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Production Systems

Effect of transport vehicles on the grain harvester idle time during harvesting

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Abstract. *The article studied the effect of transport vehicles on the grain harvester idle time during wheat, barley and rapeseed harvesting in 6 agricultural farms. In each of the farms one grain harvester and the established harvesting organization were studied without changing the unloading mode and the specific activities performed by the harvester operators and transportation vehicles. By multifactor regression analysis the effect of time for moving the transport vehicle on the grain harvester idle time was established. In addition, the value of the determination coefficient R^2=0.54 reveals that 54% of the harvester idle time for unloading the grain hopper (T1) change is due to the change of significant times and 46% to the effect of unmanageable factors. It has been established that the change in the time from opening the unloading auger to its activation depends on the position of transport vehicles on the field (t_1) and the time for their movement to the harvester auger (t_2). The results obtained can be used to minimize costs in the technological process of crop harvesting.*

Keywords: grain harvester, idle time, joint work between harvester and transport vehicle, multifactor regression analysis

Introduction

Harvesting, incl. cereals, is one of the most stressful and responsible periods in agriculture (Mandradzhiev, 2006; Li et al., 2013; Petrovna, 2014; Tihanov, 2017). In order to prevent production losses caused by the extended harvesting period, harvest should take place in a very short time (Delchev et al., 2015). Harvesting is also related to the organization of people, harvesters and vehicles.

The main technical and economic indicator of harvesters is their productivity (Tihanov, 2019). This indicator depends mainly on the technical parameters of the machines, but logistical factors have a significant influence on some of them. This is the case with grain harvesters. A key factor in productivity is the harvester idle time for unloading the full grain hopper. During unloading, coordinated operations are carried out by harvester operators and by the vehicles, which are of a certain sequence and duration (Delchev et al., 2015; Tihanov, 2018).

It turns out that 20% of the working time of harevesters is used for unloading the hopper and for auxiliary operations before and after unloading – activation of the harvester alarm, opening the unloading auger and activation of the latter. The time of these operations is as long as the time of operation of the unloading auger. The hopper unloading time at standstill also depends on the duration of the operations (activities) performed by the vehicle, such as the time from activation of the harvester alarm to the start of the vehicle and the time from the start of the vehicle to its arrival under the unloading auger of the harvester (Tihanov, 2018). These times vary greatly as they are greatly influenced by the overall organization of the harvesting process.

The use of harvesters with the same productivity and grain hopper volume, as well as vehicles with the same productivity, allows rhythmical filling of harvester hoppers and stable mode of operation of vehicles (Eliseev et al., 1984). According to Webster (2012), grain harvester productivity can be improved if the logistics of the process is improved. For the practical choice of grain harvesters it is important to know the throughput of harvesters based on trials, formulas or regression dependencies (Vezirov et al., 2014).

According to Dinov and Monev (1979), the use of time for proper harvest when working with a grain harvester is unsatisfactory - an average of 50-60% of the total time. This is due to various organizational and operational factors, but one of them is the time for unloading the hopper at standstill, which is of considerable duration. In connection with finding the right time for unloading grain harvesters, some researchers have developed computer programs through which they generate different variants of positioning the vehicle and harvester in order to optimize their joint operation. They consider two options for unloading, namely unloading on the move and at a standstill and use of working time and fuel consumption as optimization criteria (Jansen et al., 2012). Some authors describe a chart that includes harvest duration and idle time (Buckmaster and Hilton, 2005). According to other authors, harvesting efficiency can be significantly improved by creating optimal harvesting

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models in order to minimize idle time (Bochtis et al., 2007). It has been found that with good time management, the waiting time of the vehicle was 9.25 min within one shift, while with poor management it was 54.9 min (Lkhagvasuren, 2013).

The objective of this paper is to investigate the impact of vehicles on harvester idle time for unloading during wheat, barley and rapeseed harvest.

Material and methods

The studies were conducted on 6 agricultural farms during harvesting three crops: wheat, barley and rapeseed. A total of 6 grain harvesters were observed. On all farms the unloading of the hopper was carried out at standstill of the harvester. The harvest organization, the unloading mode and the specific actions of the operators have not been changed.

The following times were measured by harvester operators and vehicle drivers in seconds:

a) by the grain harvester operators:

T1 – harvester idle time for unloading the grain hopper, s.

b) by the vehicle drivers:

t_1 – the time from activation of the grain harvester alarm to the start of the vehicle, s;

t_2 – time from departure of the vehicle to arrival under the grain harvester unloading auger, s.

The effect of the time from activation of the grain harvester alarm to the start of the vehicle (t_1) and the time from the start of the vehicle to its arrival under the grain harvester unloading auger (t_2) on the harvester idle time for unloading the hopper (*T1*) was evaluated by multivariate regression analysis (Mitkov, 2011).

Results and discussion

Table 1 presents the results of the regression analysis about the effect of time duration t_1 and t_2 on the harvester idle time for unloading the hopper - *T1* in different grain harvesters. It can be seen that the effect of the movement time of the vehicle on the time from opening the unloading auger to its activation in the studied harvesters is significant. From the value of the coefficient of determination R^2=0.54, it is evident that 54% of the change in *T1* is due to the change of material times and 46% to the effect of unmanageable factors. The model coefficients t_1 = 0.0025, t_2 = 0.4027 and $t_1.t_2$ = 0.0017 are significant since the probability p = 0.00000 << 0.05. Fisher's criterion F(3, 83) = 33.201 and its corresponding probability p = 0.0000 << 0.05 indicates that the model is significant. In different harvesters the model takes the form:

$$T1 = -11.7884 + 0.0025.t_1 + 0.4027.t_2 + 0.0017.t_1.t_2 \quad (1)$$

Table 1. Results of the multivariate regression analysis of the effect of the times t_1 and t_2 on the harvester waiting time (harvester idle time for unloading the hopper - T1)

	Regression summary for Dependent Variable: T1 (Spreadsheet 1) R = .73855500 R^2 = .54546348 Adjusted R^2 = .52903445 F(3, 83) = 33.201 p < .00000 Std. Error of estimate: 32.994					
N=87	Beta	Std. Err. of Beta	B	Std. Err. of B	t (143)	p-level
Intercept			- 11.7884	18.49816	- 0.637276	0.525699
t_1	0.004944	0.133119	0.0025	0.06662	0.036812	0.970724
t_2	0.418494	0.176805	0.4027	0.17015	2.366984	0.020261
t_1*t_2	0.386014	0.171470	0.0017	0.00075	2.251196	0.027016

Statistically reliable strong correlations can be found between harvesting time and idling time, as well as between fuel consumption during harvesting and idling modes. On average, roughly 20% of the operating time consists of idling and roughly 15% of transportation; moreover, roughly 14% of the diesel fuel is used per year in the aforementioned engine modes (Savickas et al., 2020). Tihanov (2018) found out that in 49% of the duration of the operations the drivers of the transport vehicles wait before going to the grain harvester.

Mihov (2013) proposed a criterion for evaluating the efficiency and optimization of the quantity of the main and service machines in their joint work in harvesting cereals.

The graphical representation of the regression model for *T1* (harvester idle time for unloading the hopper) was made by taking into account the effect of the times t_1 (time from activation of the harvester alarm to the start of the vehicle) and t_2 (time from the start of the vehicle until it arrives under the harvester unloading auger). Figure 1 presents graphically the response surface for *T1*= *f*(t_1 , t_2). On Figure 1 it can be seen that the change in the harvester idle time for unloading the hopper (*T1*) depends on the vehicle position in the field (t_1) and the time for moving them to the unloading auger of the grain harvester (t_2). The duration of this operation can be minimized by the proper operation of harvester operators and vehicle drivers and the correct setting of the sensor for the first level of hopper filling. The figure shows that the waiting time (*T1*) is of the highest duration due to incorrectly configured sensors. In fact, the drivers of the vehicles decide for themselves when to go to the grain harvesters after activating the signal light. It is also apparent that the minimum time values are about 50 *s* and the maximum ones - 350 *s*.

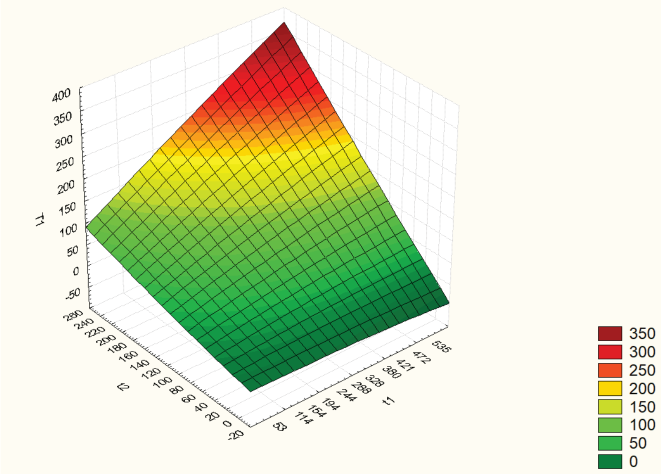

Figure 1. Change of harvester idle time for unloading the hopper (T1), depending on the time from activating the alarm to the start of the vehicle (t_1) and the time from the start of the vehicle to its arrival under the unloading auger of the grain harvester (t_2) in different harvesters

On Figure 2 the lines of the same response *T1*= *f*(t_1, t_2) = *const* are graphically shown for the mathematical model obtained for the harvester idle time for unloading the hopper - *T1*.

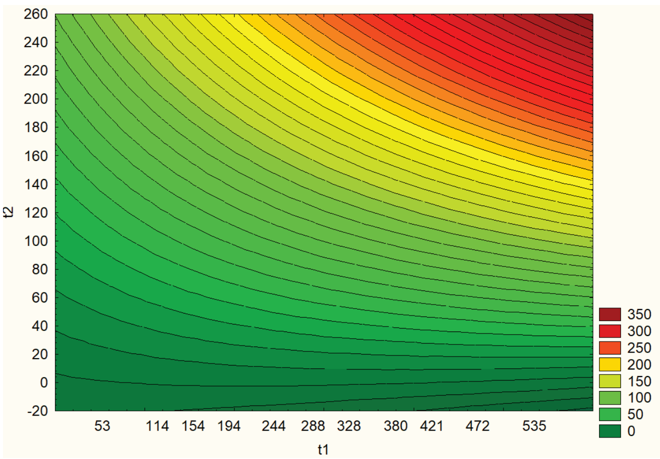

Figure 2. Lines of uniform response to the harvester idle time for unloading the hopper (T1), depending on the time from activation of the alarm to the start of the vehicle (t1) and the time from the start of the vehicle to its arrival under the unloading auger of the grain harvester (t_2)

On Figure 2 it can be seen that the results obtained for the two parameters - the time from activation of the alarm to the start of the vehicle and the time from the start of the vehicle to its arrival under the unloading auger of the grain harvesters can be used to optimize the transport service. These results can also be used to minimize the cost of the harvesting process. The figure shows the scope of change of factors in which the parameter has the highest values. This happens when both factors are at their upper levels.

Conclusion

Based on the results obtained it was found that: (i) the effect of the vehicle travel time on the harvester idle time for unloading the hopper is significant; (ii) the coefficient of determination value (R^2=0.54) shows that 54% of the change of *T1* is due to the change of material times and 46% to the effect of unmanageable factors; (iii) the change in the harvester idle time for unloading the hopper (*T1*) depends on the vehicle position in the field (t_1) and the time for moving them to the unloading auger of the grain harvester (t_2); (iv) the waiting time (*T1*) is of the highest duration due to incorrectly configured sensors located in the grain harvester hopper. The results obtained can be used to minimize the cost of the harvesting process.

References

Bochtis D, Vougioukas S, Tsatsarelis C and Ampatzidis Y, 2007. Optimal dynamic motion sequence generation for multiple harvesters. Agricultural Engineering International: the CIGR Ejournal, Manuscript ATOE 07 001, IX.

Buckmaster D and Hilton J, 2005. Computerized cycle analysis of harvest, transport, and unload systems. Computers and Electronics in Agriculture 47, 137-147.

Dinov D and Monev I, 1979. Mechanization of the agricultural industrial production. Zemizdat Publ. house, Sofia, Bulgaria (Bg).

Delchev N and Trendafilov K, 2015. Structural analysis of the operations and time for tank unloading of grain harvesters. International Journal of Science and Research (IJSR), 4, 1890-1894.

Eliseev BG, Labodaev VD and Chernomorets NA, 1984. Use of transport in agriculture, Minsk, Uradzhay (Ru).

Jansen MAF, Bochtis D, Sørensen CG, Blas MR and Lykkegaard KL, 2012. In-field and inter-field path planning for agricultural transport units. Computers & Industrial Engineering, 63, 1054-1061.

Li Yu, Yi Shu, Song Hai and Liu Na, 2013. Control of crop harvesting and transport process by Kanban mechanism. The Open Automation and Control Systems Journal, 5, 67-72.

Lkhagvasuren S, 2013. Results of comparative study on performance parameters of grain harvesting combine utilized in Mongolia. In: Proceedings of the International Scientifically-practical Conference of Young Scientists "Scientific Research and Development in the Agricultural-industrial Complex", 17-18 April, Part II, pp. 233-236.

Mandradzhiev S, 2006. Agricultural machinery, Plovdiv, Bulgaria (Bg).

Mitkov A, 2011. Experimental theory. Dunav press, Ruse, Bulgaria (Bg).

Mihov M, 2013. Mathematical model for optimization of the operation of servicing machines in harvesting production. Agricultural Mechanization, 6, 11-15.

Petrovna K, 2014. Increase of efficiency in using grain harvesters at the expense of optimizing energy loss under the conditions of Amur region. Thesis for MSc (Technical Sciences), Blagoveshtensk, Russia, 20 (Ru).

Savickas D, Steponavičius D, Kliopova I and Saldukaitė L, 2020. Combine harvester fuel consumption and air pollution reduction. Water, Air & Soil Pollution, 231, 1-11. doi: 10.1007/s11270-020-4466-5

Tihanov G, 2017. Study of the time for unloading grain harvester hoppers at standstill in relation to optimizing their output. Thesis for PhD, University of Ruse “Angel Kanchev” (Bg).

Tihanov G, 2018. Study on the duration of operations performed by transport vehicles during unloading of the grain harvester hopper. Applied Researches in Technics, Technologies and Education, 6, 232-236.

Tihanov G, 2019. A grain harvester performance according to unloading time and modes. Agricultural Science And Technology, 11, 59-62.

Vezirov Ch, **Velikova D and Hristov Hr**, 2014. Scientific works of Ruse University, 53, series 1.1, 72-77 (Bg).

Webster KE, Darr MJ and Peyton KS, 2012. Single-pass baling productivity and grain logistics analysis. Agricultural and Biosystems Engineering. Conference Proceedings and Presentations, Iowa State University, USA, Paper number: 12-1337653. http://lib.dr.iastate.edu/abe_eng_conf/292.