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Investigating the potential of fibre-reinforced foams in wind energy applications

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OptiFoam is a project aiming at using reinforced foam core materials in the manufacture of rotor blades for wind energy applications. It is supported by the Fraunhofer Institute for Wind Energy Systems (IWES) with the Saertex GmbH & Co KG company, which is a supplier of NCFs and SAERfoam reinforced foam, as well as a number of other industry partners. The solution based on engineered foams this consortium offers might prove effective to compensate for the shortage of balsa core materials caused by the global expansion of wind energy.

The increasing threat posed by climate change highlights the importance of a global transition to a sustainable economy with lower fossil fuel consumption and greenhouse gas emissions. Progress has already been made worldwide in implementing the energy transition. To bring about this transformation, existing processes need to be optimized and new technologies to be developed. In this context, wind energy has an important role to play.

To support the energy transition, the Fraunhofer Institute for Wind Energy Systems (IWES) together with Saertex GmbH & Co KG, supplier of NCFs and SAERfoam reinforced foam, teamed up with different industry partners to launch the OptiFoam project. The project is funded by the German Government, assigned to the area "Research and development in the field of renewable energies" and refers to the Federal Government's 7th Energy Research Program, entitled "Innovation for the Energy Transition" of June 18, 2021.

Securing the supply chain for core materials

The main goal of the OptiFoam project, which started in January of 2023, is to use reinforced foam core materials in rotor blade manufacturing, relating directly to the fundamental goal of accelerating the expansion of renewable energies. Besides the extension of the possible functionalities of fibre-reinforced foams to meet wind energy requirements, the development of new manufacturing processes for heterogeneous core materials is also investigated. The global expansion of wind energy is creating a shortage of balsa core materials, inducing a risk of rising costs and material supply bottlenecks. This could slow down the expansion of wind energy. Researching new types of core materials, such as 3D reinforced engineered core materials, enables the substitution of balsa core materials to ensure steady supply chains for core materials. In addition to supporting the Federal Ministry for Economic Affairs and Climate Action's (BMWK) goal of ensuring supply security, the use of reinforced foam cores could also increase wind turbine efficiency.

Alternative core materials have to meet the wind industry's high demands in terms of mechanical properties and be able to cope with its specific challenges. Heterogeneous core materials represent a completely new option for adapting materials to specific needs and optimizing their inner structure according to the requirements. This makes it possible to adapt material properties and thus generate a weight advantage compared to homogeneously-structured core materials with constant material properties.

Fig. 1: The sandwich areas made of balsa and PET foam can be seen on an unpainted blade blank

Ultimately, the project also addresses the challenge of wind turbine blade recycling – a subject that has recently come into the focus of public discussion – by showing how the introduction of new materials can help meet the necessary recycling requirements. This way, the environmental impact is considered right from the start, thereby increasing acceptance of wind energy expansion.

In addition to conventional rotor blade materials, new material combinations are being considered in order to determine their medium- to long-term potential. From a sustainability point of view, materials can be selected to be compatible with one another, which makes it much easier to recover valuable materials during recycling.

Project motivation

The secondary structures of modern wind turbines, such as rotor blade shells, have to meet high demands in terms of both stability and low weight. To meet these requirements, a sandwich construction is used that combines a core material and a cover laminate made of fibre-reinforced plastic. To date, balsa wood and rigid plastic foams such as PVC and PET are the main core materials used in rotor blade construction. Due to its high compressive strength, balsa wood is used primarily in the areas near the root that are subject to greater loads while lighter foam materials are used near the blade tip.

Balsa wood is mainly grown on plantations in South America. Due to the high demand, there is a growing shortage and thus a wood price increase on the world market. In addition, there are deficits in sustainability and resource efficiency, as the transport distances are very long and the yield in the development of the required end-grain wood is very low (less than 50%). Furthermore, the mechanical properties of a natural material vary greatly. Many rotor blade manufacturers are therefore endeavouring to use alternative materials to replace balsa.

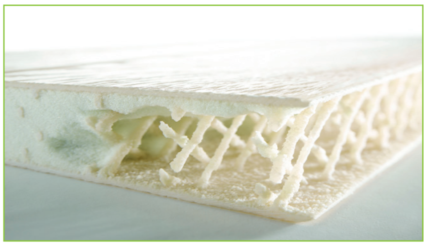

Fig. 2: Reinforced foam core with the foam partially removed to show the internal structure

Conventional foam materials, such as those used today in less stressed areas of the rotor blade, cannot achieve the strength and stiffness characteristics of balsa wood. Balsa wood has an outstanding compressive stiffness and its strength and shear stiffness are generally higher than those of conventional foams. To date, there has consequently been no clear alternative to balsa wood in the highly stressed areas of the rotor blade.

Reinforcing foam materials with unidirectional glass fibre composite (GRP) bridges is an innovative technology for significantly increasing their mechanical properties (see Figure 2). Depending on the angle and number of bridges introduced, the core material's pressure and shear properties can be adjusted in three dimensions, resulting in a very heterogeneous core material structure with known and uniform properties. For this reason, these reinforced foam materials are also known as engineered foam. In principle, any foam material can be reinforced this way and produced industrially.

Due to the high characteristic values that can be achieved and the freedom to specifically design the material according to the requirements, engineered foams are a promising option for substituting balsa in rotor blades and achieving material and weight savings compared to conventional homogeneous core materials. A lower weight reduces the dynamic gravitational loads and thus has a positive effect on the rotor blade's fatigue strength. This is highly relevant to the development of future very long rotor blades, which should help further reduce energy production costs.

All these characteristics are combined in the "SAERfoam for Wind" product. This reinforced foam core material developed by Saertex can replace balsa in the lower loaded area, where otherwise only a very-high-density PET core could be used. SAERfoam for Wind offers cost savings compared to balsa and high-density PET. As an engineered product, the supply chain is much more reliable than that of balsa and it can be produced locally using an industrialized process.

Compared to natural materials such as balsa wood, engineered foams have a very low degree of material parameter deviations, which allows for the reduction of safety factors in the design. In addition, by selecting the core and matrix materials appropriately, the material mix in the rotor blade can be standardised. The materials can be rendered compatible with each other in such way that completely new possibilities of direct recycling become attainable, for instance when only thermoplastic materials are used.

Approaches to using engineered foams as core materials are already known from other composite sectors such as rail transport (ICE-3 floor panels) and boatbuilding. These approaches have not yet been considered for wind energy, neither have they been investigated in terms of rotor blade requirements. This is where the OptiFoam project comes in, as it identifies the challenges and potential for use in rotor blades and takes appropriate steps to develop the required semi-finished products.

Innovative foam materials such as Saertex's SAERfoam for Wind contribute to the transition to a green economy. Besides the direct influence of lightweight materials on the performance of rotor blades, the risks of rising costs or even supply bottlenecks are minimized. These solutions not only leave a smaller carbon footprint, but also offer recycling benefits by taking into account the necessary recycling paths right from the start. These factors make innovative foam solutions a sensible alternative for future-oriented projects in the field of wind energy. ◻

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