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Slicing sugar beet with high pressure water jets

In diverse landwirtschaftliche Erntetechniken sind Schneidverfahren integriert, die mit einer mechanischen, „ausgeprägten“ Klinge arbeiten, jedoch unter rauen Arbeitsbedingungen erhöhtem Verschleiß ausgesetzt sind. Bei diesen Techniken handelt es sich um weitestgehend ausgereifte Systeme. Neben einer weiteren Optimierung der bestehenden Verfahren wird am Institut für Landmaschinen und Fluidtechnik der TU Braunschweig derzeit im Rahmen eines DFG-geförderten Forschungsvorhabens der Einsatz des Wasserstrahlschneidens als grundlegend neues, der Landtechnik bisher fremdes Schneidverfahren untersucht.

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Keywords

Cutting technologies, water-jet cutting, sugar beets

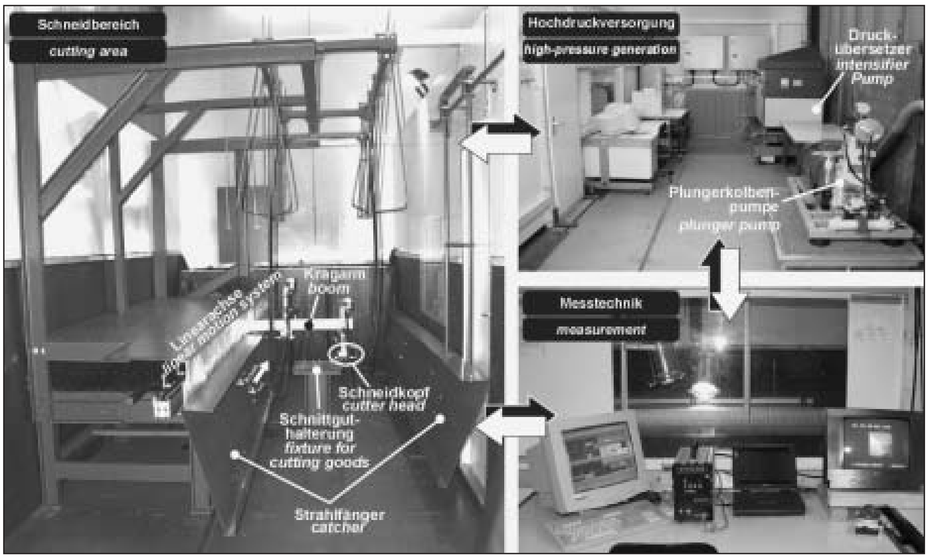

Fig. 1: Test rig

The high pressure water jet technique is increasingly used in cleaning, removing and separating different materials and substances in metalwork, construction, ship building, in the automobile industry and in the preparation of food.

Why shouldn’t this technique also find a use in agricultural harvest machinery? Some advantages of water jet cutting could be attractive in agricultural application:
- continuous renewal of the cutting surfaces so that no wear signs appear as with mechanical cutting
- non-susceptibility to damage through contact with hard, solid objects
- in ideal cases, no rotating parts and thus no danger of wrapping
- almost inertia-less starting and stopping of the „blade“
- limited mechanical characteristics required of the objects to be cut (only a small amount of tensile resistance)
- high flexibility because no mechanical drive for the „blade“ is required

The water jet cutting test stand

The developed and, in [1], already working test stand presented here (*fig. 1*) consists mainly of a „wet area“ for the actual cutting process and a „dry area“ wherein the high pressure is produced and the measurement technology and operator are situated during trials.

Core of the test stand is a high-precision linear axle driven by servo-motor with frequency converter which has a movement range of 4.5 m and a maximum sliding speed of 6 m/s.

Over a beam a maximum of two horizontally positioned cutting heads can be accelerated with the linear axle. These move over a cutting table within jet reach during the cutting action. Basically both cutting heads can be used for jetting pure water or an abrasive mix. Used for dosing the abrasive mix is equipment especially developed for the test stand and which is moved on the linear axle to ensure as short a distance as possible between the dosing and the cutting head? High-pressure supply comes via pipeline system supplied either by a hydraulic 37 kW pressure converter (up to 380 MPa and 3.7 l/min) or a 45 kW plunger piston pump (up to 190 MPa and 11 l/min). The water mains served as low-pressure water supply.

The most important investigation factors were recorded with the help of a MAT-

LAB/Simulink program packet and hardware from the company dSpace.

In direct form these comprised:

- momentary mechanical pump drive moment and momentary pump rpm
- cutting pressure and water volume flow
- total water consumption during cutting
- material flow velocity
- cutting direction.

Additionally, a high-speed camera (up to 10 000 images per second) was available for documentation and cutting analysis work.

Slicing sugar beet

An area of use for the water jet cutting technique could be the slicing of sugar beet before the extraction process in the factory. In the total processing of sugar beet a very large amount of water is necessary for cleaning the beet and this could be used for a later cutting operations.

After optimising the cutting process with regard to amount of water, it could also be possible to replace the mechanical sugar beet precision head in self-propelled harvesters with an intermittent water jet.

During the 2001/02 harvest comprehensive beet cutting trials were conduced at the presented test stand. During these, the following parameters were varied:

1. *Material flow velocity*
   Basic parameter: 1500 mm/s
   Variation range: 100...3000 mm/s
2. *Working pressure*
   Basic parameter: 350 MPa
   Variation range: 100...350 MPa
3. *Gap between nozzles <> harvest material*
   Basic parameter: 5 mm
   Variation range: 5...150 mm
4. *Nozzle diameter*
   Basic parameter: 0.254 mm
   Variation range: 0.076...0.33 mm

During a trial series only one parameter would be altered in each case within the framework of the variation range whilst the other variables were kept constant (basic parameter).

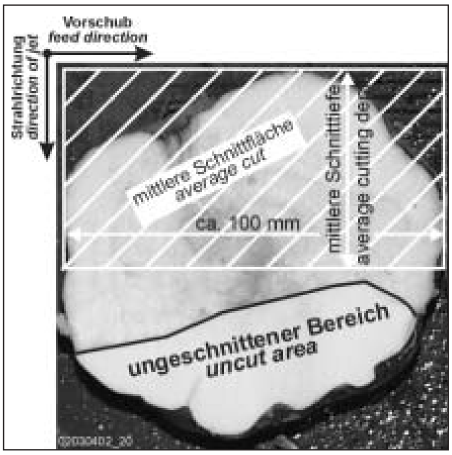

Fig. 2: Exemplary cutting result

Amongst each other the parameters are so successively set that no cutting-through of the material can take place – otherwise it could not be ensured that the total jet energy would be converted into cutting energy within the material.

For better comparability of results the same unit of sugar beet (comprising three single beet) was always used during a trial series.

After „part-cutting" was completed the cut depth was determined by manual measurement at a number of points in the material. Together with the length of the cut, this allowed determination of cut surface area for use in later evaluations.

A result from the cutting tests is shown in *figure 2*. The total length of cut was ~ 100 mm. Material flow velocity was determined as 1.5 m/s. Selected working pressure was according to basic parameter 350 MPa with a cutting nozzle diameter of 0.254 mm which, based on the given length of cut, meant a water consumption of 1.8 ml. Cutting was with pure water without mix of abrasive material. 5 mm was chosen as the gap between cutting head and material. The average cut depth with these parameters was ~ 67 mm whereby an energy of ~ 550 Nm was applied to the material. The single cut demonstrated comes from a test series where the cutting pressure was the variable. The result from the total series of 39 individual cuts can be taken from *figure 3*. Alongside the cut depth over the parameter pressure, the total water consumption over the average cut depth and the specific cutting energy per area over the pressure are presented here.

Summary and outlook

At the ILF a flexible test stand was created for investigation of water jet cutting for application with agricultural machinery. So far, investigations into cutting sugar beet indicate a basic potential for cutting the roots in this way. For stationary application the required amount of water per beet cut is so small that there is scope for an increase in cutting depth in the main through applying larger nozzle diameters with simultaneous reduction in cutting pressure. This approach could allow the avoidance of expensive high-pressure components (pressure converter)

Optimisation potential is also seen for mobile application through mixing abrasive material for the jet. Trials in association with this are planned for the 2002/03 harvest season.

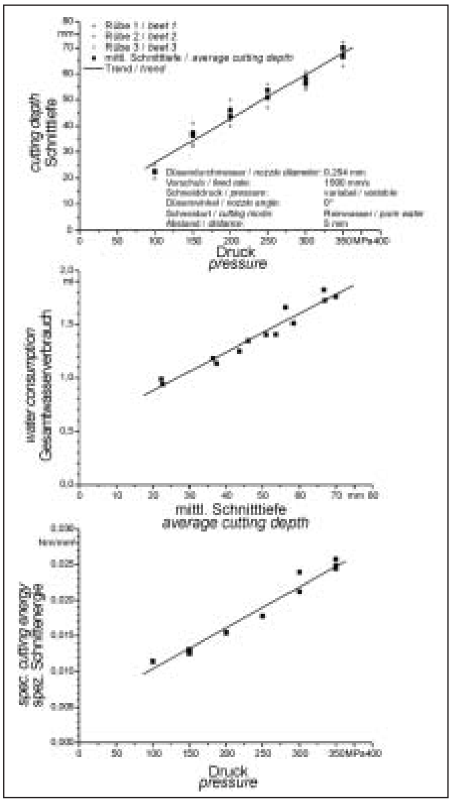

Fig. 3: Abstract of test series results

Literature

[1] *Ligocki, A.*: Wasserstrahlschneiden als alternatives Schneidverfahren für die Landtechnik. Landtechnik 56 (2001), H. 5, S. 324-325