Abstract

For almost thirty years bast fibers such as flax, hemp, kenaf, sisal and jute have been used as reinforcing material in the molding process of both thermoplastic and thermoset matrices. The main application areas of these natural fiber reinforced composites in Europe are limited almost exclusively to the passenger car range. Typical components are door panels, rear parcel shelves, instrument boards and trunk linings. Natural fiber reinforced composites have become prevalent due to their good mechanical properties and their low production costs. The main advantage in applying natural fibers as reinforcement in composite materials is the price. Nowadays this argument becomes more and more important due to the scarcity of synthetic raw materials and consequently, their rising prices. Additionally the low density (approx. 1.5 g/cm³) of natural fibers confers them a very good lightweight potential. Other advantageous features of natural fiber composites include very good processing and acoustic properties. Further benefits such as good life cycle assessment and easier processability compared to glass fiber material should also be taken into account.

Disadvantages of natural fibers are unevenness of the fiber quality and varying fiber characteristics due to differences in soil, climate and fiber separation and their low heat resistance (at temperatures exceeding 220 °C, some fiber components start thermal degradation). Another disadvantage of natural fiber reinforced materials is that with some matrices (mostly thermoplastic polymers) a sufficient impregnation of the fibers can only be achieved if the fiber content in the composite is kept low, usually below 50 wt.-%. Under these conditions the best performance of the natural fiber reinforcement can not be realized. Another disadvantage of non-impregnated thermoplastic prepregs is the long processing cycle times, which result from heating up the enclosed air in the prepreg during the process. Alternatively pure natural fiber based non-woven fabrics are impregnated with thermoset systems. Due to the relatively simple handling compared to alternative procedures, the thermoforming of thermoset bonded prepregs is a very promising method for manufacturing natural fiber reinforced components.

In this work, a novel general concept for natural fiber reinforced composites with a natural fiber content of approx. 80 wt.-% and a thermoset matrix is developed. A suitable material combination as well as an optimal process execution that help to meet the technical requirements for the natural fiber reinforced composites will be demonstrated.

Hemp and kenaf have been chosen as reinforcement fibers. In this work it is shown that hemp and kenaf can be used as successful reinforcement alternatives to the more established flax fibers in composite materials. Short flax fibers, which are commonly used as reinforcement in composites (approx. 67 % for the German automotive applications), are the “waste” of the long fiber production and their availability and price strongly depend on the demand of the long fibers from the textile industry and therefore their cost can strongly fluctuate, as it has been demonstrated in the past few years. In contrast fiber plants such as hemp and kenaf are especifically cultivated for technical applications and their availability and price is much more stable. For their application a profound knowledge of the structural and mechanical properties of the fibers is indispensable. In this work single filament tensile tests on these two types of natural fibers are carried out. The cross-section area of both fibers, necessary for the calculation of the tensile properties, was intensively studied using light microscopy and Scanning Electron Microscopy (SEM) analysis. Because the occurrence of flaws within the fiber is random in nature, tensile strength data of these fibers was statistically analyzed using the Weibull distribution. The strengths were estimated by means of Weibull statistics and then were compared to experimentally measured strengths.

For a better handling of the material, both kenaf and hemp fibers were manufactured to needle punched fiber mats. For the impregnation of the natural fiber mats, a Foulard-process with the thermoset matrix as an aqueous solution was employed. The reproducibility of this impregnation process was examined. Different matrix systems with different chemical compositions were applied on the needle punched fiber mats. The impregnated prepregs were heated and consolidated to components in a one-step-process. A big advantage of this procedure is the short cycle times, since no additional pre-heating process is required, in contrast to thermoplastic bonded prepregs. Additionally, a parameter study of the mechanical properties of the composites was performed. The best matrix system satisfying the work conditions and properties of the composites was chosen to carry out the next working step, namely optimization of the compression molding process for the thermoset bonded natural fiber prepregs.

Apart from the material composition of prepregs, general processing parameters such as temperature, time and pressure play a decisive role for the quality of structures made of natural fiber reinforced polymers. The impregnated prepregs were consolidated in a one-step-process to components. A systematic parameter study of the influence of the relevant process parameters on the characteristics of manufactured components was performed. Mould temperatures over 200 °C lead to thermal degradation of the fibers. This temperature should not be exceeded when working with natural fibers. Furthermore, the composites clearly display a dependence on the processing pressure. The flexural properties increase with increasing manufacturing pressures between 15 and 60 bar, reaching a maximum at 60 bar. At higher pressures (80 to 200 bar) a decrease of the flexural properties is demonstrated. SEM images of the fracture surface of the composites show that the decrease of the mechanical properties is related to structural damage of the fiber.

A new technology allowing pressing under vacuum conditions was developed and tested. The press is equipped with a vacuum chamber and achieves very short cycle processing times (up to less than one minute during the compression molding). The aspiration connections of the vacuum chamber ensure that the residual moisture and the condensation products of the matrix chemical reaction could be directly evacuated. This type of press ensures also very safe processing and working conditions.

The properties of the components fulfill the technical specifications for natural fiber reinforced polymers for use in the car interior. This versatile composite material is not only limited to automotive applications, but may also be used for product manufacturing in other industries. This work shows that the process parameters can be optimized to fit a particular application.