# On the rain erosion damage modelling of wind turbine blade coatings. A Material and Process approach

E.Cortés[1], F.Sánchez[2*], L.Domenech[2], T.M.Young[3], A. O'Carroll[3], and F.Chinesta[4]
[1]Aerox Advanced Polymers, ecortes@aerox.es, web page: http://www.aerox.es
[2] Universidad CEUnCardenal Herrera, Valencia, Spain
fernando.sanchez@uch.ceu.es (*corresponding author), web page: http://www.uchceu.es
[3] Universidad of Limerick, Ireland
[4]Institut de Recherche en Génie Civil et Mécanique, Ecole Centrale Nantes

**WIND TURBINE BLADE MANUFACTURE 2016**
**Düsseldorf, Germany, 12th -14th December 2016**

## INTRODUCTION. MOTIVATION

The **renewable energy sector** has to be severely expanded in order to supply 20% of electricity from **renewable sources to 2020**. To achieve this goal, it is required the installation of **very large wind turbines** standing in wind farms of several hundred MW, in deeper offshore waters (not only on-shore). In this case, **wind blades with increased tip speeds** from 80 m/s to over 110 m/s will be operating. A typical wind turbine may be expected to operate continuously over its service life. During these years, the materials of the blade are exposed to a varied environmental conditions and fatigue load. The erosion of wind turbine blade leading edges has seen a dramatic increase in both the frequency of occurrence, and the rate at which leading edges are eroding. The **costs associated with erosion** in terms of loss of power performance and repair and downtime costs have a large impact on the LCoE (Levelized Cost of Energy) for wind. **An erosion solution needs to be developed**.


*Figure 1: Leading Edge erosion damage*

## KEY ISSUES ON COATING DEVELOPMENT

Composites perform poorly under **transverse rain droplet impact** (i.e perpendicular to the reinforcement direction). Manufacturers employ surface coatings to protect the composite structure. Two **most common technologies** used are In-mould coating (a moulded layer of a similar material of the matrix one epoxy/polyester) or a post-Mould application (applied after moulding through open moulding, painting or spraying with different material choice). The material design **objective is to match the Leading Edge Protection coating properties to the blade structure** of the composite laminate. Standard industrial process are based on a **multilayer system**,. The integral solution depends on the **elastic and viscoelastic responses** of the **blade structure**, **surface preparation, coating application** and the **interactions** between them.

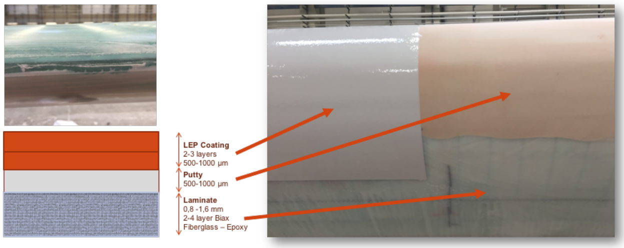


*Figure 2: Industrial process defines the Leading Edge Protection system on the blade surface. **Several configurations** can be outlined as a multilayered system*

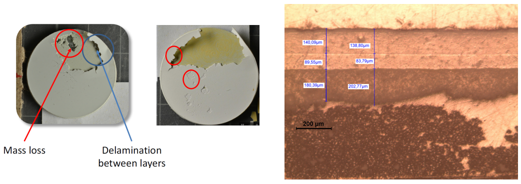


*Figure 4: In a **typical multilayer scheme**, the **lack of adhesion at interface** play a key role on its deterioration. **Delamination may occur between layers of coating or at the coating-laminate interface**.*


*Figure 3: **Coating application during processing** is a major concern on erosion performance due to its **capability of reducing defects** and defining the system interfaces. A fewer number of coating layers are recommendable because of the reduction of interfaces.*

## COATING FACTORS WHICH AFFECT EROSION PERFORMANCE. VALIDATION

The analysis of the behavior of a **single waterdrop impact** is a **meaningful point for investigating** the multiple impact sequences that produce leading edge erosion. The approach can be used to **identify suitable coating** and substrate combinations and their potential stress reduction due to the coating. The **stress waves will be transmitted to the substrate interface**. Surface erosion and **delamination may occur** and the coating **capability of loss/transfer wave energy in the integrated multilayered system** will allow avoid damage. In order to reduce the stress in the substrate and determine the **suitability of the candidate materials** for leading edge applications, an acoustic and **viscoelastic approach** is proposed.

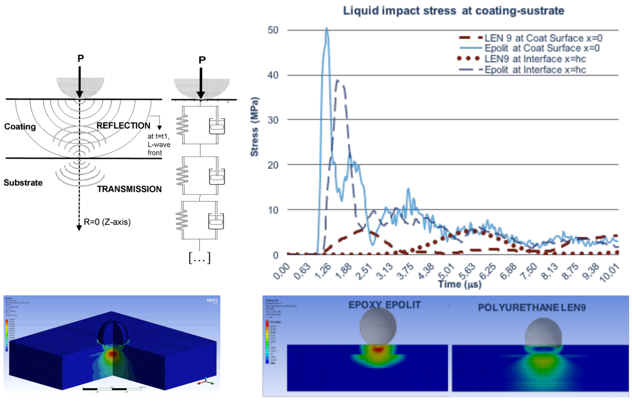


***Figure 5:** Stress reflections oscillate repeatedly through the coating and structure until damped by the **material properties to reduce the energy of the initial shockwave**. In a Rigid Glass Fiber Epoxy Composite substrate, an elastomeric material **coating will damp trough the thickness** the stress waves insofar as the **recovery time of the material is rapid and the loss of energy enough** (depending on the polymer dynamic properties).*

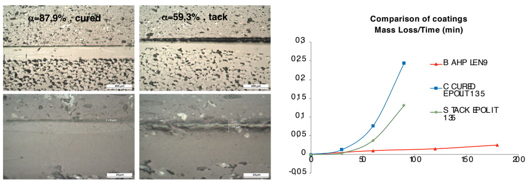


***Figure 6:** The **rain erosion testing** indicated that samples of laminate substrate with two layer biaxial epoxy-GF, 0.7 mm thick and a gel coat layer of 0.3 mm, manufactured with a **higher degree of cure coating**, **performed worse**. These **results correlate with peeling testing**. A **Polyurethane based polymer coating LEN9**, was also tested showing better results comparing with **Epoxy EPOLIT** ones By matching acoustic impedance between the coating and the blade structure, **coating life time can be extended**.*

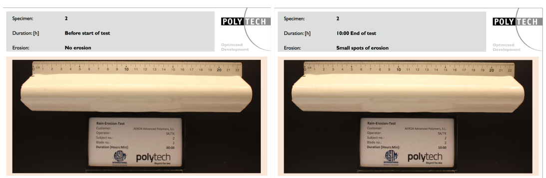


***Figure 7 Rain Erosion Test: ASTM G73-10.** Rain erosion testing has been conducted at **Polytech** which generates a nominal rainfall rate of 30-35 mm/h at impact speeds up 126-160 m/s. Samples **no signs of damage** and small spots of erosion.*

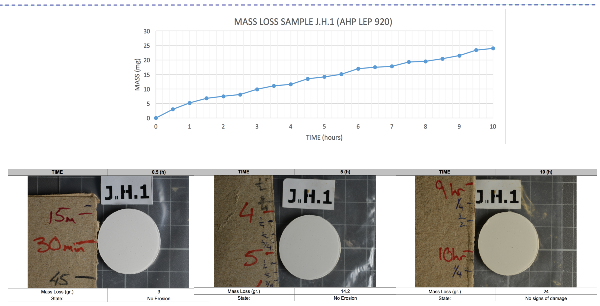


***Figure 8 : Rain Erosion Test: ASTM G73-10.** Rain erosion testing has been conducted in a **whirling arm rain erosion facility (WARER, U.Limerick)**, which generates a nominal rainfall rate of 25.4 mm/h at impact speeds up 135 m/s. The mass loss due to erosion is less than 1.05% of the initial mass of the sample with **no signs of damage**.*