Theses

Applicability of flax fiber as reinforcement in biocomposites

PhD dissertation
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Thesis 1 An *in situ* test method has been developed to monitor the failure mechanism of flax fibers under tensile load in scanning electron microscope (SEM). According to my investigations the failure of flax fibers occurs according to the following mechanism: first the pectin interlayer between the elementary flax fibers split longitudinally, followed by the micro-cracking of the elementary fibers, finally the process is finished by the gradual rupture of the elementary fibers.

Thesis 2 By the study of the acoustic emission (AE) events observed during the failure process of technical flax fibers it has been established that AE events of amplitude below 35 dB can be attributed to the longitudinal splitting of the pectin interlayer, AE events of 35-60 dB magnitude correspond to the micro-cracking of elementary fibers, while AE events exceeding 60 dB amplitude belong to the rupture of the elementary fibers.

Thesis 3 From the tensile tests of technical flax fibers of various gauge lengths it has been established that the average tensile strength of the technical flax fiber ($\bar{\sigma}_{Bf}$) as a function of the gauge length (l_f) under the given test conditions varies according to the following function:

$$\bar{\sigma}_{Bf}(l_f) = \bar{\sigma}_{Bf}(l_{f0}) \cdot \left[1 + A \cdot \left(\left(\frac{B+1}{B + l_f / l_{f0}}\right)^C - 1\right)\right],$$

where l_{f0}=3,5 mm; $\bar{\sigma}_{Bf}(l_{f0})$=800 MPa; A=0,91; B=1887; C=115.

Thesis 4 It has been proved by measurements that biocomposites made of thermoplastic starch and technical flax fibers exhibit maximum tensile strength at a flax fiber content of 40 wt%. By the application of the AE method typical failure modes of the biocomposite have been identified, which can be well distinguished in three different stages of the loading process. Below 30 dB the typical failure mode is the separation of the elementary fibers and fiber-matrix debonding, between 30 and 55 dB fiber-pull-out, above 55 dB rupture of the reinforcing flax fibers dominate.

Thesis 5 An algorithm has been developed to follow the progression of the damage zone using the localization of the AE events. Localized AE events have been divided into groups so that the cumulated amplitudes (*KA*) of the events belonging to certain groups are equal. Afterwards the cumulated amplitude distribution of the AE events belonging to the various groups has been determined along the surface of the test sample, then the center of gravity of the events has been determined, which indicates the actual position of the damage zone. The most advantageous *KA* value has been determined iteratively so that the AE events could be divided into possibly maximum ranges under the condition that the coordinate characterizing the position of the damage zone increases monotonously. By fitting a function to the coordinates of the center of gravity of the damage zone plotted against time the movement of the center of gravity of the damage zone was obtained as a function of time. The reliability of the method was checked by IR camera.

Thesis 6 Using the crack-monitoring method presented under point 5. and applying the principles of plastic fracture mechanics the crack-propagation resistance (J-R) curve of the biocomposite has been determined and from that the critical J value (J_0) at crossed fiber arrangement, as a function of the fiber content. Based on the results it has been concluded that the low fiber content reduces the crack-propagation resistance of the non-reinforced matrix material. The reason for this is that the discontinuities in the matrix because of the presence of the flax fibers act as stress-concentrators. The J_0 value of the biocomposite reaches that of the non-reinforced matrix only at 40 wt% fiber content and exceeds it afterwards. It means that in this fiber content interval the positive, crack-stopping effect of the fibers is grater than the negative effect of stress-concentrations due to the fibers.