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Fibre Quality Testing

Bast fibres are increasingly being used for industrial purposes because of their distinctive characteristics. The quality demands made on the fibres differ from those in the clothing industry. For the composite material sector they must be odourless, dry and tearproof, as well as facilitate good fibre/matrix adhesion, since they are not chemically treated anymore.

All the quality testing procedures for bast fibres are characterised by considerable manual labour in preparing and testing samples. Due to the coarseness of bast fibres, it is currently impossible to examine them completely by machine. Chemical analysis is impossible because of bast fibre inhomogeneity and its cementing substances.

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Keywords

Hemp fibres, quality inspection, bast fibres, fibre properties

Literature

Literature references can be called up under LT 04409 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

Industrial hemp processing raises the requirements on the fibres; their fulfilment must be checked by corresponding tests. A defining feature of bast fibres is their inhomogeneity. This makes quality inspections considerably more difficult. For this reason it is impossible to use so-called High Volume Instruments (HVI) such as are used in cotton testing.

With bast fibres increasingly being used for industrial purposes because of their distinctive properties, the quality demands made on the fibres are different from those applying in the clothing industry. They must be odour-free, dry and tearproof, and they must facilitate good fibre/matrix adhesion for the composite material sector because they are not subjected to chemical treatment.

From harvesting to processing, the following properties are the same for all application areas: water content of the hemp straw, retting degree of the hemp straw, fibre content of the hemp straw, fineness of fibres and fibre bundles, strength (tensile strength, breaking strength, elongation at break, Young's modulus).

In addition to presenting the most common and widely accepted measuring and testing methods for dry mechanical fibre separation in hemp straw, the following will demonstrate what are the problems of batch examination.

Retting degree of hemp straw

Hemp straw retting is a biological and in part chemical decomposition of substances such as pectins and lignins which act as cementing agents for the elementary fibres of hemp straw. Retting is accompanied by colour changes in stem and fibres. Depending on the retting degree, colours range from light beige to deep brown (dark brown). Hitherto the retting degree of hemp straw was assessed subjectively by visual means. For this purpose Nova Institute [6] sells colour scales with which the colour of the straw can be determined. Since this method depends on the subjective judgement of the person carrying out the assessment, and since the human eye is subject to the interference of sunlight, [5] developed a reproducible measuring method by which the retting degree of flax can be determined. [2] developed a way of applying to hemp the measuring method developed by [5], with measurements being based on spectroscopic examinations in the near infrared range.

Fibre content of hemp straw

The examination of fibre content is based on mechanical fibre separation. The stems are bent so that the woody components become detached from the fibres. At the Institute for Agricultural Engineering of Bonn University, Beckmann [1] developed a method for determining the proportion of flax fibres suitable for technical purposes. This method can be applied to hemp straw. The hemp stems are bent by four pairs of grooved rollers. In the standardised procedure the stems are first passed through the flax breaker three times so that an interim result can be achieved by reference to initial weight. Subsequently another seven passes are executed so that a total of ten decortication passes are performed. Afterwards, the weight of the fibres is again related to the initial weight.

This method was applied in research concerning the mechanical decortication of hemp at the Institute for Agricultural Engineering of Bonn University. The proportion of technically usable fibre is calculated according to:

$$w_{tmF} = \frac{m_{4x10}}{m_E} \cdot 100\,[\%]$$

m_E = initial mass

$m_{4\cdot10}$ = mass after decortication by ten passes with four pairs or rollers

Decorticatability was calculated according to the following formula:

$$\eta_{tnF} = \frac{m_E - m_{4*2}}{m_E - m_{4*6}} \cdot 100$$

$m_{4\cdot2}$ = mass after three passes

$m_{4\cdot6}$ = mass after ten passes through a flax breaker with four pairs of rollers.

t_{nF} = fibre suitable for technical uses

According to [4] it is possible to make reliable statements on decorticatability if the

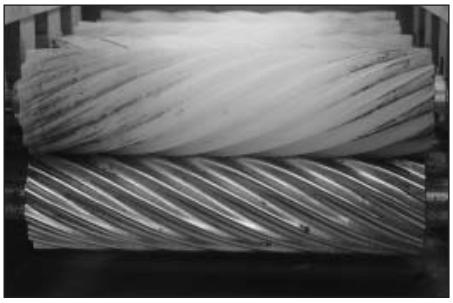

Fig. 1: Frontal view of a flax breaker

Fig. 2: Laser gauge for measuring fibre bundle diameters

fibre material is re-weighed after the second and the sixth pass, respectively. Observations made by the present author's concerning his own tests have revealed that more decortication becomes necessary, if the material to be decorticated is older. However, exact tests concerning this have not been carried out so that at this point a qualitative statement cannot be made.

By this method the proportion of technically usable fibre is determined with reference to dry initial mass. The proportion of fibres fit for technical uses is defined as the proportion of short fibres which still contain impurities such as hurds/shives, which in many cases do not have any negative effects on technical applications [1].

Fineness of fibres and fibre bundles

The fineness of a fibre or a fibre bundle is the quotient of the mass and the length of the fibre or fibre bundle. In the determination of fineness, the density and the cross-section of the fibre are assumed to be constant.

Fineness is determined (1) gravimetrically and (2) by means of the airflow technique.

In the gravimetric approach the weight of the fibre bundle is determined and related to its length. Prior to strength testing, the fineness of each fibre bundle is determined [3]; this is because in tensile tests different degrees of fineness result in different data. It is useful to take fineness-related tensile force as described below as a measure.

The airflow method is an indirect approach based on the relation between the fineness of the fibres and the flow resistance of air flowing through a fibre layer. The dynamic pressure of an airflow through a chamber containing a defined number of fibres is set to a constant value. The flow resistance of the fibres causes a drop in pressure. The surface area of the fibres can be determined on the basis of the pressure difference between inlet and outlet.

Other methods of determining fibre fineness are based on optical measurements of fibres and fibre bundles. These employ light microscope projections and automatic image analysis systems. Such methods are rarely used because they are very time-consuming.

Strength

The mechanical properties of fibres can refer to several parameters. Tensile strength is defined as maximum force relative to initial cross-sectional area [3].

To determine maximum force relative to fineness, force is related to the fineness of the stem or fibre bundle under consideration. Elongation at break is another important measurand. It is defined as the sample's proportional length change at maximum force. On the basis of the gradient in the resulting strength/elongation diagram the modulus of elasticity (Young's modulus) can be calculated. This describes the resistance of the sample to the length change.

According to [4], individual fibre strength is greater than that of fibre strands. However, individual fibre strength is very difficult to test. In the textile industry elementary fibres are spun into thread after chemical fibre separation. As a rule, the tensile strength of bast fibres is determined by testing bundles of fibres after as fine a separation of fibres as possible. Even in the case of very fine separation, fibres can only be tested in bundles in tensile tests. Fibre bundles are reduced manually to 0.1 and 0.05 mm in diameter and 100 mm in length. Breaking of fibre bundles must be avoided. According to the method manual for flax as an industrial fibre, 24 meaningful individual tests per sample are required for results to be statistically reliable [3]. This corresponds to an actual effort of approx. 50 individual tests.

To this purpose, a fibre bundle is fastened in the clamping device of a tensile testing machine, and a weight of 2 g is affixed to it in order to generate a constant initial force. Then the diameter of the fibre bundle is measured with a laser diameter gauge at intervals of 30°. The theoretical cross-sectional area of the bundle is calculated from the mean of the six resulting individual measurements. Then the lower end of the fibre bundle is fastened in a second clamping device and the weight is removed. Before the proper examining process is started, a starting force of 0.05 N is applied to ensure that all fibre

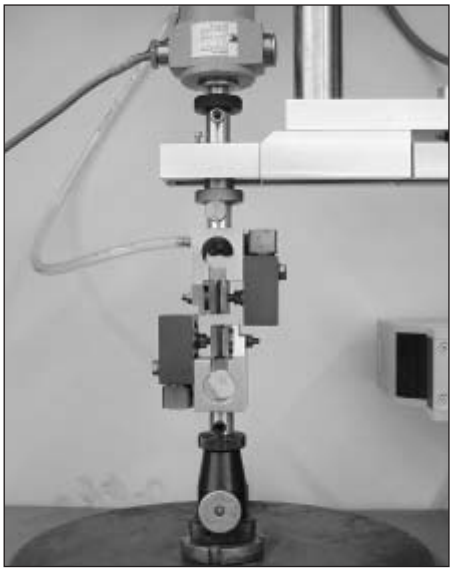

Fig. 3: Tensile test of a fibre bundle

bundles have the same orientation. The resulting tensile force/distance diagram yields data concerning maximum tensile force - in most fibre bundles equal to breaking force - and elongation at break.

Some samples must be rejected, e.g. (1) when a clean break occurs, which is due to previous mechanical damage, (2) when the bundle breaks immediately at the clamping device, which must be rejected so that an influence of the clamping device can be ruled out, and (3) when the bundle slips from the clamping device. Thus, the only samples left for analysis are those that splice at break.

To avoid such complications, it is possible to test fibre strands with a stelometer (strength elongation metre) originally developed for cotton fibres.

With different measurement methods producing different data, it is always necessary to pay attention to the method of testing by which published data have been produced.

Moreover, in all tests room ambient conditions such as ambient temperature and atmospheric humidity are very important influencing factors.

Conclusions

All the quality testing procedures for bast fibres described above require a lot of manual work for the preparation and the testing of samples. Due to the roughness of bast fibres it is at present impossible to examine them purely by machine, for example with so-called High Volume Instruments (HVI) such as are used for cotton. A chemical examination of bast quality fails because of the inhomogeneity of bast fibres and of their cementing substances.