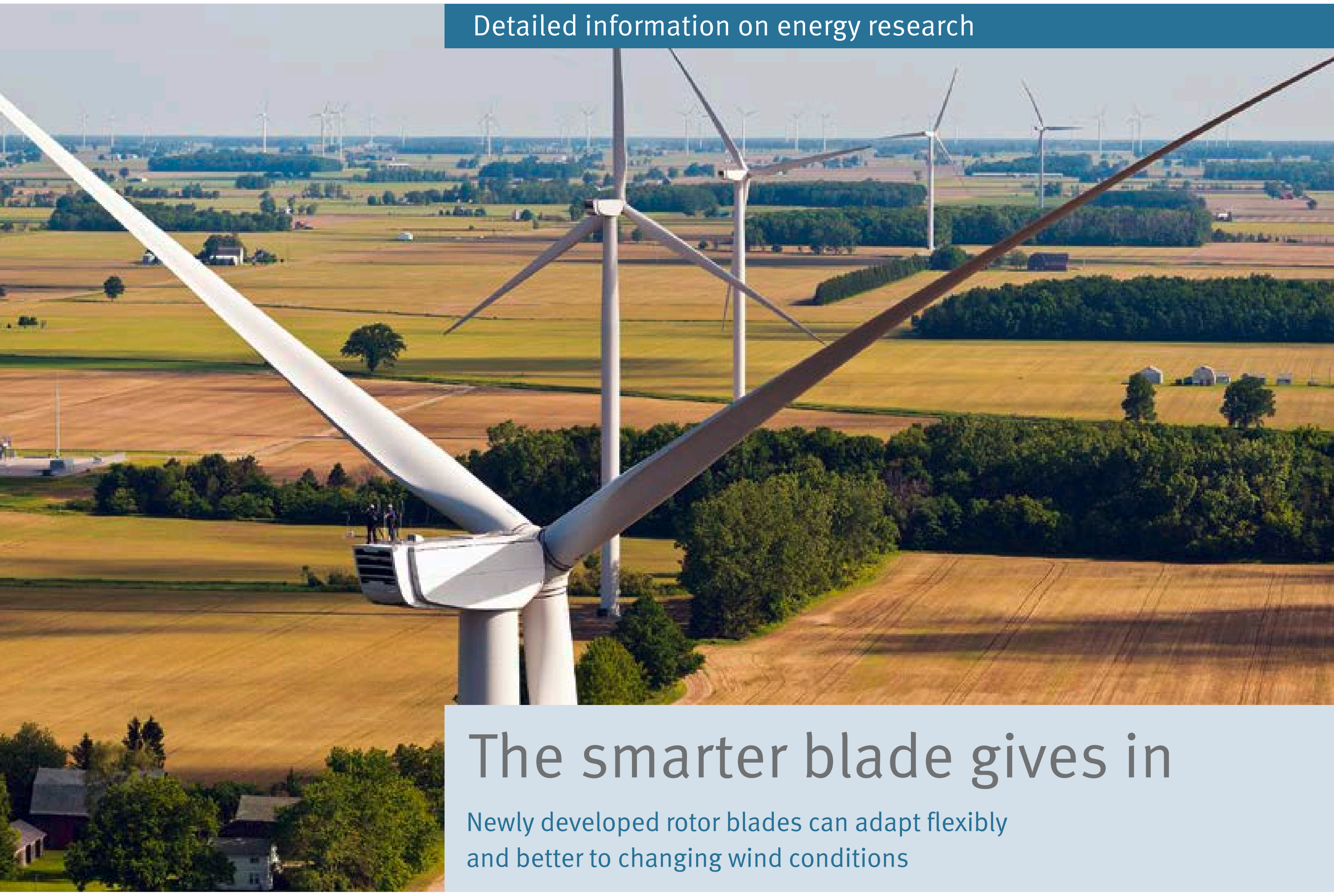

# The smarter blade gives in

## Newly developed rotor blades can adapt flexibly and better to changing wind conditions

BINE Information Service

*Onshore and offshore, rotor blades need to be able to withstand rapidly changing wind directions and variable wind intensities. But how can rotor blades be better equipped for such situations than previously? Researchers have designed so-called smart blades that can adapt to changing wind conditions passively or with active components – and at the same time maximise the energy yield of the wind turbine.*

Rotor blades now measure up to 85 metres and the towers reach heights of over 200 metres – with a rising trend. As the rotor diameter lengthens, the energy yield also increases. However, the blades are subjected to loads from wind gusts and wind shear close to the ground and near the upper part of the wind turbines. These cause considerable stress on the materials. At the same time, wind turbine manufacturers are reaching their limits in terms of the scalability, as the aerodynamic vibrational loads also increase with increasing blade lengths. Existing control systems are barely capable of balancing out the loads on longer blades. In the case of larger wind turbines, the weight then becomes the decisive factor. Although mathematically the output would be quadrupled if the rotor blade were to double in size, this would also lead to an eightfold increase in the weight – which would also lead to higher costs. Therefore the material consumption, weight and costs need to be reduced and the wind turbines made more efficient and economical. A greater energy yield could be achieved if the aerodynamically related extreme and fatigue loads were reduced; this would then enable longer rotor blades to be constructed with the same weight. Wind turbines equipped with longer blades are particularly required in weak wind areas. This is the only way to ensure a high yield, which is ultimately significantly more important than a higher rated capacity.

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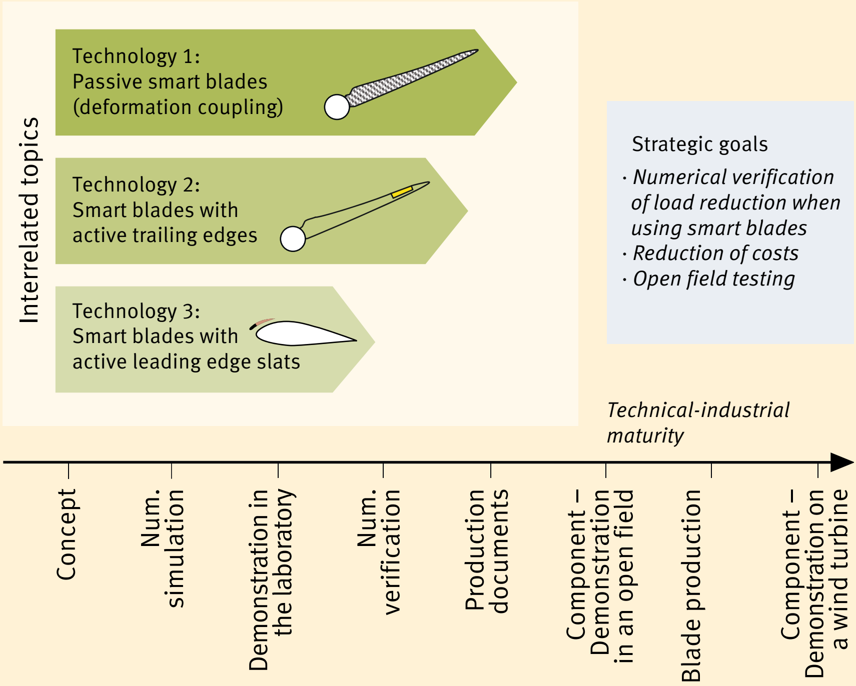



**Fig. 1** *The overview shows the three investigated and developed technologies: Passive smart blades (Technology 1), smart blades with active trailing edges (Technology 2) and with active leading edge slats (Technology 3).*

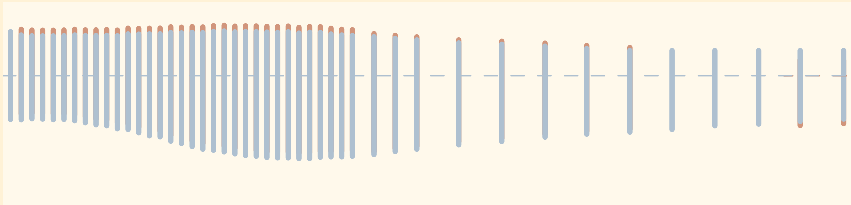


**Fig. 2** *The figure shows the comparison with a standard blade shape (blue) and a sickle-shaped*

**Fig. 3** *The image shows a flexible, actively controllable trailing edge that can influence the lift*

Ideal would therefore be rotor blades that combine all advantages: they should be lightweight, durable but also cost-efficient and flexible. This is what scientists have been working on from the German Aerospace Centre (DLR), the Fraunhofer Institute for Wind Energy and Energy Systems IWES and the Center for Wind Energy Research (ForWind). The researchers have developed intelligent rotor blades called smart blades. These can better adapt their geometry to local wind effects than previous blade concepts. Within the „Smart Blades“ research project, the research group has investigated three different technologies. These include passive and active concepts that adapt and change the aerodynamic behaviour to relieve the structure (Fig.1).

## Reducing loads geometrically and structurally

If a rotor blade not only bends in a strong wind but also twists axially, experts refer to bend-twist coupling (BTC). In order to minimise the wind loads, the researchers examined two different approaches to this concept: geometric and structural BTC. The scientists analysed conventional rotor blades and compared them with so-called sickle blades (Fig. 2). The investigations showed that flexible, 80-metre-long blades with geometric BTC reduce the loads compared with conventional blades. It was also shown that the torsional deformations of the sickle blades in the outer blade area already significantly impact on the wind turbine‘s output and loads once the rated wind speed is reached. In the case of high wind velocities, the flow separation also occurs later.
With the structural approach, a special means for constructing the rotor blade ensures this effect. The fibre layers are laid not only longitudinally but also anisotropically, in a diagonal direction from the leading to the trailing edge of the blade (Fig.1, Technology 1 above). These blades are also able to not only bend through changes in the load but also twist around their axis. The blades thus change their pitch and passively counteract the load change. „The loads can be reduced much more using the geometric bend-twist coupling approach,“ says project manager Dr Jan Teßmer from DLR, in summarising the results so far for the passive approach. The research consortium wants to test the methodological effects of the smart blades with a 20-metre-long demonstration blade on a real wind turbine.

## Passive and active control elements on and in rotor blades

The idea of active smart blades is not new. Extendable leading edge slats and trailing edges have been regulating the flow conditions on aircraft wings for decades. However, until now the costs have borne no economic relation to wind energy: while with aircraft the material costs 100 to 1,000 euros per kg, rotor blades may only cost about 10 to 15 euros per kg. And this is despite the fact that they have to withstand equally high structural loads and even greater fatigue requirements. „Active elements generally have to be maintained more intensively, so the mechanisms for smart blades have to be robust and economical,“ explains the project manager.
Flexible or rigid trailing edge flaps as well as moveable leading edge slats on the front of the blades actively influence the flow and reduce fatigue loads on the rotor blade structure (Fig. 3). In contrast to the passive elements, however, energy is required for this. Sensors and actuators control the active elements in such a way that the rotor blade responds to the changing flow conditions and regulates the aerodynamic loads.
The scientists initially investigated moveable trailing edges and rigid trailing edge flaps. The flaps regulate the loads on each blade individually and locally.
Flexible, actively controllable trailing edges can influence the lift on the rotor blade – comparable to the rudder on the wing of an aircraft. Compared

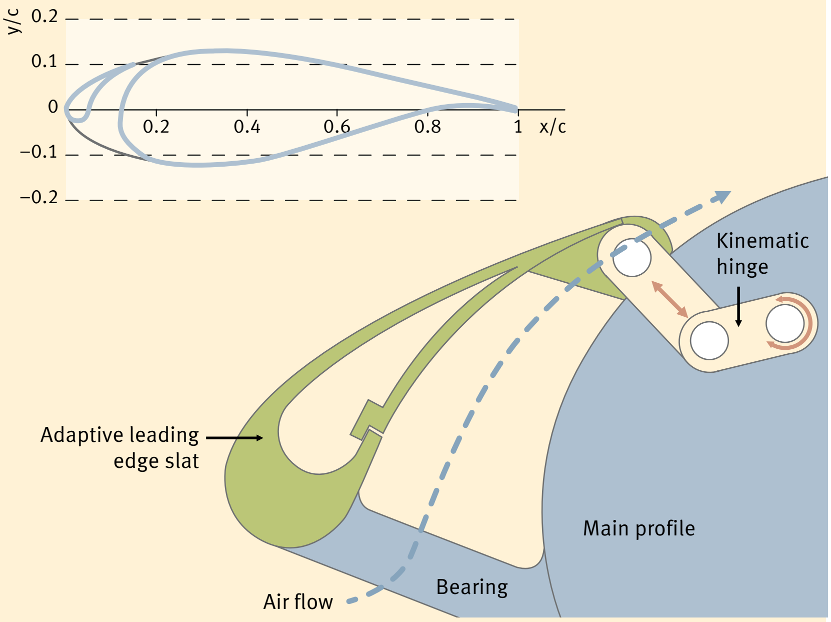
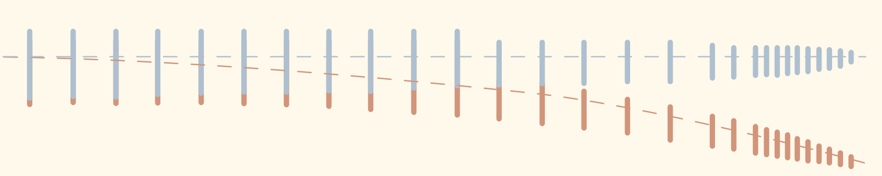
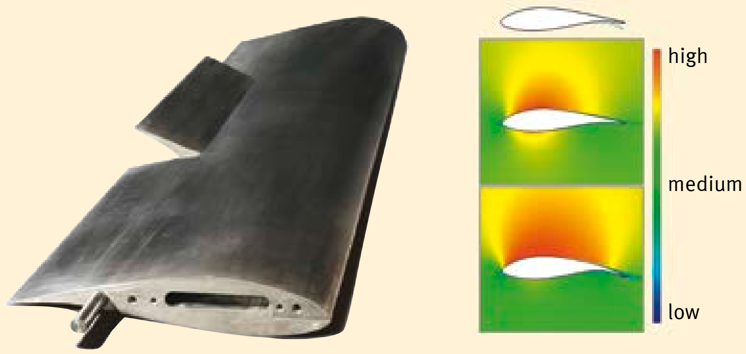



Fig. 4 *Optimal geometry: The integrated leading edge slat (top) was experimentally tested in wind tunnel tests. As a second variant, the original profile of the reference blade was retained and the leading edge slat was placed on the profile (bottom)*



*rotor blade with structural bend-twist coupling (red).*




*on the rotor blade – comparable to the rudder on the wing of an aircraft.*

with adjusting the entire rotor blade, this has the advantage that the active trailing edge has substantially less moving mass. Both are advantageous for regulating cyclic loads. The goal: to increase the service life and reduce the structural mass – while maintaining the same blade size.
Although active technologies have already proven themselves in aviation, they still have to prove their robustness in wind energy. However, the investigations have shown that both methods effectively reduce the loads on rotor blades. Teßmer takes stock: „The maintenance efforts required for rigid trailing edge flaps are, however, so high due to soiling that the advantages of moveable trailing edges outweigh them substantially.“

## Moveable leading edge slats deploy diversionary tactic

As a third technology, integrated leading edge slats were experimentally tested in wind tunnel tests. For this purpose, measuring instruments recorded the reaction dynamics with respect to the acting forces on the wind tunnel model and provided information as to the extent to which these forces can be influenced. This resulted in characteristic turbulences that the model was subjected to in the wind tunnel in order to measure changes in the aerodynamic values. The optimal geometry is shown in Fig. 4 (top).
The scientists also investigated whether a moveable leading edge slat on a rotor blade can improve the efficiency of wind turbines under strongly fluctuating, turbulent wind conditions. This moving mechanism ensures that the rotor blade also optimally exploits wind speeds with high turbulence. The advantage lies in the reaction speed of the leading edge slat: it can quickly influence the acting aerodynamic forces during turbulent inflow conditions. In contrast to the integrated variant, the original profile of the reference blade was retained and the leading edge slat was placed on the profile (Fig. 4, bottom).
The results are highly promising: „We hope to be able to achieve higher yields in the medium, single-digit percentage range with these technologies,“ says the project manager optimistically. In simulations, they compared all mechanisms with a state-of-the-art reference wind turbine with an 80-metre-long rotor blade. In a next step, the researchers want to demonstrate and test their concepts in the field.

## Demonstration blade and further development

The SmartBlades2 project, which is concerned with further developing the aforementioned intelligent rotor blade technologies, was launched in the summer of 2016. This is aimed at increasing the technological maturity of the new methods. Together with several industrial partners, the scientists now want to produce four rotor blades with geometrically induced BTC, which will have rotor diameters of around 40 metres in length. The rotor blade segment with a moveable, active trailing edge will be subjected to centrifugal forces on a centrifugal test rig and to fatigue loads in a durability test, and will then also be tested under controlled conditions in a wind tunnel. The design and simulation methods can then be validated with the measurement data. In addition, three different concepts for leading edge slats will also be investigated in various wind tunnel tests and ultimately a full-scale test will also be conducted for a rigid concept variant. The scientists are also developing further intelligent control methods for active mechanisms, which will then be tested in the wind tunnel.

# Machine production of rotor blades

Rotor blades account for about one-fifth of the total cost of an onshore wind turbine. This is due to the high percentage of manual work and materials used. Moulds are used for the vacuum infusion process with glass fibre mats. By means of a vacuum, resin is then injected that bonds the mats. Once this has cured, the segments are pieced together to form a blade and are then varnished. This is mostly done manually. But how can rotor blades and new design approaches such as for passive bend-twist coupling be produced faster, more cost-effectively and in better quality in the future? Scientists from the Fraunhofer Institute for Wind Energy and Energy Systems Engineering IWES are working on this together with their partners. In the BladeMaker project, they are looking to cut production costs by more than 10 %. They want to achieve this with an automatic lay-up of glass fibre mats and individual rovings. This way, even complex laying patterns can be created and thus innovative blade structures produced.

In addition to processes, the project is also concerned with new materials, such as innovative epoxy resins, polyurethane-based core materials and adhesives, as well as with the rotor blade design. The Bremerhaven-based demonstration centre started operation in April 2016 for this purpose. The centrepiece comprises a portal system with two independently moveable, rail-bound gantries. It works with the precision of a standard milling machine, but can do much more than milling. It carries out the various production steps that are otherwise handled by different machines. By autumn 2017, the IWES experts are intending to produce an 18-metre-long rotor blade segment with the portal system – which will prove whether it works in practice and also conclude the joint project. In addition, they are testing how the blade can be automatically freed from adhesive residues and optimally prepared for the paint application. In the long term, the BladeMaker Demonstration Centre will serve as a national and international hub for researching and developing rotor blade production.

## Project participants

- **Project coordination:** German Aerospace Center (DLR), Braunschweig, Dr Jan Teßmer, jan.tessmer@dlr.de
- **Design and production methods for adaptive blade technologies:** German Aerospace Center (DLR), Institute of Composite Structures and Adaptive Systems, Prof. Dr Martin Wiedemann
- **Preliminary work for the industrial launch:** Leibniz Universität Hannover, Faculty of Civil Engineering and Geodetic Science, Institute of Structural Analysis, Prof. Dr Raimund Rolfes
- **Aeroelastic and structural models:** Fraunhofer Institute for Wind Energy and Energy Systems IWES, Bremerhaven, Prof. Dr Andreas Reuter
- **Turbulence description, aerodynamics, aeroelastics, system dynamics as well as sensors and regulation:** Carl von Ossietzky, University of Oldenburg, Faculty V – Mathematics and Natural Sciences, Institute of Physics, ForWind – Center for Wind Energy Research, Prof. Dr Joachim Peinke

## Link

- www.smartblades.info

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