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Cutting Agricultural Goods with a High-pressure Water-Jet

Results from three years of DFG-research

Within the framework of a DFG-sponsored project, the Institute of Farm Machines and Fluid Power at the TU Braunschweig is testing the cutting of agricultural goods with a high-pressure water-jet in a specifically developed test rig as a basically new, hitherto untried cutting method. Besides ascertaining functional relationships between the parameters of a water-jet cutting facility and the various agricultural goods being investigated, the basic assessment of the "cutting potential" and analysis of the cutting process are in the foreground.

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Keywords

Cutting technologies, water-jet cutting

Literature

[1] *Ligocki, A. und H.-H. Harms*: Schneiden von Zuckerrüben mit Hochdruckwasserstrahl. Landtechnik 57 (2002), H. 6, S. 360-361

In this article, results of a three years DFG-financed research-project with the subject of water-jet cutting of agricultural goods will be presented.

The results are based on experiments at the water-jet cutting test rig of the Institute of Agricultural Machinery and Fluid Power at the TU Braunschweig.

The technology of water-jet cutting and the function of the test rig were already presented in [1].

Testing strategies

The targets of the researches were to find basic knowledge on cutting agricultural goods by using the tool "high-pressure water-jet".

The boundary conditions (i.e. feed rate, water consumption) are very different to known uses so far, so the regularities of other industry branches cannot simply be transferred.

In addition to new determination of these functional relationships by variation of nearly all system-parameters, a basic estimation of the cutting-potential for selected agricultural goods is in the front.

A testing strategy was generated with two groups of goods.

The first group represents the intensively analysed goods to acquire universal laws and the second group builds the less intensive analysed goods, to appraise the cutting-potential.

For a better analysis of the cutting-process, photos from a high-speed camera accompanied the tests.

Resultant from these demands and by multiplication of the illustrated parameters in *Figure 1*, there are more than 17,000 test series, each with x-single-tests per cutting-good. By defining basic parameters and variating only one parameter within a test series, it was possible to reduce the volume to 80 test series with more than 600 single-tests.

Thereby the following cutting-goods were analysed:

- sugar beets (intensively analysed),
- packages of Gras (intensively analysed),
- potatoes (intensively analysed),
- maize (appraisal of the cutting-potential),
- maize stems (appraisal of the cutting-potential),
- carrots (appraisal of the cutting-potential).

In order to pronounce the functional interrelations of all analysed goods, the basic parameters were adapted to the respective good characteristics.

As a consequence, the achieved cutting depths are significant in their characteristics, but quantitative comparisons of different cutting-goods are not possible.

	Parameter / *parameter*		Kartoffeln *potatoes*	Zuckerrüben *sugar beets*	Graspakete *packages of gras*
Reinwasser / *pure water*	Vorschub *feed rate*	Basis	**1500 mm/s**	**1500 mm/s**	**15 mm/s**
		Variation	100 ... 3000 mm/s	100 ... 3000 mm/s	10 ... 120 mm/s
	Schneiddruck *pressure*	Basis	**350 MPa**	**350 MPa**	**350 MPa**
		Variation	100 ... 350 MPa	100 ... 350 MPa	100 ... 350 MPa
	Freistrahllänge *jet length*	Basis	**5 mm**	**5 mm**	**35 mm**
		Variation	5 ... 150 mm	5 ... 200 mm	35 ... 120 mm
	Düsenanstellwinkel *angle of nozzle*	Basis	**0°**	**0°**	**0°**
		Variation	0° ... ±45°	—	—
	Düsendurchmesser *nozzle diameter*	Basis	**0,152 mm**	**0,152 / 0,254 / 0,33 mm**	**0,254 / 0,33 mm**
		Variation	0,076 ... 0,33 mm	0,076 ... 0,33 mm	0,076 ... 0,33 mm
Abrasivstrahl / *jet for abrasives*	Abrasivmittelmenge *abrasive flow rate*	Basis	—	**2,6 g/s**	**2,6 g/s**
		Variation	—	1,1 ... 7,6 g/s	1,1 ... 7,6 g/s
	Vorschub *feed rate*	Basis	—	**1500 mm/s**	**40 / 60 mm/s**
		Variation	—	100 ... 3000 mm/s	40 ... 140 mm/s
	Freistrahllänge *jet length*	Basis	—	**5 mm**	**35 mm**
		Variation	—	5 ... 200 mm	35 ... 120 mm
	Sandkörnung *sand granulation*	Basis	—	**120 / 80 mesh**	**120 / 80 mesh**
		Variation	—	80 ... 220 mesh	80 ... 220 mesh
	Altern. Abrasivmittel alternative abrasives	Basis	—	**Sand**	**Sand**
		Variation	—	Kochsalz / Zucker	Kochsalz / Zucker
	Vorpressdruck pre compression	Basis	—	—	**0,2 MPa**
		Variation	—	—	0,4 MPa

Fig. 1: Synopsis of test parameters (intensively analysed goods)

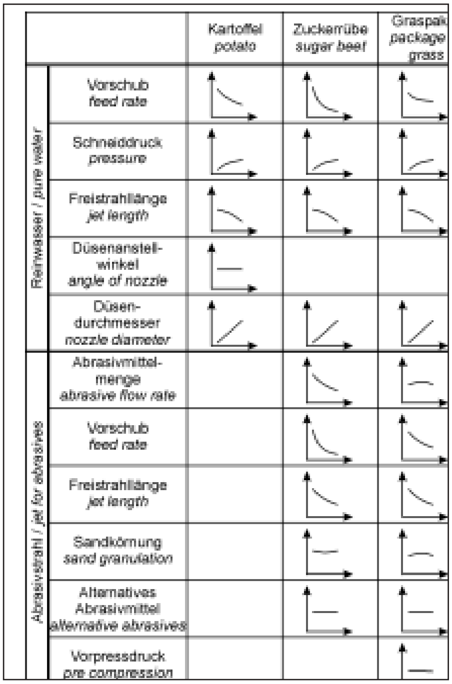

Fig. 2: Functional relationship between cutting-depth and variation parameter with different cutting-goods

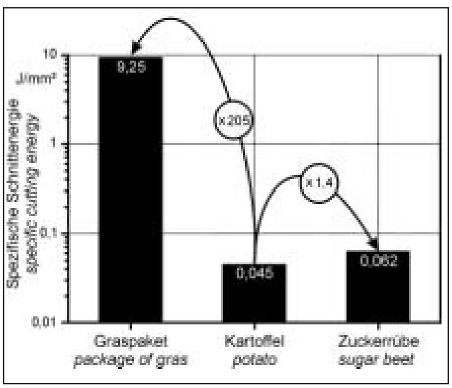

Fig. 3: Comparing specific cutting energies

Therefore, the specific cutting energy was used, which is a comparable and appraisable dimension.

Deviating from the usual convention in the agricultural engineering (energy per mass), in the water-jet technology this dimension represents the energy per area cut, because using this technique it is irrelevant, which mass has to be separated by the water-jet.

Observing the specific cutting energies of different goods, there are clear differences. *Figure 3* shows exemplary results of the specific cutting energies from three comparable tests.

The specific cutting energies of potatoes and sugar beets are similar. The differences are slight and are based on different structures of the goods. The differences between the cutting-good package of grass and sugar beet resp. potato are much bigger. The specific energy used for this cut is about factor 200 bigger than for potatoes or sugar beets.

This can be explained by using two theoretical approaches:

1. The sugar beets resp. potato has a homogeneous structure. The package of grass consists of a multiplicity of different stalks. These stalks can be leafs or can have hollow bodies. In addition, there are always air pockets in the good. The cutting process can be fragmented in a great variety of single-stalk-cuts. Thereby, the water-jet interfuses the different stalks and looses coherence in the process of frequent transitions between the stalks resp. stalks and air pockets. Consequently, it looses energy density and therefore the cutting depth sinks. This phenomenon could also be shown by high-speed photos of a puncture-test, using a maize stem as cutting-good. *Figure 4* shows single photos of a high-speed sequence, using a pressure of 300 MPa. It is clearly shown how the jet impinges on the stem. 0,0055 seconds later the 14 mm stem is interleaved and on the outlet side the jet expansion can be seen. A similar attitude can be expected by grass stalks.
2. In comparison to a mechanical blade, a water-jet is not subject to a mechanical guidance. So it would attempt to take the way of lowest resistance. The jet begins to “dance”. The direction of the jet is not kept, the acting-time and consequently the energy in the particles imported goes down. The package of grass thins out, because only leaf-elements are cut. The cutting depth sinks.

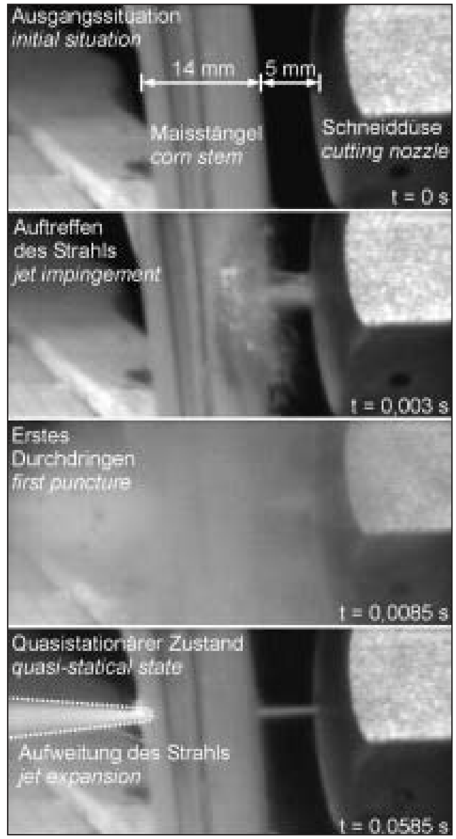

Fig. 4: Puncture-test of maize stem

Under equal conditions, both phenomena lead to an increase of the specific energy.

Conclusion and outlook

In principle, agricultural goods can be cut by water-jet. Often a multiplication of the cutting power is possible by using abrasives. A higher energy requirement particularly is expected for inhomogeneous goods or goods with a hollow structure.

Consequently homogeneous goods, like carrots, potatoes or sugar beets are predestined for water-jet cutting.

After acquisition of the fundamental principles, the Institute of Agricultural Machinery and Fluid Power now works on a reali sation of the water-jet technology in a real application with simultaneous reduction of cutting energy.