EVALUATION OF COMBINE HARVESTER FUEL CONSUMPTION AND OPERATION COSTS

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Abstract. The aim of this paper is a comparison of the operating parameters of combine harvesters on a selected farm. The working parameters were measured and evaluated on combine harvesters of the CLAAS and CASE IH brand by different ages and different concepts of threshing. Measuring took place in the season of 2013 and 2014 (Lexion 770 in 2012 too). Working parameters in this case mean the performance and economic indicators of the operation, i.e., the fuel consumption and operational costs. Performance of the machines was measured per hectare, number of harvested hectares per day, respectively per hour or season. Fuel consumption was measured in litres and converted per hectare. Costs are calculated as fixed and variable and then summarized as total cost for a given machine.

Key words: Claas, Case IH, New Holland, combine harvester, harvesting, performance, fuel consumption, costs.

Introduction

Combine harvesters play a crucial role of grain harvest. That is the reason that today they are very widespread in agricultural production companies as well as in service companies of agricultural machinery. Wide use of a self-propelled combine harvester started in 1938 [1]. Since then, the combine harvesters have undergone development of structural elements, which resulted in increasing throughput materials through combine harvesters. Self-propelled harvesting combines are the key machines to realize performance in grain harvesting. Currently the development focuses on increasing productivity, user comfort and improvement of energy efficiency in particular without changing the well-known concept of a self-propelled and fully to the task tailored single machine. In the last two decades the development of combines was characterized by the improvement of productivity and efficiency driving an increase of size and total weight of the machines and the application of growing engine power [2].

Investigation in the new concept of harvesting machines is concentrated on increasing productivity and efficiency [3].

It is possible to say that mechanization of the threshing process was the major step forward in the 20th century. Power availability from the combustion engine and development of machines which combine cutting, threshing and cleaning within one machine is the biggest benefit to contemporary agriculture. Fig. 1 shows an overview and a linear extrapolated forecast on a representative European line-up of combine harvester technology [2].

Combine harvesters have also been evaluated according to a different concept of grain threshing and separation. Depending on the direction of the material flow through the threshing mechanisms the combine harvesters are described as tangential (direction of flow in the tangent of the threshing drum) and axial (flow of material in the direction of the axis of the threshing-separating drum). According to Kumhála et al. [4] combine harvesters could be termed “conventional” and “unconventional“. By the conventional combine harvesters they mean all the classic technological conceptions, using the tangential way of threshing and keyboard straw walkers. By the conventional combine harvesters they mean all the other machines that use axial rotational elements for both separation of grain or grain threshing and separation. The third group of combine harvesters has a tangential threshing system but separation is equipped by an axial unit (one or two rotors). Rotary separators, both axial and tangential, appear better suited to handling stripped material than straw walkers do because their more aggressive action teases out the material and allows easier release of the grain [5].

The performance of a combine harvester is determined by the maximum throughput at acceptable grain losses. At optimum throughput, the cleaning system reacts very sensitive to variations of the inclination, whereby the influence of lateral inclination is much higher than the influence of longitudinal inclination [6]. By harvesting the sloped field the operator must take more care to set up the machine according to the value of grain losses. The influence of longitudinal inclination is marginal.

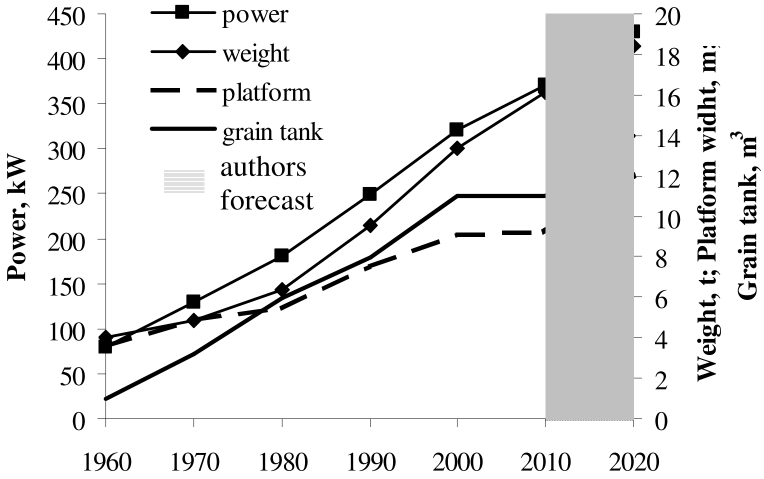

Fig. 1. **Combine growth 1960 till today and forecast to 2020 [2]**

The combine harvester has a seasonal work characteristic in only a few weeks or months in a year. To buy a new combine harvester is a big investment. For economic efficiency it is recommended to provide the highest possible performance with the lowest possible operating costs. It means to harvest as much as possible area. There is very high influence of fuel consumption to the total cost [7]. In the article evaluation of costs and fuel consumptions of different types of combine harvesters equipped with different systems of threshing and separation are described.

Materials and methods

The working parameters were measured in the cooperatives on Claas combine harvesters of different ages and of different conceptions of threshing (Fig. 2), specifically tangential threshing concept Claas Mega 208 and hybrid concept (tangential threshing with double axial rotors) Claas Lexion 600 and Claas Lexion 770. The measurements were carried out at harvests of cereals, specifically spring barley (variety Sebastian, average yield 6 $t \cdot ha^{-1}$, average moister content 12.3 %), winter wheat (variety Sultan, average yield 8.4 $t \cdot ha^{-1}$, average moister content 11.8 %) and winter rape (variety Ladoga, average yield 3.6 $t \cdot ha^{-1}$, average moister content 10.2 %). The Claas Lexion 770 was compared with the CASE AF 9320 combine harvester in spring barley harvest. In all measurements the combine harvesters were on the same field together. The total area harvested for evaluation was cca 50 ha for every crop. The working parameters evaluated are the fuel consumption, performance, losses and costs of individual combine harvesters.

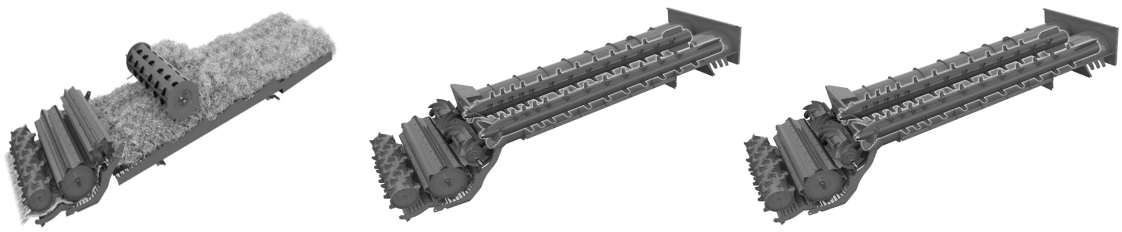

Fig. 2. **Working mechanisms of Claas combine harvester:**
from left Mega 208, Lexion 600 and Lexion 770 [8]

Fuel consumption

Total daily fuel consumption (Q_{Total}) was measured every morning when refuelling the tank of the combine harvester. It was daily filled with diesel fuel by the fuelling nozzle up to the fuel tank filler neck. The volume of refuelling fuel was recoded. The total consumption was divided per harvested hectare and per kilometre travelled.

Consumption per kilometre was measured as follows.

- Filling up to the fuel tank filler neck.
- Travelling distance of the combine harvester coupled with cart with a header.

- Refilling to the fuel tank filler neck and recoding of the volume.

$$Q_{km} = \frac{q_p}{S}, \tag{1}$$

where Q_{km} – fuel consumption per kilometre, $l \cdot km^{-1}$;
q_p – fuel consumed, l;
s – distance travelled, km.

The consumption per hectare has been already calculated from the total daily consumption (see formula 2). The daily harvested area was read from the CEBIS board system.

$$Q_{ha} = \frac{Q_{Total} - (Q_{km} . s_d)}{A_d}, \tag{2}$$

where Q_{ha} – fuel consumption per 1 ha of the harvested area, $l \cdot ha^{-1}$;
Q_{total} – total daily fuel consumption, l;
s_d – daily travelled distance, km;
A_d – daily harvested area, ha.

Performance

The data about the performance connected with the total harvested area were achieved from the board system CEBIS (or AFS by Case) after each harvested plot. The system can read the working width of the header in steps (or rows for row crop adapter) thereby allowing measuring the harvested area precisely even in case of irregular shape of plots (wedges, narrow lanes etc.).

Costs

Total cost C_{Total} expended on the machine is calculated as a sum of fixed and variable costs.

$$C_{Total} = C_F + C_V, \tag{3}$$

where C_F – fixed costs;
C_V – variable costs.

Fixed costs C_F calculated using (4):

$$C_F = C_D + C_I + C_G, \tag{4}$$

where C_D – depreciation;
C_I – insurance;
C_G – garage place;

Variable costs C_V calculated using (5):

$$C_V = C_{FC} + C_{RS} + C_{LO}, \tag{5}$$

where C_{FC} – fuel costs;
C_{RS} – costs of repairs and servicing;
C_{LO} – labour costs for operators of the combine harvester.

The costs of maintenance, repair and service, labour cost were read from the company accounting system. The average grain moisture and average crop yield which are important for influencing the fuel consumption and performance parameters were taken from the board information system CEBIS by Claas and AFS by Case.

Losses are evaluated during the harvest – there was signed a sheeted area perpendicular to the driving direction. From this sheet grain losses after taking out the straw were collected. The collected material was cleaned in laboratory and then the weight of grains was determined. After that relative losses compared to the total grain yield were calculated.

Results and discussion

Fuel consumption

Results shows that consumption per 1 kilometre travelled is on average value 1.1 $l \cdot km^{-1}$ for all the measured combines. For new models it is a little lower, but not significantly. As there was not a long distance between the harvested fields, the fuel consumption was not so important. Consumption for working on the field is very important. Fig. 3 shows a difference in consumption between the tangential and axial system of threshing in spring barley harvest. An interesting fact has appeared that consumption of the axial system is about 5 % lower than of the tangential threshing system. The difference may be affected by a different width of the header and the difference in the power engine system. There is not statistically significant difference in fuel consumption. The energy demand of the tangential threshing system is lower, but axial separation affected the increasing of fuel consumption caused by the energy demand of this kind of separation process.

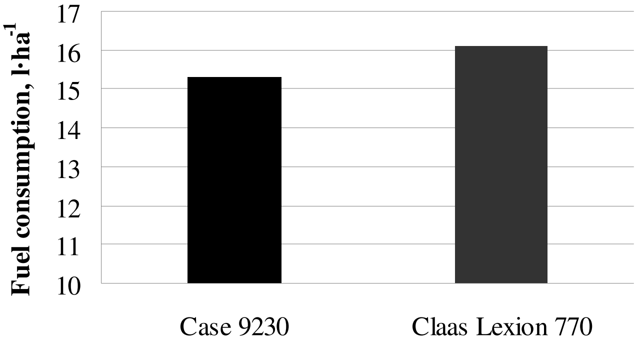

Fig. 3. **Fuel consumption of Case 9230 and Claas Lexion 770 in spring barley harvest**

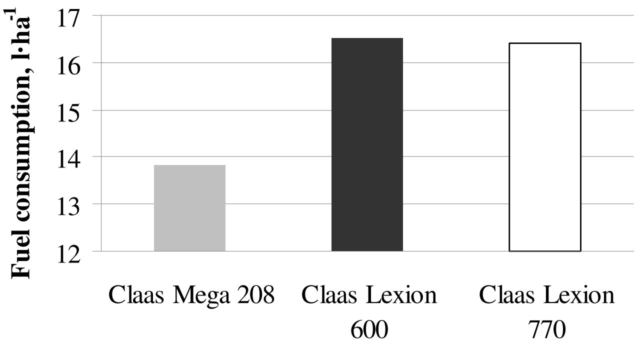

Fig. 4. **Evaluation of fuel consumption – Claas Mega 208, Lexion 600 and Lexion 770 in winter wheat harvest**

ClaasMega 208 showed minimal fuel consumption per harvested hectare due to a less powerful aggregate and different separation technologies where straw walkers have less power demand than the axial separation rotors. Comparison in Fig. 4 shows that Lexion 600 has the greatest fuel consumption. Comparing the two Lexion models 600 and 770 it is not true that a powerful power engine leads to greater fuel consumption. In this case, the result of lower fuel consumption by Lexion 770 is due to a wider header than by the Lexion 600, but it is no statistically significant at the chosen significance level.

Performance

Fig. 5 shows the difference in performance between the classical tangential system (Mega 208) and the hybrid system (tangential threshing with axial separation). The machine equipped with the hybrid system (Lexion 600 and 770) achieved a higher level of material throughput. The difference in throughput between Lexion 600 and Lexion 770 is due to different width of the header and power engine.

During performance evaluation the evaluation of grain losses was accented, too. Fig. 6 presents the results of Claas group evaluation. All machines in this group have relative losses lower than 1 %.

Comparison of relative grain losses of Lexion 770 and Case 9230 in spring barley harvest are below 1 %, too.

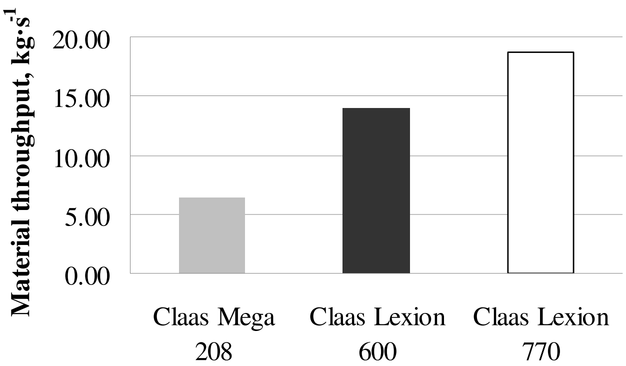

Fig. 5. **Material throughput – winter wheat harvest**

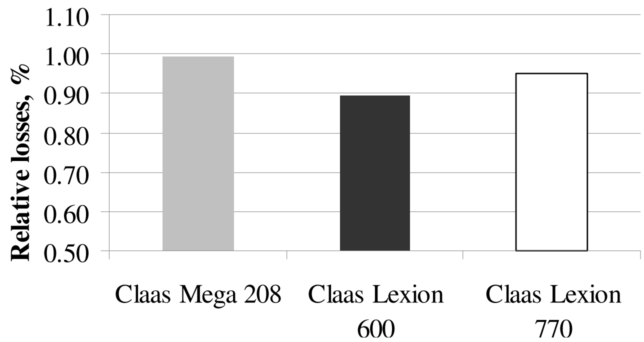

Fig. 6. **Relative losses of grain (winter wheat)**

For evaluation of grain losses in winter rape harvest all evaluated combine harvesters worked on the same field. The results (Fig. 7) show that all combines had relative losses level below 1 %. The best results were achieved by Claas Mega 208 (0.63 %). But in this case we have to evaluate the throughput of material. Lexion 770 (21.72 $kg \cdot s^{-1}$) had the highest throughput, Lexion 600 and CASE 9320 were on the same value 19.3 $kg \cdot s^{-1}$, and the lowest level was achieved by Mega 208 – 6.85 $kg \cdot s^{-1}$.

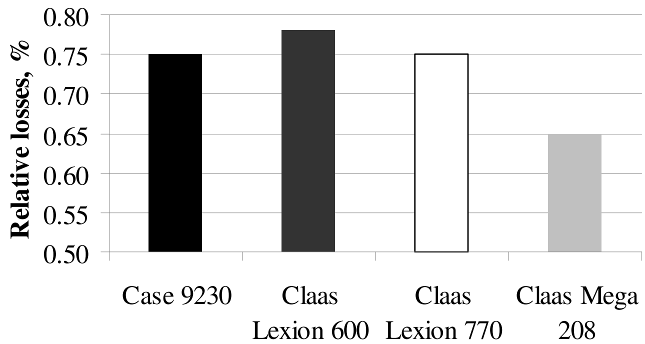

Fig. 7. **Relative losses of grain (winter rape)**

The results of cost analysis are depending in terms of annual utilization of the machine. There is a big influence of the depreciation period. According to the Czech Act on Accountancy it is 5 years, but in practice the technical life is longer, typically 8 to 9 years. During longer time the amount of the annual fixed cost is lower for every year; that means a positive benefit on economic evaluation of operation costs. Fig. 8 shows the influence of the depreciation period on minimal annual performance (*rW*).

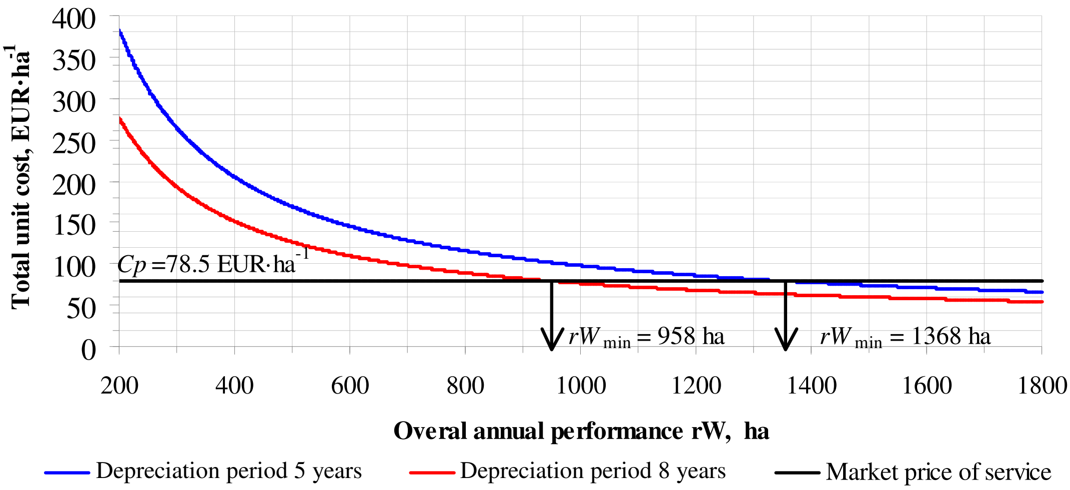

Fig. 8. **Total unit cost dependence on annual performance of Claas Lexion 770 by different depreciation periods (C_p – average price of harvesting service)**

Conclusions

The throughput of material during threshing and performance of combine harvesters depends on different age of the machine, different concepts of threshing and the separating mechanism. The measurements showed that the measured parameters are depending on the conditions of the season, especially on the condition of crop vegetation, i.e., the proportion of the grain and straw yield.

Typically the oldest tangential combine harvester Claas Mega 208 had on average hourly performance of 1.5 $ha \cdot h^{-1}$, the newer concept of Claas Lexion 770 had an average hourly performance of 4.2 $ha \cdot h^{-1}$. The performance is closely related to fuel consumption. Our research confirmed higher energy demands of the axial concept of threshing (Case) and separation (Lexion 600, 770) according to the conventional threshing system. Beneficial effect of the working width of the header is confirmed. To compare Lexion 600 and 770 despite the higher power of Lexion 770 power engine, the fuel consumption per hectare harvested is lower due to using larger width of the header.

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