Enabling a stronger wind energy industry with innovative coating technologies

How Covestro and Quarzwerke division HPF The Mineral Engineers combined **Pasquick®**-based coatings with functional fillers to achieve longer lifetimes for wind turbine blades.

Pasquick®

HPF The Mineral Engineers
A DIVISION OF QUARZWERKE GROUP

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Meet the companies collaborating to make wind turbines stand the test of time

Covestro applied its industrial expertise in high-tech polymer materials to develop innovative polyurethane (PU) solutions for wind turbine applications that offer performance benefits and lower blade costs. With Covestro's **Pasquick®** (PAS) technology, high-quality coatings based on the **Desmophen® NH** and **Desmodur® N** product groups were used to coat rotor blades and prolong the working lives of wind turbines

Quarzwerke HPF The Mineral Engineers, a specialist in the extraction, processing, and refining of industrial minerals, selected functional fillers, such as quartz, wollastonite, or feldspar, for further evaluation of the blade erosion in combination with Covestro's **Pasquick®** technology. The final performance of the coating was investigated through rain erosion testing (RET) conducted by AeroNordic ApS.

Key finding: Pasquick®-based coatings deliver excellent erosion protection

The findings indicate that Covestro's **Pasquick®** technology, combined with silica fillers such as **SILBOND® 600 AST**, reduces blade coating erosion and improves efficiency. The **Pasquick®**-based coating brings longer durability and makes maintenance simpler. The high durability of the coating based on PU raw materials provides strong protection against erosion, reducing the blade's repair frequency and maintenance costs over its lifetime.

Key benefits of Covestro's Pasquick® coating solution

- Polyaspartic technology in combination with the right functional filler enables long-lasting windmill blade coatings.
- Rain erosion test performance confirmed higher durability with silica fillers in the **Pasquick®** (PAS) primer.
- Polyaspartic primer allows for extended coating lifetime with lower maintenance need.

Toughening demands on wind turbines

The EU's 'Fit for 55 Package', part of the European Green Deal, is paving the way toward climate neutrality by 2050. To deliver on this ambitious target and align with megatrends, substantially improved technology solutions are needed to support the growth of the wind energy industry.

In particular, new coating solutions are needed to support the growth of wind turbines. Offshore wind farms are expanding to address the need for green energy. As wind-energy developers aim for increased power output with fewer wind turbines, the turbines and their platforms are getting larger. Energy output is also increasing, with high tip speeds of up to 500 km/h. The long blades on these turbines must also be able to withstand severe external conditions such as rain, seawater corrosion, and UV radiation. Today, wind turbine rotor blades often need repairing due to these harsh weather conditions and increased rotor speeds.

More sustainable coatings with improved performance and durability can prolong the service life of a wind turbine. Therefore, it is important to investigate how to improve the longevity of these protective coating systems.

In this study, Covestro and Quarzwerke/HPF aimed to improve the rain erosion performance of a blade coating, applying a standard testing method primarily relevant for testing leading-edge protection (LEP). By enabling reduced maintenance and longer turbine lifetimes, their improved coating solution contributes to making wind energy a practical, economically viable alternative to traditional energy, in line with the EU's climate-neutrality goals.

Driving durability with coating technology

Pasquick® (PAS) is the name of a 2-component (2C) coating technology that provides increased productivity in painting operations due to its fast-curing characteristics. However, It also offers long-lasting protection against UV exposure and rain, and, when compared to conventional 2C PU coatings, low levels of volatile organic compounds (VOCs). Polyaspartics are formed during the reaction of sterically hindered secondary diamines – polyaspartic acid esters – with aliphatic polyisocyanates (Figure 1). The significantly increased productivity during the application process allows for earlier handling of the coated parts, as well as much higher film thickness in a single operation. **Pasquick®** is a proven technology and has been used in rotor blades for more than fifteen years.

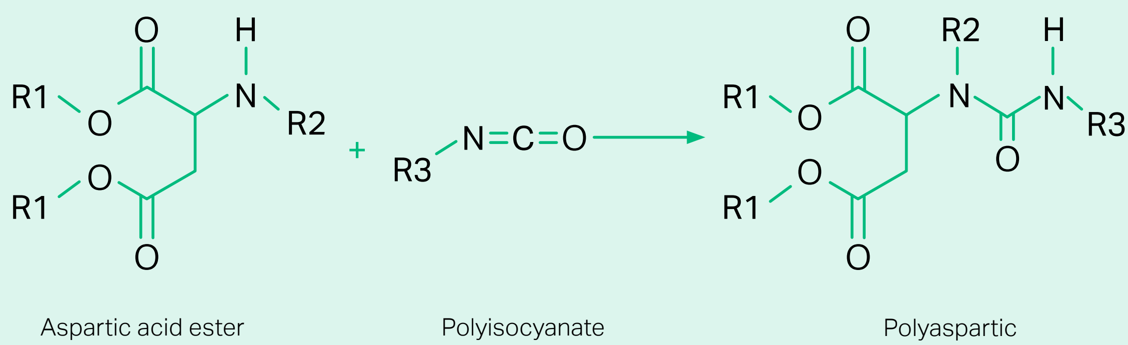


Figure 1. Reaction of polyaspartic acid ester with aliphatic polyisocyanate.

Choosing the right functional filler

A filler's primary function in a coating is often filling volume and reducing overall costs. However, the addition of functional fillers into a coating system also improves the overall performance, specifically the durability, of a wind turbine blade coating, as shown in this study with 2C PAS technology. Quarzwerke's innovative, functional, high-performance fillers have proved their worth for decades, providing polymer systems with excellent functional and/or optical properties.

For pre-selection, **Pasquick®** technology was combined with various fillers. The coating, consisting of a bonding primer, gel coat, pore filler, and topcoat, was subjected to a tailor-made rotation plate to evaluate erosion performance. This pre-study was intended to generate an initial understanding of the performance and facilitate the right selection for the subsequent rain erosion testing (RET).

Standard fillers, such as kaolin, mica, talc, corundum, and aluminum oxide, did not withstand erosion and were not considered further. The best resistance of the rotor-blade coatings against rain erosion was observed for the layers containing functional fillers cuboid wollastonite (**TREMIN®**), tabular feldspar (**MICROSPAR®**), and angular fine silica powder (**SILBOND®**).

The fillers talc and barium sulfate were replaced 1:1 in volume to ensure comparative systems. A further key learning from the pre-study was that surface treatment of the high-performance fillers increases the resistance. Based on these findings, it is recommended to use fillers ranging from tabular or short-needled to cuboid, blocky, and surface-coated.

Angular fine silica powder (SIKRON®, SILBOND®)

For silica to be used as a raw material, it must undergo complex washing, classifying, drying, and iron-free grinding processes. The production of silica fine flours with a defined grain size also requires separation processes. By combining grinding and classifying technology, silica powders with a grain size of up to 1 µm can be produced. A further refinement step is customized surface modification with silanes or silane-based chemical compounds, tailored to the specific application.

Cuboid wollastonite (TREMIN®)

Wollastonite is a naturally occurring calcium silicate that forms from silicon dioxide and calcium carbonate at approximately 450°C. The structure of the individual wollastonite particles is dependent on their geological formation on the one hand, and strongly determined by the selected processing technology on the other hand. The possible target products can have both a pronounced needle shape, (i.e., a high aspect ratio), and a partially destroyed needle shape with a low aspect ratio (cuboid). Due to the low influence on viscosity, the cuboid wollastonite grade was used.

Tabular feldspar (MICROSPAR®)

Feldspar is a chemically resistant tectosilicate with a thick tabular grain morphology. Making up almost 60% of the earth's crust by weight, feldspars are by far the most common mineral group. Correspondingly, they are a main and secondary component in the structure of numerous rocks. Feldspars have a high degree of whiteness (Y > 90) and are transparent in many binder systems. There are both potash and sodium feldspars, which are processed and separated by an elaborate screening technique, then classified and micro-ground.

How the right filler and topcoat improve coating performance

Combining the benefits from **Pasquick®** technology with the right functional filler results in improved performance coatings for rotor blades. For this purpose, a three-layer system comprising a gel coat, primer, and topcoat was applied to the specimen for performance studies. The functional silica filler's effect on the coating system's performance was investigated in the primer by direct comparison to a reference system with a standard filler. The gel coat and topcoat were kept constant throughout the layers. Different **Desmophen® NH** types were selected in combination with **Desmodur® N** types. **SILBOND® 600 AST**, a promising candidate identified during the pre-study, was used to replace the standard fillers in the primer.

Desmophen® NH binders and Desmodur® N hardeners

The binders, hardeners, and fillers applied for the three layers (gel coat, primer, and topcoat) are summarized in Table 1.

	BINDER	HARDENER
Topcoat	Desmophen® NH 1420	Desmodur® ultra N 3600 Desmodur® ultra N 3800
Primer	Desmophen® NH 1420 Desmophen® NH 1520	Desmodur® ultra N 3800 Desmodur® ultra N 3900
	Primer A: Standard filler (reference) magnesium silicate, calcium carbonate, kaolin, barium sulfate **Primer B:** Silica filler SILBOND® 600 AST	
Gel coat	Desmophen® NH 1420 Desmophen® NH 1520 Desmophen® NH 1720	Desmodur® ultra N 3300 Desmodur® ultra N 3800
Substrate	Laminate (RET specimen)	

Table 1. Covestro **Desmophen® NH** binders and **Desmodur® N** hardeners applied on the different systems. Within each coating system, all combinations of binder and hardener types are possible. Detailed formulations available upon request.

Polyaspartic primer formulation with SILBOND® 600 AST

For a better comparison of the filler effect, a 1:1 (by volume) replacement of the filler in the primer layer was chosen. A detailed primer formulation with **SILBOND® 600 AST** is shown in Table 2.

For each layer in the three-layer system, three specimens were coated with the above composition. The rain erosion test (RET) was conducted by AeroNordic ApS.

POS.	PRODUCT	% BY WEIGHT
Component A		
1	Desmophen® NH 1420	6.0
2	Desmophen® NH 1520	10.9
3	Bentone® SD 2	0.4
4	Disperbyk® 111	0.1
5	Byk® 141	0.3
6	Butylacetat / Methylpropylacetat / Xylol	11.4
7	Bayferrox® 318	0.4
8	Crenox® R – KB 4	6.9
9	Heucophos® ZPA	4.4
10	SYLOSIV® A 4	1.1
11	SILBOND® 600 AST	39.9
Component B		
12	Desmodur® ultra N 3800	3.0
13	Desmodur® ultra N 3900	9.2
14	Butylacetat / Methylpropylacetat / Xylol	7.1

Table 2. Polyaspartic primer formulation with **SILBOND® 600 AST**

Putting **Pasquick®** to the test with RET

Because the coating solutions have to withstand extreme conditions, it is essential to test them and understand their performance and erosion behavior. Therefore, the blade coatings underwent rain erosion testing (RET) according to DNV GL's Recommended Practice (DNVGL-RP-0171) to test their rotor blade erosion protection systems. The RET was conducted by AeroNordic ApS.

The accelerated testing makes the coating performance very similar to what it would be in real-life harsh weather conditions. The test is based on a three-bladed helicopter principle, with a test specimen reflecting the actual blade substrate construction. RET is primarily relevant for testing leading-edge protection (LEP) coating solutions, as this part of the rotor blade is exposed to rough conditions during operation.

In this study, RET was performed with the three-layer coating system to evaluate the influence of functional fillers in the **Pasquick®** coating. This three-layer coating system is intended for use on the entire blade and does not necessarily substitute an LEP layer. Typically, an LEP system would be used on top of the coating at the leading edge.

When analyzing the reference system comprising standard fillers in the primer layer, observed failure modes include erosion and peeling of the three-layer coating system. The visual inspection after five hours is shown in Figure 2.

Session ID: 620, Group 5
Accumulated erosion time: 05:00:00 Scale unit: 10 mm.

Figure 2. Specimen image of the three-layer coating system consisting of primer A (standard filler) at an accumulated erosion time of five hours (scale unit 10 mm).

The erosion starting point is at 75 minutes (105 minutes on the other specimen) of RET testing under standard testing conditions. Erosion initiation is defined as the first appearance of unintended discontinuity in the surface that is not present at the beginning of the test and caused by droplet impacts. The peeling starts from the topcoat and migrates through all the layers to the laminate. The fatigue generally begins at the end of the highest rotation speed, in this case at a tip speed of 125 m/s, which is reflected by a starting failure on the left side of the specimen. The breakthrough to the laminate is observed after 180 minutes (240 minutes on the other specimen).

Breakthrough is defined as the first appearance of the exposed underlying substrate, meaning the erosion has progressed through the entirety of that layer. The RET was stopped after five hours of running and not further continued due to the fatigue of the entire coating system.

The RET results for this system are summarized in Table 3.

Test parameter	Result
Failure mode	Erosion and peeling
Erosion starting point	Specimen 1: 75 min
	Specimen 2: 105 min
	Specimen 3: 75 min
Breakthrough	Specimen 1: 180 min
	Specimen 2: 180 min
	Specimen 3: 240 min
Stage of erosion progress	Erosion starting point & breakthrough

Table 3. Results for the three-layer coating system consisting of primer A (standard filler)

When applying **SILBOND® 600 AST** in primer B while keeping the composition of the other layers constant, the erosion starting point is observed at a similar range at 75 minutes (135 minutes on the other specimen). The visual inspection after five hours running is shown in Figure 3.

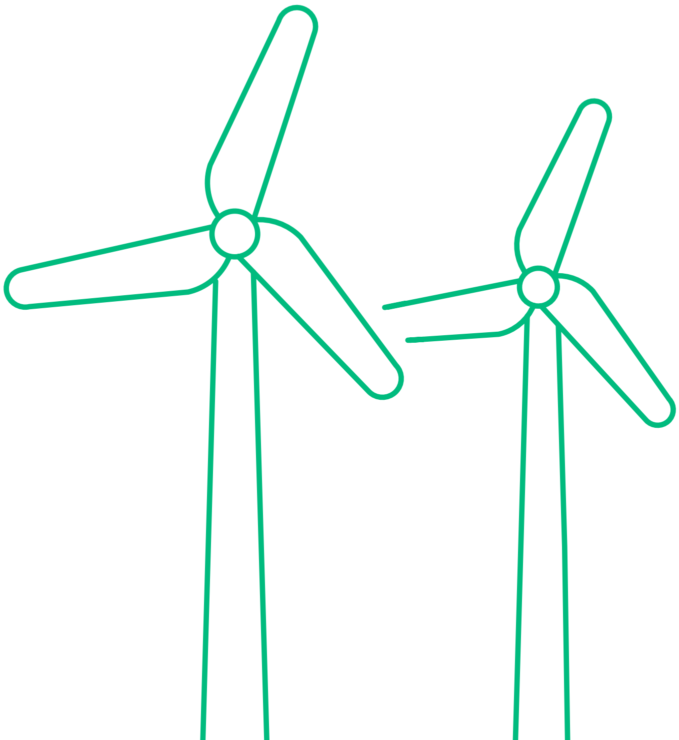
Session ID: 621, group 4
Accumulated erosion time: 05:00:00 Scale unit: 10 mm

Figure 3. Specimen image of the three-layer coating system consisting of primer B (silica filler **SILBOND® 600 AST**) at an accumulated erosion time of five hours (scale unit 10 mm).

The change in the primer composition has a huge performance benefit as this coating system does not show any breakthrough to the laminate. The fatigue is limited to the topcoat layer only. The RET run was stopped after eight hours of testing as no breakthrough was observed, compared to the coating system with primer A which was already destroyed after five hours. The RET results for this coating system are summarized in Table 4.

Test parameter	Result
Failure mode	Erosion and peeling
Erosion starting point	Specimen 1: 75 min
	Specimen 2: 135 min
	Specimen 3: 135 min
Breakthrough	Specimen 1: N/A
	Specimen 2: N/A
	Specimen 3: N/A
Stage of erosion progress	Erosion starting point & breakthrough

Table 4. Results for the three-layer coating system consisting of primer B (silica filler)



Conclusion

Pasquick® plus the right filler means longer-lasting turbine blades

Based on **Pasquick®** technology, a well established technology for rotor blades for more than fifteen years, a coating system was improved by the addition of silica filler **SILBOND® 600 AST**, enabling it to withstand harsh weather conditions at increased rotor speeds. The replacement of conventional fillers in the primer reduces blade coating erosion and increases the efficiency of the coating protection. This is confirmed by an extended RET lifetime.

The proven benefit to the primer layer can be transferred to any other layer within the coating system, including the potential for a leading-edge protection layer.

Covestro is one of the world's leading polymer companies

With sales of EUR 15.9 billion in the fiscal year of 2021, with 50 production sites worldwide and approximately 17,900 employees, Covestro is among the world's largest polymer companies. Its business activities focus on the manufacture of high-tech polymer materials and the development of innovative, sustainable solutions to the greatest challenges of our time. Covestro is focusing its efforts on the Circular Economy and renewable energy is a major driver for the company.

For the wind industry in particular, Covestro is striving for more cost-effective, more sustainable material solutions to support the further expansion of wind energy. The company leverages its global materials and processing expertise for this purpose.

Quarzwerke is a specialist in the extraction, processing, and refining of industrial minerals

The Quarzwerke division HPF The Mineral Engineers has been developing and selling high-performance fillers and additives for polymer systems based on natural and synthetic minerals for years. Whether in plastics like agricultural or packaging films, compounds for automotive parts, electrical devices, paints and coatings, kitchen sinks, solid surfaces and engineered stone, or even dental and cosmetics applications, functional mineral fillers, surface treated or not, find use in an astonishingly large variety of everyday products.

Quarzwerke Group, headquartered in Germany, is an independent international family business with more than 137 years of tradition and a significant market position in the extraction, processing, and refining of industrial minerals, mainly from its own deposits. It has more than 30 production sites in Europe and a state-of-the-art plant in South Korea. Approximately 3,500 employees in the Quarzwerke Group work on contributing to the success of their customers worldwide.

If you're interested in one of the Covestro solutions highlighted in this paper, they're available as **Desmodur® N** and **Desmophen NH®** – wherever you are in the world.

To learn about other ways to use these products, or more about Covestro's wind-energy solutions, visit **wind-energy.covestro.com**

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Edition: September 2022 · Printed in Germany