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Chopping procedure in the silage harvester

High-performance self-propelled harvesters with chopper drum for chopping the forage material and accelerating it to the next aggregate are favoured nowadays. The system means a large proportion of the processing energy is devoted to the chopping action. Using a test stand at the Institute for Agricultural Machinery and Fluid Technology the chopping drum action was observed in detail and analysed with single cuts applied to a pre-pressed wad of harvest material. The cutting procedure was documented and evaluated with force sensors on knife and shear bar as well as high speed photography

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Keywords

Forage harvester, cutting, cutting energy

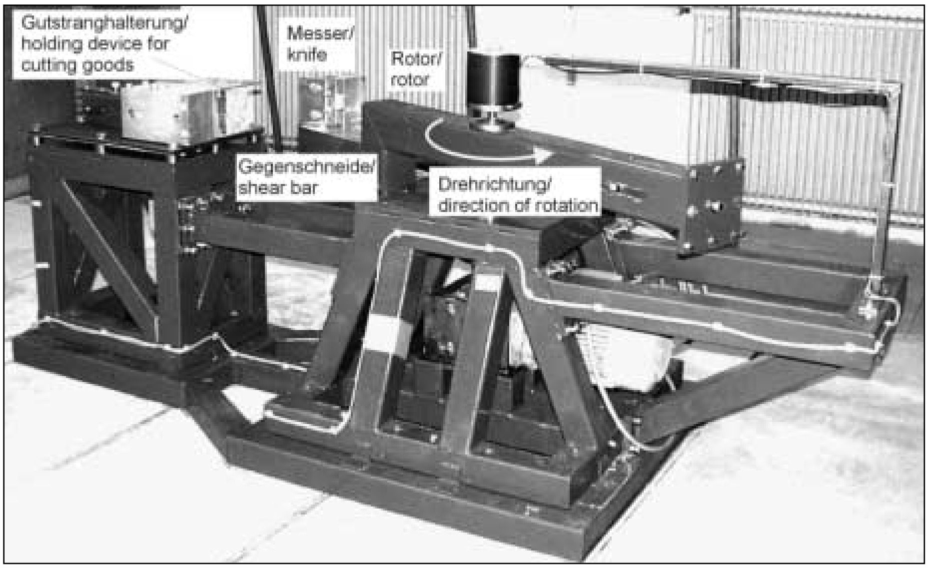

Fig. 1: Cutting test rig

The cutting and conveying procedure within the drum silage harvester has been already intensely investigated in [1] with performance recorded using different chopping drum geometries and the required energy for cutting, accelerating and in overcoming friction on the drum bottom determined. Here the cutting procedure is analysed on a test stand as an individual part of the complete process.

Test stand

The aforementioned stationary chopping test stand (*fig. 1*) comprises a horizontally revolving rotor mounted within a solidly built frame with a harvested material wad holder and integrated shear bar fixed to the frame. The rotor is driven by a frequency-controlled electric motor with steplessly adjustable rpm. The knife which is vertically aligned to the rotor end is affixed to a bracket bolted on one side to the rotor (*fig. 2*). In this way the cutting procedure and material flow at the knife during and after the cutting process can be documented from above by a high-speed camera. To minimize as much as possible the influence of centrifugal force a considerable radius of 1015 mm was chosen between fulcrum rotor and knife blade. The harvest material wad was formed and held in position with a special holder. The layering and defined preliminary pressing of the material took place in separate equipment. Using force sensors the cutting forces at the knife were measured in tangential as well as vertical direction and vertically to the shear bar at the wad (*fig. 2*). Through the geometry and construction of the test stand the following trial spectra could be realized:

- Wad height 50 mm to 170 mm
- Wad width 150 mm
- Cutting gap > 0.5 mm
- Cutting angle 25°, 40° and 55°
- Pre-press pressure in wad 0.025 Mpa to 0.8 Mpa
- Chop length 0 mm to 70 mm
- Chopping speed 5 m/s to 40 m/s

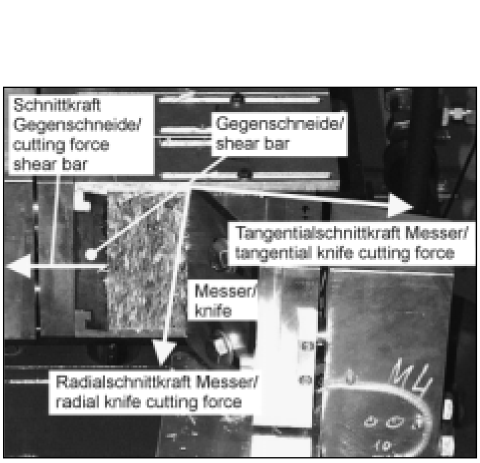

Fig. 2: Force measurement at knive and shear bar

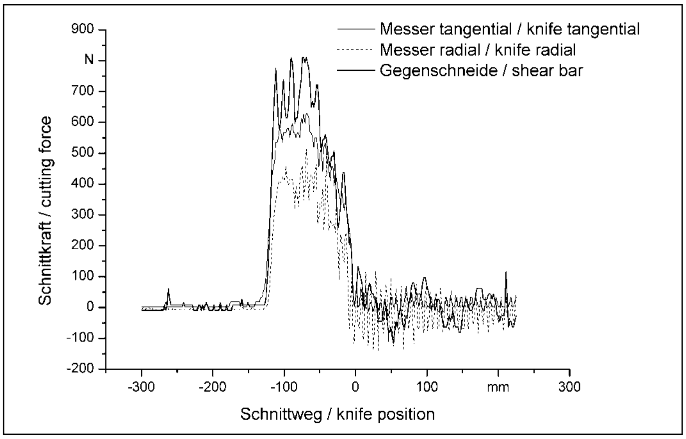

Fig. 3: Cutting forces at cutting velocity of 5 m/s applied to raigras

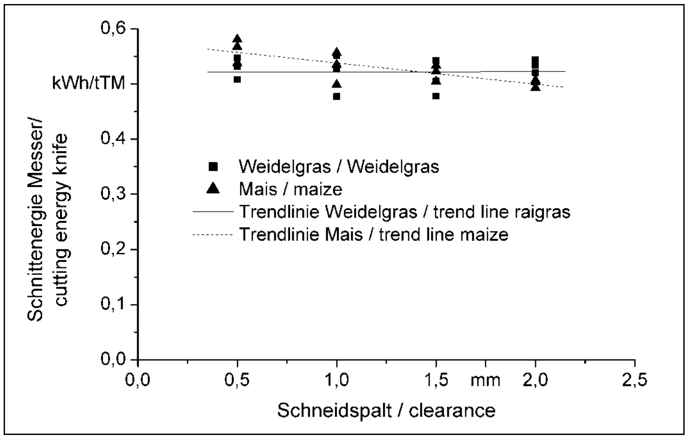

Fig. 4: Cutting energy depending on clearance for raigras and maize (cutting velocity 5 m/s)

Trial method

The desired chopping speed was adjusted via the rotor rpm. Subsequently the pre-pressed wad was pushed forward to a predetermined chop length during a revolution of the knife and cut once. Through a special segmentation of the wad holder three chops per wad (per trial setting) were able to be carried out and the results determined. The movement of the material was filmed by high-speed camera and evaluated for direction and speed. In the foreground were trial series with grass and maize. In order to secure an overview of the influence of different cutting parameters through a manageable number of trials, cutting parameters were first determined as bases. These were:

- Trial material: grass/maize
- Material moisture content: fresh
- Cutting angle: 40°
- Taper angle: 40°
- Free angle: 0°
- Position angle: 0°
- Wad width: 150 mm
- Wad height: ~ 150 mm
- Chop length: 15 mm
- Pre-press pressure: 0.2 MPa
- Chopping speed: 5 and 40 m/s
- Cutting cleft: 0.5 mm
- Knife blade: sharp

In the trial series only one of these parameters was varied in each case, allowing a good classification of the results.

Results

Displayed in *figure 3* is a cutting force graph recorded whilst perennial ryegrass was being cut at a speed of 5 m/s. The start of the cutting process is clearly recognizable through the rise in power in the negative area of the knife position. The cutting process is completed at knife position 0 (position of shear bar). Cutting procedures can be compared via specific cutting energy required in association with the dry matter of the wad. This is the product of tangential force and the path of the knife (the area beneath the tangential graphic curve) in relationship to wad moisture content and bite size (amount of harvested material per cut). During the investigations into the influence of the gap between knife and shear bar (cutting cleft) the tendency of the results from [1] and [2] were confirmed. A cutting cleft from 0.5 to 2 mm was investigated. Shown in *figure 4* is the specific energy requirement in relation to wad dry matter over the cutting cleft for ryegrass and maize. When the cleft is increased no serious alteration in specific cutting energy was determined. The slight reduction of cutting energy with maize can also be explained by the variations in trial results. Especially with maize, different stalk and cob contents in the cutting area lead unavoidably to greater variability in results compared with grass.

A greater cutting cleft led in the main to separation of the wad lower layers because the missing support underlying layers led to a reduced rigidity of the material still to be chopped. This can cause blockage between knife and shear bar which then leads to friction losses. This effect is further increased when the knife has a certain amount of wear on the edge (greater cutting force => increased deformation of the wad). The results presented in *figure 4* are from trials with a large wad height and a sharp knife (see also base parameters in trial procedure). In this way the very small changes can be explained.

Summary

Using a forage chopping test stand the effect of different cutting parameters can be experimentally analysed. Measurements give information on the magnitude and direction of cutting forces and the size of specific energy requirement for the cutting procedure in each case. Further, high-speed photography allows the study of the dynamics of the material wad and chopped particles with regard to velocity and direction.

Literature

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[2] *Heinrich, A.*: H ckselmesser und Gegenschneide eines Feldh ckslers. Landtechnik 55 (2000), H. 6, S. 440-441