differing in their application and design, are used for logging now. The large part of this equipment consists of wheel machines with special tires mounted on them. These tires have various diameters, width, tread, number of plies, inner pressure and other parameters resulting in variations of their elastic damping properties. The tires shall be chosen in accordance with application, operation conditions and required properties.

1. Load distribution between the wheels of the MLH-414 feller-delimber-crosscutter machine as a function of the tire rate: the investigation. Theoretical and experimental investigations demonstrate that the interaction between the feller-delimber-crosscutter machine (FDCM) and the tree is significantly affected not only by the external forces but also by the tires mounted on the machine. Fig. 1–3 demonstrate the tree falling process with the maximum extension of the hydraulic arm rotated 90º right from the harvester's longitudinal axis.

It has been found that the increase of tire rate results in higher response under the power module's wheel unloaded during the process operations (see Fig. 1). If the tires with 500 kN/m rate are used instead of those with 200 kN/m rate, the response under the wheel grows 1.54 times and becomes as high as 9,022.0 N. For tire rate 1,250…2,500 kN/m, the minimum response under the wheel is 9,938–1,0214 N.

With the tire rates less than 500 kN/m or higher than 1,250 kN/m, the process module becomes less stable, and the wheel breakaway time becomes longer (see Fig. 2). For the tire rate 1,250 kN/m, the left wheel broke away four times, with the total breakaway time 2,87 s. For tire rates 200 kN/m and 500 kN/m, the similar oscillatory processes were observed.

For the tire rate 2.500 kN/m, the process module lost its stability six times while the tree fell, and there was no response under the unloaded wheel even after the tree falling.

To assess the logging machine stability, the total response had been analyzed under the MLH-414 harvester's side that was unloaded. It should be noted that the minimum response, 5,861.0 N, was recorded for harvesters with the tire rate 200 kN/m. For the tire rate 500 kN/m, the stability became 1.54 times higher; for 1,250…2,500 kN/m, 1.70…1.74 times higher.

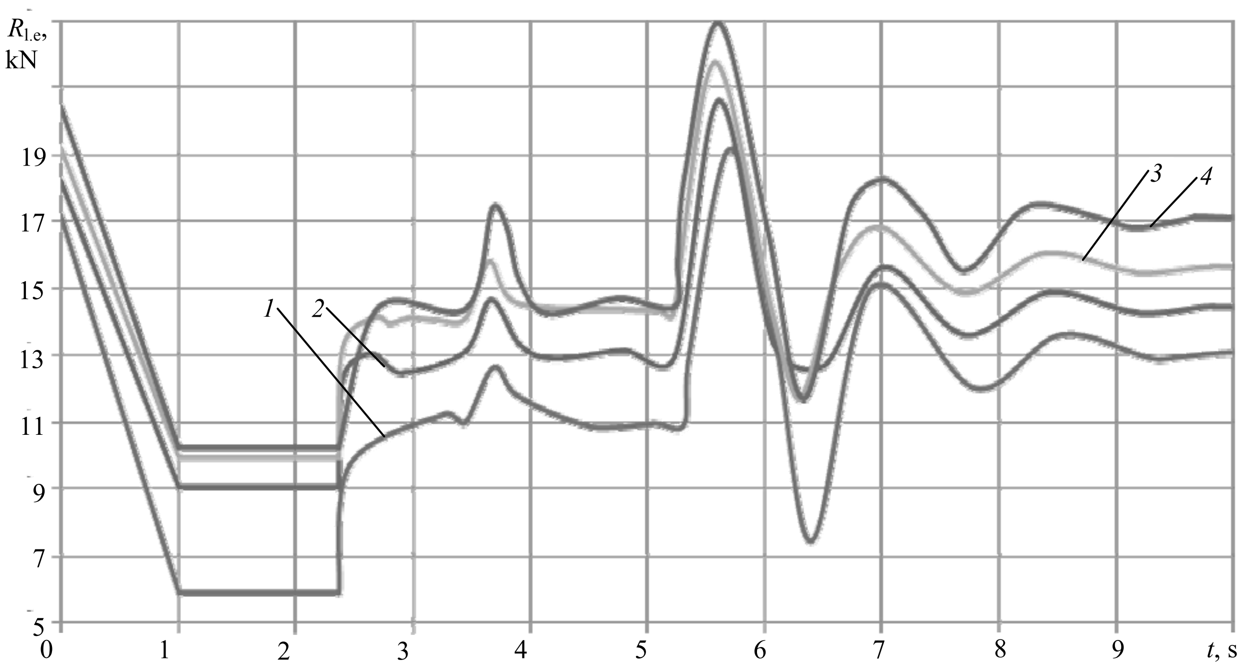

Fig. 1. The response under the power module's left wheel during the tree falling as a function of the tire rate: *1* – 200 kN/m; *2* – 500 kN/m; *3* – 1250 kN/m; *4* – 2500 kN/m

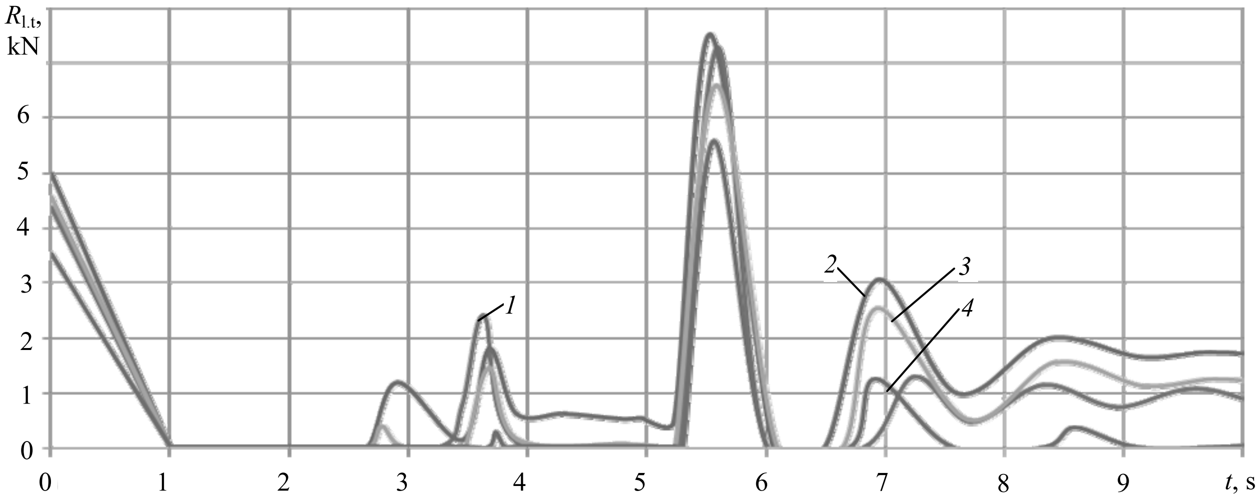

Fig. 2. The response under the process module's left wheel during the tree falling as a function of the tire rate:
1 – 200 kN/m; *2* – 500 kN/m; *3* – 1250 kN/m; *4* – 2500 kN/m

2. MLH-414 harvester stability as a function of the tire rate: the investigation. The FDCM parameters, in terms of weight and dimensions, were determined to ensure the logging machine operation safety for various types of intermediate fellings and to calculate more exactly the recommended tire rate for mounted tires. For these purposes, the stability was considered as a logging machine's basic operational characteristic for calculation and selection of parameters. To estimate the stability, R. Lyumanov [1] recommends to use the stability factor under working conditions calculated as follows [1–3]:

$$K = \frac{M_{rest} - M_{tur}}{M_{gr}},$$

where M_{rest} is the restoring moment (N·m); M_{tur} is the overturning moment not including the tree effect (N·m); M_{gr} is the moment exerted by a tree (N·m).

The stability factor under working conditions must exceed 1.15, if the inertial forces and dynamic processes are taken into consideration, and 1.4, if the process is considered as the static one [1–5]. G. Sh. Gasymov [6] found that the dynamic response factor is 1.08…1.22, when the hang-up tree lifting is in progress, and 1.18…1.37, when the arm is lifting or lowering a tree.

E.V. Shuvalov [7, p. 65] has specified the stability loss criteria as follows for articulated machines: one of wheels breaks away from the slope surface; irreversible loss of stability of one tractor's section, resulting in its overturn and fall to the limit stops of another section; irreversible loss of stability of the machine as a whole, resulting in its overturn.

From these modes of stability loss, the one wheel breakaway shall be specified as the critical case, because safety cannot be guaranteed when the FDCM is operated on a slope.

As a result of this investigation, the characteristics of the stability factor under working conditions for the power module (K_1), the process module (K_2) and the MLH-414 harvester (K_3) versus the tire rate were described for the forest stand volume 0.27 m^3 with the arm extension 7.3 m (see Fig. 3).

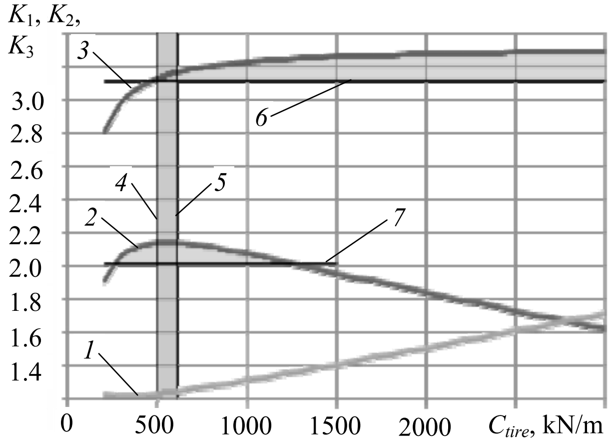

Fig. 3. Harvester (MLH-414) stability versus tire rate:
1 – stability factor for the power module (K_1);
2 – stability factor for the process module (K_2);
3 – stability factor for the harvester (K_3);
4 – 90% of the effective tire rate; *5* – 110% of the effective tire rate; *6* – 95% of K_3; *7* – 95% of K_2

For tire rates higher than 465 kN/m, the factor K_3 drops less than by 5% of its maximum value, 3.49. Tire rates within 260 kN/m…1,230 kN/m result in the process module stability higher than 95% of maximum possible value, and the harvester stability within 80…99%. Tire rate reduction results in lower stability of the process module and the harvester. Tire rates higher than 1230 kN/m result in reduction of stability of the process module; at the same time, the FDCM stability slightly grows.

The theoretical analysis has demonstrated that the effective tire rate for MLH-414 is 550 kN/m. Also, tire rate variation within the 20% range (495…605 kN/m) does not result in reduction of stability of the process module, but, in such a way, the stability of the machine as a whole can be set within 5% of its maximum possible value.

Also, this investigation has demonstrated that the harvester operation in the forest stand with the average stem volume 0.27 m^3 or less and with the maximum hydraulic arm extension is possible with the process module wheel breakaway when the harvester's stability factor margin under working conditions is 1.63. The process module tires can be filled with water in order to increase the total machine weight and the tire rate, resulting in the stability factor margin under working conditions as high as 1.51 for the process module and 2.38 for the harvester. If all four wheels are filled with liquid, these factors are 1.28 and 3.03 respectively.

3. Nominal tire rates for harvesters to be used for various types of intermediate fellings. For each type of felling, up-to-date feller-delimber-crosscutter machines with high operational characteristics must be used. These characteristics significantly depend on the mounted implements, resulting in variations of parameters of the carrier vehicle and the harvester as a whole, and the harvester weight varying within a wide range. Depending on the harvester weight / width ratio, various tire rates are required (see Fig. 4).

For harvesters used for cleaning / weeding and thinning, the wider these harvesters are, the lesser tire rate is required; for the harvester width 2.7 m and the maximum weight of mounted implements, the tire rate shall be 415 kN/m. If the weight of implements is minimum, the nominal tire rate shall be as low as 460 kN/m, for the harvester width 2.2 m. For wider harvesters, the tire rate must be higher to improve the power module stability.

It has been proved that for wider harvesters, higher tire rates are necessary, and the tire rate shall be chosen to maximize the power module's stability factor under working conditions. If the feller-delimber-crosscutter machine width is reduced, the process module's stability factor shall be used as a basic characteristic for determination of the nominal tire rate and the minimum operating weight. The logging machinery for improvement fellings and severance fellings, with the minimum weight of implements, demonstrates clear minimum of the effective tire rate, with the stability factors under working conditions approximately equal for the power module and the process module.

For the forestry machinery used for selective sanitary fellings, the tire rate must be 10.9…20.5% higher than that for the machinery used for severance fellings. In several cases, if the weight of mounted implements is minimum and the FDCM width is 3.1 m, the tire rate must be 24.7% less, as low as 365 kN/m.

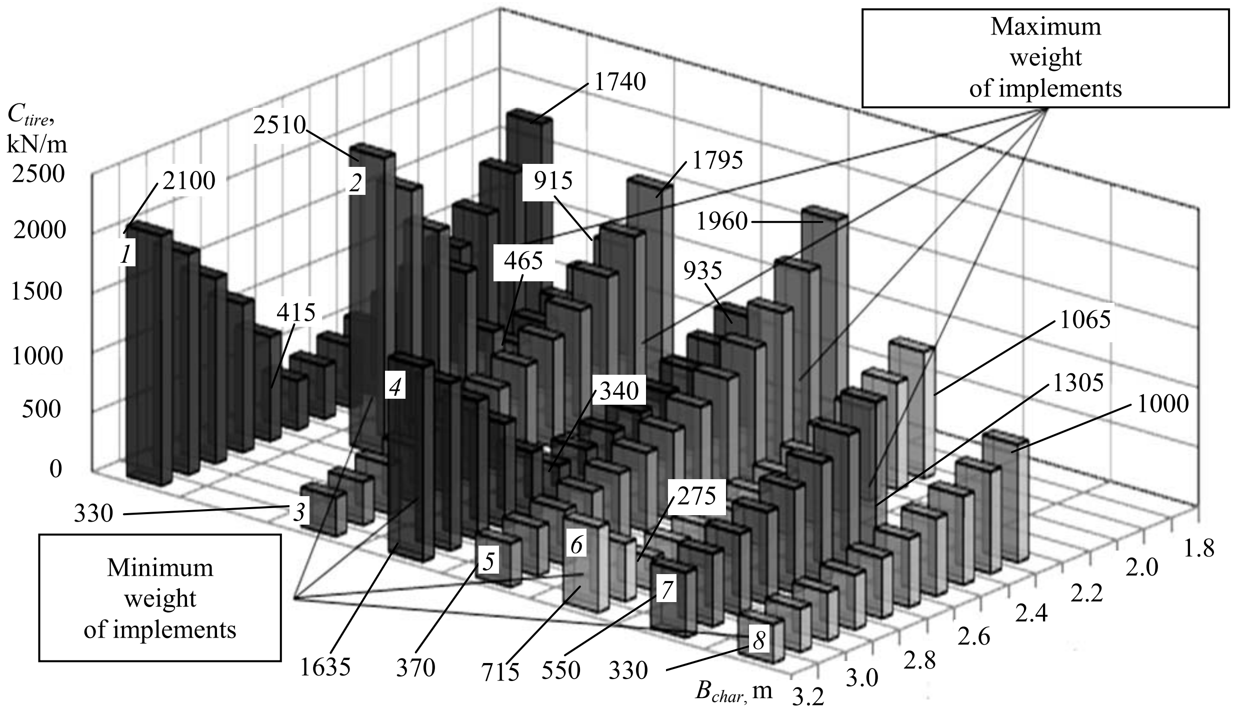

Fig. 4. Recommended tire rates for harvesters operated at works as follows: *1*, *2* – cleaning / weeding and thinning; *3*, *4* – improvement felling under conditions typical for the Republic of Belarus; *5*, *6* – severance felling; *7*, *8* – selective sanitary felling

The characteristic describing the required tire rate versus the machine width is approximately parabolic, with the minimum corresponding to the stability factors under working conditions for the power module and the process module equal to 1.15. Under real operation conditions, the nominal tire rate depends on several factors, such as dynamic loading modes, bearing surface shape, tire material temperature, tire inflation pressure.

V. I. Knoroz [8] has published the data demonstrating that in various tire sections the tire rate can vary within 10%; in the resonant frequency range, for radial and bias tires, the nominal tire rate becomes 18…25% higher. Also, for bias tires, under equal air pressure, the nominal tire rate is 10…20% higher than that for radial tires. Wide cross-section tires with tire rates 200 kN/m or higher improve road-holding stability and controllability of logging machines with articulated frames [9].

As a result of this research, the recommended tire rate ranges were determined for various types of fellings; these ranges are 90…110% of nominal tire rates.

The comparison of characteristics describing variations of recommended tire rates for various types of felling has demonstrated that for higher weights of mounted implements, the minimum tire rate changes towards higher widths of logging machines. This is clear if tire rates are analyzed for harvesters used for cleaning / weeding and thinning. In harvesters used for improvement fellings (with the maximum weight of implements and the stem volume exceeding 0.18 m^2) and for selective sanitary fellings (with the stem volume exceeding 0.24 m^2), the process module loses stability earlier than the power module, irrespective of the process module weight.

It should be noted that for higher weights of implements and the carrier vehicle, with the similar sizes, higher tire rates are necessary. For the FDCM with maximum (or minimum) weight of implements, tire rates as follows are recommended: 730…1275 kN/m (410…675 kN/m) for cleaning / weeding and thinning; 550…1335 kN/m (280…720 kN/m), for improvement fellings with the average stem volume 0.18 m^3; 520…1310 kN/m (300…735 kN/m), for operation at severance fellings; 485…970 kN/m (290…565 kN/m), for selective sanitary fellings.

Conclusion. The researches have demonstrated that the attempts to use the same tires for logging machines used for different purposes result in many cases in degradation of several operational properties. For FDCM, the most important property is the stability; to estimate it, the stability factor under working conditions is used.

This parameter strongly depends on the rate of tires mounted on the logging machine. The tire rate, as a function of the weight of implements, weight of a carrier vehicle and width of logging machine, varies within a wide range. For harvesters with the minimum weight of implements, the nominal tire rate varies from 290 kN/m (for selective sanitary fellings) to 735 kN/m (for improvement fellings with the average stem volume 0.18 m^3).

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