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Clean technologies in natural fibre processing

With a new type of cleaning technology, a by-product from the natural fibre processing (shive-fibre mixture) can be prepared effectively. In addition to the recovered short fibres, cleaned shives in high quality are made available for the industry. The cleaned by-products, the simple construction resulting in an economical cleaning machine, improve the efficiency of fibre decortication operation. The aim of this study is, to achieve an optimization of the cleaning machine by simulating the material flow in the cleaning process, using the discrete element method (DEM) and the variation of machine parameters.

Keywords
Hemp, shives, axial fractionator, short fibres

Abstract
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In recent years, shortages in supply as well as increasing costs of raw materials for the wood processing and composite industry could be noted. Intensified use of wood for energy generation has led to an additional demand in cellulose raw materials [1]. Wood-like raw materials, e. g. from agricultural production are an alternative, or substitution respectively to the classical raw material range. A large part of the produced natural fibres is used for the manufacturing of insulation material and fibre fleeces. A substitution of synthetic fibres (e. g. glass fibre) with natural fibres by maintaining similar composite properties is potentially possible [2]. In addition to fibre, shives provide for the potentially larger proportion with 50–60 mass percent in hemp straw [3]. Their sales are currently secured by a stable market of litter bedding for small animals and horses at currently low production volumes. Cleaned, high quality shives are becoming increasingly interesting for composite boards production in the wood- and composite processing industry as a partial or full substitution of wood particles.

In recent years, the Leibniz Institute for Agricultural Engineering Potsdam-Bornim has carried out intensive research for the development of more efficient technologies for decortication [4; 5] as well as for the cleaning of fibre and shives [6; 7]. As a result of the research of various processes for the cleaning of shives, a solution was developed; successfully tested under lab conditions [7]; and the application for a patent was filed [8].

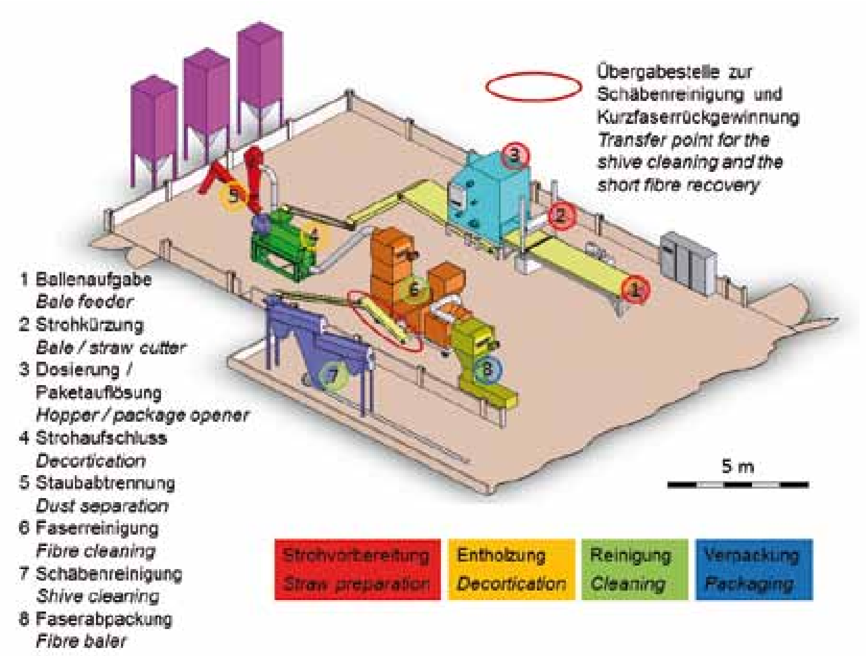
Decortication of hemp straw

In a decortication plant, developed by ATB and successfully operated in practice, natural fibres are generated by rebounding decortication. The use of hammer mills, or classifier mills for the decortication of straw – the core process of the overall processing [1] – is common in high performance decortication plants. Here, the actual decortication takes place, i. e. the fibre is removed from the ligneous core of the hemp stalks (**Figure 1**). The shives are the crushed part of the ligneous core of the hemp stalks. In a subsequently arranged cleaning line, the fibres are separated from the shives. The share of decorticated fibre constitutes about 30 mass percent [9; 10], dependent on the type of straw and the respective growth conditions. Consequently, this means that app. 70 mass percent in by-products accumulate in fibre production. To efficiently operate a decortication plant, these by-products must be processed in such way that they can profitably be marketed for industrial utilization. An economic fibre production can be facilitated with a hemp straw throughput of about 4 t/h [5]. Since the shive-fibre mixture represents the largest proportion in the by-product of the decortication process, an efficient cleaning technology must at least be capable of processing 2 t/h of such mixture.

The Problem

The composition of the shive-fibre-mixture to be cleaned is dependent on the retting grade of the used hemp straw. Different types of straw require adapted operation settings of the decortication plant, which changes the composition of the shive-fibre mixture. Generally, the mixture consists of the main components: dust, shives and short fibres. The main problem for the cleaning of this mixture is that the shives are locked in the fibre flakes, partly entangled, as well as in solid connection with the fibres. Therefore, a separation of the mixture in a sufficient manner cannot be achieved with the conventional classifying

Fig. 1



Schematic of an industrial fibre decortication plant

technologies. Since shives and fibres are very light weight and show similar equilibrium velocities, there is a lack of ‚driving' weight force for separation, i. e. the neutralization/overcoming of the adhering forces between fibres and shives. Only mechanical intervention allows for a reliable separation of the mixture into its main components. The not yet completely decorticated components must be collected separately, since a further decortication will not be achieved by cleaning. This fraction, however, can be directed again into the decortication process, or directly be marketed, e. g. as loose filling insulation.

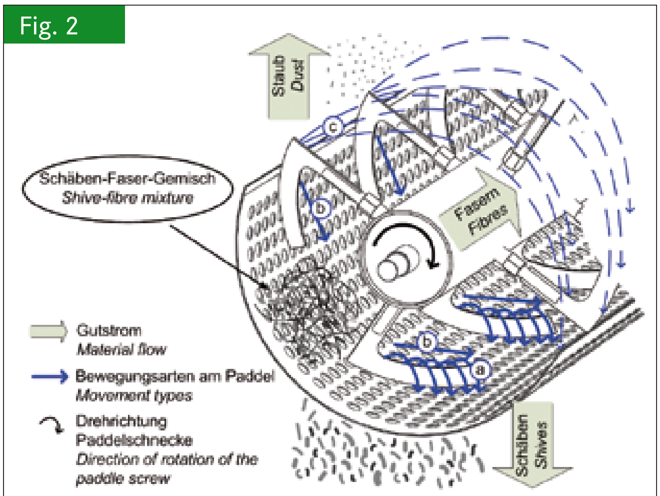
Solution approach for an efficient cleaning technology

The new fractioner and cleaning machine for the processing of a wide range of different shive-fibre mixtures is based on the principle of an axial fractioner. The machine consists of two cleaning stages, whose tools work similar to a paddle auger conveyor. The movement trajectories of the particles at the paddle as well as the respective material flows are depicted schematically in **Figure 2**. Dependent on the parameters paddle form, blade angle, and rim speed, the three different movement types can be realized that allow for an effective separation of the shive-fibre mixture. The shive-fibre mixture is transported in axial direction across a strainer plate. This way, first the lose shives are separated from the mixture in the entry area at low revolution range. By combining higher revolution speeds in the second part of the machine, the shives locked in the fibre flakes can be disentangled. At the end of the strainer plate, clean and widely shive free short fibres are recovered. Utilizing variations of different strainer mesh widths, the grading of the cleaned shives can be controlled. A separation of dust and, above all, sand is facilitated in the first part using a close-mesh strainer.

Results

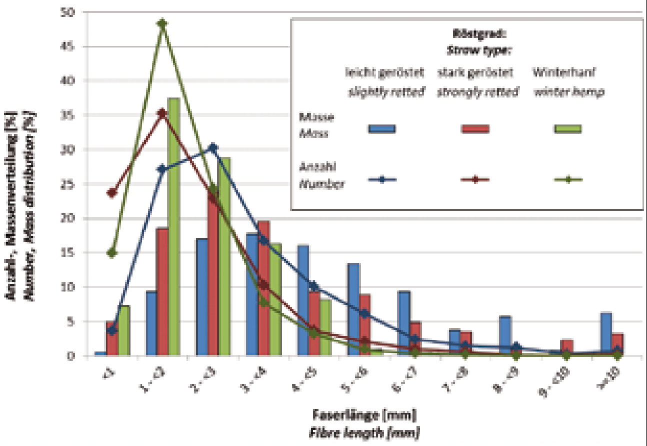
In practice tests, short fibre with up to 5 mass percent, relative to the containing shive-fibre-mixture could be recovered (**Figure 3**). At present, the strainer space geometry and the paddle configuration of the cleaning machine are optimized, employing DEM. For example, different mass flows and discriminate sieving behaviour can be seen at the same number of paddles used, but under varying paddle configurations. An anticipatory

Fig. 2



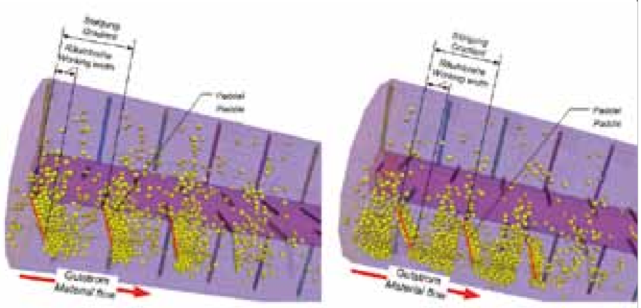
Material flow and straining process of a shive-fibre mixture in the axial fractionator
a) flow over the paddle; b) flow along the paddle;
c) dropping from paddle

Fig. 3



Number and mass distribution for fibres recovered from the shive-fibre mixture of different types of straw

Fig. 4



Visualization of the movement of the material by a paddle auger in a tube (discrete element method; PFC3D_EV 4.0, Itasca)
left: trailing configuration; right: anticipatory configuration

configuration shows better sieving behaviour than a trailing configuration. However, this involves lower mass flow capacities. **Figure 4** shows the material movement in two different paddle configurations. For simplification, the shives are regarded as spheres, shown here as yellow particles. Due to the trailing arrangement of the paddles, the shives are more strongly rotated and thrown upwards. Therefore, less time remains for the shives to fall through the strainer. However, the material movement in axial direction is faster. In the anticipatory paddle configuration there are fewer shives moved in axial direction at paddle contact, and more shives rest on the strainer plate. The sieving behaviour is thus improved.

Conclusions

The investigations on the axial fractioner have shown that with the developed machine concept, hemp shives can be cleaned efficiently and due to their high quality are also suitable for the use in wood composites. In practice tests, short fibres with up to 5 mass percent, relative to the containing shive-fibre-mixture could be recovered. Due to their short fibre length compared to conventional technical hemp fibres, they are well suitable for the use in injection moulding materials. Since the fibres constitute the higher quality part of the finished product, this has led to a significant economic improvement of the plant operation. A share of shives in the cleaned short fibre of less than 6 mass percent is aimed at. By optimizing the model configuration it is also feasible to simulate long-shaped, shive-like particles. The impact of further variants of the auger and tool constructions on the cleaning of the shive-fibre mixtures, e.g. meshing paddle augers with double paddle numbers, is still to be investigated.

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