Unleashing the potential of wind energy with protective turbine coating technologies

How **Pasquick®**-based coatings are enabling longer-lasting protection for wind turbine blades

Pasquick®

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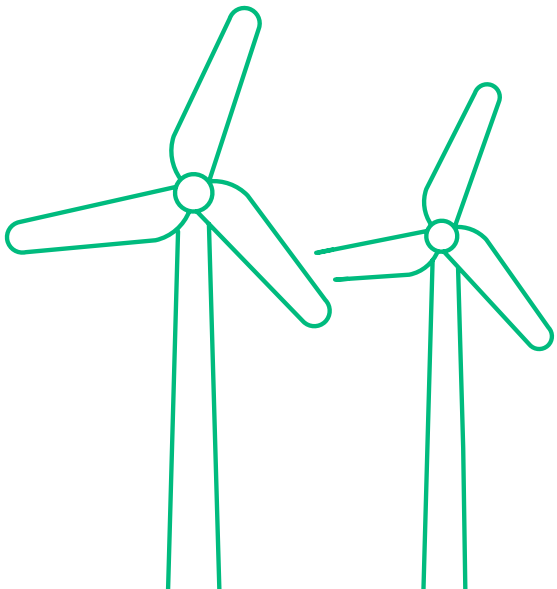
covestro

PU solutions to support the energy transition

Harnessing its expertise in material science, Covestro is developing state-of-the-art polyurethane (PU) solutions to support the energy transition. **Pasquick®** coating technology, which delivers robust, long-lasting protection for wind turbine blades, is a key example of the materials needed to turn the energy transition into a reality. This protection prolongs turbine lifetimes and helps to enhance the efficiency and scalability of renewable energy production.



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

The third-party tests we conducted indicate that **Pasquick®**-based coatings, combined with the right hardener, demonstrate excellent performance in accelerated rain erosion tests (RETs). The proven resilience and durability of the coatings protects wind turbines from the rough conditions they will experience during their operational lifetimes. As a result, manufacturers can reduce their maintenance costs and design larger, more efficient wind-power systems.

Key benefits of Covestro's Pasquick® coating solution:

- Polyaspartic technology, in combination with the right hardener, enables long-lasting coatings for wind turbine blades
- In addition to rain erosion protection, **Pasquick®** coatings deliver protection from prolonged UV exposure and support the overall durability of wind turbines
- Covestro offers specific protection for the leading edge of turbines, which faces the greatest strain in outdoor conditions; these coatings demonstrate high performance in rain erosion tests

Introduction:
Harnessing the winds of change

The wind turbine industry has grown significantly in recent years. This expansion is driven by increasing demand for renewable energy sources that can support reductions in greenhouse gas (GHG) emissions. Wind power has become one of the most cost-effective and rapidly deployable sources of renewable energy worldwide, making it an attractive option for many countries and regions.

As of the end of 2023, global installed wind power capacity totals around 1,047 GW, with over 116 GW of new capacity added in 2023 alone. [1]

At a recent United Nations Climate Change Conference (COP28), governments agreed to triple global renewable capacity and double energy efficiency by 2030. To achieve this goal, capacity will have to reach 2,000 GW of capacity in the next six years – an imperative that will drive continued growth throughout the sector. [2,3]

This need to increase capacity (while reducing costs) means that manufacturers have been continuously increasing the size of their turbines. Modern offshore wind turbines can have rotor diameters exceeding 200 meters and hub heights of over 100 meters, allowing them to capture more wind energy and generate more electricity with greater efficiency.

However, as wind turbine blades grow larger, so too does the need for advanced coatings that can withstand the stresses and strains of operational usage. Over a typical 20-year blade lifetime, coatings play a crucial role in protecting blades from environmental factors such as UV radiation, moisture, and erosion caused by rain, hail, and airborne particles.

On larger wind blades, tip speeds reach up to 500 km/h. This makes them especially vulnerable to particle impact damage, especially on the 'leading edge' that directly faces the direction of acceleration. Considering this context, it is more important than ever for manufacturers to identify and implement effective coatings that can extend blade lifespan and improve the overall performance of their wind turbines.

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Coating technology with a track record of driving durability

Pasquick® is a two-component (2C) topcoat technology, developed by Covestro, that significantly enhances the performance and durability of coatings, including those applied to wind turbine blades. Produced by the reaction between sterically hindered amines and polyisocyanates, the result is a coating technology that helps to prolong the lifetime of turbine blades in harsh outdoor conditions.

Its advantages include:

- Rapid curing times, enabling fast processability and high efficiency
- Excellent mechanical properties, including strong durability against rain erosion and long-lasting protection against prolonged UV exposure
- Easy application across a wide range of environmental conditions
- Low levels of volatile organic compounds (VOCs) compared to conventional 2C PU coatings, with near-zero levels of VOC possible in certain applications.

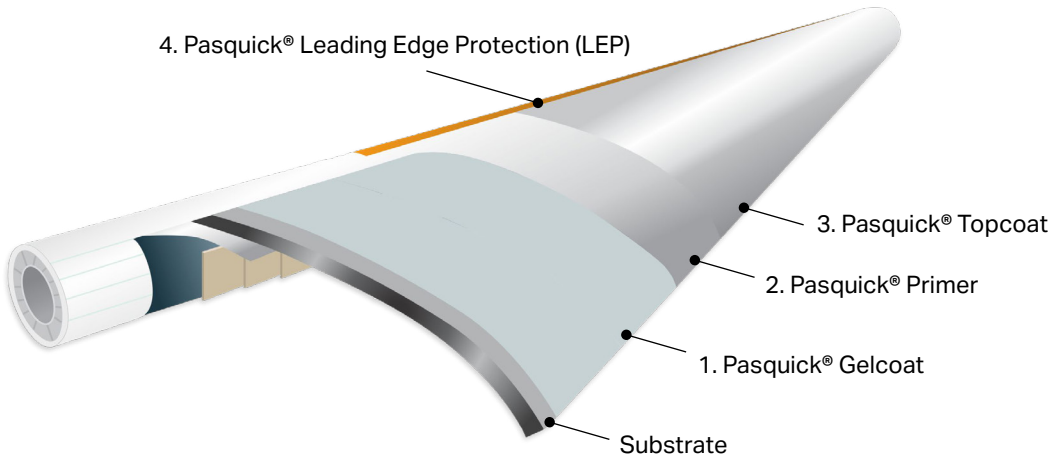

Figure 1. Coating layer build-up for wind blades based on **Pasquick®**.

1. Pasquick® Gelcoat

- Smooth finish: enhances the aerodynamic efficiency of the blades
- Near-zero VOC

2. Pasquick® Primer

- Formulated to create a strong bond between the substrate and subsequent coating layers
- This ensures optimal adhesion, reducing the risk of delamination

3. Pasquick® Topcoat

- Engineered to withstand extreme weather conditions, including high winds, rain, and UV radiation. This allows the topcoat to maintain its protective properties and aesthetic quality over time
- Excellent color retention ensures that blades remain visually appealing
- Possibility for high degree of matting

4. Pasquick® Leading Edge Protection (LEP)

- Specifically designed to have viscoelastic properties; these protect the leading edge of the blades from erosion, especially that caused by rain
- This significantly reduces maintenance costs and downtime

The building blocks of each **Pasquick®** layer

The layers in a **Pasquick®** coating system for wind turbine blades can be formulated using various combinations of Desmophen® CQ NH binders and Desmodur® hardeners, as shown below. All Desmophen® CQ NH types displayed here are also available as LF versions. These offer improved industrial hygiene due to lower diethyl fumarate content.

	Gelcoat	Primer	Topcoat	LEP
Binder	• Desmophen® CQ NH 1420 • Desmophen® CQ NH 1520 • Desmophen® CQ NH 1720	• Desmophen® CQ NH 1420 • Desmophen® CQ NH 1520	• Desmophen® CQ NH 1420	• Desmophen® CQ NH 1220 • Desmophen® CQ NH 1423 LF
Hardener	• Desmodur® ultra N 3300 • Desmodur® ultra N 3800	• Desmodur® ultra N 3800 • Desmodur® ultra N 3900	• Desmodur® ultra N 3600 • Desmodur® ultra N 3800	• Desmodur® E 40480 MPA • Desmodur® Z 4470 BA

Table 1. Combinations of Covestro Desmophen® CQ NH and Desmodur® hardeners for different layers of a wind blade coating system. Detailed formulations are available upon request.

Putting Pasquick® to the test

To evaluate the performance and erosion characteristics of **Pasquick®** technology in harsh conditions, an accelerated rain erosion test (RET) was conducted on a **Pasquick®**-based wind blade coating with the composition shown above. The tests were performed in accordance with DNV GL's Recommended Practice (DNV-GL-RP-0171) at an independent third-party test facility.

During RETs, analysts evaluate the performance of coating solutions by simulating the rain exposure of an operational wind turbine blade. This involves mounting coated substrates on blades that rotate at high speed through a rain curtain. For specific test conditions, see Table 2 below.

The test substrates are designed to reflect the properties of commercial wind blades. The performance of leading-edge coating solutions is a key focus in this test configuration, as this part of a wind blade faces the greatest strain. After 75 minutes of running the test (135 minutes for other specimens) the three-layer coating system consisting of **Pasquick®** Gelcoat, Primer, and Topcoat shows the first signs of erosion.

Rain erosion test	
Speed [rpm]	1,000
Linear velocity [m/s]	125
Water flow [l/h]	65
Mean droplet size Ø [nm]	2,566

Table 2. Rain erosion test parameters.

Fatigue typically starts at the highest rotation speed: in this case, a tip speed of 125 m/s. This is evidenced by the onset of failure on the higher accelerated side of the test specimen, which can be seen on the left side of Figure 2 below.

During this RET, however, no damage severe enough to make the substrate visible was observed, even after 8 hours of testing. Even LEP coatings specifically designed to withstand rain erosion do not usually last much longer than this.

The test was therefore concluded after this time, as the coating system had already demonstrated excellent performance. For more details, see the results summary in Table 3 below.

In addition, a **Pasquick®** LEP coating was tested for its protective performance against rain erosion. Under the same conditions as the first RET, a system consisting of an adhesion primer plus **Pasquick®** LEP coating was put to the test. One test specimen lasted 9 hours before breakthrough was detected; this was most likely due to a defect caused during application of the coating. Two other specimens were still intact even after 10 hours of testing, at which point the test was discontinued. For more details, see Figure 3 and Table 4 below.

The LEP coating has a very low Tg of -41 °C (from G''max dynamic mechanical analysis (DMA) in shear mode at 1 Hz) and a relatively high elongation at break of 398 %. Both properties are potential indicators of its high resilience.

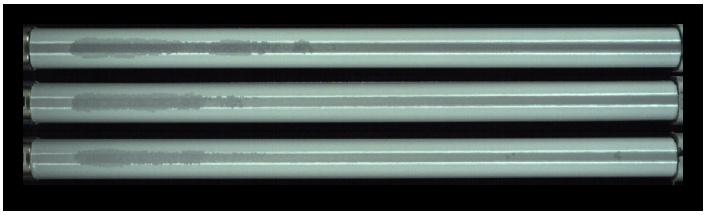

Figure 2. Rain erosion test specimens with a three-layer coating system consisting of **Pasquick®** Gelcoat, Primer, and Topcoat after 8 hours of testing.

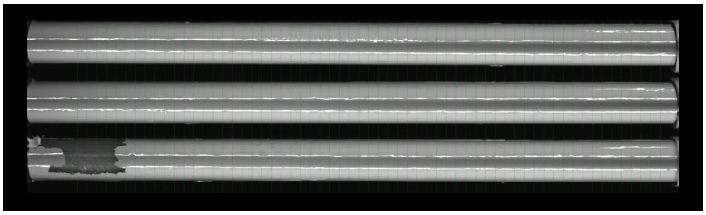

Figure 3. RET specimens, consisting of an adhesion primer and **Pasquick®** LEP, after 10 hours of testing.

Results	
Failure mode	Erosion and peeling
End of incubation [min]	Specimen 1: 75 Specimen 2: 135 Specimen 3: 135
Breakthrough [min]	Specimen 1: N/A Specimen 2: N/A Specimen 3: N/A

Table 3. Rain erosion test results for a three-layer coating system consisting of **Pasquick®** Gelcoat, Primer, and Topcoat

Results	
Failure mode	Erosion and peeling
Breakthrough [min]	Specimen 1: N/A Specimen 2: N/A Specimen 3: 555

Table 4. Rain erosion test results for a coating system consisting of an adhesion primer and **Pasquick®** LEP.

"The result is a coating technology that helps to prolong the lifetime of turbine blades in harsh outdoor conditions."

Conclusion: Pasquick® meets the tough requirements for turbine protection

The **Pasquick®** system demonstrated exceptional performance in RET. The three-layer coating (Gelcoat, Primer, and Topcoat) withstood 8 hours of testing without severe damage, while the leading-edge protection (LEP) coating showcased its resilience by lasting up to 10 hours.

In summary, **Pasquick®** coating technology from Covestro offers a comprehensive, high-performance protective system tailored to the rigorous demands of wind turbine blades. With its proven rain erosion resistance, UV and weather protection, and overall durability, the **Pasquick®** system can play a vital role in enabling the wind power industry to achieve its ambitious growth targets while ensuring the longevity and optimal performance of wind turbine blades.

Covestro is one of the world's leading polymer companies

With sales of EUR 14.4 billion in the fiscal year of 2023, 48 production sites worldwide, and approximately 17,500 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.

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

Scan the QR code to learn about other ways to use these products, and more about Covestro's wind-energy solutions.

[1] WWEA Annual Report 2023.
[2] COP28 UAE (2023) Global Renewables and Energy Efficiency Pledge [online] https://www.cop28.com/en/global-renewables-and-energy-efficiency-pledge [05.08.2024].
[3] IEA, Renewables 2023 – Analysis and forecast to 2028.

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