STUDY OF MANUFACTURING DEFECTS AND SURFACE PREPARATION OF COATED COMPOSITE LAMINATES IN WIND TURBINE BLADES. A VIBRO-ACOUSTIC APPROACH

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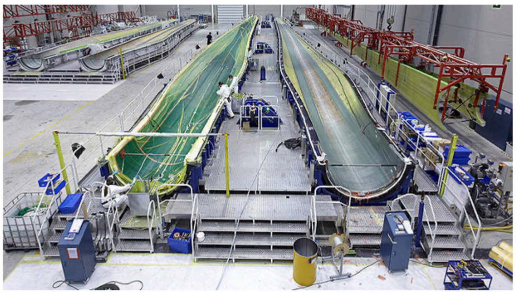
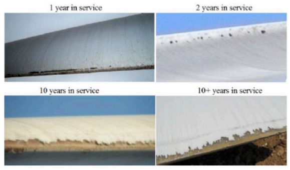
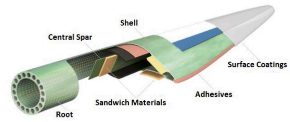
INTRODUCTION. OBJECTIVES

Resin Infusion (RI) is increasingly **used in wind energy systems where** the large and ever-growing scale of modern blades utilize **composite technologies** due to high specific strength, stiffness and fatigue performance. Composites **perform poorly under transverse rain impact** and being sensitive to environmental factors. **The erosion of wind turbine blade leading edges** has seen a dramatic increase. Two most common **coating technologies used to protect** structural laminates 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). This research is focused on **relating coating processing** with **rain erosion damage**.

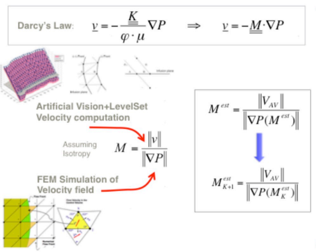


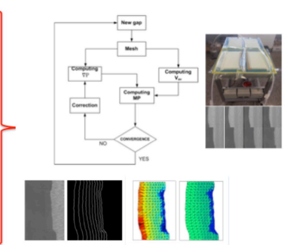


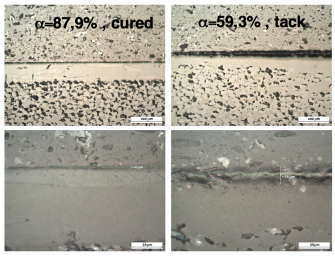


EFFECT OF THE IN MOULD SURFACE COATING CURING ON THE COAT-LAMINATE INTERFACE ADHESION

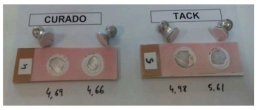
A mixed numerical/experimental technique based on artificial vision is used for **estimating the induced effect** of the **surface coating curing** in the laminate impregnation and the flow front advance during filling. It can be observed how the **less-cured coating** (curing conversion α=59,3% instead of α=87,9% for the same **epoxy based polymer, EPOLIT**) defines a **broader interface area** with the infused GF laminate with epoxy resin due to a **higher chemical adhesion**. In order to asses the macroscopic behavior of the interface, **Pull-off strength testing** of the samples showed the failure in the composite laminate and specifically developed **Peeling test for interface** showed the force of failure with a value of 19,3 (N) for the cured coating and of 25,1 (N) for the less cured one.

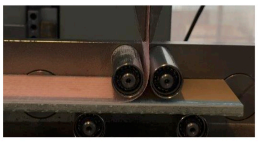


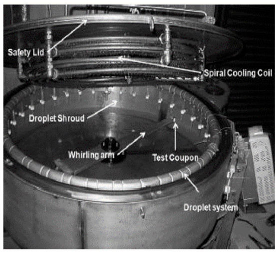


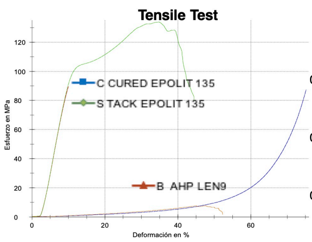


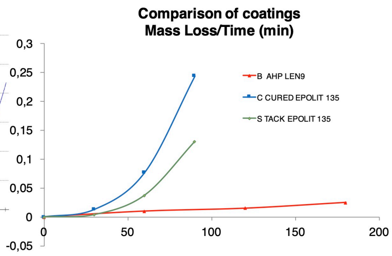
The **rain erosion testing** indicated that samples of laminate substrate with two layer biaxial epoxy-GF, 0.7 mm thick and a gel coat layer of 0.3 mm, manufactured with a **higher degree of cure coating**, **performed worse**. These results correlate with peeling testing. A **Polyurethane based polymer coating LEN9**, was also tested showing better results comparing with **Epoxy EPOLIT** ones.

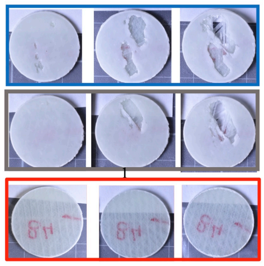






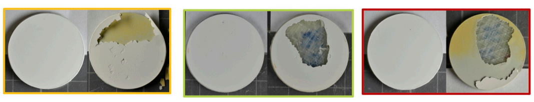


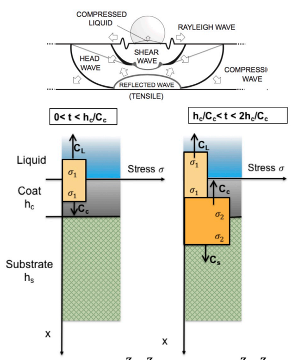




LIQUID IMPACT MODELLING TO IDENTIFY SUITABLE COATING AND STRESS REDUCTION ON INTERFACE

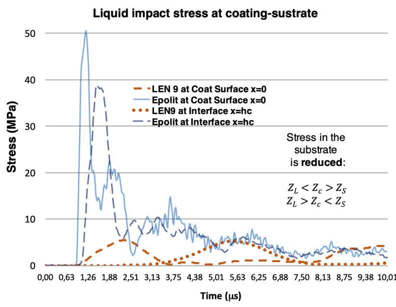
The erosion damage is affected by the **repetitive shock wave caused by the collapsing water droplet on impact**. The stress waves will be transmitted to the substrate, so microestructural defects as **void contents** and **lack of adhesion at interface** play a key role on its deterioration (delamination may occur at interface). Upon impingement, the wave front in the coating further advances towards the coating-substrate interface, where a portion of the **stress wave is reflected back into the coating** with a different amplitude **depending on the material acoustic impedances** and the remaining part is transmitted to the substrate.

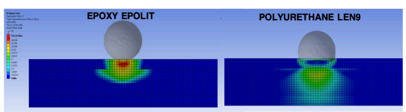


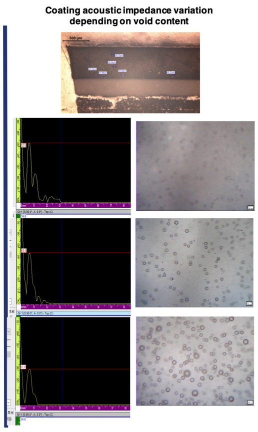


$$Z = \rho C \;;\; \varphi_{Lc} = \frac{Z_L - Z_c}{Z_L + Z_c} \;;\; \varphi_{sc} = \frac{Z_s - Z_c}{Z_s + Z_c}$$

$$\sigma_\infty = \sigma_1 \lim_{k\to\infty} \sigma_{2k} = \sigma_1 \frac{1 + \varphi_{sc}}{1 - \varphi_{sc}\varphi_{Lc}}$$







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** can be used to **identify suitable coating and substrate combinations** and their potential stress reduction. Coating capability of loss/transfer wave energy will allow avoid damage and elastomeric material coating with low modulus and high resilience will damp the stress waves insofar as the recovery time of the material is rapid. **On Going work**: Determine **variable properties characterization through the thickness** and its vibro-acoustic properties. Develop **reflecting interfaces (void content)** as impact shockwave diminisher.