Jünemann, Dennis; Harms, Hans-Heinrich and Lang, Thorsten

Water processing for high-pressure water-jet cutting of sugar beets

For mobile application of high pressure water jet cutting of agricultural goods it is necessary to carry the sufficient water amount for the cutting process. This requires additional place and increases the machine weight. Due to this the feasibility to reduce the required amount of fresh water by recycling the cutting water is examined at the Institute of Agricultural Machinery and Fluid Power, Technical University Braunschweig. This project is supported by the German Research Foundation (DFG). Present results show that this is generally possible and several process steps are necessary.

Keywords
Alternative cutting technologies, water processing, water jet cutting, sugar beet

Abstract
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In the first part of the research project the jet diffusion and the jet impact during high pressure water jet cutting of sugar beets were examined. These examinations have shown that nearly all soiled cutting water can be collected in a compact area [1]. The size of this area depends on the parameters cutting pressure, cutting speed and cutting depth. The in the following described second part of the project has the goal to identify an appropriate cleaning process for the soiled water to reach the water quality requirements of the high pressure pumps.

Soiled process water

The soiled process water of the cutting process has dry matter contents between 10 % up to 55 %. In the following the process water will be termed as beet sludge. A standard method was defined to produce the beet sludge with the parameters 1.5 m/s cutting speed, 0.6 mm nozzle diameter and 150 MPa cutting pressure. With these parameters a cutting depth of more than 100 mm can be reached in sugar beets. If used in sugar beet harvesters unsoiled water can additionally be collected while the topping unit covers the distance between the sugar beets in a row.

Additionally unsoiled cutting water would be collected by using this operation in sugar beet harvesters while the topping unit discovers the distance between the sugar beets in a row. Thus the beet sludge was diluted with fresh water. The diluted sludge contained 50 % beet sludge and 50 % fresh water.

In a first step the diluted beet sludge with larger pollutions was analysed with an edge detection tool. With this photo analysis it was possible to detect particles beginning from a size of 300 µm. A large quantitiy of particles was detected in a range of particle size between 300 and 1000 µm. The largest particles had a size of nearly 5 mm. Further examinations to identify the particle size distribution were done with a laser diffraction sensor. This sensor was able to detect particles up to the size of 875 µm. Because of that the laser diffraction sensor could be used only for preliminary cleaned fluids.

Preliminary Cleaning

To recyce the cutting water it is necessary to separate the solid and liquid phases of the beet sludge firstly. According to Stieß [2] a solid-liquid separation can be done by sedimentation, filtration or pressing. The solid matter content in the beet sludge is high. This would be cause a fast blocking of the filters. Therefore a method with several cleaning steps is required (**figure 1**). In the first process step a solid-liquid separation by centrifugation or pressing has to be done to separate a suspension from the sludge. Both, centrifugation and pressing, afford a continuously mass throughput, which is necessary for mobile use.

At first tests were done with a laboratory centrifuge. The centrifugal forces separated the beet sludge in three layers. The lowermost layer on the bottom of the centrifugation tube was sludge. The layer in the middle consisted of a suspension with small suspended particles and the third layer was a floating layer above the suspension. By centrifuging the undiluted beet sludge about 50 % suspension can be obtained. Furthermore pressing was tested as a process for preliminary cleaning. The cleaning effect can be influenced by the used sieves or filters in the press. The particle size distribution depends on the used press method and the used sieves or filters. By pressing the diluted beet sludge about 80 % suspension can be obtained by

Fig. 1

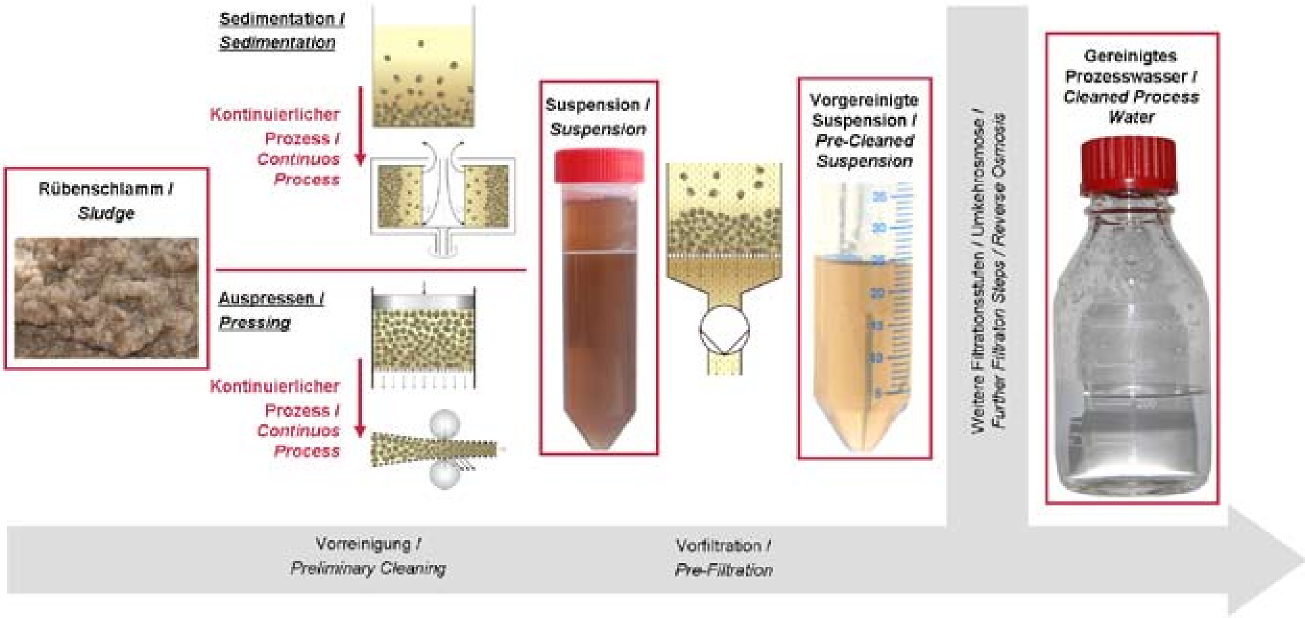

Fig. 1: Process steps for separation of solid and aqueous phases of beet sludge

using a filter paper with an average retention capacity of 7 – 12 µm. Out of this was estimated that 55 – 60 % suspension can be obtained from undiluted beet sludge. So the degree of obtainment is higher with pressing than with centrifugation. When pressing with higher pressures a marginal higher degree of obtainment is expected. The limiting factor is the durability of the filter paper.

Filtration

As following cleaning step the usage of different qualitative filter papers and quantitative membrane filters with defined pore size were examined. The filtrated specimens were analysed with the laser diffraction sensor and with a microscope. Pumpmanufactures rate the water quality with the help of chosen ingredients. Some specimens were tested sor these ingredients. These tests were done in a laboratory scale by using small filters. Thus one or two pre filtration steps were necessary to counter the blocking effect of the filters.

Figure 2 shows the particle size distribution of different specimens after filtration and for comparison the particle size distribution of centrifuged specimen. The curves were measured with the laser diffraction sensor. The diagram shows two charts per specimen which are plotted against the particle size distribution. One chart corresponds to the cumulative distribution and shows which percentage fraction of the particles is smaller than the corresponding value on the x-axis. The second chart gives information about the distribution density and corresponds to the gradient of the first chart. After centrifugation the maximum particle size was below 735 µm and after pre filtration below 15 µm. The chart of the distribution density of the centrifuged specimens shows a significant maximum which position varied between 100 µm and 400 µm in different test replications. The chart of the pre filtration shows two repeatable maxima between 1 µm and 1.5 µm and at 4 µm.

The charts which are corresponding to the centrifugation and the pre filtration show consistent and well-defined courses. Whereas the charts of the distribution density of the fine filter steps (1 – 2 µm and 0.8 µm) show several maxima. In addition to the expected peaks corresponding to the pore size of the used filters (between 1 – 2 µm and at 0.8 µm) further maxima above the used pore size exist. Because of the used filters these maxima can theoretically not be caused by particles. Two reasons are thinkable: The first possibility is agglomeration after filtration. Against this hypothesis stands the fact that these agglomerates could not be detected. It also could not be proved that the specimens tend strongly toward agglomeration and the peaks above the used pore size were not repeatable.

The second thinkable reason – small air inclusions influencing the measurements – is more likely. These air inclusions are partly visible to the naked eye. As the laser diffraction sensor mixes the suspension permanently it is difficult to remove the air inclusions from the suspension. The results of microscopic examinations approve the hypothesis that no particles were in the specimens which correspond to the peaks above the pore size.

Figure 3 shows microscopic pictures of different specimens. The denoted filter mesh is equivalent to the last filtration step. The maximum particle size and the number of viewable particles decreases with increasing filter mesh. Beginning from a pore size of 0.8 µm only a few small particles are visible. Beginning from a pore size of 0.45 µm no particles are visible with the used microscope. The particle size in the centrifuged speci-

Fig. 2

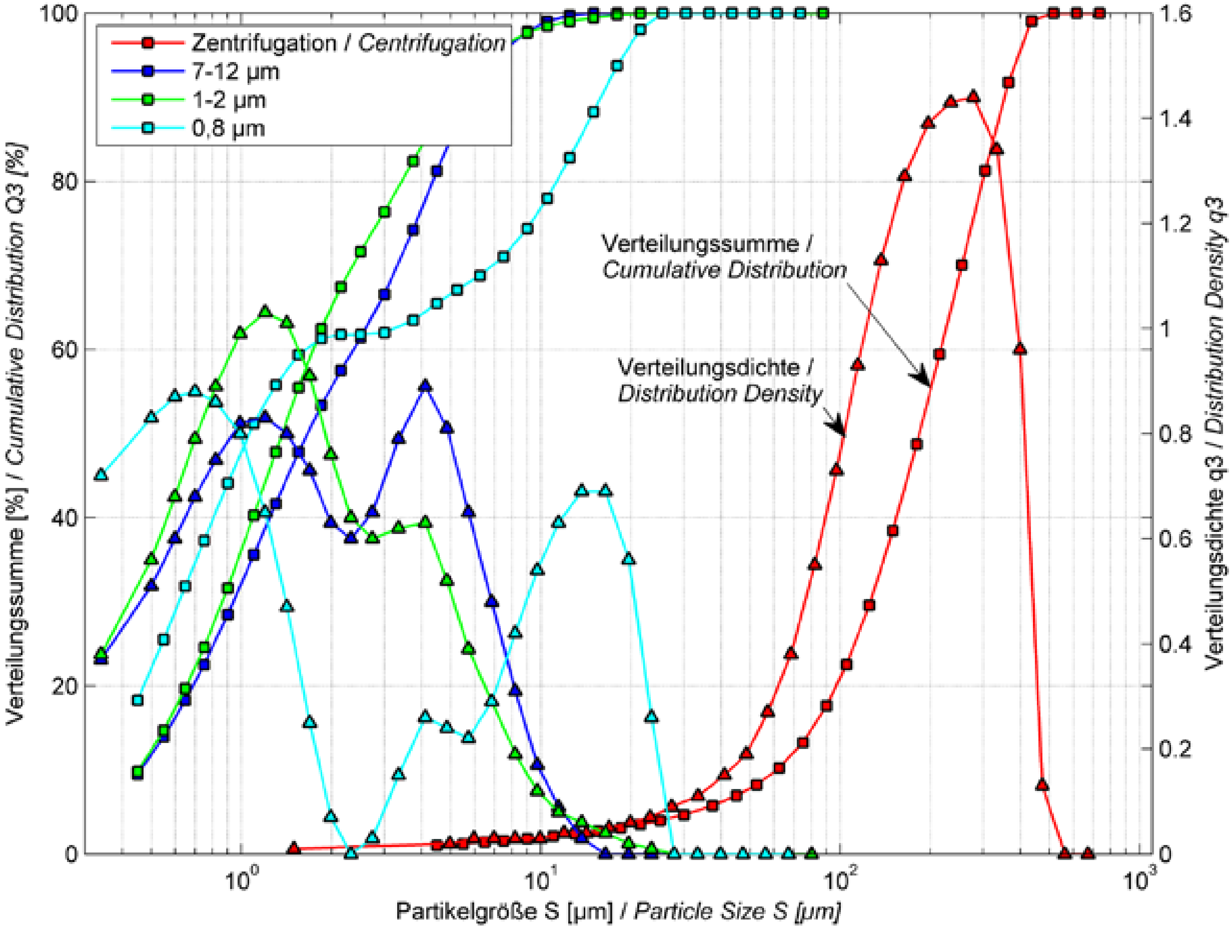

Fig. 2: Particle size distribution

men is significantly larger and the number of visible particles is significantly smaller. Because of this the centrifugation is especially suitable for the preliminary cleaning. A higher durability of following filter steps is expected caused by a reduced blocking effect.

In line with the experimental filtration series filter membranes with a pore size up to 0.05 µm were tested. From a pore size of 0.8 µm the opacity increases significantly. The filtrate changes to a clear yellowish fluid with decreasing colouration (Fig. 1). This colour was still visible after using a filter with 0.05 µm pore size. The analysis of the ingredients is consistent with this. The pump requirements for the water quality were not met. The quantity of dissolved ingredients and the conductivity were too high. Big quantities of the dissolved ingredients were glucose, fructose and saccharose. To remove these ingredients from the filtrate another process step is required. Further tests with reverse osmosis were done. This process step reduces the ingredients sufficiently. A small exceedance is caused by saccharose. It is expected that this exceeding is removed by using a different reverse osmosis membrane. After the reverse osmosis no discoloration of the water was visible.

Conclusions

The examinations show the feasibility of the mobile water recycling to reduce the freshwater demand during high pressure water jet cutting of sugar beets. Several process steps are necessary. Particularly the centrifugation is suitable for preliminary cleaning. After preliminary cleaning several filter steps are used to under-run the maximum particle size of 0.5 µm or rather 1 µm. To remove dissolved ingredients, especially sugar, a further cleaning step is necessary. This can be realized with reverse osmosis.

Among other factors reverse osmosis reduces the water hardness. So it has to be discussed if water conditioning is required. Furthermore the durability of the filters and a possible contamination with microorganisms have to be examined.

Literature

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Fig. 3

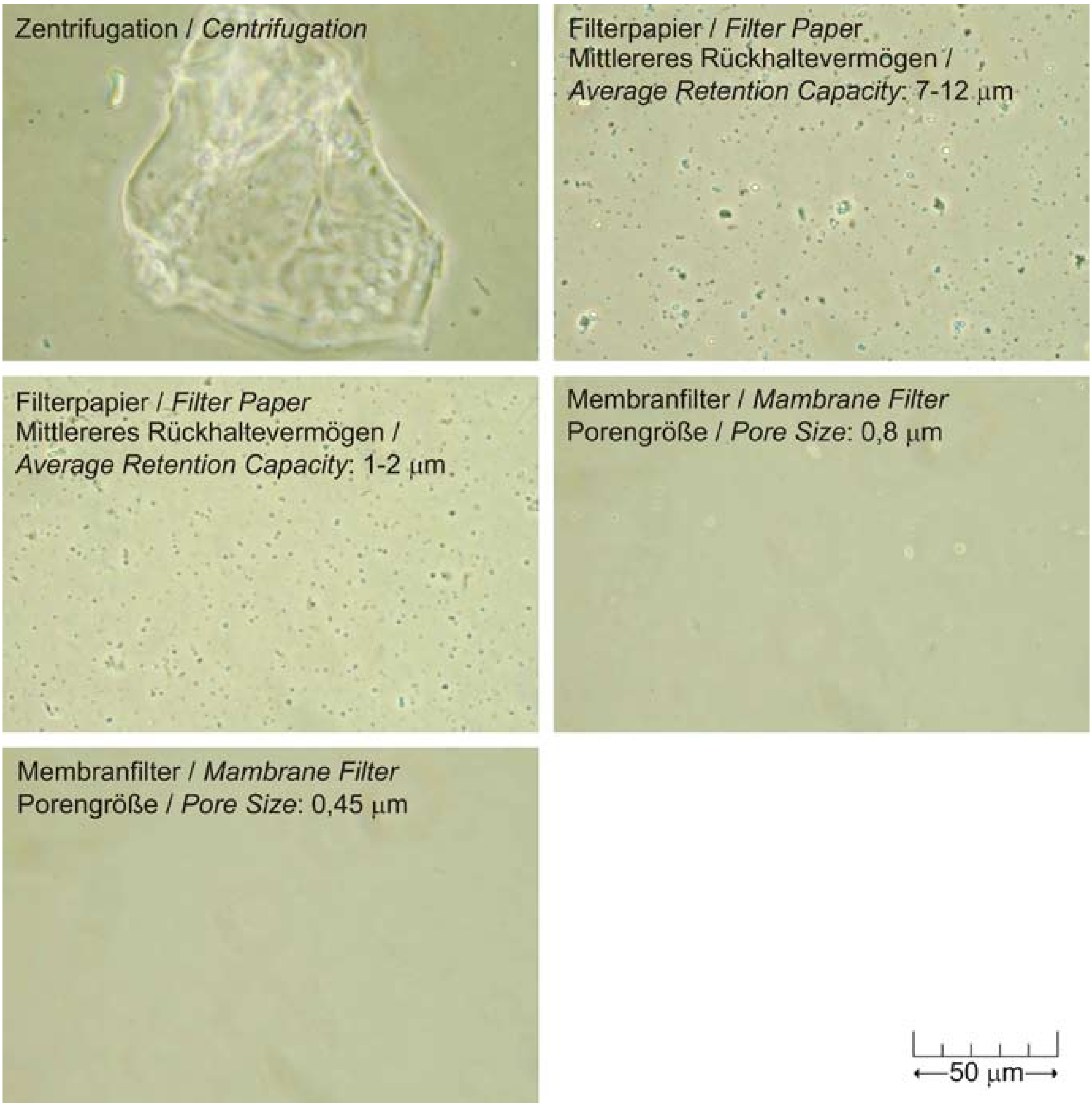

Fig. 3: Microscopical shots of different samples

Authors

Dipl.-Ing. Dennis Jünemann is research assistant at the Institute of Agricultural Machinery and Fluid Power at Technische Universität Braunschweig (doctoral advisor: **Prof. i.R. Dr.-Ing. Dr. h.c. H.-H. Harms**, director: **Prof. Dr.-Ing. T. Lang**), Langer Kamp 19a, 38106 Braunschweig, Germany, e-mail: d.juenemann@tu-braunschweig.de

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