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Separation of hemp fibres by hammer-action

Business competition means that the costs of separating hemp fibres will have to be greatly reduced in the future. For this reason, an investigation into optimising hammer-action separation has been initiated by the ATB Potsdam-Bornim. Results from trials with retted hemp indicate that a high fibre yield of over 28% and defective fibre losses of only 1 to 2% could be achieved. From the total shives proportion, up to over 50% was separated in a single run-through.

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The use of hemp and flax fibres is currently of importance for processing into building and insulation materials for the substitution of glass fibres and eventually even carbon fibres, in high value compound materials, as well as in the manufacture of various textile products. The advantages are based, above all, on the CO_2 neutrality of regenerative raw materials and in the problem-free re-entry of the products into natural material circulation (recycling through composting). Economic viability under present conditions and material performance figures comparable to traditionally utilised materials has also been demonstrated. Whilst the techniques of cultivation, harvest and also further-processing can be regarded as solved for the most part, there remain problems in fibre separation. For this reason a new working principle based on utilising hammer action for separating woody material and fibre is being investigated as part of basic research at the Institute for Agricultural Technology in Potsdam-Bornim [1].

Research aims

Competitive pressure means that investments in new plant for fibre separation must be roughly halved, and the fibre production costs substantially lowered. This is why, with the help of a suitable trial station, ways of optimising the construction and working parameters for a new de-wooding plant are being looked at. If possible, scutching should also take place as part of the operation.

Analysis of parameters

Using hammer-action for chopping is a proven method in various sectors of material processing. The energy required for the chopping operation depends on the material being treated. This is the decisive point for the fibre separation. The woody components (shives) can be chopped with less energy application compared with the very resilient fibres.

The mechanical power requirement P_{mech} in the context of hammer chopping consists of the power requirement for the chopping P_z, for overcoming bearing friction, and for ventilation losses [2]. With regard to the working efficiency of the transmission, the resultant formula is:

$$P_{mech} = (P_Z + P_R + P_V)/\eta_G \quad (1)$$

The chopping energy comprises the energy share transmitted from the hammers onto the material P_{zs} and the friction energy on the sieve P_{zr}, multiplied by the factor k_v which takes account of the portion of the losses caused by material flow hindrance at the intake. Introducing the specific energy ΔW, the rotor rpm n_R, the number of hammer rows z, and the number of hammers per row i_H gives the formula:

$$P_Z = k_v (P_{ZS} + P_{ZR}) = k_v \cdot \Delta W \cdot n_R \cdot z \cdot i_H \quad (2)$$

By taking a partly elastic hammer blow with identification sign k between the hammers with the mass ml and the speed v_l and a material particle with the mass $m_2 = \infty$, because of the solid support on the framework, and the material speed $v_2 = 0$, the transmitted energy from a hammer blow represented ΔW_{ZS}:

$$\Delta W_{ZS} = (1 - k^2) \cdot m_1 \cdot v_1^2/2 \quad (3)$$

The specific energy requirement for the movement of the material on the sieve ΔW_{ZR} represented, in connection with the centrifugal force of the material F_{GZ}, the coefficient of friction μ_{RG} and the sieve length l_R:

$$\Delta W_{ZR} = F_{GZ} \cdot \mu_{RG} \cdot l_R \quad (4)$$

The ventilation loss P_V is, above all, influenced by the circumferential velocity of the hammers and their cross sectional areas.

The analysis of the power proportions indicates that the chopping energy is in the first place increased through increasing the rotor rpm and the number of hammers. An additional chopping effect is achieved when the shock of the material hitting the milling chamber inside wall is utilised through specially prepared impact plates. The increasing of the coefficient of friction μ_{RG} is not practical. The separation of the shives from the fibres is influenced by the constructive design of the sieve bottom, that is, by the sieve free area, the size of the sieve holes and the form of the sieve holes.

Trials and trial evaluation

In the investigation the fibre yield, the defective fibre losses and shive throughput efficiency, were looked at in connection with the main parameters hammer circumferential velocity, impact plate design and sieve holes:

fibre yield $\varphi_{FFS} = (m_{FFS}/m_{AG}) \cdot 100\%$

shive throughput efficiency

$$L_{Sch} = (m_{SchSchS}/m_{Schges.}) \cdot 100\%$$

defective fibres loss

$$\varphi_{FSchS} = (m_{FSchS}/m_{AG}) \cdot 100\%$$

m_{FFS} mass of fibres in fibre flow

m_{AG} total mass of hemp for processing

($m_{AG} = m_{FSchS} + m_{SchSchS} + m_{SchFS<4} + m_{SchFS4...8} + m_{SchFS8...11} + m_{SchFS>11} + m_{FFS}$)

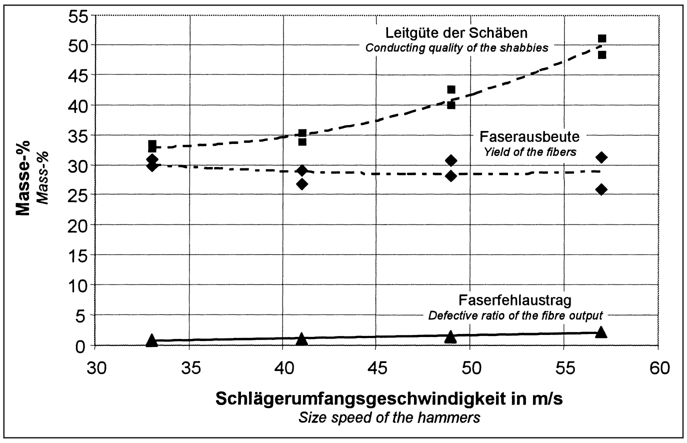

Fig.1: Fiber yield, defective ratio of fibre output and conducting quality of shives vs. circumferential velocity of the hammers (Free area of the sievs: 0.23; lid inserts: roof conducting facility and fidding flat; chopped length: 8 cm, mass flow: 1 t/h)

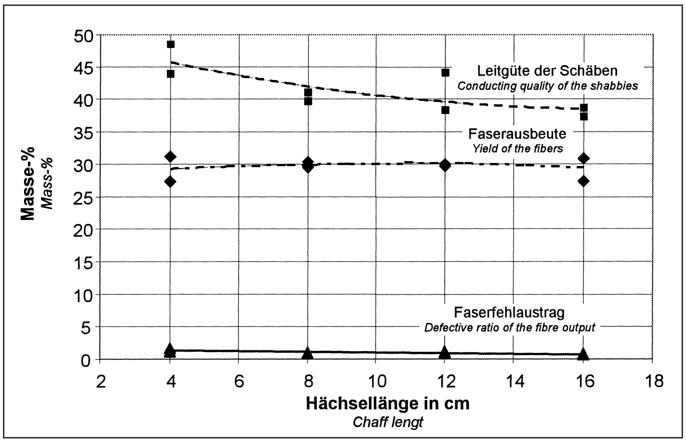

Fig.2: Fiber yield, defective ratio of the fibre output and conducting quality of the shives vs. chopped length (Free area of the sieves: 0.23; lid inserts: roof conducting facility and fidding flat; circumferential velocity of the hammers: 49 m/s, mass flow: 1 t/h)

$m_{SchSchS}$ mass of shives in shive throughput
$m_{Schges.}$ total mass of shives
$m_{Schges.}$ amount of fibres in shive flow
m_{FSchS} mass of fibres in shive throughput

The influence of the chop length and the mass flow continues to be investigated.

Results

By increasing the circumferential velocity of the hammers from 33 to 57 m/s the throughput efficiency of the shives increased from 33 to 55% mass-%, whilst at the same time the defective fibre losses also rose from <1 to around 2% M-%. In context, however, this figure is very small. The fibre yield was minimally reduced in connection with the hammer circumferential velocity from around 30 to 28 M-%. (*Fig. 1*). Fibre strength was affected only a little by the increased processing stress. The fibre strength as measured in an accredited laboratory still lay, even under the effect of the investigated maximum hammer circumferential velocity, within the advised standards for using in compound material.

Through increasing the hemp straw chop length from 4 to 16 cm it was established that there was a small digressive reduction in the shive throughput efficiency from 46 to 38 M-% and a halving of the defective fibre loss to 0.7 M-%. The fibre yield reached a maximum of 30 M-% where chop length was from 8 to 12 cm (*Fig. 2*).

One by one, the lid installations roof deflector, fidding flat, web plate and impact plate were investigated and compared with variants without installations. In the case of the roof deflector, shive throughput efficiency and defective fibre losses were least. With the fidding flat, the highest shive throughput efficiency of nearly 64 M-% was achieved with, however, a high fibre defective loss of around 4 M-% and a fibre yield of only 24%. The reason for this was the long throughput time because of slower axial movements of the material in the direction of the fibre transport channel (*Fig. 3*).

Where lid installations were combined, the combination of the roof deflector and the fidding flat was superior to all other combinations. With low defective fibre loss of under 1% M-%, this combination achieved the highest shive throughflow efficiency of 40 M-% and the highest fibre yield of 30 M-%.

Conclusions

The investigations with retted hemp indicated that the use of hammer action for fibre separation is possible and can be optimised by the choice of particular plant construction and working parameters. Fibre yield, at over 28%, is high and the defective fibre loss of 1 to 2% is minimal. From the total shive portion more than 50% could be separated in one run-through. This result is sufficient for a number of uses. Where the degree of purity required is higher, further processing steps must be incorporated.

Literature

Books are signified by •

[1] *Fürll, Ch., H. Hempel* und *H. Baldauf*: Fasergrobaufschluss bei Hanf . LANDTECHNIK 53 (1998), H. 1, S. 12 -13
[2] • *Höffl, K.*: Zerkleinerungs- und Klassiermaschinen. VEB Deutscher Verlag für Grundstoffindustrie, Leipzig, 1985

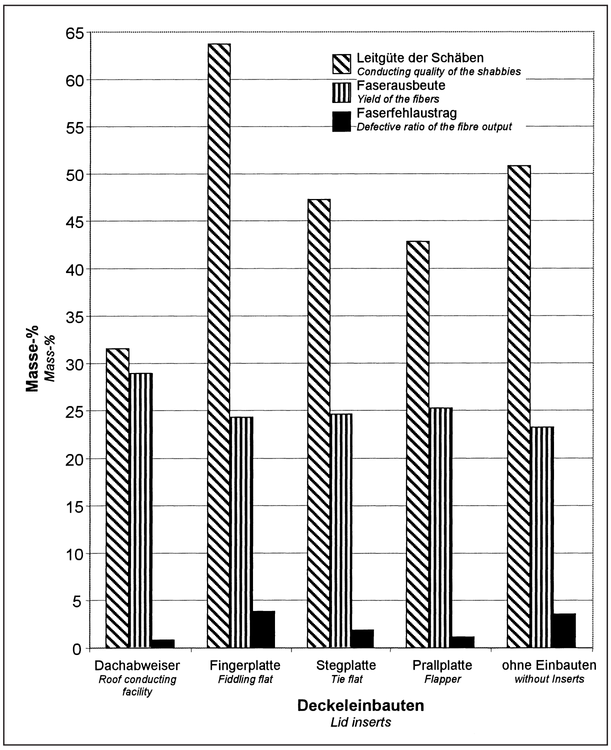

Fig.3: Fiber yield, defective ratio of the fibre output and conducting quality of the shives vs. lid inserts (Free area of the sieves: 0.23; chopped length: 8 cm, circumferencial velocity of the