# Beyond rain erosion: the growing role of UV resistance

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## UV exposure is an often overlooked factor in blade durability. As wind assets operate for longer, material selection and long-term resistance to environmental ageing are becoming increasingly important.

For much of the wind industry's history, discussions around leading-edge erosion have centred on the most visible threats to blade integrity: rain, hail, airborne particulates, salt spray, insects and icing events. These environmental forces can cause physical damage, gradually degrading blade surfaces, reducing aerodynamic efficiency and ultimately requiring costly maintenance interventions.

As the global wind fleet matures, however, the conversation is evolving. Asset owners are no longer focused solely on repairing erosion once it occurs. They are taking a broader view of blade lifecycle management, considering how protection systems perform over decades rather than years and how materials respond to the full range of environmental stresses encountered throughout a turbine's operating life.

In that context, ultraviolet (UV) radiation is emerging as an important consideration.

Historically, UV exposure has received far less attention than rain erosion. While rain damage can often become visible relatively early in the blade lifecycle, UV degradation typically develops gradually over an extended period. Its effects are therefore less obvious but no less relevant. As turbine lifetimes increase and operators seek to maximise availability while managing maintenance expenditure, understanding the role of UV exposure in long-term durability is becoming more important.

For Armour Edge, UV resistance was not treated as an afterthought or secondary design consideration. From the earliest stages of product development, durability against environmental ageing was recognised as a requirement alongside impact resistance, aerodynamic performance and ease of installation. Today, with installations on thousands of blades across four continents, the company says this emphasis on long-term durability aligns with the priorities of wind farm owners and operators.

### The growing importance of long-term blade protection

Leading-edge erosion remains one of the most significant maintenance challenges facing wind turbine operators worldwide.

Modern turbines operate with blade tip speeds that can exceed 300 km/h. At these velocities, even small raindrops carry considerable impact energy. Over time, repeated impacts can erode the leading edge of the blade, affecting the aerodynamic profile that underpins efficient energy production.

The consequences extend beyond the visible damage itself. Reduced aerodynamic performance can negatively affect annual energy production (AEP), while repair campaigns require specialist technicians, access equipment and turbine downtime. Offshore repairs can be particularly complex, involving vessel logistics, adverse weather constraints and elevated operational costs.

For these reasons, leading-edge protection (LEP) systems have become an established part of blade maintenance strategies across the industry.

Historically, discussions around LEP systems focused on several key criteria:

- Resistance to rain erosion
- Expected service life
- Ease of installation
- Downtime requirements
- Aerodynamic performance

These remain important considerations. However, asset owners are also asking how protection systems age in service and respond to prolonged environmental exposure.

This broader perspective is bringing UV resistance into sharper focus.

### Why UV exposure matters

Unlike rain erosion, UV degradation can be difficult to detect until noticeable changes have already occurred.

Extended exposure to ultraviolet radiation can alter the physical and chemical properties of many polymers and composite materials. Depending on the material selected, this may lead to embrittlement, loss of flexibility, cracking, surface degradation or reductions in mechanical performance.

For a leading-edge protection system, these effects can be significant.

A material may perform well when new, but if environmental ageing gradually compromises its toughness or structural integrity, its ability to withstand other stresses may also diminish over time.

The issue is particularly relevant as wind power deployment expands across a wide range of climates and environmental conditions.

Wind farms now operate across an extraordinary range of environments. In addition to northern European sites, turbines are routinely deployed in locations characterised by intense solar radiation, including Australia, India, southern Europe and the southwestern United States. Even in more temperate regions, turbine blades remain exposed to UV radiation throughout their operational lives.

As a result, some owners are beginning to view UV resistance as part of a broader durability strategy rather than a stand-alone material property.

The question is no longer simply whether a protection system can withstand rain. It is whether that system can maintain its performance after years of combined exposure to UV radiation, rain, salt, moisture, temperature cycling and airborne contaminants.

### Why material selection matters

At Armour Edge, these considerations influenced the material selection process from the outset.

The Armour Edge shield is manufactured using a bespoke version of Luran SC, an ASA-PC (acrylonitrile styrene acrylate-polycarbonate) thermoplastic supplied by INEOS Styrolution exclusively to Armour Edge. During development, the objective was to select a material capable of not only resisting erosion but also retaining its key mechanical properties after prolonged environmental exposure.

Typical leading-edge erosion

This distinction is important because engineering plastics can respond differently to outdoor weathering.

Some conventional polymers can experience reductions in impact resistance and toughness after extended UV exposure. While these changes may occur gradually, they become more significant when components are expected to perform reliably for decades.

Weathering data supplied by INEOS Styrolution for the specific grade of Luran SC used within the Armour Edge system indicate strong retention of impact toughness compared with a number of other commonly used engineering plastics following extended outdoor exposure. In practical terms, this means the material is reported to retain its ability to absorb impacts and resist physical damage after years of weathering.

That characteristic is particularly relevant in leading-edge protection applications, where impact resistance forms a fundamental part of the product's protective function.

For operators managing multi-million-pound renewable energy assets, confidence in the long-term stability of materials can be as important as initial performance data.

### Independent validation

The UV performance of the Armour Edge shield material is supported by independent testing.

Accelerated weathering testing undertaken in accordance with ISO 16474-3 found no significant reduction in measured tensile properties or hardness, and no evidence of blistering, cracking or delamination. Observed changes were limited primarily to colour variation and reductions in surface gloss, while functional mechanical properties were maintained.

This distinction is important.

Many outdoor materials will experience cosmetic changes over time. From an asset management perspective, however, the more relevant question is whether the material continues to perform its intended protective role.

Durability depends not only on the protective shield itself but also on the integrity of the bonding system. The adhesive supplied as part of the Armour Edge system was also selected with UV stability in mind. According to the manufacturer, it is UV stable, with testing showing no yellowing and only minimal changes in measured properties following ageing studies.

Comparative testing also demonstrated continued performance under both UV exposure and cyclic ageing conditions.

### Real-world experience across four continents

Laboratory testing provides important performance data, but operational experience remains another source of insight.

Armour Edge has now been installed on thousands of blades across four continents, with deployments spanning both onshore and offshore wind farms. These installations cover a range of environmental conditions, from offshore North Sea environments and northern European climates to icing conditions in the US Midwest, dust-laden sites in Texas and New Mexico, monsoon-affected regions of India and high-UV environments in Australia.

Few materials face such a diverse combination of environmental stresses.

The breadth of these operating conditions is relevant because different sites place different demands on blade protection systems, while environmental stressors rarely occur in isolation. Rain, UV exposure, temperature cycling, salt and airborne particulates frequently combine to create challenges that cannot be fully replicated through individual laboratory tests.

This body of field experience therefore provides a complement to formal testing programmes.

### Installation consistency and lifecycle performance

Durability is influenced not only by material properties but also by installation quality.

Even the most advanced protection system must be installed consistently if it is to deliver reliable long-term performance. This is one reason asset owners and service providers value solutions that reduce installation variability.

Armour Edge was designed with repeatability and simplicity in mind. The system can be installed using rope access teams, platforms or baskets, and requires minimal preparation for Category 1 to Category 3 erosion repairs. Installation programmes are supported by technician training, while adhesive characteristics are intended to provide a broad operating window and minimise weather-related delays.

For operators, reduced variability can contribute to more predictable outcomes, shorter downtime periods and greater confidence in long-term performance.

### Durability beyond the laboratory

The most meaningful test of any leading-edge protection system is performance in service.

Armour Edge's earliest offshore installations have now accumulated six years of operational experience in demanding offshore conditions. During this period, customers have continued to place repeat orders to extend protection to additional turbines. The company reports that it has recorded no instances of shield debonding since commercial deployment began.

This real-world performance has been achieved across a range of climates where UV exposure, moisture, rain erosion and other environmental factors interact continuously.

It reinforces an important industry consideration: durability should not be defined solely by resistance to a single degradation mechanism. Rather, it can be assessed in terms of a system's ability to withstand the cumulative effects of multiple environmental stresses throughout the operational life of a turbine.

Richard Scullion

### A changing industry perspective

The wind industry is moving from reactive maintenance towards more proactive asset stewardship.

Owners now have access to more operational data than ever before and are seeking to optimise blade performance over longer operating lives. In this environment, durability is becoming a more sophisticated concept, encompassing not only impact resistance but also long-term environmental stability.

Discussions around leading-edge protection have historically been dominated by rain erosion performance and installation methodology. Today, owners are also asking broader questions about lifecycle performance, long-term reliability and material ageing.

For Armour Edge, that shift reflects a philosophy embedded in the product from the beginning. While resistance to traditional erosion mechanisms, durability and ease of installation were primary design drivers, UV resistance was also recognised as a consideration during material selection and development.

As wind assets continue to age, operating lives extend and maintenance budgets face greater scrutiny, UV resistance is likely to become a more significant part of the blade protection conversation.

The future of leading-edge protection will not be defined by a single performance metric. Instead, the most effective solutions will need to maintain their protective function across prolonged exposure to rain, UV radiation, salt, dust, temperature cycling and other environmental challenges.

In that respect, UV resistance is becoming more than simply a desirable feature. It is emerging as an important component of long-term durability and a factor that may influence how owners evaluate blade protection systems in the years ahead.

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Newly installed Armour Edge LEP