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Reducing fuel consumption for chopping maize with a self-propelling forage harvester

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Study on behalf of Busatis Austria

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Reducing fuel consumption for chopping maize with a self-propelling forage harvester

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Abstract

First, operators of forage choppers have been surveyed about their schemes for knife grinding and clearance adjustment. The results show, that there is a great variability. Operators are grinding from 1 to 6 times per day with 1 to more than 75. About 75 % of the operators are immediately adjusting the clearance after grinding. Second, field tests have been carried out with a forage harvester (372 kW). Fuel consumption, driving speed, knife wear, parameters of the chopped maize, and other data have been measured. The highest influence on the specific fuel consumption (litre fuel per ton of chopped maize) was caused by the throughput (R^2 > 90 %). Therefore, for reducing the fuel consumption the throughput has to be maximized. With the test machine up to about 50 ha of maize could be chopped without grinding and without a significant increase in fuel consumption or loss in chopping quality. This means that for these tests the grinding had to be carried out only every second day and with 10 cycles at most. Therefore, many operators have to change their schemes for grinding intervals and intensities.

1. Introduction and objectives

Forage chopping is very energy-intensive due to the large amount of energy that must be spent to reduce the forage to small particles. Chopping is achieved on most machines by slicing the material between moving knives on the periphery of a rotating cylinder and a stationary cutterbar. The highest energy efficiencies, productivities, and quality of cutting are achieved when the edges of the knives and cutterbar are sharp and then they are aligned with little clearance [1-9]. Knowing these issues, contemporary forage harvester operators frequently sharpen their knives and adjust their cutterbar. However, even automated sharpening with its short cycle time negatively impacts productivity by causing the harvesting to be paused for the sharpening operation. In addition, each sharpening removes some of the life of the expensive knives.

Many of the above mentioned studies were conducted some time ago. Due to great changes in knife design and materials, material flow changes within the harvesters, and the high flow rates of contemporary machines the current schemes for sharpening the knives in order to reduce fuel consumption may not be adequate any more.

Many operators of forage choppers have presumably developed an intuitive understanding of the need for sharpening in their conditions. So, the first objective of this research was to carry out a survey of operators on their schemes for knifes grinding and clearance adjustment. The second objective was to study knife wear and sharpening on a forage harvester in order to optimize the effort for sharpening, increase the lifetime of the knives while gaining a good quality of cutting and keep the fuel consumption of the chopper low.

2. Survey of operators of forage harvesters

Operators of forage harvesters have been asked about their schemes for knifes grinding and clearance adjustment. The interviewed operators have been divided into two groups: “A” (n=20) and “B” (n=8). The difference between the two groups was that a couple of years before the survey operators of group “B” have been provided with information based on our experiences on strategies for grinding and clearance adjustment. With 28 interviewed operators the data is not representative, but as the results show a few conclusions can de drawn (Fig. 1-3).

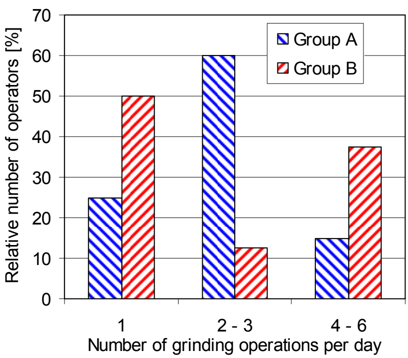

Fig. 1: Grinding operations per day

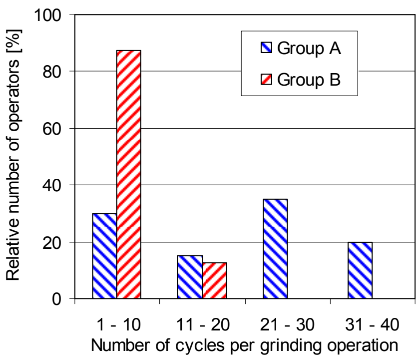

Fig. 2: Cycles per grinding operation

One of the conclusions is that there is great variability. Operators are grinding from 1 to 6 times per day. Also, the number of cycles per grinding operation has a wide spread (Fig. 2).

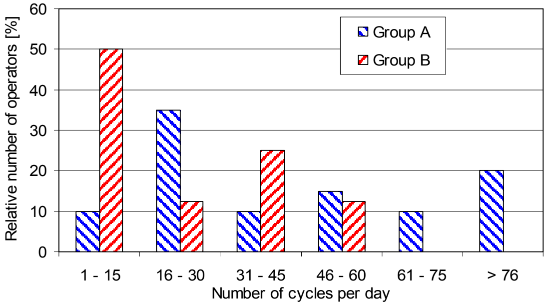

Fig. 3: Total grinding cycles per day

The total number of grinding cycles per day shows a great variability, too (Fig.3). Again, it is obvious that there are differences between group A and B. Especially by the number of cycles per grinding operation the two groups can be distinguished (Fig. 2). In summary, the operators of group B apply less cycles per day than operators of group A (Fig. 3).

For adjusting the clearance the variability is lower. About 75 % of the operators are adjusting immediately after grinding, almost 10 % carry out this task after every second grinding operation only, the remaining operators do it 2 to 3 times between grinding operations.

3. Field tests with the forage harvester

For developing a good scheme for knife sharpening and clearance adjustment for today's high-quality knives while optimizing the effort for sharpening, increase the lifetime of the knives combined with a good quality of cutting and a low fuel consumption field tests have been conducted.

3.1. Material and method

The chopper used for the experiments was a Claas Jaguar 950. This 372 kW machine has a cutting drum composed of 24 knives in two rows. The knives were original Claas universal knives ("J-knives") manufactured by Busatis GmbH, Purgstall in Austria. They cut against an original Claas universal shearbar ("Premium line") also manufactured by Busatis GmbH. A PC-based data acquisition system on the chopper recorded the fuel consumption, the forward speed, the pitch and roll of the harvester (for identifying flat areas in the field) and when material was flowing towards the chopping unit. All grinding operations and clearance adjustments have been logged. The radius of the cutting edge and the length of the hard facing remaining on the knife were manually determined as described in [10].

Every harvested wagon or truck load was weighed on a scale. Random samples of chopped material were selected from the load and tested for dry matter and ash content. The data were analyzed on a per-load basis. The average forage flow rate, fuel consumption, and speed were all calculated for the time when forage was being chopped. Data from headland turns and other non-productive times was not included in any of the analysis. The chopper was used to gather data during the maize harvest in 2008 near Dresden. The theoretical length-of-cut was 12 mm with a few loads being done at 14 mm. Most of the corn had a dry matter content of 31 to 33%, with all the loads falling between 28% and 35%. The ash content, including sand, was between 3.0% and 4.3%.

3.2. Results and discussion

Figure 4 shows the load-average during-chopping throughput, fuel consumption, and travel speed during a typical thirty-six-load portion of maize harvest. The knives were ground and the knife-cutterbar clearance adjusted after the 19th load.

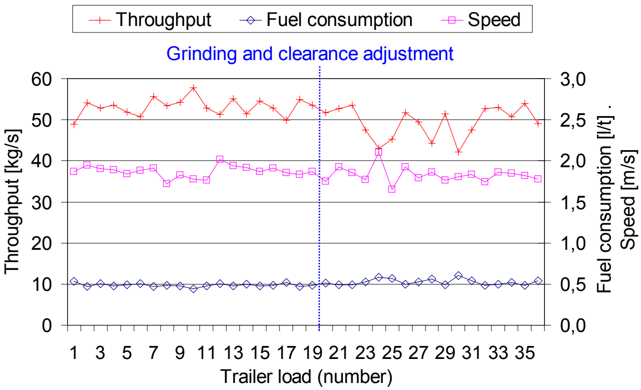

Fig 4: Typical data for maize harvest on 23 September 2008

The strongest correlation in the data was a negative linear correlation between flow rate and fuel consumption per ton. As the flow rate was increased, the diesel fuel consumption per ton harvested decreased. Figure 5 illustrates these results. Therefore, the implication is that for both maximum productivity and maximum fuel efficiency, the chopper should be operated at the maximum forage material flow rate. This negative correlation tends to indicate that there is a constant parasitic power load in operating the chopper. Besides the chopping unit, the traction drive has the highest power requirement which depends greatly on the forward speed. Therefore, the forward speed was taken into consideration (Fig 5).

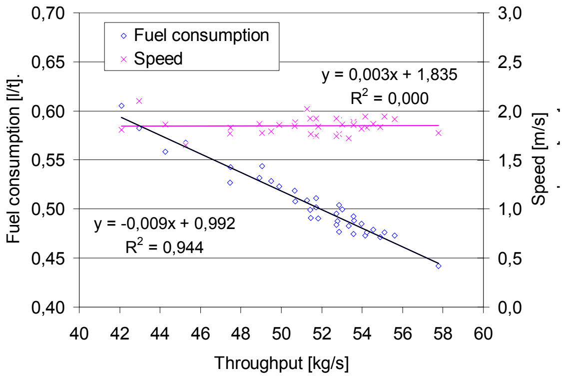

Fig 5: Fuel consumption and forward speed as a function of forage material throughput for maize harvest on 23 September 2008

As it can be seen, there is no correlation between the throughput and the forward speed. The throughput is the important influence factor. In the observed speed area the speed is of lower significance for the fuel consumption.

After the 19th load there was no decrease in the fuel consumption (Fig. 4). So, the grinding and the clearance adjustment had no effect. Therefore the radius of the cutting edges of the knives was measured. It resulted in about 0.1 mm before and also about 0.1 mm after grinding. The knives have been still sharp before grinding. The operator was grinding two times a day with 20 cycles each, which is about average in comparison with the survey data. From now on the operator started to reduce the grinding intensity (Fig. 6).

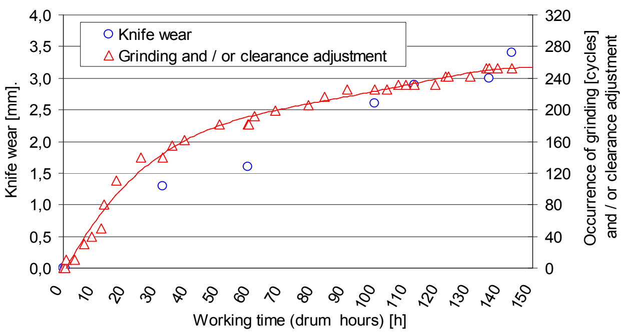

Fig. 6: Knife wear, grinding and clearance adjustment

Besides increasing the intervals between grinding, reducing the number of cycles per grinding operation the operator also adjusted the clearance between grinding operations. Finally he grinded every second day with 10 cycles at most. The resulting longer harvesting times (as much as 16 drum hours and 52 hectares) did not cause the fuel consumption to increase significantly before grinding. The total knife wear (abrasion of the hard facing) during the maize harvest in 2008 (almost 500 ha) was only about 4 mm (while 15 mm are still available on the knives).

4. Conclusions

The results show that fuel consumption is negatively linearly correlated to forage flow rate and that chopper operators should therefore try to operate at full load. The studies indicate that modern high-quality knives stay sharp for a long time. Therefore the intervals between sharpenings should be longer and the number of grinding cycles should be reduced.

5. References

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Acknowledgements

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