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Chopping knives and shear bar in a forage harvester

General observations on knife clearance and wear

With regard to the power requirements for the continually increasing throughput capacities of modern forage harvesters, a critical role for the required cutting energy is played by the influence of the knife clearance and wear on knives and shear bar. Here, an overview of the technical stand in wear measurement and cutting clearance settings and an explanation of the importance of such tasks is presented.

Knife clearance and wear of the chopper knives and shear bar have a decisive influence on correct and energy-efficient chopping. The sharpening and maintaining of knife edges and the associated clearance adjustment are thus important, and represent tasks which must be carried out regularly during the chopping of silage material. To ensure that the chopping process is interrupted minimally and at the most suitable time, there is a requirement for a controlling of the stage of wear, a sharpening procedure which is as short as possible, and an automated adjustment of knife clearance. The influence of the parameters knife clearance and wear on the cutting energy required and the technical possibilities for control of these parameters will be discussed in the following report.

Influence of knife clearance and wear on energy requirement

In association with Chair of Agricultural Machinery investigations into wear measurement and knife clearance adjustment, cutting power measurements were carried out with a stationary chopping system and the cutting energies thus determined. Materials used were wheat straw, wilted material and maize. The results shown in *figure 1 and 2* were obtained using wheat straw: the cutting energy was determined through integration from the progression of the cutting power, $F_s(t)$.

$$\int_{t0}^{t1} k_S \cdot F_S(t)\,dt \qquad k_S = U_T \cdot n_T$$

t_0: Beginning of cutting process of a knife
t_1: End of cutting process of a knife
U_T: Chopper drum circumference:
n_T: Chopper drum rpm

The cutting energy determined for the parameters – keenly sharpened knife, sharp shear bar and 0.25 mm knife clearance – was set at 100%. The cutting energies determined with other parameters are presented based on this value. The influence of knife sharpness (cutting edge radius) on the cutting energy can be clearly seen. This lead, even with a wear of only 0.3 mm on the cutting edge radius, to an around 100% increase in cutting energy requirement when compared with those of with a keenly sharpened knife (*fig. 1*). The influence of knife clearance on cutting energy is rather limited where the knife is keenly sharpened. But even with a small degree of knife wear, the clearance then has a considerable influence on cutting energy. [2] determined similar tendencies in a laboratory test.

The shear bar had a similar influence on cutting energy. Here, a 2.5 mm blade edge radius at the shear bar when compared with a sharp shear bar lead to an increase in cutting energy requirement of about 90% (*fig. 2*). Because of the sharp knives used here, the knife clearance played a comparatively minor role. A reduction in required cutting energies where wear of the shear bar was even more marked could, above all, be asso-

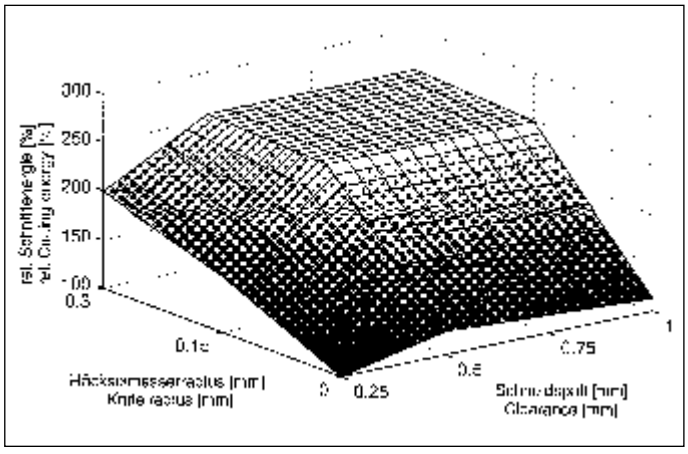

Fig. 1: Relative cutting energy depending on knife radius and clearance

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ciated with the resultant extremely poor chopping performance. The straw in such cases was regularly wound around the edge of the shear bar and either pulled through the knife clearance by the knives or only first cut by the following knife.

Possible measures for the retention of favourable cutting conditions

Favourable cutting conditions are therefore not only important with relevance to chopping quality but also from the point of view of energy requirements. Basically, two ways can be identified for keeping cutting energy down to the lowest possible level:

- Keeping knife clearance and wear constant during the chopping procedure
- Monitoring the wear and resharpening the knives and adjusting the knife clearance when a specific state of wear is reached

However, at the moment there exists no applicable technical solution for keeping the knife clearance and wear constant. The following, therefore, will concentrate on the monitoring of rate of wear and the service involvement of knife sharpening and clearance adjustment.

Recognising the state of wear

In practical conditions the driver decides on the time for sharpening from the sound, the power reserves of the engine, or the quality of the chop (higher cob husk proportion with maize). Because this method does not involve a precise identification of amount of wear, knife sharpening is often , in such cases, not thorough enough [1].

Patented solutions are known which allow technical measurement and determination of wear:

- Measuring the contour via electromagnetic sensors/distance initiators: During the passage of the knife, the sensor produces an electric signal from which the contour of the knife edge can be calculated. This measurement procedure only allows the sharpness of the knife to be determined at the point where the sensors are positioned.
- Measurement of cutting power forces: Here, the cutting and horizontal forces acting on the knives and the shear bar are measured. The conclusion as to the wear is drawn from the relationship, and therefore the direction, of the acting forces. Here, the wear is not evaluated at particular points but is assessed instead in sum over the complete breadth of the knife drum.

In this instance, the requirements for recognising the extent of knife clearance in the chopping procedure and the sharpness of the shear bar play only a comparatively minor role, in that the sharpness of the knife is the factor which alters most during the process and an exact adjustment of the knife clearance takes place after the re-sharpening of the knife. Also, the shear bar is in any case not sharpened. Moreover, the sharpness of the counter shear in comparison with that of the knife has substantially less influence of the cutting energy (where cutting edge radii are similar)

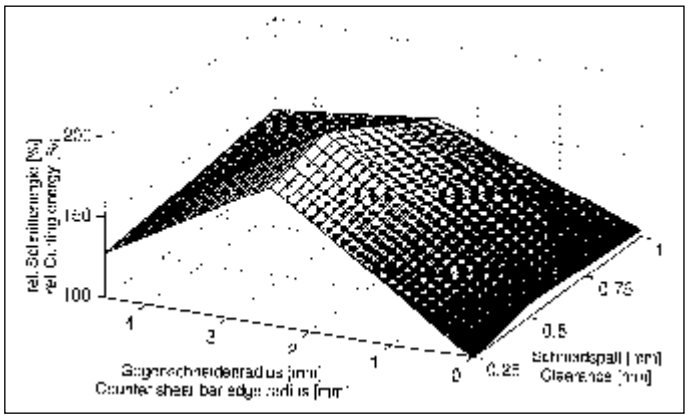

Fig. 2: Relative cutting energy depending on Counter shear bar radius and clearance

Knife clearance

In practical conditions the adjustment of the knife clearance in modern forage harvesters mostly takes place via a knock sensor. Here, the knife clearance is reduced by moving the shear bar right up until it makes contact with the knives, a point which is recognised by the knock sensor. Subsequently, the shear bar is withdrawn by a predetermined amount to give the required clearance. Another possibility is through the adjustment of the knife clearance by the driver. Here, the shear bar is also moved forward until contact with the knives takes place. The driver hears this. The necessary subsequent retro-positioning of the shear bar takes place according to the judgement of the driver. Thus, the precision of this adjustment method depends very strongly on the knowledge and experience of the driver.

Other known patented solutions for technical measurement of the knife clearance and determination of a threshold are:

- Knife clearance measurement through back pressure: Air is blown in the direction of the knife drum through a nozzle in the shear bar. The back pressure, or the amount of air emitted through the nozzle, is used in calculation of the clearance. With this method, only the clearance at the knife position involved is determined.
- Knife clearance through circuit completion/contact: The shear bar and the knife drum are electrically insulated from one another and represent two adjacent poles. A weak current is applied to both. When a knife touches the shear bar a circuit is completed. With this method, too, only the position of the least clearance is determined.
- Measuring of the knife clearance via electromagnetic sensors/distance initiators: During the passage of the knives the sensor produces an electrical signal from which can be calculated the distance of the knives.This procedure is based on the same principle as that for the identification of knife wear and can, where necessary, be linked to this. With this method, only the clearance at point of measurement can be determined.

In the circuit-closing/contact method of measuring clearance, the shear bar must be positioned by pushing the bar right up to the knives and subsequently withdrawing it. The other methods enable repositioning to be achieved by directly positioning the bar in one movement at the desired knife clearance point.

If knife clearance is determined only at defined points then a reference between the measurement points and the point of least knife clearance is absolutely necessary. The counter shear bar state of wear, especially, must be included in this reference.

Summary

The influence of wear and knife clearance gap on cutting energy was observed and, with this, the necessity for sufficient aids to cutting such as sharp knives and a minimum knife clearance, established and explained. Moreover, two procedures for the retention of suitable cutting conditions, and the technical possibilities of their realisation, were discussed.

Literature

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[2] *Lilijedhal, J.B., G.L. Jackson, R.P. de Graff* and *M.E. Schroeder*: Measurement of shearing energy. Agricultural Engineering 42, (1961), pp. 298 – 301