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Water-jet cutting as alternative cutting system in agricultural machinery

Nowadays, increased labour productivity and efficiency is demanded to a greater extent than ever before in the fulfilling of the role demanded from agriculture. Because of the characteristic dependency on weather this applies especially to harvesting machinery, a sector already well known for the large number of cutting operations involved. The cutting systems used nowadays have been developed to a very high level. Along with further optimisation there's an argument for taking a closer look at „alternative" cutting systems that can be applied in agricultural machinery.

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In the search for new „alternative" cutting systems the most different concepts have been investigated [1, 2]. Water-jet cutting is a system which fundamentally promises greatest development potential as „alternative" cutting method but has yet to be thoroughly investigated.

Alongside presenting the actual method „water-jet cutting", this report will also look at first cutting results from a preliminary trial series as well as presenting the test rig being constructed at the Institute for Agricultural Machinery and Fluid Technology, TU Brunswick.

Fundamentals of water-jet cutting

Water-jet cutting is a purely mechanically method involving no characteristic blade. The energy required for the cutting action in this context is achieved through a high velocity water-jet whereby the potential energy of the water (with a pressure of up to 400 MPa) is transformed via special cutting nozzles into kinetic energy with velocities of up to 900 m/s.

The required pressure is achieved through hydraulic pressure transformers or mechanical high-pressure pumps.

Cutting nozzles of sapphire or hard metal with opening diameters from 0.1 to ~0.35 mm give the required jet form. Depending on working pressure and nozzle diameter, water volume flows are achieved of less than 1 l/min. To increase cutting performance abrasive material such as sand, salt or sugar can be added to the water. The mixing takes place with precisely dosed amounts directly in the cutting nozzle (*fig. 1*).

The high emergence velocity of the cutting water from the nozzle opening gives a „free cut". Additionally, the mechanical effect on the treated material in the area of the cut action is extremely limited and minimal resistance force is thus required.

Other clear advantages of water-jet cutting include a cutting „blade" that is continuously renewed, a narrow cutting action and almost inertia-free stopping and starting of the cutting jet.

There are many parameters which have to be adjusted to suit the treated material so that a satisfactory cut can be achieved (*fig. 2*).

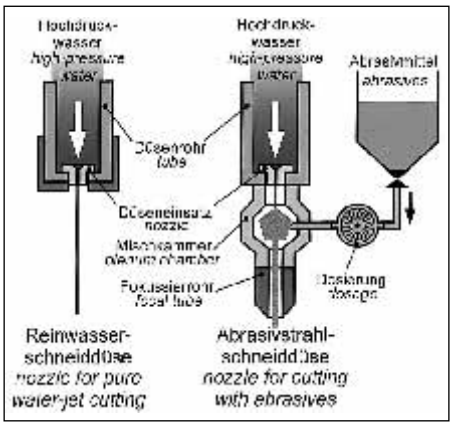

Fig. 1: Water-jet nozzle assembly

The required experience of this method used on farm products is not yet available and identifying the required values is one target of the project presented here.

First preliminary trial results

Working together with the TU Hanover, comprehensive preliminary trial series were carried out on water-jet cutting of agricultural materials.

With variation of parameters working pressure, free jet length, type and amount of abrasive material the following materials were investigated:

- wheat straw (single stalks, unconsolidated packets)
- grass (single stalks, unconsolidated packets)
- sugar beet roots, and
- sugar beet leaves (with stem)

Fig. 2: Parameters of a water-jet cutting system

A conventional x-/y- cutting table specially modified for higher material throughflow velocities was used for the tests.

Depending on the material to be cut, the tests were carried out with working pressures in the area of 400 MPa. The water used initially flowed at a maximum 1 l/min. Abrasive sand as well as commercial cooking salt were used as abrasive material. The blend consisted of ~ 3 to 6 g/s. The following results were achieved:

- The materials grass, sugar beet roots and sugar beet leaves could be perfectly cut-through where sufficiently high cutting velocities were applied.
- Basically higher speeds were achievable with grass (presentation speed $v_{Vorschub} > 10$ m/s). The presentation speeds = driving speeds currently achievable in farm machinery lie way below these values.
- Straw was possible to cut through as single stalks in unconsolidated form but the system was critical at higher cutting speeds.

Figure 3 underlines a few cutting results.

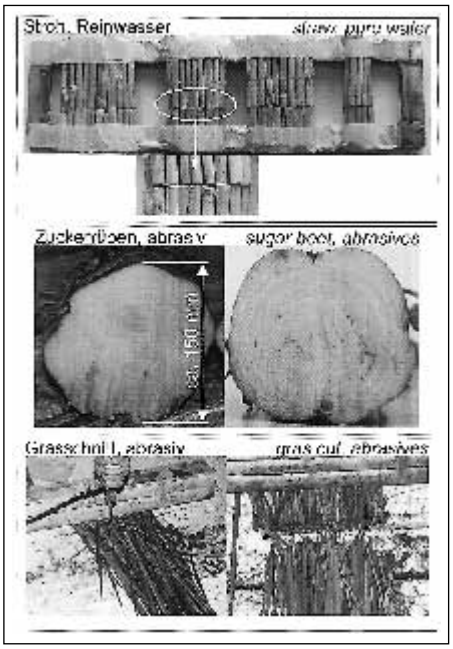

Fig. 3: Pre-test cutting results

Test rig

Currently a stationary test rig for investigating high-pressure water-jet cutting capabilities with farm products is being built at the Institute for Agricultural Machinery and Fluid Technology, TU Brunswick (*fig. 4*). The test rig consists of two pressure production aggregates which are nearly the same in performance but, through different working systems, (hydraulic and mechanical), can give working pressures from 0 to 380 MPa and water volume transport of 0 to 11 l/min. Thus it was possible to present a very wide spectrum of working pressures and volume streams for investigating cutting performance with the most different materials.

Core of the test rig was a 5.5 m long linear axis unit in which up to two cutting jets could be fixed and which could be accelerated to a maximum speed of 6 m/s (= crop material presentation speed). Cutting is possible with pure water as well as abrasive/water. During the tests the material to be cut is fixed in a holder and separated by the moving cutting jet.

The cutting operation can be recorded by high-speed camera at up to 10000 frames per second.

In addition to specifications of the material subjected to cutting, working pressure, volume flow, cutting velocity, type and amount of abrasive material and required power for the pump were all recorded.

Because required power for cutting is very low through the eroding action of a water jet, depth and shape of cut are, where necessary, used in evaluating results.

Summary and outlook

The water-jet cutting of agricultural materials as possible alternative cutting method in agricultural machinery has not been scientifically investigated.

First preliminary trials in this area have been very positive. Currently, a water-jet cutting test rig at the Institute for Agricultural Machinery and Fluid Technology, TU Brunswick is in construction. Aims are as follows:

- Recording of important trial parameters such as presentation speed, pressure, cutting water volume flow
- Targeted variation of agricultural materials as well as water-jet cutting parameters under recording of the influences of the aimed-for cutting result
- Recording of cutting process using high-speed camera with up to 10000 frames/s.
- Processing the results for evaluation of water-jet cutting as an „alternative cutting method in agricultural machinery."

Results so far indicate water-jet cutting as a possible method in sugar beet harvesting machinery

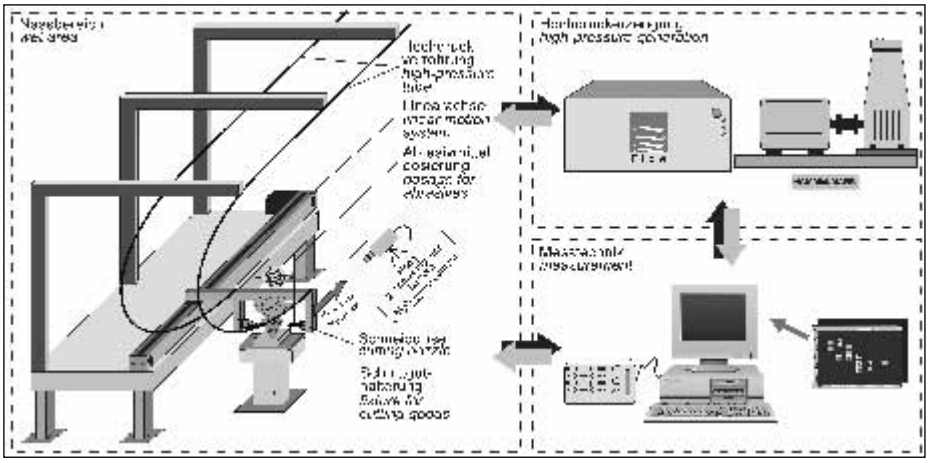

Fig. 4: Test rig

Literature

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