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Preexaminations for a water catcher to cut sugar beets with water jet

The cutting process of agricultural materials by a high pressure water jet was examined and optimized at the Institute of Agricultural Machinery and Fluid Power in the recent past. For mobile applications of this process it is necessary to carry an amount of water on the machine which is sufficient for the cutting process. This requires more place and increases the machine weight. In an ongoing project the feasibility of collecting and recycling used cutting water is examined in order to reduce the water amount which has to be carried-up.

Keywords

Alternative cutting technologies, catcher, water jet cutting, sugar beet, agricultural materials

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The purpose of the project supported by the German Research Foundation (Deutsche Forschungsgemeinschaft DFG) is to examine how to collect, process and return the cutting water from high pressure water jet cutting of sugar beets.

The project is divided in two main parts. The first part deals with the development of a catcher unit for the high pressure water jet. In the second part an appropriate water recycling process has to be identified to facilitate the cleaning of the soiled water so it can be returned to the high pressure pump. **Figure 1** shows the scheme of a possible recycling circuit for sugar beet harvest.

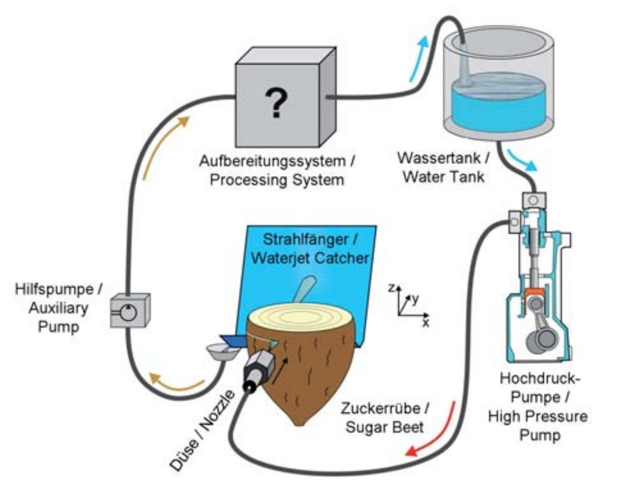
In the first step of this project a device to catch the water jet after the cutting of sugar beets is developed.

Against the background of the mobile application of this process on a self propelled sugar beet harvester there are two kinds of problems. The first one is the conflict of aims between a small sized and compact design of the catcher to satisfy the demands in a lifter unit and a design with a big opening cross section to collect a large quantity of water from the expanded water jet after the cutting process. The second problem when developing the catcher is the abrasion of the material hit by the high pressure water jet.

Jet Impact

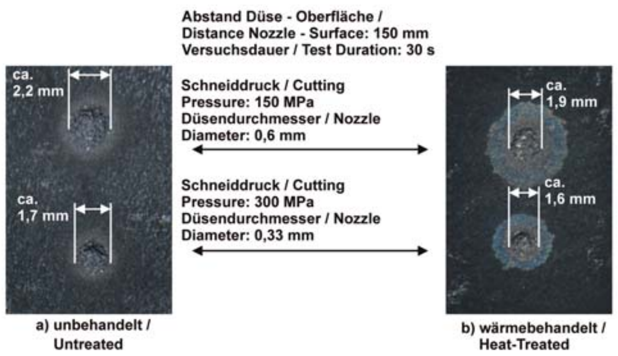
Figure 2 shows the damage of a titanium based alloy (Ti V15 Cr3 Al3 Sn3) at the stagnation point caused by a water jet hitting on the alloy surface in a right angle. This test is done with an untreated (shown in **figure 2a**) and a heat-treated (shown in **figure 2b**) alloy. The chosen values for the cutting pressure and nozzle diameter allow cutting depths in sugar beets between 80 up to more than 110 mm [1; 2]; Brüser, 2008). The test duration is 30 s and the distance between nozzle and titanium sheet is 150 mm. This is approximately the distance which is corresponding to the necessary distance between nozzle and catcher when topping sugar beets. In **figure 2** it is recognizable that the effect of the water jet is much

Fig. 1



Possible recycling circuit for sugar beet harvest

Fig. 2



Effect of the high pressure water jet on a titanium based alloy (Ti V15 Cr3 Al3 Sn3)

higher with the parameter combination 150 MPa pressure and 0.6 mm nozzle diameter than with a pressure of 300 MPa and a nozzle diameter of 0.33 mm. The reason is in the higher water hydraulic power of the water jet with the parameter combination 150 MPa pressure and 0.6 mm nozzle diameter.

The heat treatment of the work piece (**figure 2b**) to increase the hardness only leads to marginal advancement of the durability. Titanium sheets with a thickness of 3 mm are used for the test. It takes only a few minutes until they are completely permeated by the water jet. The endurance of conventional sheet steel is clearly shorter. E.g. an aluminium sheet stands only a few seconds.

According to [3] a free jet leaving a nozzle can be divided into three zones. In the first zone after the nozzle is a compact water jet followed by the second zone with a drop shaped jet and the third zone with a spraying jet. This classification results from interaction between the water jet and the jet encircling air. The impact point of the water catcher is in the zone of the compact water jet. This compact water jet is surrounded by a cone of nebulisation. The cross sectional areas of compact water jet and surrounding cone of nebulisation exceed with increasing distance from the nozzle.

Because of the high water hydraulic power in the zone of the compact water jet it is necessary to use wear parts or movable objects for the impact point of the water jet. By that it is possible to decrease the effect of the hitting jet by converting jet energy into kinetic energy of objects which can be decelerated by damping elements.

At the moment two alternative solutions are tested. In the first solution brushes are used to decrease the jet energy. The brushes are fixed on one side and can evade the jet with the free end. Simultaneously this movement is retarded by the internal damping of the brushes. In the second tested solution the jet hits on hardened steel balls which are bedded moveable in a housing. The jet moves the steel balls and jet energy is converted to kinetic energy. Slabstock foam in the housing decelerates the steel balls.

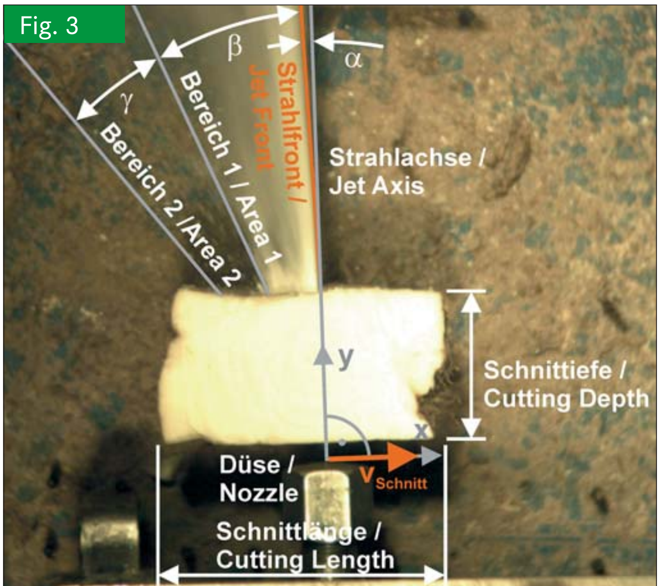
Jet Diffusion

Several tests are pursued in order to get information about the diffusion of the water after the cutting process. With this information the required opening cross section of a water catcher can be identified. The diffusion is observed with a high speed camera in horizontal and vertical plane.

In several test runs the parameters pressure, nozzle diameter, cutting speed and cutting depth are varied. In order to make the tests comparable, they are pursued with a defined cutting depth. For this the used sugar beets are sized to widths of 50, 75 and 100 mm. This generates parallel cut sections and constant cutting depths.

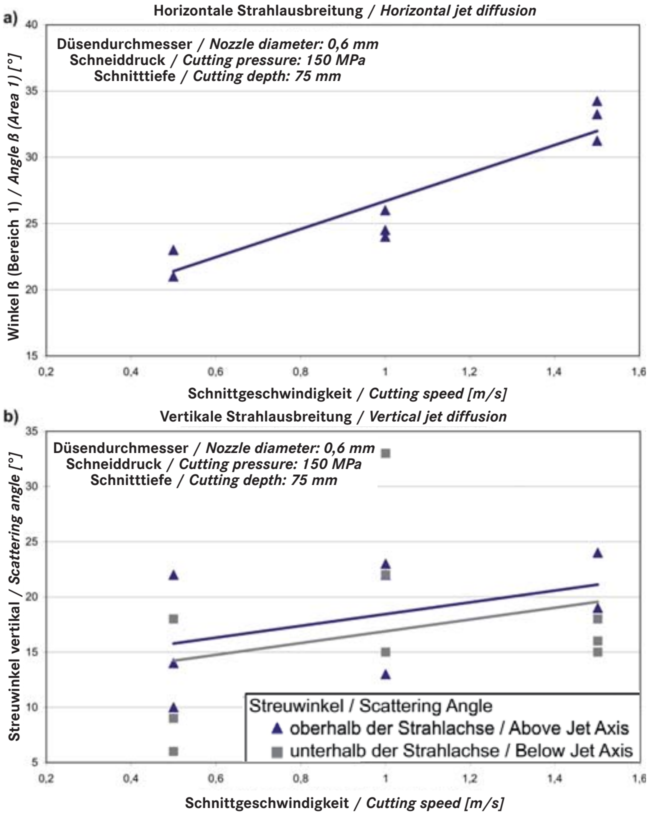
Figure 3 shows exemplarily the top view of a cutting process of a sugar beet and the jet diffusion after cutting in a horizontal plane. The sugar beet is fixed while the nozzle moves horizontally with the velocity v_{cut} in direction of the x-axis of the given coordinate system.

Fig. 3



Jet diffusion after cutting process

Fig. 4



Effect of cutting speed variation on the beam width of area 1

The jet front which is well defined against the surrounding area runs at the angle α to the jet axis. The jet front is inclined from the jet axis away from the moving direction of the nozzle. The cutting water disperses fan shaped behind the beet. This water fan can be divided in two areas including the angles β and γ.

Area 1: The cutting water disperses in straight and continuously water threads, which are surrounded by water fog.

Area 2: The cutting water disperses in drop shaped threads. This threads are interrupted. Multiple drops have the same moving direction.

First test rows show relations between the described angles (α, β, γ) and the varied parameters cutting depth, pressure, nozzle diameter and cutting speed.

Figure 4 shows the relations between the angles of the fan shaped water diffusion and the cutting speed in horizontal plane (**figure 4a**) and vertical plane (**figure 4b**).

The results document a relative big mean variation between the test iterations. Nevertheless it is clearly shown for the applied parameter that the spread angle of the fan shaped diffusion increases with higher cutting speed.

Conclusions

In addition to the up to now realized first tests it is necessary to validate the detected connections in further test rows with varied parameters. Likewise the water distribution in the out of the beet flowing fan shaped jet has to be determined to define the required size of the water catcher. For this a test device is constructed, that facilitates the catching of defined areas of the fan shaped water diffusion and the quantifying of the amount of water in these defined areas.

On the basis of this test results it is possible to design a preferably compact catcher and a statement to the cutting water losses can be given.

Literature

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