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Power requirement at the combine chopper

For a more efficient use of energy in combine harvesters a decoupling of the power train between combustion engine and different drives is analyzed. Therefore all power sinks and the essential load spectra for the layout of the drive system are identified. At the University of Hohenheim a combine harvester was equipped with a CAN-Bus based measurement device to determine the mechanical power at the combine chopper in action. Furthermore the effect of the chopper driving speed and the design of the blades (standard compared to paddle blade) on the power requirement were investigated and verified by a DLG e.V. straw distribution measurement device.

Keywords

Combine harvester, chopper, power requirement, CAN-Bus, measurement hub, straw distribution

Abstract

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Until today the state-of-the-art technology regarding power distribution in self-propelled combine harvesters are the V-belt or poly-V-belt drives due to their high mechanical efficiency. But space and power transfer requirements does not allow an infinitely variable adjustment for every drive unit. If a combustion engine is always operating at maximum efficiency, the variability of torque and speed is very small. One object in the development of new power trains is high flexibility in speed setting of the several drive units according to their requirements in order to maintain this most efficient operating range of the engine. First it is necessary to identify the power requirements of the several units. Especially the power consumption of combine choppers is very high, therefore this unit was chosen for the experiments to start with.

Measuring technique

To measure the torque, a measuring hub was designed which offers the possibility to run the chopper with two different pulleys at 1700 and 3400 1/min respectively, just as the original unit does. The strain gauges were applied to a thin-walled, shear force free zone of the quill shaft, **figure 1.** The data is contact-free transmitted by a telemetric system. The drive speed of the chopper shaft, necessary to determine the mechanical power, is detected by a hall generator[1].

To refer the data of the combine chopper to other measuring data, the standard CAN bus of the combine was chosen to transfer the measured data **figure 2.** As an interface a CAN module is programmed on the CAN bus to transfer the data. The resolution of the torque signal is 0–10 V with 10 bit, the smallest value is about 0,9 Nm/10 mV. The signal is available on the CAN bus with a sampling rate of max. 10 Hz. The using rate of the bus increases by 15 % points. Using the diagnostic socket, the documentation and analyse of the data is realized in the cabin with the interface CANcaseXL offered by the company VECTOR. In this interface the identifiers of all CAN nodes as well as the calculation of the chopper power (CANoe), are deposed.

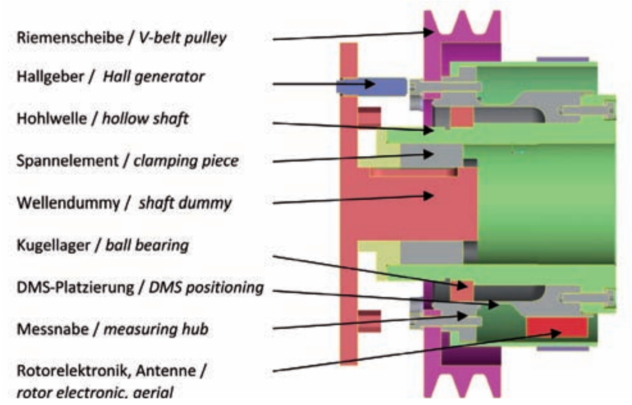
Experimental design and -analysis

The plan intends six experiments with three repetitions each **(see figure 3)**, to examine the influence of the grain throughput, the grain type and the chopper shaft speed as well as the influence exerted by the type of chopper blade to the power requirement of the combine chopper.

The experiments were realized ona barley and a wheat field,both belonging to theinvestigation farms of the University of Hohenheim. The measuring distance was 100m. The test was made during three lanes measuring the power of the chopper shaft and additionally, in the middle of the distance, the distribution of the chopped straw with a mobile straw distribution measurement device to collect the straw. This distribution measuring wagon (DMW) was provided by the DLG e. V. (German Agricultural Society) [2]. The side wind influence could be neglected. The throughput of material other than grain (MOG) could not be specified in these experiments. To compare the results, the power requirement is referred to the grain throughput assuming a constant grain/MOG relation.

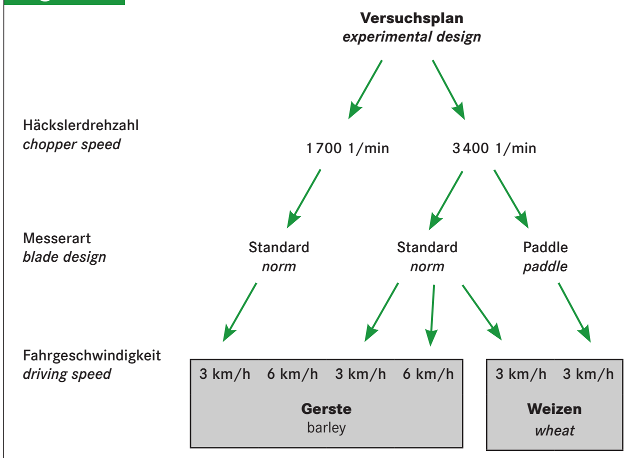
The analysis of the horizontal distribution and the quality of the chopped material follows the test frame determined by the DLG for harvesters, Group 7f [4]. Due to the asymmetri-

Fig. 1



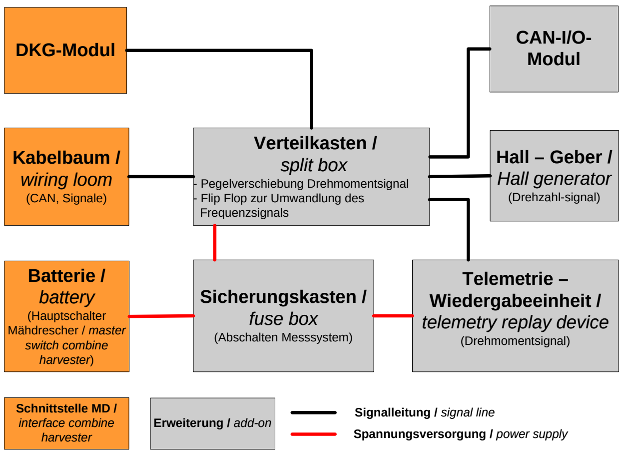
Design of the measurement hub

Fig. 3



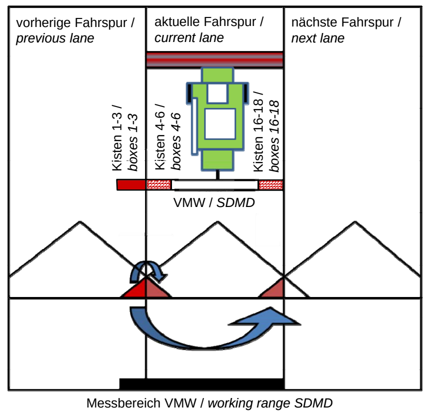
Experimental design

Fig. 2



Wiring of the torque measurement unit

Fig. 4



Experimental procedure for distribution and quality of chopped straw

cal structure of the distribution measurement wagon, it is possible to consider the straw quantity within the cutting width as well as the overlapping section of the next or previous lane **figure 4.** The distribution measurement device covers 9 m working width, the cutting width is 7,5 m and the width of a box is 0,5 m.

To examine a single measurement, the straw weight of every box is referred to the arithmetic mean. The coefficient of variation is used for validation. The average chopping length determines the chopped straw quality.

Before analysing the influence of the paddle blades of the Rasspe company, it was necessary to optimize the blade positioning on the used combine CLAAS Lexion 470. The standard blades were mostly replaced by paddle blades in order to achieve a flow rate distribution at the blow-out according to the experience made by Rasspe. The flow rates were measured with an anemometer directly at the blow-out of the straw distributor without grain throughput.

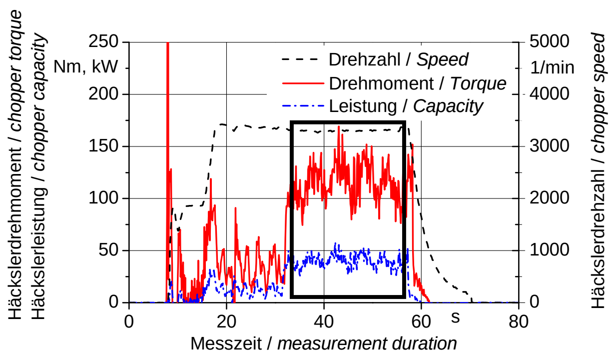
The main objective of the experimental design was the validation of the new measuring system.To provide indisputable data regarding the influence of the blade type on combine choppers on the straw distribution, the chopped material quality as well as on the power requirement, there has to be created a considerably larger data base.

The data range taken as a basefor the analysis is shown in **figure 5.** This measurement shows the start of the chopper with following test run of the combine. The power requirement was calculated by averaging. The diagram shows clearly the momentum peak when starting the chopper. Remarkable is also the wide range of torque values in idle state.

Results and Discussion

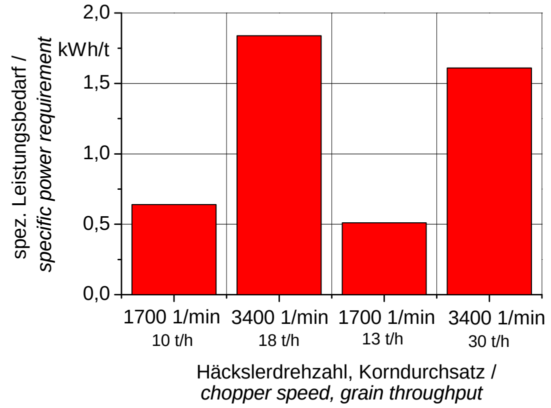
Slight modifications of the MOG throughput cause a significant alteration to the power requirement of the chopper equipped with serial blades. The test results show a tendency to 3 saving potentials.

Fig. 5



Data area for evaluation of the chopper tests

Fig. 6



Effect of chopper speed on power requirement

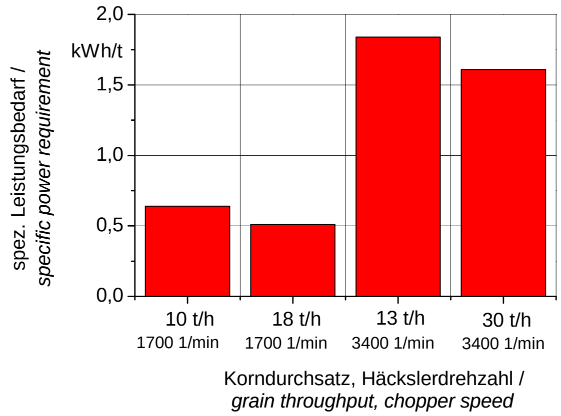
The highest saving potential is, as expected, the torque influence. Reducing the chopper torque from 3400 to 1700 1/min leads to a decrease in power consumption of about 60 %. At the same time, the coefficient of variation of the straw distribution increases by 5–20 %-points and the average chopped straw length extends **figure 6.** This means a less appropriate use for the reduced soil preparation [1, 3]. The torque reduction makes only sense if the straw will be used for erosion prevention.

Increasing the grain throughput from 13 to 30 t/h reduces the specific power requirement at the chopper shaft from 1,9 to 1,6 kWh/t grain as well as the coefficient of variation from 40,4 to 31,3 % at a set chopper torque of 3400 1/min. The influence exerted on the chopped straw length is insignificant, because the length does not change at this high chopper torque. At a speed of 1700 1/min and an increased grain throughput from 10 to 18 t/h, the power requirement decreases also from 0,79 to 0,71 kWh/t grain, but this time the coefficient of variation worsens from 45,1 to 49,8 %, **figure 7.** The chopped material quality improves slightly, because the higher filling rate of the chopper leads to more contacts between straw and blades [2,3].

The use of paddle blades instead of the standard blades causes, due to additional pneumatic power requirement, a higher power requirement of about 20 % at the chopper shaft. Although the coefficient of variation of the lateral distribution improves in this example from 49,9 to 40,2 %, **figure 8, 9.** Equipped with standard blades, the proportion of chopped straw lengths over 100 mm is under 5 %, which makes it suitable for direct drilling in autumn. The results of the tests with paddle blades show the same tendency. Here, too, the use in direct drilling is possible [2, 3]. The random check to control the chopped straw quality did not deliver any advantages of the standard blades.

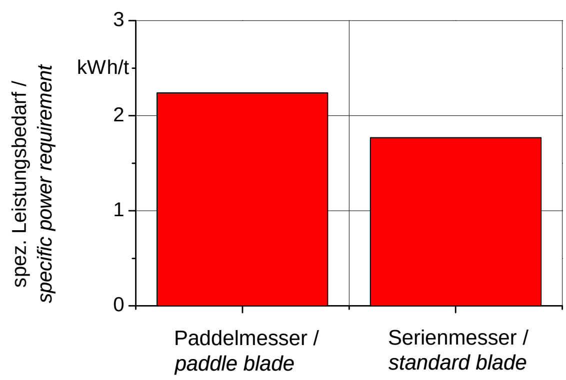
Comparing the blade equipment of the chopper regarding the specific power requirement, the paddle blades come off worse. The difference is between 0,5 kWh/t grain in favour of the standard blades. But to this the fuel requirement is reciprocal, thus the use of paddle blades means an improvement of 0,2 l/t grain.This effect is due to the actual operating point of the engine. Because the engine didn't run at the optimal operating point, the higher output momentum at constant engine speed decreases the fuel consumption.

Fig. 7



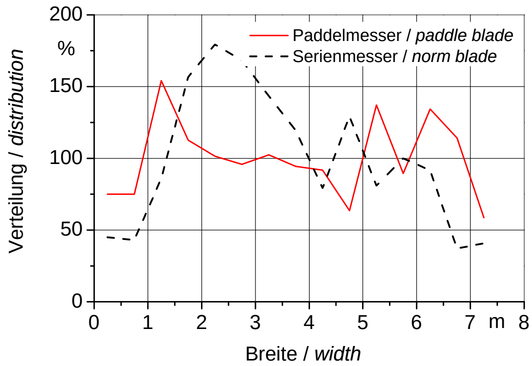
Effect of corn throughput

Fig. 8



Effect of blade design in test field wheat, chopper speed 3400 1/min

Fig. 9



MOG-lateral distribution

Summary/Outlook

The CAN bus based measuring system works reliable but offers limited validity for the analysis of load spectrum data because the sampling rate or the possible increase of the BUS-load is not sufficient for a detailed examination. The maximum BUS-load is too quickly attained to extend the envisaged increase of the measuring section. Therefore another CAN bus will be added and communicates with the original CAN bus of the machine.

One approach for future developments to optimize the straw distribution is the chopper equipment with different kind of blades, as already proposed by Voßhenrich [5]. If the outer sections of the chopper shaft are equipped with paddle blades for a better distribution and the inner section of the shaft with standard blades for a reduced power requirement as well as for higher chopped straw quality, then the straw distribution should improve with only slight additional fuel demand. These results will be verified and confirmed by more extensive series of experiments.

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