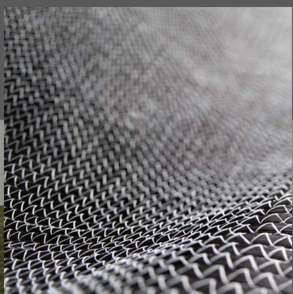
SAERTEX®

REINFORCING SPAR CAPS IN ROTOR BLADES

COMPARISON OF PULTRUDED PLANKS AND THE NEXT GENERATION OF CARBON FIBER NON-CRIMP FABRICS



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INTRODUCTION

Wind energy is already among the cheapest sources of energy available. Nevertheless, the sector is striving to further reduce the Levelized Costs of Energy (LCOE), both for onshore and off-shore turbines.

Furthermore, it wants to expand its potential by exploiting sites with lower wind speeds. Both factors drive the development of continuously increasing blade lengths.

Many OEMs and blade manufacturers choose to use carbon fiber for the spar caps of these blades and most new designs are based on pultruded carbon planks for that application, because they offer a sufficient performance for a reasonable price on the market.

However, also in Non-Crimp Fabrics (NCF), a well-established material technology for rotor blades, new developments are showing major improvements compared to previous versions. While the performance in mechanical values has ever since been undoubted, latest innovation also shows improvements in the processability and cost saving potentials for thick carbon laminates.

So, now the question is: can these improved carbon NCFs compete in terms of weight savings, quality and cost with the benefits of using pultruded planks for spar caps in rotor blades? And if yes, when to use which material.

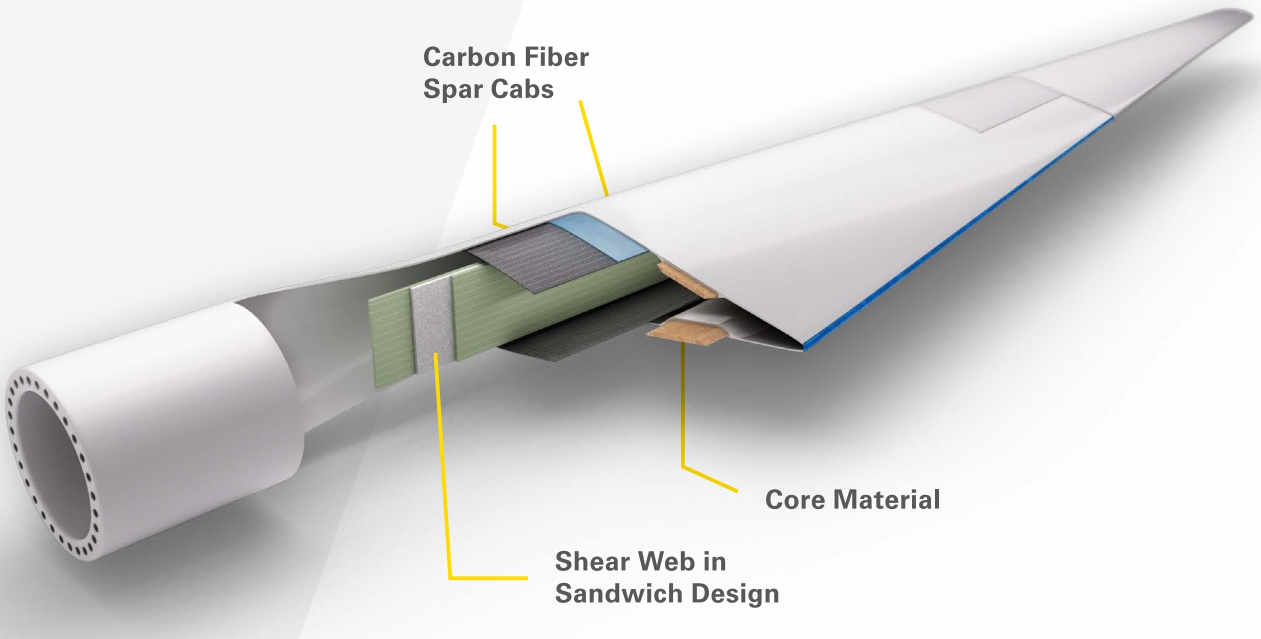
WHAT IS A WIND BLADE SPAR CAP?

Modern rotor blades have typically a very similar construction scheme. The main load bearing structure of a wind turbine blade is the spar component.

It is either integrated into a structural shell as a spar cap or mostly constructed in a parallel production step as a separate spar structure - completed with shear webs.

The spar cap is located in the complete length of the rotor blade, starting from the root area to the top of the rotor blade.

TYPICAL ROTOR BLADE DESIGN WITH CARBON FIBER SPAR CAP



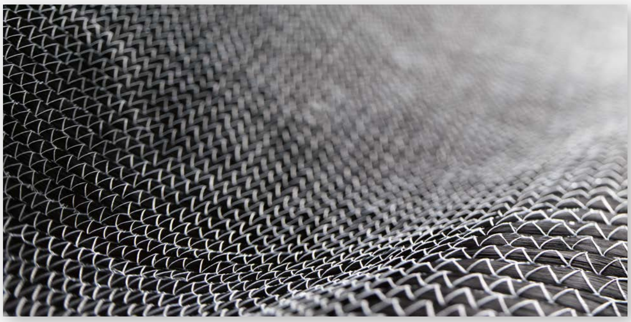
THE NEXT GENERATION OF CARBON MATERIALS FOR SPAR CAPS

As a composite specialist for reinforcement in rotorblades SAERTEX has delivered customized glass and carbon fiber materials for the wind industry over decades. In cooperation with its customers in rotorblade production SAERTEX has developed different glass, carbon and hybrid fiber styles of Non-Crimp Fabrics for shear webs, shells, and girders.

For the key application of spar caps the company has delivered carbon fiber Unidirectionals (UDs) for years. To support its customers in the wind industry - to bring down cost of rotor blade production and contribute to accelerating the energy transition - the company has developed a next generation of carbon materials for spar caps. At JEC WORLD 2023 in Paris (APR 25–27), they are firstly introduced to the market.

MAGIC FLOW UD

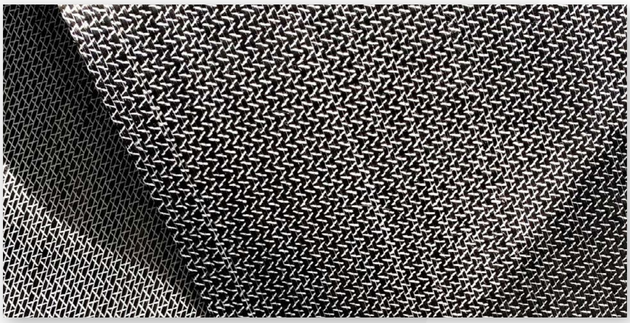
SAERTEX developed a next generation of carbon fiber Non-crimp fabrics based on the experience and customer feedback on existing generations. For the Magic Flow UD the focus was on the efficient processability in vacuum infusion for thick laminates of up to 200 layers – for very long blades.



Magic Flow UD
// for thick laminates of 200 layers and more
// fast impregnation speed
// excellent drapability
// excellent mechanical properties
// established recycling process for ressidues
// Made in Europe

STEADY PLUS UD

A new kind of Carbon fiber NCF is the Steady Plus UD with reachable fiber volume fraction of 60 % – to save resin consumption. This Unidirectional fabric has an outstanding drapability for a perfect match in complex blade designs. This is based on a unique evenness and wrinkle-free behavior. The Steady Plus UD also shows excellent flow speed and impregnation for thick laminates of up to 120 layers.

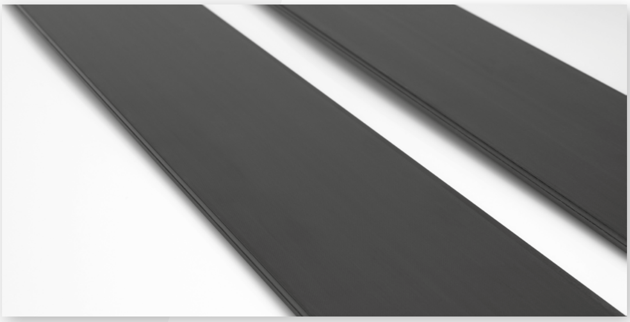


Steady Plus UD
// reduce resin consumption – 60 % fiber volume fraction
// high design freedom – drapability
// high flow speed in vacuum infusion
// no glass fiber stabilization
// established recycling process for ressidues
// Made in Europe

PULTRUDED PLANKS FROM SAERTEX: SAERplanks

For the usage in spars of rotor blades, SAERTEX has also developed its own product range of pultruded planks, so called SAERplanks.

An in-house production process based on resin injection to build up a very high resin pressure and secure an excellent impregnation of the carbon fibers. Also, the use of a new developed hybrid resin system allows a high speed production increasing cost efficiency.



SAERplanks
// high process reliability with resin injection instead of resin bath
// high efficiency thanks to hybrid resin system
// Made in Europe

THE PRODUCT PROPERTIES IN COMPARISON

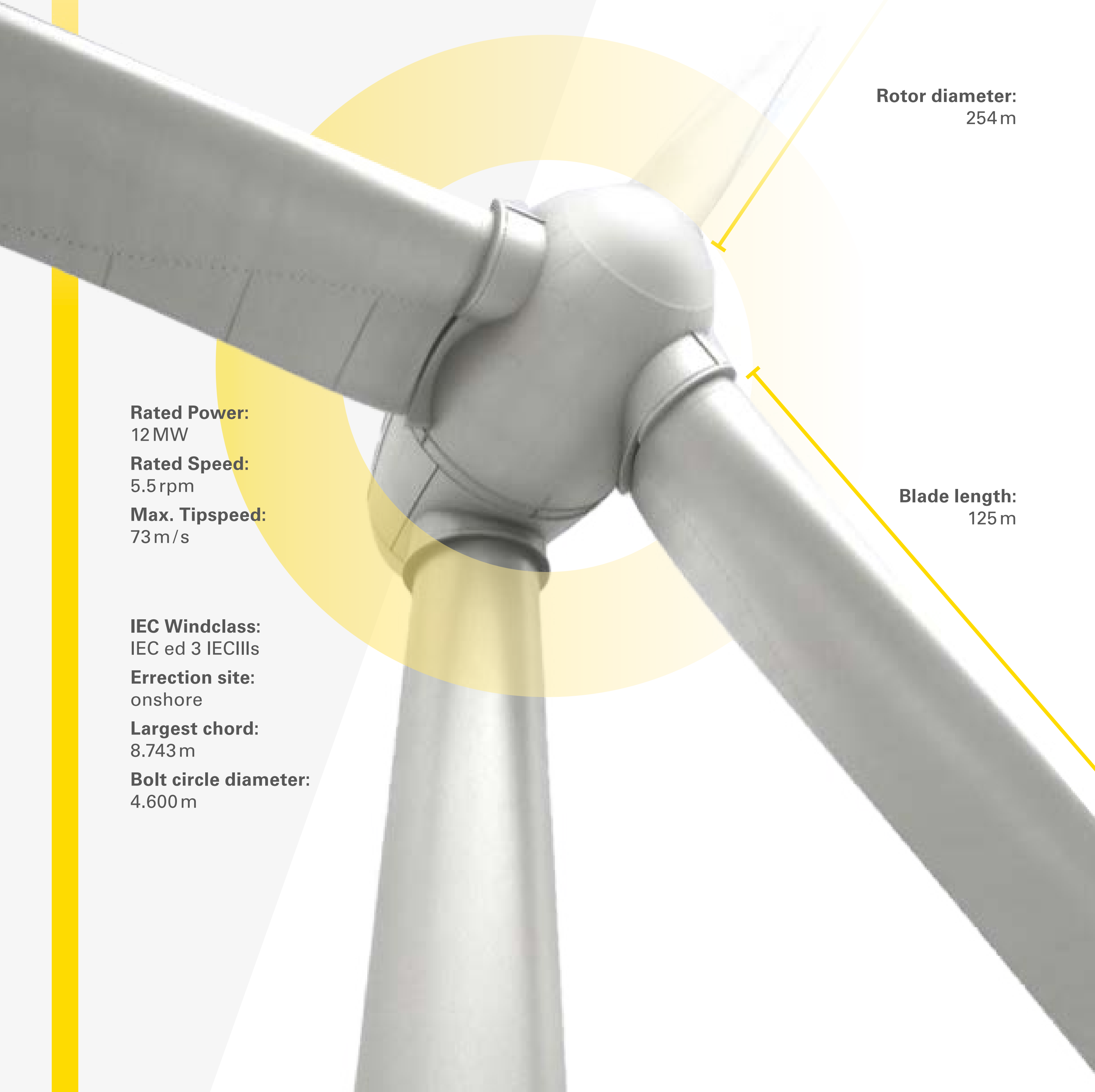
	MagicFlow UD	Steady Plus UD	SAERplanks
Fibre content	55 %	60 %	63–69 %
E-Modulus (avg. Compression/tensile)	113 GPa	125 GPa	135–150 GPa
Tensile failure strain	> 1,2 %	> 1,2 %	> 1,2 %
Compression failure strain (characteristic)	> 0,9 %	> 0,9 %	> 1,0 %
Resin used for testing	Epoxy: CTP AM 3325 A/B	Epoxy: CTP AM 3325 A/B	Epoxy: CTP AM 3325 A/B

WHICH MATERIAL FOR WHICH REQUIREMENT?

A CASE STUDY IN COOPERATION WITH BLADE ENGINEERING COMPANY ADC

In cooperation with the blade engineering company ADC we analyzed the right usage of those three new materials for the usage in a rotor blade design.

Reference blade design



Rotor diameter:
254 m

Rated Power:
12 MW

Rated Speed:
5.5 rpm

Max. Tipspeed:
73 m/s

Blade length:
125 m

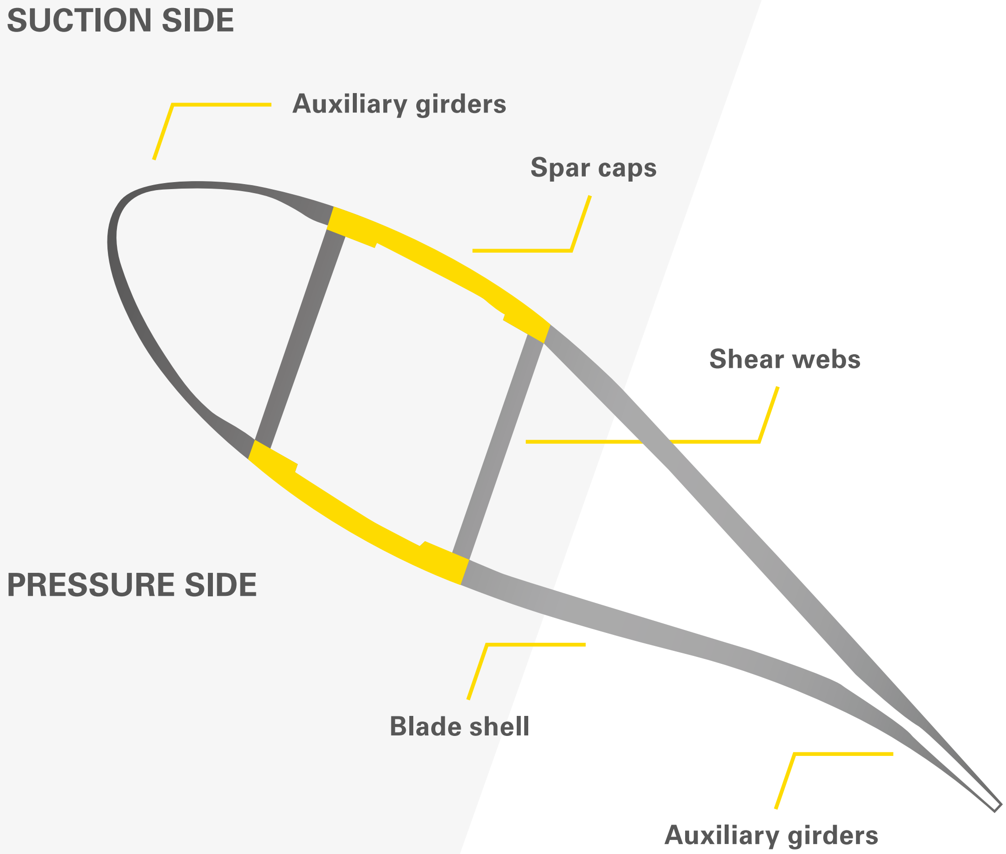
IEC Windclass:
IEC ed 3 IECIIIs

Errection site:
onshore

Largest chord:
8.743 m

Bolt circle diameter:
4.600 m

The two spar caps on the suction and pressure sides respectively give the rotor blade its stiffness in flap wise direction. They are dimensioned in such a way that the required tower clearance is ensured during every operating state of the turbine.



Used Materials

The materials of these spar caps were varied to evaluate the different materials. Not all variants lead to the same weight of the spar cap and therefore same blade weight. This influences again the edgewise behaviour.

This is where the four auxiliary girders come into play. These are located at the leading and trailing edge. They give the rotor blade stiffness in the edgewise direction and their dimension was adjusted to make sure that the edgewise natural frequency does not fall below a minimum permissible value.

In our comparison, the blade shell is laminated with fiberglass fabrics. As sandwich core material PET is used. The main girder is designed to be a sandwich itself using balsa material as core.

The main and the auxiliary spar caps are made of carbon fiber UD or pultruded planks. In case of the pultrusion spar cap, a 200 gsm fabric is placed between the planks to support the resin flow and the interlaminar adhesion.

The CFRP material properties used for the blade design are shown on this slide.

THE MATERIAL PROPERTIES IN COMPARISON

	MagicFlow UD	Steady Plus UD	CF pultruded planks 5 mm
FVC	55 %	60 %	65 %
Density	1497	1528	1560
Layer Thickness	0.719	0.556	5
Usage	Spar cap	Spar cap	Spar cap
Grammage	704	594	-
E1	113100	124890	146827
E2	9700	11313	8895
G	3520	4380	3500
hu	0.283	0.274	0.283
R1+	1607	1749	2323
R1-	1142	1243	1430
R2+	61	61	50
R2-	151	151	170
R12	50	50	50

Analysis

The required structural integrity of the blade had to be secured for all 3 variants of the blade design. Therefore ADC has performed the analysis on the blade covering the extreme loads in flapwise and edgewise direction. Furthermore, a load case is calculated for evaluating the maximum deflection of the tip to guarantee the tower clearance.

In order to meet these requirements with the specified materials and their aforementioned properties, ADC has run an optimization first targeting the lowest material usage in the spar cap, followed by adjusting the quantity of reinforcements of the leading and trailing edge girders to compensate for the different resulting blade weights leading to different flapwise loads.

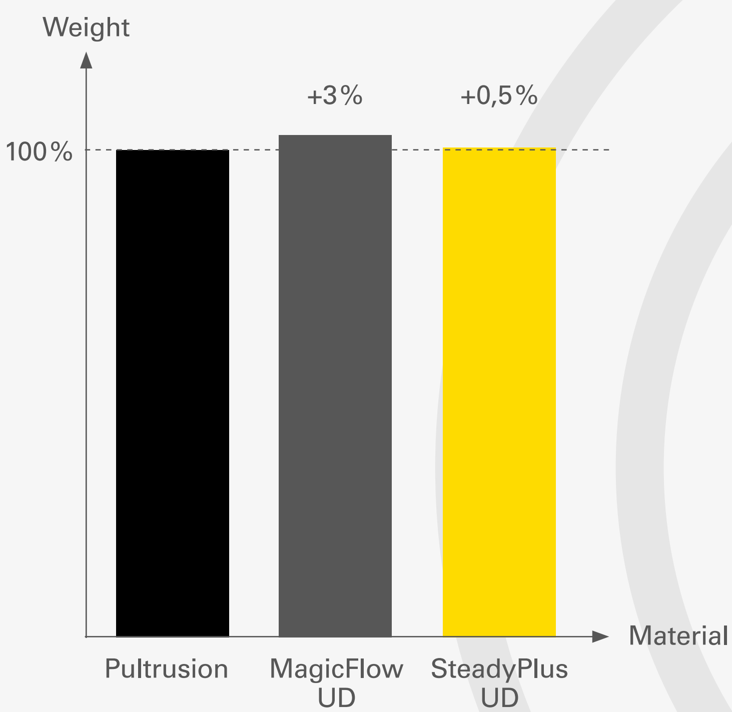
Credit: LM WIND POWER

RESULTS OF THE BLADE ANALYSIS

WEIGHT OF THE BLADE

	"Magic Flow UD"	"Steady Plus UD"	"Pultrusion"
Shell	29.36 t	29.36 t	29.61 t
Shear webs	9.65 t	9.65 t	9.65 t
Root Insert	4.14 t	4.14 t	4.14 t
Spar Cap	14.06 t	12.94 t	12.34 t
LE / TE Girders	2.31 t	1.64 t	1.62
Cores	8.54 t	8.54 t	8.54 t
Bondings	2.32 t	2.30 t	2.32 t
Other	2.00 t	2.00 t	2.00 t
Total weight	**72.38 t**	**70.58 t**	**70.23 t**
Difference to "Pultrusion"	**2.16 t**	**0.35 t**	**–**

Within this Table the resulting blade weights are shown, including a breakdown of the weights per component. As one can see, the lowest blade weight is the pultrusion blade and the one using the Magic Flow UD is a bit more than 2 tons heavier, due to the heavier spar cap and the heavier auxiliary girders. The Steady Plus UD however has an almost negligible weight increase, compared to the pultrusion version.



ESTIMATED TOTAL COST

The cost is mainly driven by the amount of carbon laminate required for the production of the blade.

According to the study 12.340 kg of Pultruded Planks are needed compared to 14.060 kg laminate made out of Magic Flow UD or respectively 12.940 kg of laminate made out of Steady Plus UD.

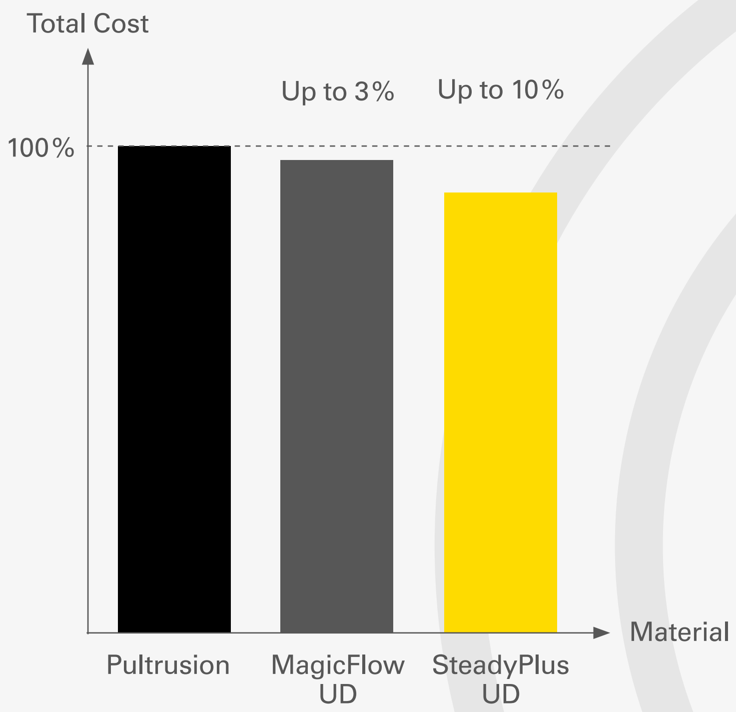
Due to the different fibre fractions the dry carbon fibre quantities are even closer together with approx. 7.600 kg of dry carbon fibre for the spar cap made with pultruded planks, while the ones produced in infusion uses approx. 8.000 kg of dry Magic Flow UD or approx. 7.700 kg of dry Steady Plus UD.

Taking into account the waste factor in the reinforcement production, which is for the pultrusion planks typically 5–10 % higher than for NCF, one realizes that producers actually need more dry carbon for the blade variant based on pultruded planks, which is driving up the costs. So the calculated usage of fibers for pultruded planks in practice is roughly at 7.980–8.360 kg.

On the other hand, if during the blade production no separate spar cap mould is required anymore, thanks to the usage of the carbon planks which may be co-infused with the shell, there is a saving on the Capital Expenditure (CapEx).

Altogether, dependent on the blade design and the production method, for a complete blade the SteadyPlus UD can save 5–10 % in total cost compared to the pultrusion variant.

Even the MagicFlow UD shows saving potentials in the total cost calculation based on fiber quantities and resin used in comparison to the pultruded planks.



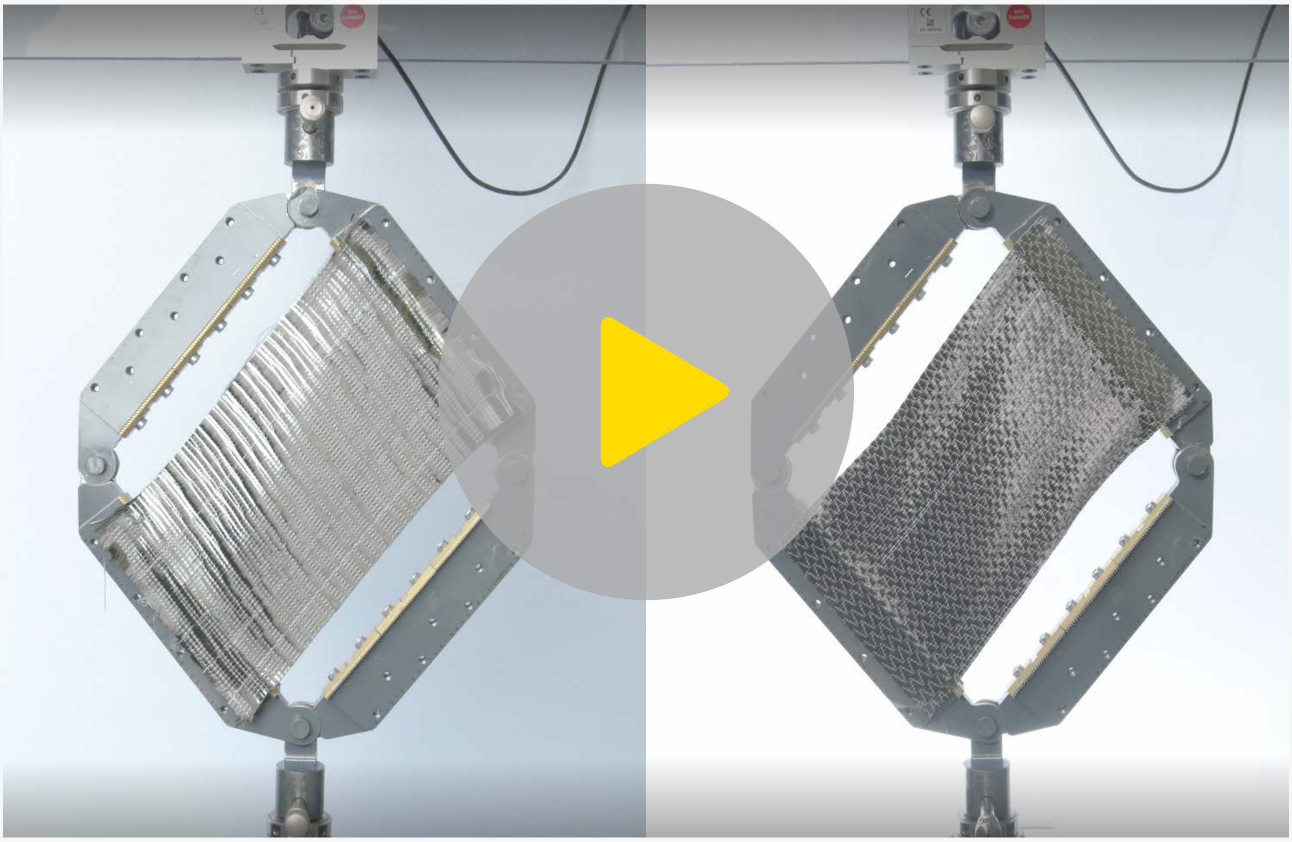
DESIGN FREEDOM AND PROCESSABILITY

The design of rotorblades depends on the application and philosophy of the blade designers. While in some cases completely straight designs are in place, there are also blade designs with a more twisted form or prebend. The form of a pultruded plank is straight. So, the usage of pultruded planks in twisted or bended rotor blade designs has limitations.

The value to compare the design freedom and forming capability of a non-crimp fabric is the drapability. It is defined as the ability of textile preforms to conform to the surface of molds. There are influencing factors of drape like stiffness, rigidity and thickness for example. The way to measure the drapability of a Unidirectional fabric is the so called picture frame test.

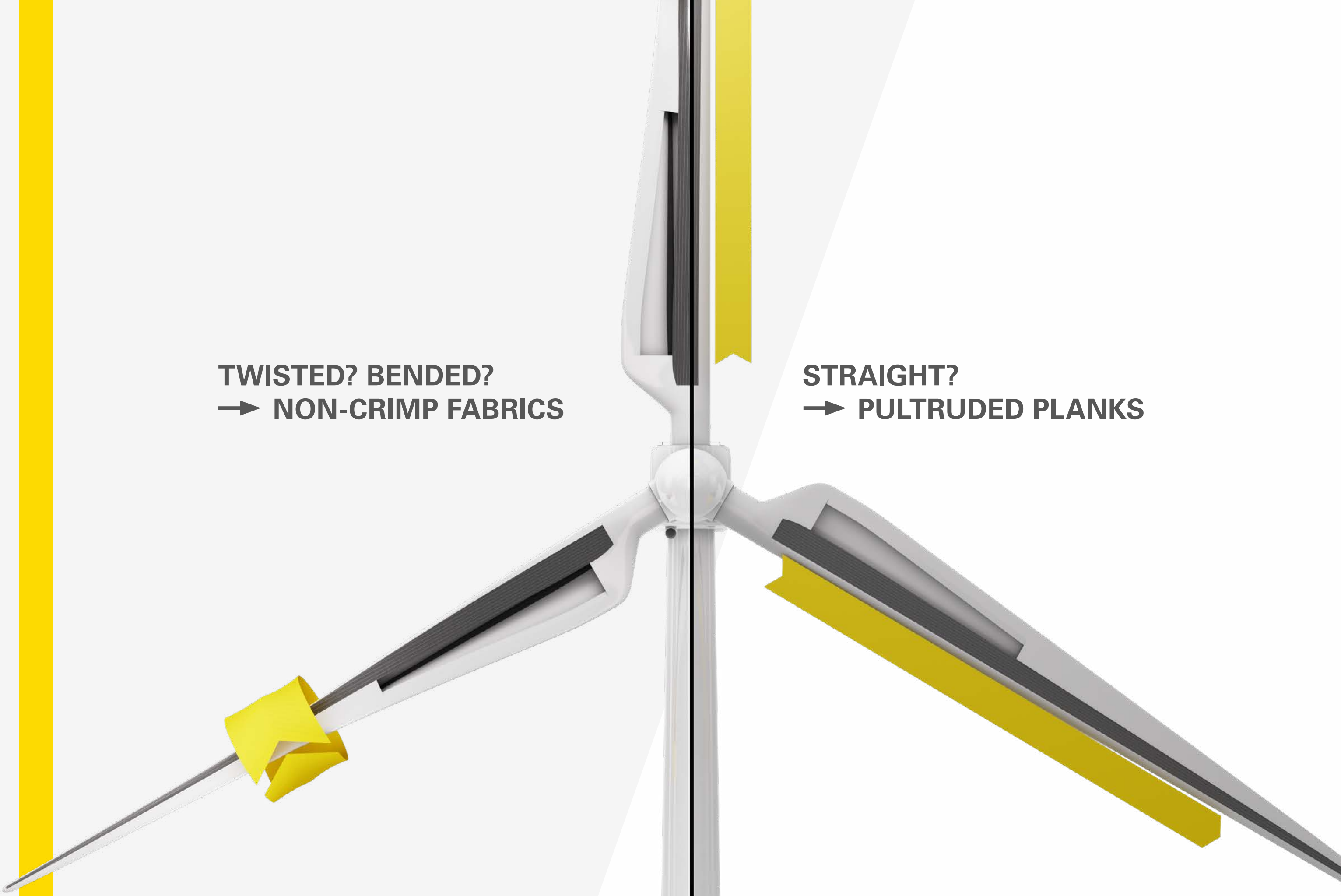
Testing of magic flow UD and steady plus UD in the picture frame test at the DNV certified laboratory of SAERTEX in Saerbeck has been done. The results show a very high degree of drapability of both articles despite their optimization on flow rate for thick laminates. Both articles show an almost wrinkle-free behaviour, suitable for twisted or bended shapes of a rotor blade design. Testing values are available on request.

Processability of the next generation Carbon UDs: see Magic flow UD and Steady Plus UD in the SAERTEX test labratory.



WHAT REINFORCEMENT TO USE FOR BLADE PRODUCTIONS?

Our analysis and testing of the new generation of Carbon UDs and pultruded planks shows, that both technologies have outstanding advantages. It is the philosophy of the blade designer and blade producer, mainly depending on the blade design and production process that differentiates the usage of the material technologies.



CHECK PRO NON-CRIMP FABRIC CARBON UDS:

- // Do you have a twisted blade design?
- // Is it a swept blade or one with prebend?
- // Are you going for optimized mechanical values? E-Modulus per €?

Then the new generation carbon UD fabrics, providing more freedom in geometrical design form an attractive new solution. They are optimized to get wave- and wrinkle-free laminates and outstanding mechanical properties at the same time.

The **SAERTEX magic flow UD** shows excellent efficiency based on draping and impregnation features when it comes to very thick laminates of up to 200 layers.

Depending on aerodynamic and geometric blade design and the production technology a cost saving potential of 5–10 % can be achieved. This is where **SAERTEX Steady Plus UD** is providing an interesting new opportunity for blade manufacturers.

CHECK PRO PULTRUSION:

- // Do you have a completely straight blade?
- // Do you have experience in processing planks?
- // Do you even manage to avoid having the separate spar cap molding process?

Then using pultruded planks is an attractive option. For this SAERTEX offers the **SAERplanks**.

With a very constant high quality based on a unique resin injection technology these carbon pultruded planks are an excellent choice for spar cap production.

ONE-STOP-SHOPPING:

Whatever spar cap design you decide to produce - SAERTEX is there to supply you the best carbon reinforcement for your specific blade design.

YOU WANT TO KNOW MORE?

Get in contact with our wind industry experts worldwide:
https://www.saertex.com/en/contact/contact-form

or via E-Mail: info@saertex.com

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