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Chopping Fibrous Materials

Energetical Investigation of Dynamic Processes

Straw is a by-product of grain production. It must often be chopped before utilisation, which is usually done by the straw chopper installed in the combine-harvester during the grain harvesting process. The chopped straw structure basically decisively influences the effectiveness of the next work phase. The question arises about how much the angle of the chopping knives influences the chopping energy requirements and if there is an optimal angle, which results in minimal energy requirements.

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Keywords

Cutting, straw chopper, energy requirements, angle position of chopping knives.

The aim of chopping is to produce a short piece an equal size structure that is more suitable for processing than large fibrous structure. Chopping homogenises and another requirement is also granted, notably that the surface of the fibres and stalks is increasing. Designed for this purpose, the features of rotary chopping equipment with free-turning knives equipped to a horizontal rotation axis are the huge energy-need. It raises the price of the technological work process. In consequence of the high chopping speed, the incidence angle of knives is basically determined by the centrifugal force therefore the straw choppers work at cutting principle.

Many authors have already examined the energy-need influenced by the incidence angle of knives to chopping. [1] has examined the breaking conditions of vegetable materials in the case of tensile, shear and bending stresses with the help of static and quasi-static measurement method. [6] has examined the technological features of sorts of grasses and its influence on the cutting process with the help of a slice equipment system. Both authors did the force measurements with low cutting speed so that the dependence of cutting energy on incidence angle of knives resulted in no adequate answers. [7] has examined the influence of incidence angle of knives on the driving power needed. He determined that the cutting process is being evolved mostly on the free cutting theory in the case of the straw chopper. He concluded that the increasing incidence angle of knives produces an effect on cutting power decrease, because the fibres are not supported perfectly by counter knife but they can slide down easily. Consequently, different factors' influencing effect on cutting energy-need is not totally determined.

The question arises how the angle position of knives influences the cutting energy-need in case of different operational parameters. The purpose of our research was to determine the factors influence on the energy-need of fibrous material chopping and to specify the connections and interactions of these factors in an achievable speed interval.

Construction and operation of measuring equipment

The purpose of our tests is to enable the exact observation and measurement of the elementary fibres with hollow circle structure cutting. For this purpose we have designed a function model and its adequate measuring methodology. Function model is such an accelerated pendulum measuring equipment, which is suitable for modifying constructional (straw position to moving knife, sharpness of knives, distance between moving and counter knives, stalk holding method), operational (speed of chopping knife, number of cutting fibres) and vegetable (moisture content, maturity, sort of crop) parameters. At the same time the model enables to measure force-need of cutting in the function of different knife speeds and knife positions. The accelerated pendulum measuring equipment models the real cutting process of straw chopper but the cutting speed applied recently (100 m/s) is cannot be reached. *Figure 1* shows the construction of measuring equipment.

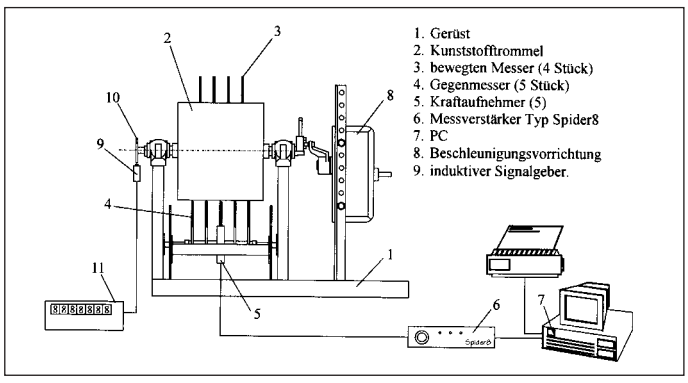

Fig.1: Sketch of measuring equipment

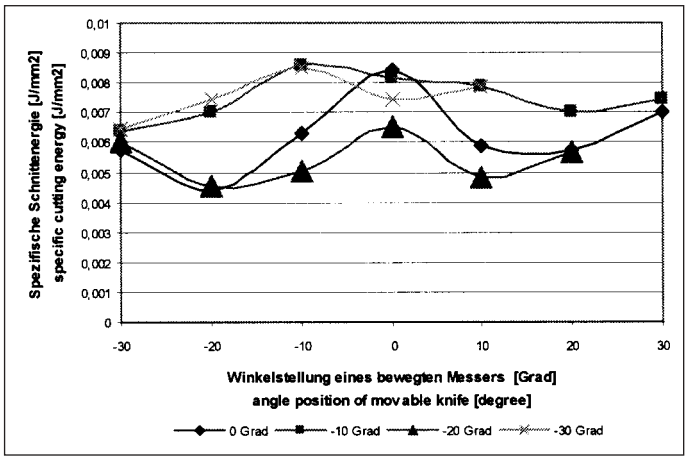

Fig. 2: Specific cutting energy versus angle position of fixed and movable knives; (rye variety Kisvardai 63; w=34%; a=10 mm; v= 11.6 m/s)

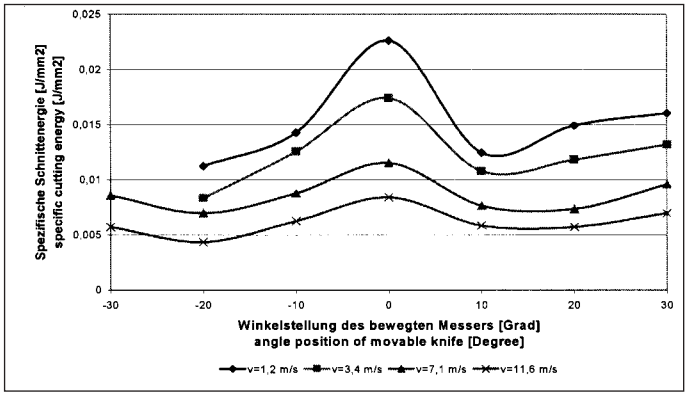

Fig. 3: The specific cutting energy versus angle position of fixed and movable knives; (rye variety Kisvardai 63; w=34%; a=10 mm; fixed knives angle position 0°)

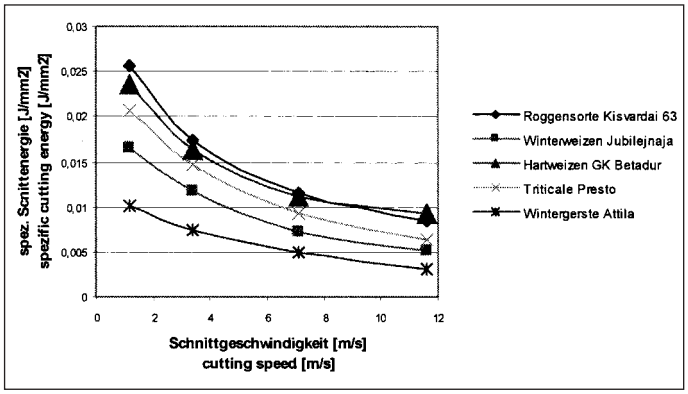

Fig. 4: Specific cutting energy consumption of various grain varieties; (w = 34%; a = 20 mm and angle position of 0° of fixed and moveable knives)

Calculation of energy need for cutting

During the test procedure we have measured the following values as the function of time (t): cutting force (F) on the stationary knife, the average speed of the moving knife during cutting (v). The numeric integration of the area under the cutting force - the cutting displacement diagram shows the cutting energy. Since the diameter and thickness are different, we have manually measured these features in each case after cutting and have calculated the specific cutting energy, supposing hollow circle cross section.

Measurement results

Figure 2 shows the specific cutting force - cutting force on unit cross section - as the function of angle position of stationary and moving knives at 11,6 m/s cutting speed.

Examining the curve of the 0 degree incidence angle of fixed knife it can be established that cutting has the biggest specific energy-need. It decreases with increasing incidence angle of moving knife, it reaches the minimum at the 15-20 degree interval and then it rises again. The possible explanation of this symptom is that the frictional co-efficient between the straw and the edge of knife is smaller than the calculated value from cutting condition in case of an incidence angle which is bigger than with 20 degrees. Therefore the stalk is slipped down to the edge of knives, which results in increasing cutting energy-need.

Figure 3 shows the change of specific cutting energy in the function of different cutting speed, incidence angle of moving knife and constant 0 degree incidence angle of fixed knife. In the case of all incidence angle of fixed knife (0°; -10°; -20°; -30°) it can be established that the specific cutting energy is significantly decreasing with the increasing of speed.

Figure 4 shows the comparison of specific cutting energy-need of 5 different sorts of grain crops with increasing cutting speed. Rye has the biggest specific cutting energy-need then it is followed by durum wheat, triticale, winter wheat and winter barley (Fig. 4). Unfortunately spring barley was not measured because of the dry weather conditions.

Conclusions, recommendations

1. It can be determined that the incidence angle of knives significantly influences the cutting energy-need.
2. Cutting has the biggest specific energy-need; in case of 15-20 degree interval of incidence angle of knife and cutting speed with edgeways component the energy-need is decreasing.
3. With the increasing of knife speed the specific cutting energy-need is decreasing.
4. Below 10 to 12 m/s cutting speed, the specific cutting energy is significantly increasing, so that below this value operation is not practical.

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