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Measurements on a precision combine straw chopper

A combine straw chopper was developed at the Institute of Agricultural Machinery and Fluid Power, TU Braunschweig, to research an alternative cutting principle. In this technique the crop is fixed and cut between the knife and a counter shear. The cutting unit resembles a conventional chopping drum but offers additional features. The construction makes it possible to adjust machine parameters, to examine several process values with sensors and to monitor the processes with a high-speed camera. This article demonstrates some possibilities to carry out measurements on a chopping drum during operation.

Keywords
Drum chopper, measurement, combine harvester, straw chopper, cutting principles

Abstract
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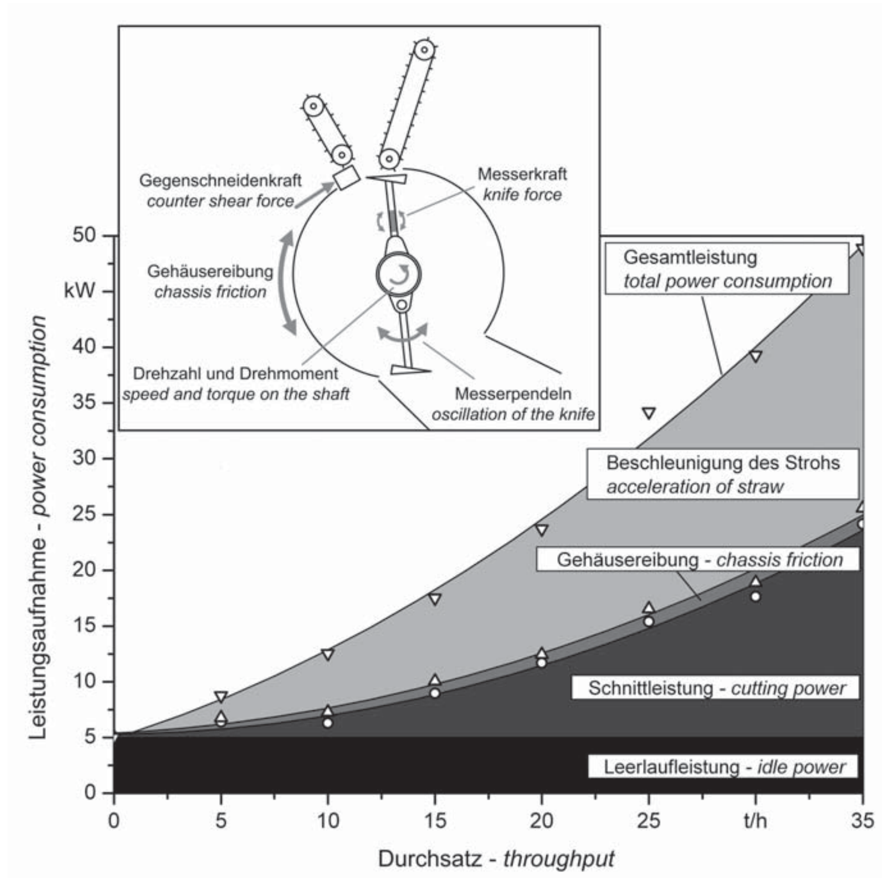
The goal of the research project at the Institute of Agricultural Machinery and Fluid Power of the Technical University of Braunschweig described here is the development and the study of a straw chopper which works with a counter edge and a clamp. For this purpose, an experimental chopper was installed and equipped with the required measuring instruments. Its principle corresponds to the design of a drum chopper. In agricultural machinery, this design principle is used in forage harvesters, for example. The requirement of foreign body tolerance led to a design which features pendulum suspension of the knives and thus allows them to avoid foreign bodies by swinging backwards when entering into contact with them. In order to realize this concept and to reduce the load on the components, the knives were segmented widthwise into eight parts. The test rig is designed such that as many parameters as possible can be varied and the most important process values can be measured simultaneously during operation [1].

Determination of power components during chopping

Figure 1 shows the arrangement of different measuring systems which serve to determine the power components in the chopper. The measurement of torque and rotational speed at the shaft drive allows both idling power, which is composed of air drag and bearing friction, and total power output during operation to be recorded. In addition, cutting power can be determined based on counter edge forces and rotational speed. For this purpose, a counter edge segment was equipped with force measuring sensors, which are scanned at a high frequency of 12 kHz so that even the short force peaks during each individual cut can be registered. In order to determine a representative power value, the average is determined during a recording period of 10 seconds while material supply is constant. In order to measure the forces at the cutting edge, the knife was rigidly attached to the knife shaft so that the forces were able to be measured by determining the flection with the aid of strain gauges. The power at the cutting edges was greater than counter edge power because the cutting edges need additional power

Fig. 1



Power consumption of the chopper

in order to accelerate the cut material to ejection speed. Hence, the difference between cutting edge and counter edge power corresponds to acceleration power. This measured component is also influenced by other effects. Examples of such influences are support effects of the material on the feeding mechanism and the air flow, which is different from the conditions during idling. Since these effects are very small, they were not fully identified experimentally in the studies described here.

Total power is the equivalent of the sum of the measured power components. In addition, it can be determined separately at the drive shaft. Its composition changes with the variation of the machine parameters, which is shown here as an example for throughput variation in **Figure 1 and 2**. Idling power remains constant. However, it accounts for a decreasing share of total power as throughput increases, which also improves the total degree of efficiency. The percentage of cutting power, i.e. actually useful power, grows with increasing throughput. Specific drive power (kW per t/h), however, diminishes as throughput grows. Therefore, a high degree of capacity utilization of the chopper improves efficiency. Whether acceleration power can be considered useful power depends on whether the high material ejection speed is used for direct distribution or whether downstream accelerators are installed which can use the high kinetic energy of the chopped material only partially.

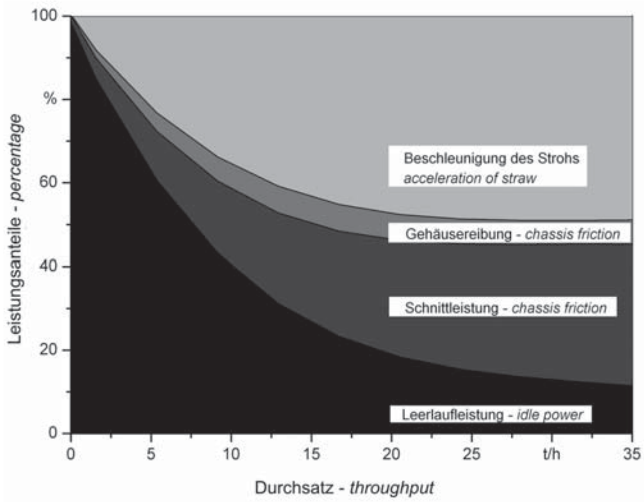
Pendulum knife suspension

A special feature of the chopper design for use in the combine is the possibility of pendulum suspension of the knives which allows them to avoid foreign bodies when entering into contact with them. In order to study operation with pendulum knives, a knife was suspended such that it was able to turn freely and equipped with a turning sensor for the registration of deflection. **Figure 3** shows the deflection of the knife during consecutive cuts and under the conditions of varying crop mat thickness. During the first five cuts, cutting force is so small that the knife is deflected backwards by one to two degrees. Thus, it swings back and comes to a standstill before the next cut. At higher forces, the deflection of the knife is so significant that it swings beyond its initial position and does not come to a standstill within one revolution. The knife is in an excited permanent oscillation which corresponds to the cutting frequency. Knife deflection can be set by choosing suitable parameters for geometry, knife mass, rotational speed, and thickness of the crop mat. This allows permanent oscillations to be prevented by means of design measures or to permit them specifically.

Summary

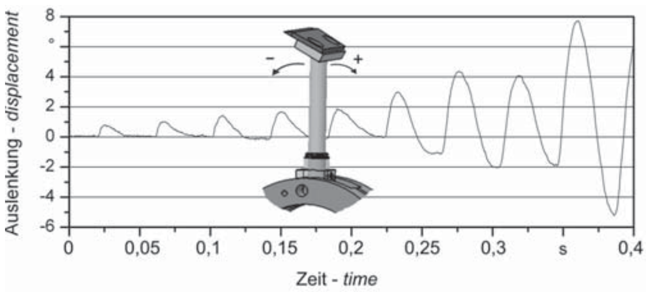
In a current research project, a test rig developed at the Institute of Agricultural Machinery and Fluid Power of the Technical University of Braunschweig serves to study the application of

Fig. 2



Power percentage of the chopper

Fig. 3



Knife oscillation

the exact cut in the combine chopper. Different measuring instruments enable chopper operation to be studied at any operating point. As shown above, chopping power can be analyzed, split up into components, and plotted over operating parameters so that individual influences on the chopping process can be documented specifically. Another measuring system presented in this contribution shows that the operation of a drum chopper with knives featuring pendulum suspension in the combine is possible without impairing operation.

In addition to the measurements taken by the systems described here, it is possible to observe the cutting and conveying processes with the aid of a high-speed camera and to measure material ejection speed as well as chopping quality. This allows influences on the chopping process to be analyzed, described, and evaluated systematically.

Literature

[1] Wiedermann, A., und Harms, H.-H.: Versuchsstand zum Häckseln von Stroh im Exaktschnitt. Landtechnik 62 (2007), H. 6, S. 402-403

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