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Load spectra and distribution of power on a combine harvester

The correct function of many working units of a combine harvester depends on their constant rotation speed. Therefore the engine always is operated with rated speed even if the engine is not fully loaded. The results are operation points with unfavourable specific fuel consumption. At the University of Hohenheim, within the project "Decoupling power train between combustion engine and different drives", the distribution and the need of power are investigated. For that the combine harvester of the Institute of Agricultural Engineering is equipped with a CAN-bus-based measure and evaluation system. In the first step three mechanical and one hydraulic measure point are installed and put into operation. In 2011 about 70 ha were harvested.

Keywords
Load spectra, distribution of power, combine harvester

Abstract
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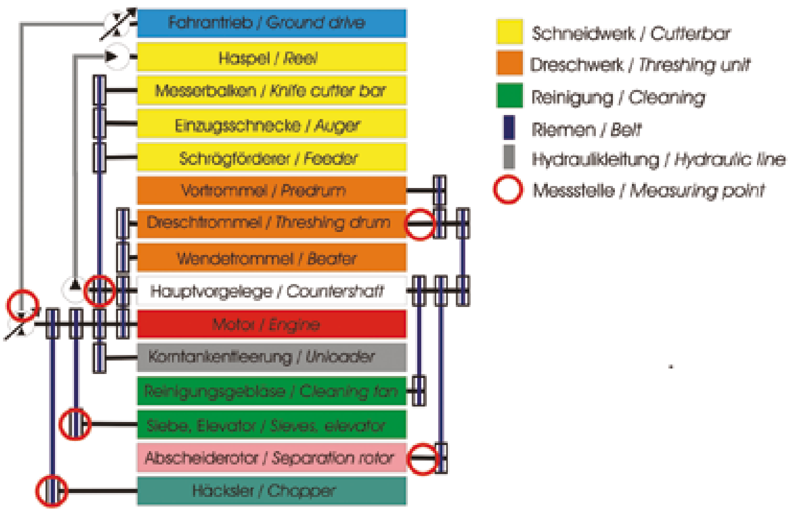
In order to examine the load spectra and the distribution of power, a combine harvester type Claas Lexikon 470 Montana was used. This combine harvester is equipped with a rated power of 236 kW and a yield mapping system. In addition to that, a measurement technology for fuel consumption (VDO EDM 1404) [1] and a measurement system based on a CAN-Bus with a torque measuring hub on the chopper [2] had been installed in earlier works.

In order to select more measurement sections, the classification in assembly groups was the first step. The objective was to cover the working units having the highest power requirement with justifiable expenditure. The placing depended on the available space and was determined by the drive layout. **Figure 1** shows the plan of the measuring points. The five designed mechanical measuring points for cutterbar, threshing unit, separation rotors, cleaning (sieves, grain augers and elevators) and chopper as well as the hydraulic measuring point of the ground drive are shown.

Structure of the measurement technology

In addition to the existing measuring points, three new ones (ground drive, threshing unit and separation rotors) had been installed for the harvest in 2011.

Fig. 1



Schematic measuring point plan of the test combine harvester Lexion 470

For the recording of the torque, strain gages were used. Hall-sensors deliver the rotation speed. The signals of the sensors are digitized by the rotor electronic and transmitted through an aerial without any contact. In the receiver, both torque and the rotation speed are converted in to CAN-messages and passed on the measuring-CAN-bus.

It turned out that the shaft of the threshing drum was the best measuring point at the threshing unit. Two double-shear-strain-gages, which were attached at an angle of 180°, were placed between belt pulley and bearing (**Figure 2**)

As it is shown in **Figure 1,** only the load of threshing drum and beater can be recorded. The power of predrum can be calculated with data fom the literature and from bench tests [3].

The measuring point of the separation rotors had been designed according to the same principle. Two strain gages had been applied at the input shaft of the right rotor gear.

For the chopper a special measuring hub, which connects the two-step pulley with the shaft, was constructed. A bearing intercepts the transverse forces of the belt, so only the torsion of the measuring hub was detected (**Figure 2**).

The calibration of the measuring points was done in static condition. With appropriate handles a defined torque was initiated. These values were stored in the measuring system.

The hydraulic power of the ground drive was calculated out of the difference of pressure (forerun and return) and the flow rate. CAN-modules process the signals and send them as CAN-messages to the CAN-bus. A data logger saves the data of both CAN-busses (measuring- and machine-bus).

During the harvest 2011, the rotation speed and the torque of threshing unit (without predrum), separation rotors and chopper as well as the pressures and the flow rate of ground drive could be recorded. The fuel measuring device, machine-internal informations (for example engine speed, forward speed) and the CEBIS (for example yield, moisture) gave additional information.

Experimental procedure

In 2011 it was the aim of the field trails to use the measuring system under practical conditions and check its robustness and suitability on the field. Therefore, fields of the university and of some farmers were available. Overall, approximately 70 ha of wheat, oat, barley, peas and beans were harvested. The field size was typical for the region (0.2 to 8 ha), the moisture varied between 13.5 and 19 %. The yield fluctuated from 3.5 to 8 t/ha (grain) and 2 to 4.5 t/ha (grain legumes). The emptying of the grain tank took place on the verge of the field.

Results

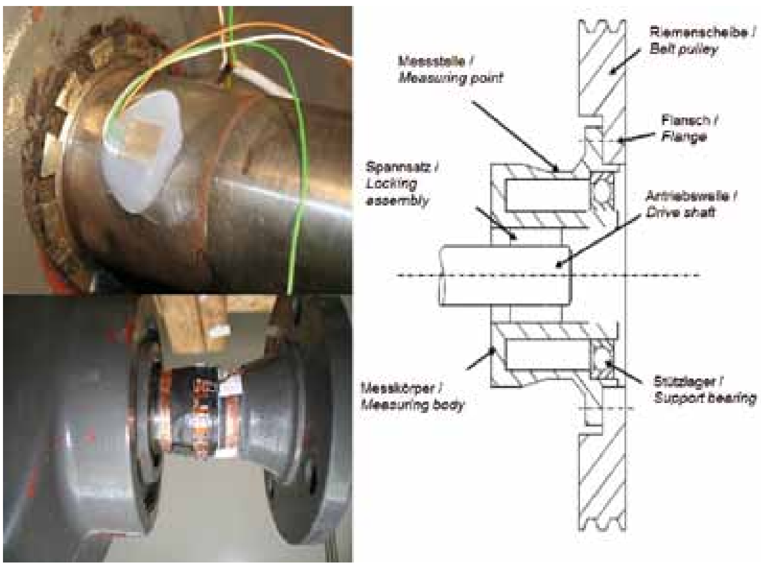
Mechanical measuring points

As expected, the load on the threshing was greatest the greatest load was noticed on the threshing. The measured torque reached up to 3000 Nm. Especially during the filling of the threshing drum, strong shocks occurred. Whereas the torque also varied great when it was filled, too. This can be attributed to the irregular feeding of the auger and the feeder as well as to the interaction of threshing concave and rasp bars. This result could be validated with signal analysis. The detected natural frequency of 90 to 100 Hz depends on the rotation speed of the threshing drum.

The torque of the two separation rotors was significantly lower (200-400 Nm) but the shocks reached roughly about 1000 Nm. During the entry into the grain inventory, the torque slowly increased after the first shock until the rotors were completely filled (**Figure 3**).

On dry conditions the torque of the chopper varied between 30 and 100 Nm. On conditions with moist straw or high weeds

Fig. 2



Top left: shaft of threshing drum with strain gages under silicon; bottom left: shaft of rotor gearbox with a rotor electronics; right: sketch of measuring hub of the chopper [2] the torque raised up to 200 Nm. Depending on the rotation speed of the separation rotors the load of the chopper started with four to seven seconds later according to the load of threshing.

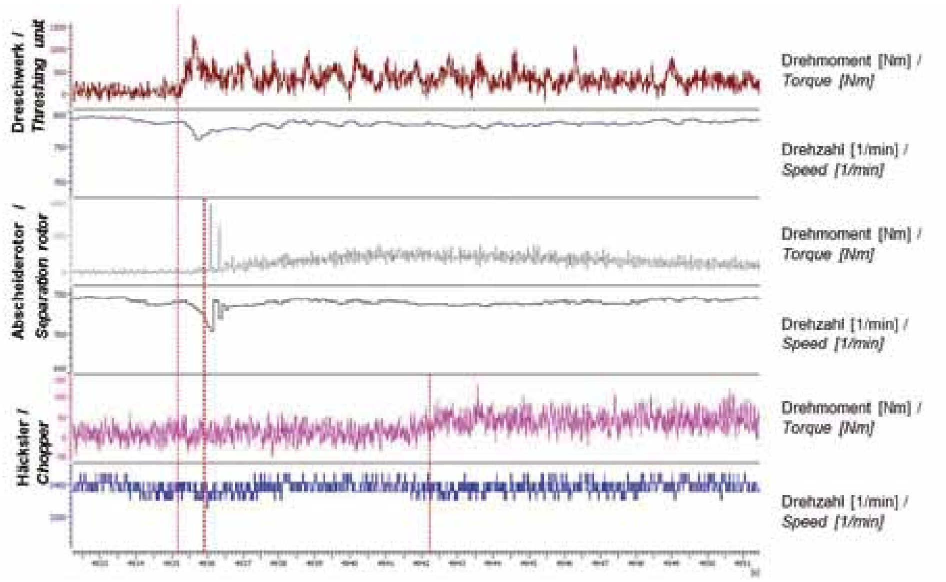
Hydraulic measuring points

The flow rate of the hydrostatic ground drive is proportional to the forward speed. The maximum output is 330 l/min. The cut-off pressure (450 bar) of both forerun and return can be reached temporarily. In typical driving maneuvers the pressure of the forerun varies between 50 up to 300 bar. The charge pressure of the return is 30 bar, except during delay. These results are comparable to other investigations [4]. Only on extreme conditions peak pressures, which take advantage of the bulk of the engine performance, occurred. Therefore its time share at the load pressure collective is short.

Power requirement

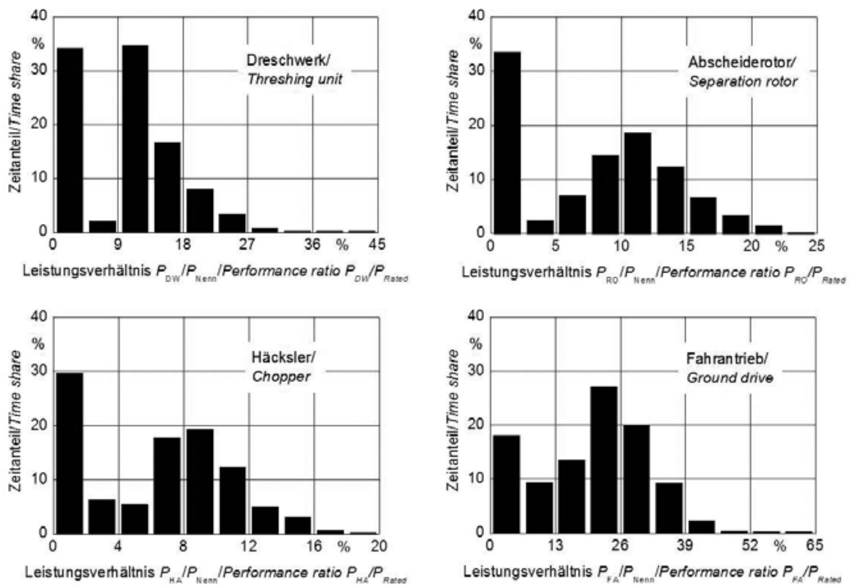
Figure 4 shows the power collectives of the four measuring points during field use (winter wheat, 3.3 ha, yield 5.45 t/ha). The high time share of the mechanical measuring points with low power was composed out of the idling (for example during reversal) and of the residual condition of the working units. Since the grain tank emptying took place at the field edge, these conditions had a high share. The power requirement of

Fig. 3



Torque and speed of the threshing unit, the rotor and the chopper during field tests with winter wheat

Fig. 4



Time share of the measured performance of threshing unit P_{DW}, rotor P_{RO}, chopper P_{HA} and ground drive P_{FA} related to rated engine performance P_{Rated}

the separation rotors and the chopper during the actual harvest process was similar. Between 5 to 20 % of the rated engine power were used. The main operating point of the threshing moved from 10 to 20 %. The maximum power requirement could increase to almost 50 % of the engine power. The distribution of power on the ground drive corresponds to the findings of [4; 5]. The maximum power took only a little. This could be attributed to the good harvesting conditions like dry ground and a flat field.

Conclusion

It turned out that the installed measure and evaluation system is robust and practicable. For the harvest 2012 further more measuring points will be installed, so the important consumers can be recorded. The power requirement of secondary consumers will be investigated with stationary tests.
In a further step the collected data of the first field trails will be used to a model-based analysis of the load and power spectra. This should allow the simulation of virtual field trails.

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