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# A study on the unloading screw operating modes of the Claas Lexion 540 and Claas Lexion 660 grain harvesters at wheat harvesting

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## Abstract

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A study has been conducted on two Claas Lexion 540 and 660 harvesters under different operating modes of the unloading screw. By chronometer, the time for emptying the cereal hopper was measured. This time in the Claas Lexion 540 harvester was reported in the three unloading modes of the grain hopper with crankshaft speed of 1031, 1650 and 2271 $min^{-1}$ and Claas Lexion 660 harvester unloading was reported at nominal crankshaft speed. It was found that: (i) the actual rotation speed of the unloading screw of the Claas Lexion 540 harvester is less than the theoretical one by 6.1%-6.8% when unloading the hopper in the three unloading modes of the crankshaft at 1031, 1650 and 2271 $min^{-1}$; (ii) when emptying the hopper at nominal rotation speed (2271 $min^{-1}$), the actual flow rate of the unloading screw is 84% of the theoretical one, and at minimum rotation speed 1031 $min^{-1}$ is 49%; (iii) the actual unloading time is 19-105% longer than the theoretical one at the at nominal and minimum crankshaft speed respectively; (iv) when unloading the hopper in motion of Claas Lexion 660 harvester, the designed flow rate was not reached, but only 84% of the unloading screw flow rate; (v) the main reason for incomplete use of the unloading system is incorrectly regulated position of the grain flow flaps.

*Keywords:* grain harvester; unloading screw; hopper unloading; productivity

## Introduction

From 1/4 to 1/3 of the arable land in Bulgaria annually is sown by cereals, and their harvesting is an important element of the whole technology in their cultivation, which in 92% is made with grain harvesters (Tihanov, 2017). The harvest of grain crops should be done in a short time to prevent the losses of crumbling down the grain and possible damages from unfavorable conditions (Delchev et al., 2016, Trendafilov et al., 2017, Dragoev, 2018a,b).

The grain hopper unloading systems of the combine harvesters consist of several consecutively operating screws located at different angles in the hopper space (Trendafilov et al., 2017). These systems are simple by device, easy to actuate and do not require special maintenance (Cole, 2002). The requirement is to have high flow rate in order to empty the hopper for a short period of time and thus provide greater hourly and daily productivity, especially when unloading hoppers at a standstill (Delchev & Trendafilov, 2002). Usually, designers match the screw flow rate to the volume of hopper, so that at 15% grain moisture the emptying to be done for 1.5-2 min (Isaacson, 1976). It has been found that dry grain damages (with low humidity) are minimum when using the maximum flow rate of the screw (Sands & Hall, 1971). It has been established that the screw slope angle has a significant effect on its flow rate, but almost no effect on grain damaging (Hall, 1974).

The main characteristic of the unloading system of grain hoppers of the harvesters is their flow rate, which is indicated as the flow rate of the unloading screw in L/s. In fact, this flow rate is maximum possible and is reached at engine nominal rotation speed. This is the rotation speed that drives all the mechanisms and systems in the harvester. When emptying the grain hopper in motion and properly well-adjusted flaps, the system‘s designed flow rate is practically used.

In more than 90% of the cases in Bulgaria the grain harvesters unloading are mostly done in a standstill (Tihanov, 2017). In this case, operators usually do not use the engine nominal speed but lower. Compared with unloading in motion, this can lead to a significant productivity reduction depending of the hoppers volume (Delchev & Trendafilov, 2002; 2015).

One of the process operations of hopper emptying is its unloading, i.e. the time from switching on the unloading screw to its shutting down. The duration of this operation depends on the parameters of unloading screw, the grain hopper volume and the grain harvester unloading mode, i.e. of the screw shaft rotation speed (Delchev & Trendafilov, 2015). According to some studies, the actual unloading time is 42.8% of the theoretical one and an average of 73.1% of the theoretical flow rate of the unloading screw is used (Trendafilov et al., 2017). These tests were performed in a real production conditions without taking notice of the engine crankshaft rotation speed during unloading. Other authors have carried out a study of the unloading of the Claas Lexion 570 harvester hopper in a standstill at wheat harvesting under the three emptying modes of the hopper (Dragoev, 2018a,b). The results obtained show that the reduction of the engine crankshaft rotation speed also reduces the flow rate of the unloading screw.

The objective of this study is to investigate the unloading screw operating modes of the Claas Lexion 540 and Claas Lexion 660 grain harvesters when unloading in a standstill and in motion at harvesting wheat.

## Materials and Methods

The study was carried out during the harvest campaign of 2018 on the fields of Byalo pole village, Opan municipality. Two Claas Lexion 540 and Claas Lexion 660 grain harvesters were included in the study. The Claas Lexion 540 harvester harvested *Renaissance* wheat at an average yield of 6.6 t/ha, and the average humidity measured by the combine on-board moisture meter – 12.2%. With the Claas Lexion 660 harvester, wheat of the *Sobel* variety was harvested, with the average yield being 5.2 t/ha and the average moisture reported by the combine board moisture meter 11.9%. The two combines have the following technical parameters: working width of the headers 6.60 m; grain hoppers volumes of 8.6 and 10 $m^3$ and unloading screw flow rates of 100 and 110 L/s.

Unloading of the grain hopper of harvester Claas Lexion 660 was made at standstill and of harvester Claas Lexion 540 it was made in motion. The two grain harvesters had two levels of signaling to fill the hopper. By the chronometer was measured: $t_D$ – the emptying time of the combine grain hopper, s. This time is measured from turning the unloading screw on until it is switched off. By measuring the time $t_D$, it is assumed that the hopper is filled to 100% of its volume as the full grain hopper signaling has been switched on. This time in the Claas Lexion 540 harvester was recorded under the three 1031, 1650 and 2271 $min^{-1}$ crankshaft speed modes at unloading the grain hopper. The Claas Lexion 660 harvester was unloaded at nominal crankshaft speed. Fig. 1 shows the control panel of the combine harvester and the switch for adjusting the speed. The screw shaft rotation speed was measured with a DT-2234C+ digital counter.


**Fig. 1. Control board:**
***1* – crankshaft speed control switch**

The theoretical time for emptying the cereal hopper using the design flow rate of the screw is calculated using the following formula:

$$t_K = V/q_K, s, \quad (1)$$

where $V$ is the volume of the grain hopper at the various combines, L;

$q_K$ – design flow rate at different combines, L/s.

The actual time for emptying the grain hopper is determined by measuring the time between switching on the unloading screw to its shutdown. The average value measured for the respective combine harvester is used to determine the actual flow rate of the unloading screw:

$$q_D = V/t_D, l/s, \quad (2)$$

where $q_D$ is the actual flow rate of the unloading screw, L/s;

$t_D$ – average value of the actual emptying time of the combine grain hopper, s.

**Table 1. Technical parameters of Claas Lexion 540 grain harvester and results of the study**

| Marking | Engine rotation speed | Indicators | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Unloading screw rotation speed without material for unloading | Unloading screw rotation speed when emptying the hopper with wheat with humidity 12.2 % | Constructive flow rate of the unloading screw | Teoretical time for unloading the hopper | Average actual time for unloading the hopper | Actual flow rate of the unloading screw | Using of flow rate of the screw | Increase of the time for unloading |
| | n, $min^{-1}$ | n, $min^{-1}$ | n, $min^{-1}$ | $q_k$, l/s | $t_k$ , s | $t_D$, s | $q_D$, l/s | % | % |
| Minimum revolutions | 1031 | 282 | 265 | – | – | 176 | 49 | 49 | 205 |
| Average revolutions | 1650 | 453 | 422 | – | – | 127 | 68 | 68 | 147 |
| Maximum revolutions | 2271 | 624 | 581 | 100 | 86 | 102 | 84 | 84 | 119 |

The percentage of using of the unloading screw flow rate is calculated by the following formula:

$$q_{\%} = q_D/q_K.100, \% \quad , \tag{3}$$

The percentage of increasing the emptying time of the grain hopper relative to the theoretical one is calculated using the formula:

$$t_{\%} = t_D/t_K.100, \%, \tag{4}$$

## Results and Discussions

Table 1 shows the results of the Claas Lexion 540 grain hopper emptying time study at the different engine rotation speed. It also lists the results for the estimated theoretical emptying time of the hopper using the design flow rate of the unloading screw, the average emptying time of the hopper and the actual flow rate of the screw.

It can be seen from the table that the change of engine crankshaft rotation speed of the harvester results in a significant change in the flow rate of the unloading screw and the emptying time of the grain hopper. The average theoretical time for emptying the hopper of the Claas Lexion 540 harvester is 86 s, i.e. the designed volume and the unloading screw flow rate of the hopper allows emptying the grain hopper within 2 min.

Fig. 2 graphically shows the variation of the unloading screw rotation speed according to the engine crankshaft rotation speed. It can be seen that between the two parameters there is a linear dependence. At minimum (1031 $min^{-1}$) and at maximum rotation speed (2271 $min^{-1}$) of the engine crankshaft, it can be seen that the unloading screw rotation speed with material decreased respectively with relative to the rotational speed of the screw without material. In relative values the decrease in the rotation speed of the emptying of the hopper is 6.1% and 6.8%, respectively.

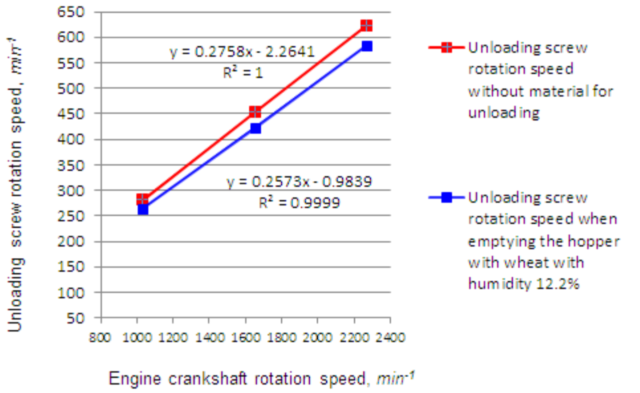


**Fig. 2. Change of rotation speed of the unloading screw depending to the engine crankshaft speed of Claas Lexion 540**

Fig. 3 shows the variation of the flow rate of the Claas Lexion 540 harvesters unloading screw. The figure shows that the actual flow rate is 84 L/s at nominal crankshaft speed of 2271 $min^{-1}$. Decreasing the flow rate of the unloading screw is leads to an increase in the emptying time of the grain hopper.

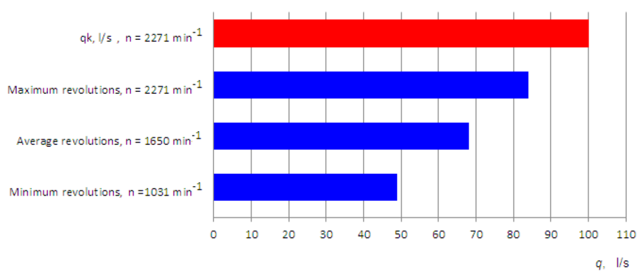


**Fig. 3. Modification of screw flow rate of grain harvester Claas Lexion 540**

Fig. 4 shows the variation of the hopper emptying time at the different crankshaft speed of the engine. It can be seen that at a nominal rotation speed 2271 $min^{-1}$, the theoretical emptying time of the hopper is 86 s and the actual is 102 s, i.e. the actual emptying time is 16% greater than the theoretical one. The actual emptying time of the hopper at 1031 $min^{-1}$ is 57.9% greater than the emptying of the hopper at 2271 $min^{-1}$.

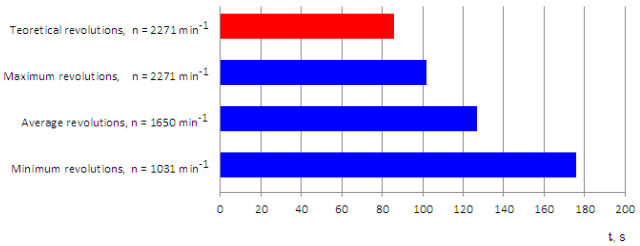


**Fig. 4. Changing the hopper emptying time of the Claas Lexion 540 grain harvester**

Table 2 shows the results of the Claas Lexion 660 grain hopper emptying time study when unloading the hopper in motion. It also lists the results for the calculated theoretical time for emptying the cereal hopper using the design flow rate of the unloading screw, the measured average emptying time of the grain hopper and the actual unloading flow rate determined by the unloading screw.

The table shows that the average actual emptying time for the hopper is 109 s. Fig. 5 graphically shows the theoretical and actual emptying time of the hopper of harvester. The average overrun of the constructive possible time of the combine is 18 s, i.e., the unloading time is increased by the theoretical one by 19%.

Fig. 6 graphically depicts the designed and the actual flow rate of the unloading screw in a harvester.

It is seen that the actual flow rate is less than the design flow rate, which is opposite the emptying time of the hopper 84% of the unloading screw flow rate is used. The emptying of the hopper is carried out at nominal engine speed. The incomplete use of the unloading screw flow rate and hence the longer unloading times are mainly due to improperly regulated grain flow flaps of the unloading system. Therefore, the

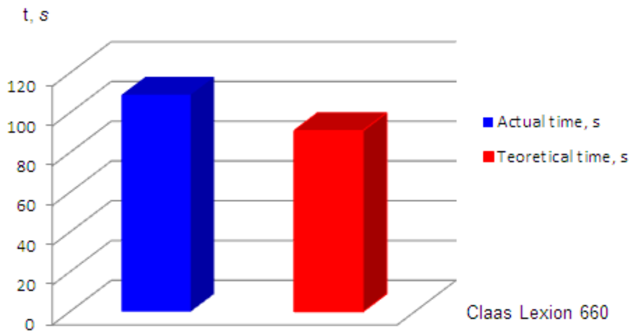


**Fig. 5. Actual and theoretical time for emptying the grain hopper of the Claas Lexion 660 harvester**

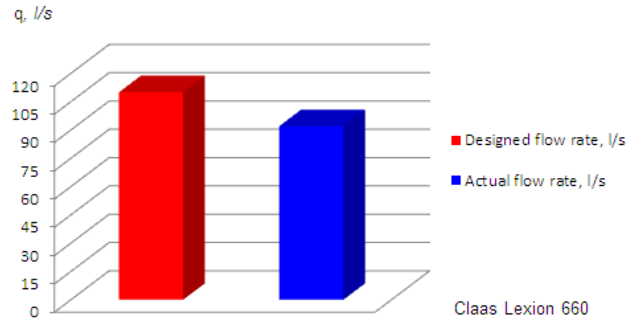


**Fig. 6. Designed and actual flow rate of the unloading screw**

design flow rate of the unloading system is not used and the unloading time is increased. This is leads to a decrease in the daily productivity of a grain harvester.

## Conclusions

It has been found that: (i) the actual unloading screw rotation speed is less than the theoretical one by 6.1%-6.8% at unloading in the three unloading modes of the hopper with crankshaft speeds of 1031, 1650 and 2271 $min^{-1}$; (ii) when emptying the hopper at nominal speed (2271 $min^{-1}$), the actual unloading screw flow rate is 84% of the theoretical one and at a minimum speed of 1031

**Table 2. Technical parameters of the Claas Lexion 660 grain harvester and results of the study**

| Marking | Indicators | | | | | | |
|---|---|---|---|---|---|---|---|
| | Volume of the hopper V, *l* | Constructive flow rate of the unloading screw, $q_k$, *l/s* | Teoretical time for unloading the hopper, $t_k$ , *s* | Average actual time for unloading the hopper, $t_D$, *s* | Actual flow rate of the unloading screw, $q_D$, *l/s* | Using of flow rate of the screw, % | Increase of unloading time, % |
| Maximum revolutions | 10 000 | 110 | 91 | 109 | 92 | 84 | 119 |

min$^{-1}$ is 49%; (iii) the actual unloading time is 19-105% greater than the theoretical one at the nominal and minimum crankshaft rotation speed respectively; (iv) when the hopper is unloaded in motion, the designed flow rate is not reached, but only 84% of the unloading screw flow rate; (v) the main reason for incomplete use of the unloading system is that the position of the grain flow flaps is not correctly adjusted.

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