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Power Analysis of a Disc Mower

A method for measuring and evaluating the cutting process and the power analysis in a disc mower are explained here. In field tests various parameters were measured during the cutting process, like cutting power and torques. In a concluding power analysis, the various power levels were determined and compared, in order to form conclusions about power losses.

As part of the project commissioned by the company Claas Bad Saulgau GmbH, which was carried out by the Institute of Agricultural Engineering and Fluid Power (ILF) at the Technical University of Brunswick, a measurement-technological analysis of the cutting processes in a disc mower was carried out. It was the goal of this project to develop a method which allows more detailed insights into the cutting process in a mower to be gained and potential weaknesses of the mower to be detected. In these studies, it was of particular interest to find out to which loads individual components are exposed during the mowing process and in which areas the greatest power losses occur.

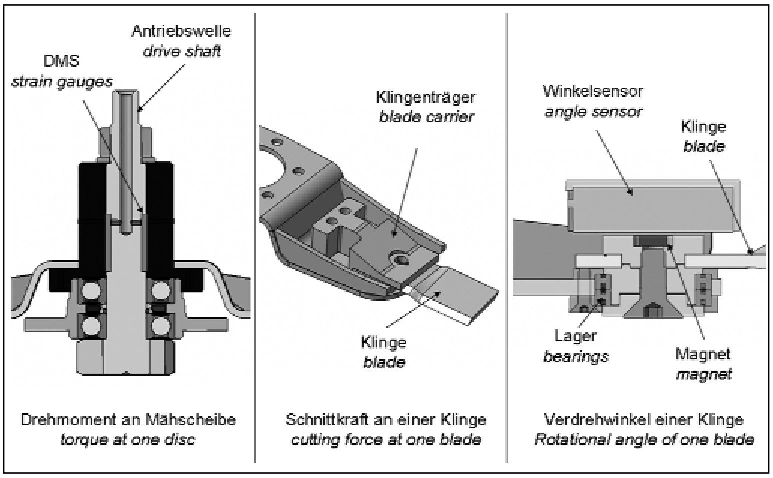

Fig. 1: Measuring technology used

Measuring Technology Used

In the project described here, beyond the torque of the PTO, the torque of a mowing disc, the cutting force of a mower blade, and the rotational angle of a mower blade were measured during the cutting process. Below, the realization of these measuring techniques is explained in more detail.

The rotational speed and the torque of the PTO drive shaft were measured with the aid of a torque measuring hub from the company Walterscheid. This sensor was installed between the PTO drive shaft of the mower and the PTO stub of the tractor.

For the measurement of the power input into a disc, the drive shaft of one disc, which comes from the mower bar, was extended by several millimetres, and a strain gauge for the measurement of the torque input was attached to it (*Fig. 1*).

For the determination of blade force, a blade of the examined disc was rigidly connected to the disc via a blade carrier (*Fig. 1*). Strain gauges were attached to the blade carrier, which allowed blade force to be measured. The rotational speed and the geometric measurements of the disc allowed the blade speed to be established, and the blade force enabled the cutting power of a blade to be determined.

For the examination of the vibration behaviour of the blade during mowing, a blade of the examined disc was installed on two bearings in the disc. An inductively working rotational angle sensor was installed in the disc above the blade bearing (*Fig. 1*). With the aid of a magnet installed in the bearing, the rotational angle of the blade relative to the disc could be measured.

The measured data of torque at the mowing disc, blade force, and the rotational angle of the blade were transmitted to a measurement computer via a slip ring and a cable.

Results of the Field Trials

The field trials provided very good results. *Figure 2* shows an example of the cutting force measured at the blade over time. Thanks to the very high measurement-technological resolution of 5,000 Hz, it is possible to examine every single cut. The diagram shows that the force measured at the blade increases significantly during the cut. Between the individual cut, the force decreases.

As another example of the measured values, the rotational angle of the blade relative to the mowing disc during the mowing process is shown. *Figure 3* shows the rotational angle over time. One sees that the blade is slightly deflected in a negative direction during the cut. After the end of the cut, the blade returns to its original position (cut 1). Depending on the deflection of the blade, the blade may overshoot while it is returning to its initial position (cut 2). After overshooting, blade vibrations subside. Depending on the duration of this process, the vibrations

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Keywords

Disc mower, power analysis

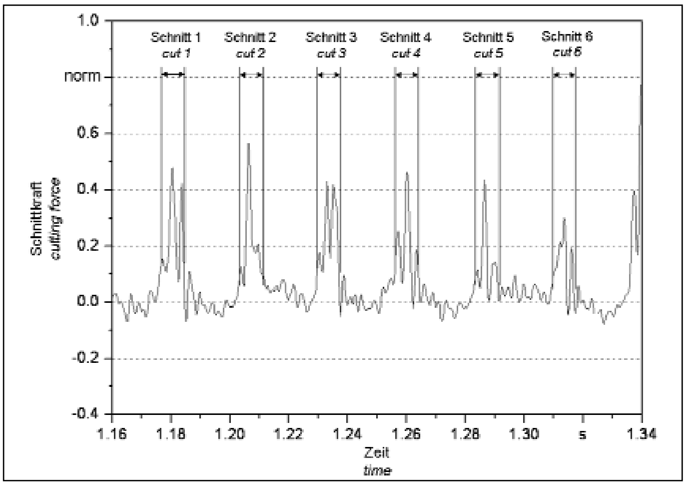

Fig. 2: Cutting force

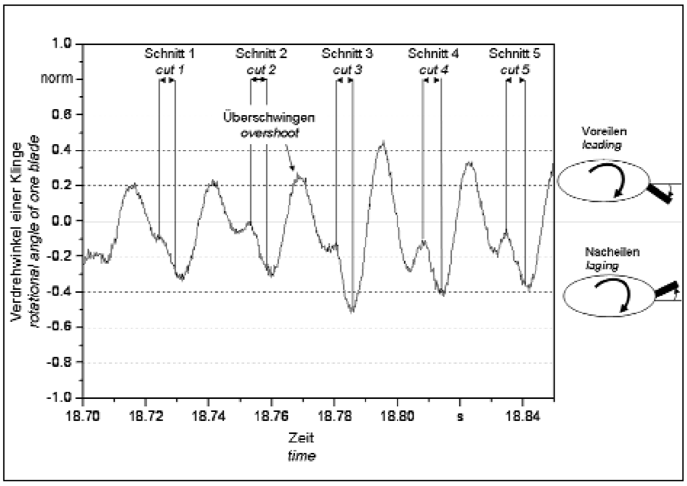

Fig. 3: Rotational angle of one blade

may not have ended by the time the next cut begins (cut 2).

Power analysis of the disc mower

For power analysis, different power values were calculated with the aid of the measured torques and rotational speeds and based on the measured blade forces and blade speeds. The values determined were total driving power at the PTO drive shaft, driving power at a mowing disc, and cutting power at a mowing blade. For the sake of better comparability of the determined power values, the driving power of one mowing disc was extrapolated to the entire number of mowing discs in the mower used (here: 7), and the cutting power of one mower blade was extrapolated to the entire number of blades in the mower (here: 14). In separate trials the wind resistance of the discs was measured. Therefore the total power of the mower was measured by stationary driving the mower with and without discs. The difference between the measured powers was calculated and can be seen as the wind resistance of the discs. *Figure 4* shows a comparison of the power values over time at a rotational speed of the disc of 3.200 rpm and a driving speed of 10 km/h.

It becomes clear that the determined power values vary greatly. The difference between the total driving power and power at the mowing discs is caused by power losses in the drive. These power losses account for ~ ~ 20% of total power. Difference between power at the mowing discs and power at the mower blades added to the wind resistance is caused by power losses due to the friction of the cut grass on the mowing discs. These power losses account for ~ 25% of total power. The wind resistance of the mower is about 20%.

The determined cutting power of the mower blades accounts for ~ 35% of total power and must be considered the actual power required for mowing. Hence, one can say that at this point of operation ~ 65% of the power input in the mower can be considered lost and ~ 35% is required for mowing.

In other trials, different parameters, such as the rotational speed of the discs or the driving speed, were varied. Here, total driving power and power losses were measured as well.

As a conclusion of the field trials, one can say that the measurement-technological method developed allows both the total power of the mower and the different power losses to be determined for different operating points of the mower by varying the above-described parameters. This enables the best operating point for the mowing process to be found. In addition, the results enable tendencies for the improvement and optimization of the disc mower to be derived.

Summary and Future Prospects

In the described project, a measurement-technological technique has been developed, which allows the cutting process in a disc mower to be examined in a detailed manner. For this purpose, a disc mower was equipped with sensors which measure driving torque at the PTO drive shaft, torque at a mowing disc, cutting force at a mower blade, and the rotational angle of a mower blade. In field trials, initial studies were carried out which showed very good results. It was shown that it is possible to measure every single cut of the mower. During subsequent power analysis, power losses during mowing were able to be determined, which were able to be quantified more precisely as power losses in the drive and power losses due to wind and grass friction. Through a variation of parameters, such as the rotational speeds of discs and driving speeds, tendencies for the improvement of the cutting process in a disc mower were able to be established. These insights are intended to be used for the future improvement and optimization of the disc mower in particular and the improvement of the mowing process in general.

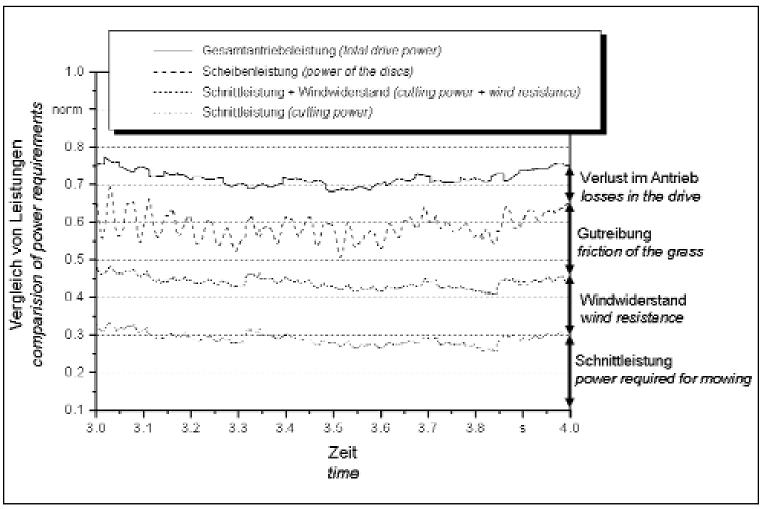

Fig. 4: Comparison of the different power requirements