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Optimization Of Flow And Rhythm Of Work Of The Harvest-Transport Link

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ABSTRACT

Using the optimization criterion for the minimum waiting time by hopper drives for loading their bodies with grain from combine harvesters working as part of a harvest transport link, a mathematical model of mutual coordination of work of combine harvesters and hopper drives has been developed. Optimized depending on the distance (field-threshing floor), the capacity of the bunkers of combines and storage drives, and their number in the link is interconnected taking into account grain yield. The work was performed with consideration of the cleaning process in the form of a system: "field - combine - vehicle - threshing floor". The connection between the subsystems, which determines the flow, the rhythm of the harvest-transport process and the effective functioning of the link machines, is established. The optimization criteria are derived from the parameters of the link machines and the distance from the field to the threshing floor, the cycle time of the drive from the distances of crossings and the capacity of the bunkers, the required number of drives for uninterrupted work of combines taking into account yield and distances from the field to the threshing floor. It has been established that with the help of modeling the harvest-transport process according to the optimization criterion mentioned above, there is a possibility of non-stop operation of combines and storage units (the mutual waiting time is zero). The software for modeling the work of the harvesting-transport link has been developed.

Keywords: modeling, optimization criterion, harvesting unit, combine, storage hopper, grain, harvest, simple, productivity, efficiency.

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INTRODUCTION

The optimal organization of work of the harvest transport unit (HTU) on the harvest of cereal crops determines the efficiency of the process. Coordination of work of combine harvesters and vehicles (VH), carrying grain from combine bins to the threshing floor for further refinement, depends on it. At present, direct transportation of VH grain from combines and with the use of hoppers is widely used. The choice of the optimal transportation technology is made on the basis of the solution of a multivariate optimization problem taking into account the variability of harvesting conditions, the class of harvesters, the type of vehicles, their load capacity, field sizes, distance of crossings, etc. threshing floor as a single system [1, p.34] using mathematical modeling. The difficulty of the task of coordinated work of combines and vehicles is to achieve minimal downtime of the machines involved in the harvesting process [2, 3]. Neither combines nor vehicles (VH) should stand idle for more time than optimal mutual waiting for unloading of grain from bunkers. Indicate ways to solve this problem and is the goal of our work.

MATERIALS AND METHODS

The method of solving the problem is a systematic approach [4, 5, 6]. The work of the harvesting-transport link (HTU) is considered as a system: a field-combine-vehicle-threshing floor (Figure 1).

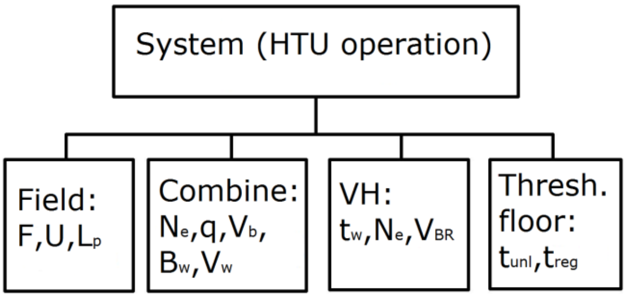

Figure 1: HTU Operation System

The field subsystem includes its area F (ha), working rut length L_p (km), grain yield U (t / ha). The second subsystem - the combine harvester - the main link of the production line. The preference of all known brands of combine harvesters is given to the domestic TORUM-740 Rostselmash plant. Its indisputable advantage in comparison with other analogues is the rotating deck, which provides a gentle threshing of the grain mass with minimal grain crushing and a reliable process with a wet mass. Combine parameters used in calculations of the model: engine power N_e (kW), bunker capacity V_b (m^3), combine class q (threshing capacity, kg / s).

The third subsystem is VH, which is taken as the bunker-reloader (BR) in the unit with a wheeled tractor. The advantage of BR is the use of conversion tracked systems (CTS) to reduce the pressure on the ground, high productivity of grain unloading (200 t / h), the presence of a weighing device and a computer to account for the amount of grain from each combine, the presence of a canopy. The database takes into account the multiple capacity of the body BR from two combines as part of the HTU.

The fourth subsystem - the mechanized threshing floor for receiving and refining grain from combines includes time t_{unl} unloading grain from BR, time t_{reg} registration of invoices for grain handed over.

All four subsystems are interconnected and predetermine the successful functioning of each. In our task, the direct transportation of grain BR from the combine to the threshing floor was taken. When coordinating the performance of the combine and BR, as well as their required quantity, preference was given to the combine as the main link of the stream, on which the duration of harvesting and yield loss depend. It is desirable that the combine is not idle because of the expectation of BR to unload grain from the bunker. Unloading of grain produced on the go.

To calculate all the parameters of HTU, a mathematical model and a block diagram of the algorithm for solving the problem were developed (Fig. 2). The block diagram includes 10 arithmetic operators and 2 logical ones. In the first operator, the initial data for the calculation are entered: k_c – the utilization of the capacity of the combine thresher; U – grain yield, t / ha; V_p – working speed of the combine, km / h; V_b - combine bunker capacity, m^3; L_w – working length rut, km; l_{dis} – distance from the field to threshing floor, km; n_b – number of combine bins in HTU; V_{BR} – storage tank capacity, m^3.

The second arithmetic operator, having received the initial information from operator 1, calculates the working width of the header of combine harvesters B_p and transfers control to the third logical operator, which limits the received values of B_p to 18 m and transfers control to the next arithmetic operator 4.

In the fourth operator, τ is calculated using the time of the change of combine harvesters, and then control is transferred to the 5th operator to calculate the hourly productivity of the combine in hectares / h, and in the sixth, it is also recalculated into t / h.

In the seventh operator, the time of filling of the combine bunker is determined, and in the eighth, the cycle time t_c of his work.

Next, the seventh operator transfers control to the eighth, where the required number of M_{BR} drives for loaders is determined. In the tenth operator, their fractional number is rounded to the whole M'_{BR}, and the necessary information is transmitted to the eleventh operator to clarify the calculation of the cycle time t'c of the drive-loader.

In the 12th operator, the value of the waiting time optimization criterion is determined. t_w=(t'_c - t_c) load grain drive-loader and is its minimum, which determines all the parameters and mode of operation of the HTU.

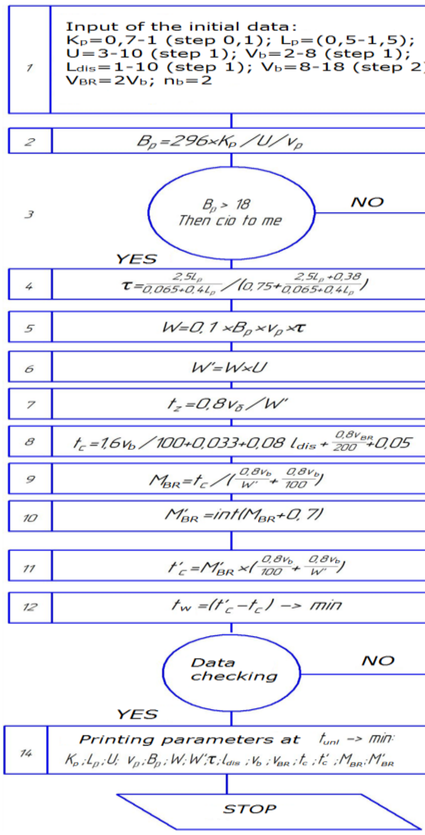

Figure 2: The block diagram of the optimization of the work of the harvest-transport link (HTU)

In the 13th logical operator, calculations are performed with all the source data, calculations are performed, and in the 14th, the calculation results are printed.

RESULTS AND DISCUSSION

Analysis of the simulation results of the harvest-transport process in the “field-combine-vehicle (VH) - threshing floor” system made it possible to establish the interrelation of all subsystems and the coordinated operation of HTU machines in compliance with the flow and rhythm. The efficient operation of the main stream link, combines, is ensured by the operative functioning of the servicing one, the accumulator-reloaders (BR), the body of each of which accommodates two grain bins from the combines. The rhythm of the work is set by the combine, more precisely, the time it takes to fill its bunker with grain t_z (Fig. 2). It depends on the yield U, the capacity of the V_b combine harvester, the productivity of the combine and the grain unloading device from the combine bunker to the body of the BR, which is aggregated with the tractor. The body of the BR accommodates grain from two combines working in one link on the same field in such a way as to remove it in one day. The task of the BR as a service unit is to ensure the operation of the main one without downtime. Having unloaded the grain from the first combine on the move, BR pulls up to the second and unloads the bunker of the second combine into his body. Then BR moves to the threshing floor, where he unloads his body and draws up the invoice. The cyclical work of BR, linked to the work of two combines, predetermines the success of the link. The time t_c of the work cycle BR (Fig. 3) depends on the yield U of the grain, the distance l_{dis} from the field to the threshing floor, the time of unloading of grain by the t_{upl} combine, the time of unloading the body to the threshing floor and the invoice.

The dependence of the cycle time t_c of work BR (Fig. 3) on Vb and l_{dis} must be taken into account to calculate the waiting time t_w (operator 12, Fig. 2). For different capacities of the BR body, figure 3 presents the dependences of the cycle time t_c on the distances of the crossings l_{dis}. For example, for a BR with a body of 20 m^3 with a distance of 1dis from the field to the threshing floor of 1 km, the cycle time is 0.4 h or 24 min, for distances of 2 km it is 0.48 h, for 3 km it is 0.54 h.

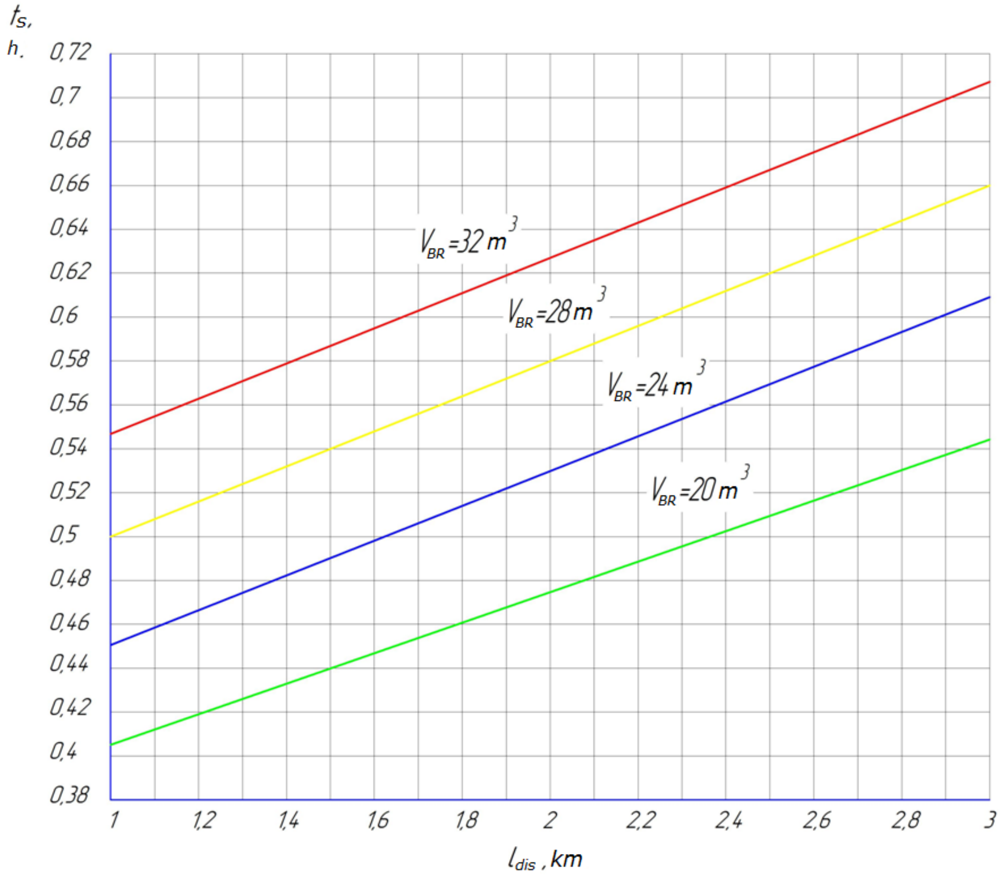

Figure 3: Dependencies of the cycle time of the grain hopper as a function of the distance of the crossings and the capacity of the combine bins

So, with an increase in body capacity up to 32 m^3, the BR cycle time also increases, and at a distance of 3 km from the field to the threshing floor it will be 0.72 h or 43 min.

At distances of crossings from 1 to 3.7 km, a link from two combines serves one BR with a grain yield of 7 t / ha. At distances of crossings from 3.7 to 8.7 km, two BR are required, from 8.7 to 10 km - three. In all these cases, harmonious rhythmic operation of combine harvesters without waiting times for BR to unload grain is provided, and BR itself can stand idle for a short time t_w (Fig. 4).

An analysis of the simulation results of the harvest-transport process showed that it is theoretically quite possible with optimal streaming and rhythm to completely eliminate the interdependent machine downtime in the HTU (Fig. 4). As follows from Figure 4, the value of the optimization criterion t_w is the waiting time for the accumulator-loader to start unloading grain from the combine hopper, varies linearly and depends on the capacity of the combine hoppers and the distances of the distances l_{dis}.

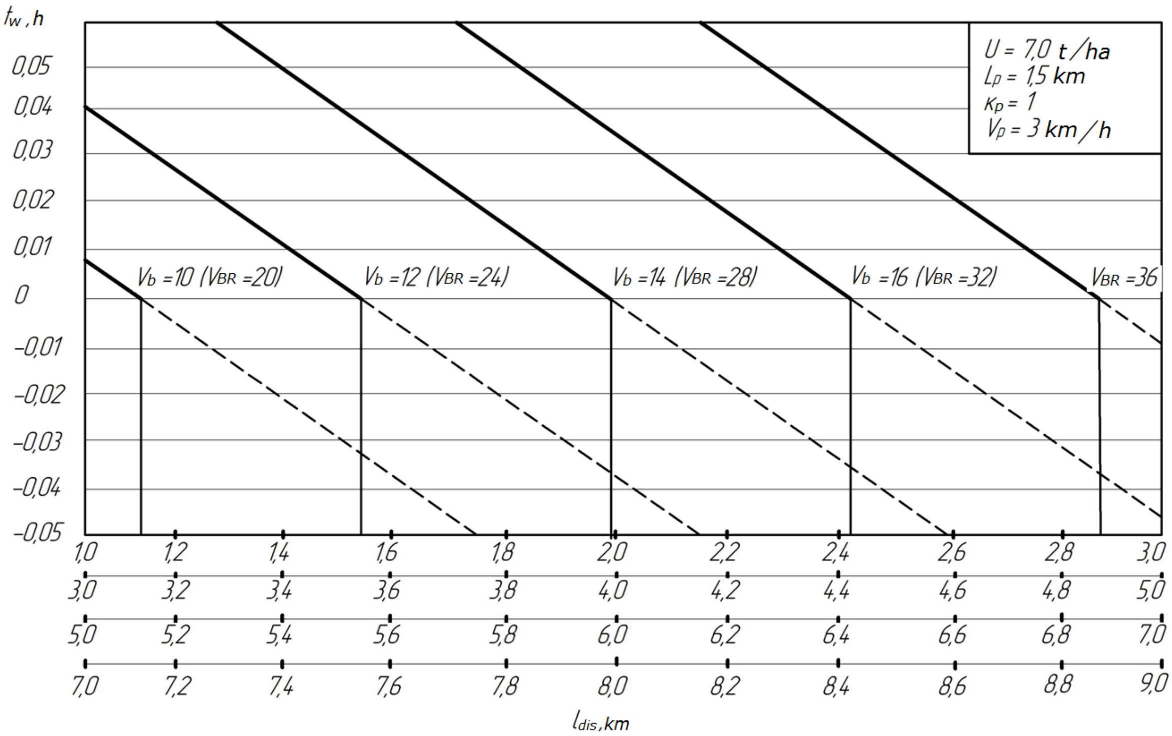

Figure 4: The dependence of the criterion for optimizing t_w on the capacity of the drive - reloader and distances l_{dis} at a yield of 7 t / ha

So, for each capacity of the combine V_b bunker, the zero value of the optimization criterion tw will take place at different distances of crossings. The BR reboiler with a body capacity of 20 m^3 (V_b = 10 m^3) has an optimal distance of l_{dis} = 1.17 km, for 24 m^3 - 1.7 km, for 36 m^3 - 2.88 km. Continuation of the line below zero indicates idle time (tw) of the combine, which is undesirable. Therefore, we provide only a positive t_w for BR. Thus, on the abscissa with zero t_w, only one BR is required with a corresponding body capacity from 20 to 36 m^3 for different combine bunkers from 10 to 18 m^3 and ldis distances from 0 to 3 km. At distances ldis greater than 3 km, a different amount of BR is required (Fig. 5). Such an interconnection between the capacities of the combine bins in the link, the BR body, their number and the distances of the ldis crossings will ensure the flow and rhythm of the harvest and transport process with the grain yield in the field of 7 t / ha. For other yields, at least t_w varies.

When modeling the harvest and transport process for different combines, distances of crossings, productivity, capacity of bunkers and BR bodies with a rational HTU composition and field sizes, we determined the need for VH serving the combine harvesters. Improper interconnection of the number of combines and vehicles always complicates the rhythm of the harvest, reduces the productivity of machines and delays harvesting time [7-10].

For example, in Figure 5 and in the table also with a grain yield of 7 t / ha for the TORUM-740 combines, the required number of VH (storage hoppers), providing high-performance machines with a minimum waiting time t_w for BR, is presented. According to the proposed schedules, the harvesters work rhythmically without stopping to wait for BR and unload grain, and the drive is almost idle.

Table 1: The need for storage drives, depending on the capacity of the combine bunkers, the drives themselves and the distance of the crossings at U = 7 t / ha with a combine engine capacity of 294 kW

Hopper capacity, m^3	The capacity of the body drive-loader, m^3	Travel distance, km	Number of reloading drives
10,0	20,0	1…3,7 3,7…8,7 8,7…10	1 2 3
12,0	24,0	1…4,6 4,6…10	1 2
14,0	28,0	1…5,5 5,5…10	1 2
16,0	32,0	1…6,5 6,5…10	1 2

According to the table and graph in Figure 5, with minimum VH downtime, waiting for a combine requires from one to three BR, depending on the capacities of the hoppers and VH bodies. Three BRs are required for servicing HTUs from two combines only with a body capacity of BR 20 m^3 at distances from 8.7 km to 10. BR with bodies from 12 to 16 m^3 with crossings up to 10 km are required in the amount of two cars. One BR with a body of 24 m^3 is needed at distances of up to 4.6 km, with a body of 28 m^3 - one at moving distances of up to 5.5 km, 32 m^3 - one at distances of up to 6.5 km. When moving up to 10 km, two BR are required: with a body of 24 m^3 - at distances from 4.6 to 10, with a body of 28 m^3 - at distances from 5.5 km and with a body of 32 m^3 - from 6.5 to 10 km .

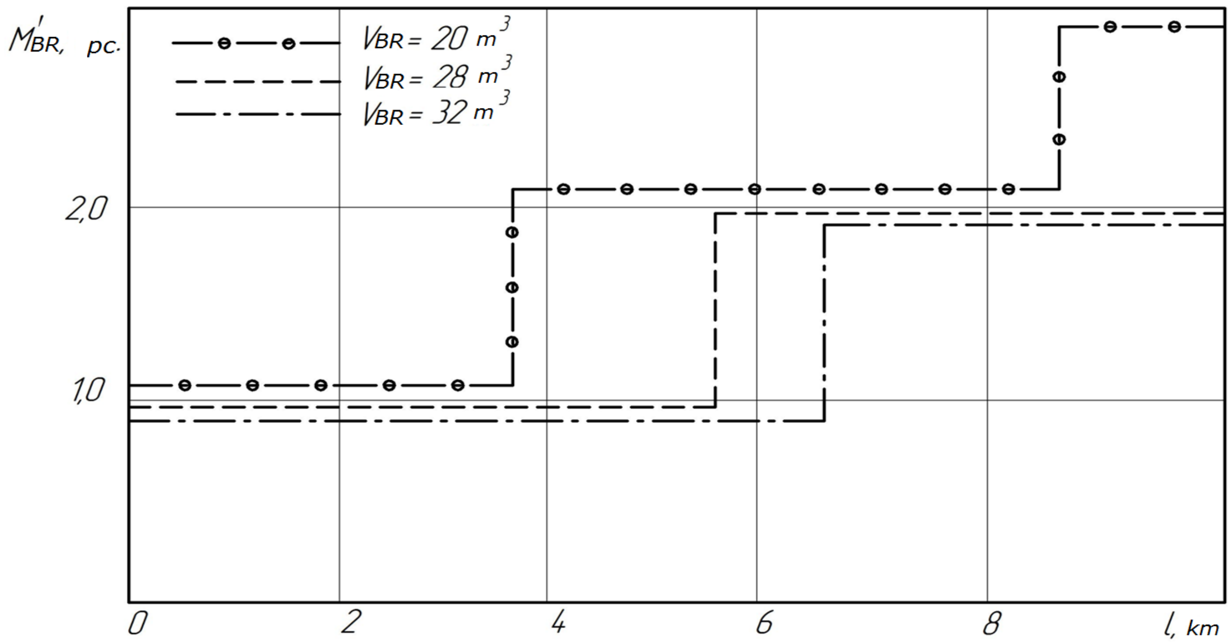

Figure 5: Required number of reloaders for HTUs taking into account grain yield, capacity of the drive body and distances from the field to the threshing floor

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CONCLUSION

An analysis of the HTU simulation results showed that when using the optimization criterion, the minimum waiting time for t_w grain storage loaders for loading their bodies with grain it is possible to completely eliminate interdependent machine downtime as part of the HTU (combine harvesters and storage hoppers). At the same time, it is important to take into account the size of fields of the crop being harvested, yield, capacity of combine and storage hoppers, combine performance, distance from the field to the threshing floor, as well as organizational factors (unloading grain from the combine bins on the move, operator mode, preparing the fields to work, etc.)

Optimum flow and rhythm of work of the HTU for harvesting cereal crops with a yield of, for example, 7 t / ha is provided when servicing two combines as part of a link operating on a field of 80 hectares with one hopper with a body capacity equal to twice the capacity of the combine harvester at a distance of crossings from the field to the threshing floor 1 ... 6.5 km depending on the capacity of the bunkers (fig. 5), cycle time (fig. 3), and the waiting time (fig. 4) by the hopper-unloading hopper (optimization criterion) also depends on grain yield, pa distances crossings and bunker tank. Two reloading hoppers are required, for example, (Fig. 5) with a body capacity of 20 m^3 at travel distances of up to 3.7 km, with a capacity of 24 m^3 - at distances of 4.6 ... 10 km, for a capacity of 32 m^3 - at distances of 6 , 5 to 10 km. And even three accumulators are required for a reservoir capacity of 20 m^3, starting from distances of crossings of 8.8 km to 10. At the same time, in all variants the capacity of the accumulator-loader body is equal to twice the capacity of the bunker.

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