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Water-jet Sugar Beet Cutting

The process of water-jet cutting has established itself in various industry branches. There the many process specific advantages which speak in favour of this geometrically indeterminate cutting edge operating system. Besides the known cutting materials like steel and or stone, agricultural materials can also be cut. Especially homogeneous goods like sugar beets and potatoes have shown favourable cutting results in this respect.

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Keywords

Water-jet cutting, sugar beet

Literature

Books are marked by •

[1] *Brüser, C., und H.-H. Harms* : Alternative Schneidtechniken zum Trennen organischer Güter. Landtechnik 60 (2005), H. 5, S. 254-255

[2] • *Ligocki, A.*: Schneiden landwirtschaftlicher Güter mit Hochdruckwasserstrahl. Dissertation, ILF, TU-BS, 2005, ISBN 3-8322-3941-3

At the Institute of Agricultural Engineering and Fluid Power of the Technical University of Braunschweig, the use of the water jet cutting technique for the cutting of organic materials is being studied. Especially for homogeneous materials, such as sugar beet, this technique proves to be an appropriate alternative to the known methods.

At present, intensified studies on the water-jet cutting of sugar beet are being carried out. These studies are mainly focusing on the reduction of cutting energies and water consumption in order to make this technique even more interesting for mobile application, in addition to stationary use.

Power analysis

Today, water jet cutting in industry is generally carried out using pressure intensifiers at high pressures of approximately 350 MPa and small nozzle diameters (about 0.254 mm). Since the water volume flow is small due to the operating principle, the largest part of the cutting power is provided by pressure. What is the cutting result, if pressure is lower and water volume flows are larger, while power is constant? In order to answer this question, a series of experiments were carried out at constant power levels and using a wide range of nozzles [1]. The results are shown in *Figure 1*.

In the left diagram, cutting depth is shown for every used nozzle over the applied water-hydraulic power. The largely identical course of the graphs can be discerned clearly. The deviations of the two smallest nozzles can be explained as a result of friction- and damping effects in the cutting gap becoming so significant when a certain cutting depth is exceeded that cutting depth cannot be increased further. In principle, this effect occurs with every nozzle. The larger the mass flow from the nozzle becomes, however, the later the course drops, which is no longer shown in the diagram for nozzle diameters in excess of 0.33 mm. At a power of 9,000 W, a cutting depth of approximately 80 mm can be maintained for each nozzle. The right diagram shows the volume flow over the nozzle pressure for each nozzle. This diagram is based on the same measured values as the left one. The connection of the measuring points of a parameter provides a hyperbola, which is shown for 9,000 W as an example. Every point on the hyperbola stands for an arbitrary combination of pressure and volume flow. If a nozzle having a diameter of 0.254 mm is used, 1.5 l of water per minute flow at an operating pressure of 360 MPa. If a 0.9 mm nozzle is used, however, an operating pressure of 61 MPa in combination with a larger volume flow of 8.8 l/min is sufficient. Therefore, constant water-hydraulic power leads to a constant cutting result in a very wide range.

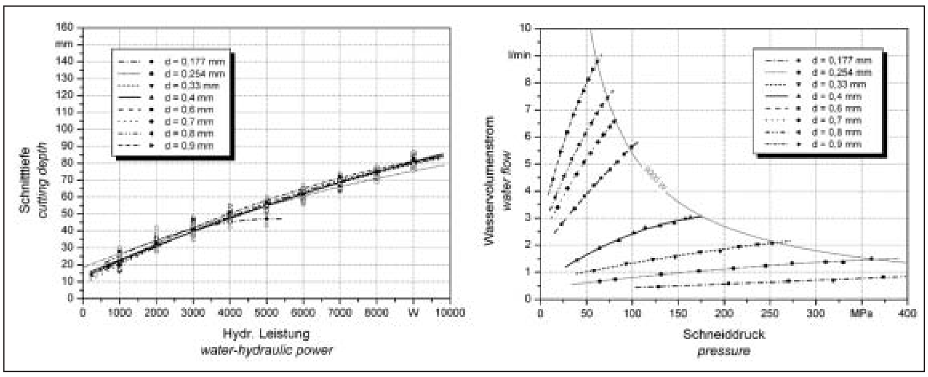

Fig. 1: Power analysis at various nozzle diameters

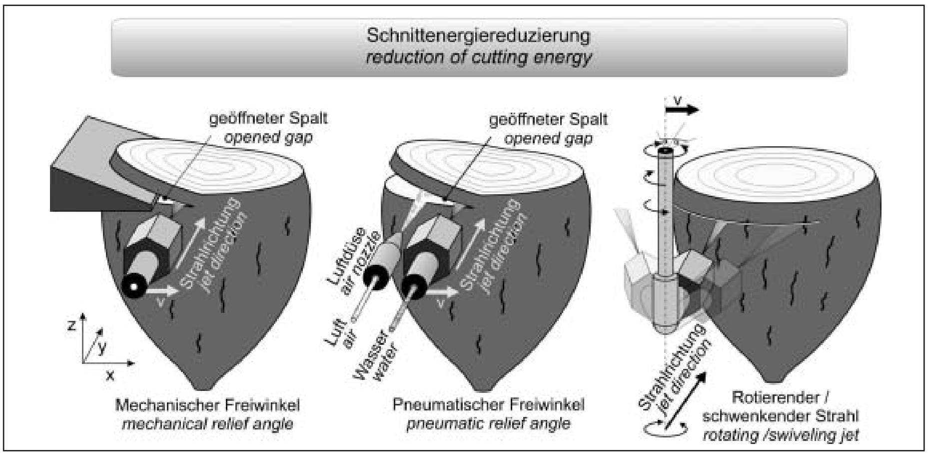

Fig. 2: Measures for the reduction of cutting energy

Measures which reduce cutting energy

As mentioned in the previous paragraph, the jet must overcome frictional and damping forces in the cutting gap which are caused by the water- and material buffer [2]. In order to reach a reduction of specific cutting energies and, hence, larger cutting depths, different systems are being studied which use the specific elastic properties of the beet material (*Fig. 2*).

In *Figure 2* (left), a wedge is used to make a mechanical relief angle unit follow the nozzle. In a pneumatic relief angle unit, compressed air is used for the same purpose (*Fig. 2*, middle). The devices which do not actively participate in the cutting process allow the cutting gap to be opened easily. The water- and material buffer can be minimized due to the improved draining behaviour. As an alternative measure, the kind of water impact can be altered, and turbulence in the cutting gap can be minimized by means of rotating or swivelling nozzles (*Fig. 2*, right). Such trials will be carried out in the coming winter.

If the cutting results of the trials with a relief angle unit are compared with the trials carried out without any device, considerable improvements can be recorded for both the mechanical and the pneumatic method. Given typical experimental settings and a relief angle of 20° together with a 0.4 mm nozzle, a larger cutting depth (or cutting energy reduction) of 17% is achieved. For a nozzle having a diameter of 0.6 mm, the reduction is 14%. In order to guarantee that the sugar beet has been cut exclusively by the water jet, forces in the direction of the feed motion are measured with the aid of strain gauges. A high-speed camera clearly showed the improved draining behaviour of the cutting water as compared with the undirected, large-area draining behaviour which occurs without a device.

Water-reducing measures

In addition to the reduction of cutting energies, water-reducing measures are being studied. The first step is to catch the process water used after the cut, to clean it and to feed it back into the pump. For this purpose, necessary cleaning mechanisms are being studied at the institute. As a second measure, a device was developed which allows the water jet to be interrupted mechanically (*Fig. 3*).

The interrupter disc shown rotates at a defined speed and enables the jet to be interrupted immediately after it leaves the nozzle. With the aid of different interrupter discs and variable drive speeds, frequencies of up to ~ 1,000 Hz can be generated. In all discs, the pulsation rate is 1:1. The shown jet interrupter is an initial test for the examination of the general cutting result. Due to the principle, this does not yet allow water to be saved. If the trials are successful, it will only be possible to save water if a quickly switching valve is used. However, the knowledge gained with the jet interrupter is indispensable for the development of a valve.

In the cutting result, bridges of uncut material can be discerned. If this method is employed in practice, these undesirable bridges caused by the operating principle prevent the simple lifting of the cut-off material lobe. For the cutting degree of the beet to be evaluated, weighed cutting depth was introduced as a criterion which establishes a relation between measured cutting depth and uncut bridge width. As a target value, a minimum of 90% of cutting depth is intended to be reached without jet interruption. As the interrupter frequencies increase, it can be shown that the cutting depth courses of the examined nozzles approximate the reference value measured without pulsation. The set value of 90% is reached at slightly less than 500 Hz. This is the lower limit for valve development. At the given pulsation rate, theoretical water savings reach a considerable 50%.

Summary and outlook

In order to improve the cuttability of sugar beet by means of a high-pressure water jet, energy- and water-saving methods are currently being studied at the Institute of Agricultural Engineering and Fluid Power. Trials at constant power have shown that the cutting result remains the same at reduced pump pressure and a larger water volume flow. Mechanical and pneumatic relief angle units allow cutting depth to be increased or cutting energy to be reduced by up to almost 20%. The effect of rotating and swivelling nozzles as well the effect of two nozzles situated opposite each other will be clarified in the coming beet season. Different nozzle geometries, such as flat-jet nozzles, will be studied as well. Given comparable cutting results, the use of an interrupted water jet enables significant water savings to be achieved as compared with conventional application. The suitability of used cutting water for filtration with the goal of recycling water into the circuit will be studied in tests in the near future.

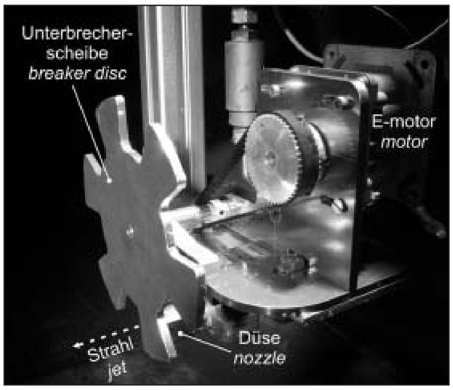

Fig. 3: Jet interrupter