coatings

MDPI

Supplementary Materials

The Development of a Novel Thin Film Test Method to Evaluate the Rain Erosion Resistance of Polyaspartate-Based Leading Edge Protection Coatings

Supplementary Materials

S1. Tensile testing and material selection

Prior to the application of the novel combined DMA+RET test method, two polyaspartate binders were first screened using comparative tensile strength analysis to shortlist one binder for further evaluation. The measurements were conducted according to DIN 53504 [24] with a zwickiLine Z2.5 TN testing machine (Zwick Roell, Ulm, Germany). Appropriate dumbbell type specimens with a total length of 75 mm were cut from corresponding free material films by using a manual notching blade. The testing speed was 200 mm minute^{-1} at standard conditions (23°C, 55% relative humidity). Two transparent erosion-resistant LEP tapes, Wind Protection Tape W8751 and W8607 (3M, USA), were used as benchmark materials to further understand the general tensile properties of commercially available LEP products (Figure S1).

Based on the tensile curves for the 3M commercial tape products as illustrated in Figure S1 and accompanied by supporting data in Table S1, it was evident that materials exhibiting rain erosion resistant properties may require high ductility in combination with ultimate tensile strength (UTS) values of > 30 MPa. In addition, the stress-strain curves for all studied materials were typified by an elastomeric response, in that a non-linear stress is observed with respect to strain and there is no identifiable plastic region. As previously detailed in Table 1, an increase in elastomeric properties and ETB has been noted as an inferred property requirement for candidate LEP products. It is proposed that the presence of elastomeric properties enables sufficient dampening of raindrop impact and subsequent material recoverability. The polyaspartate binder formulations listed in this study were therefore deemed appropriate for further investigation due to their relatively high ETB values (> 350%) and elastomeric properties. [14,16] Figure S1 illustrates two unfilled candidate polyaspartate binder formulations, PA-U and PA-V. The binder formulation PA-U was selected for further investigation due to exhibiting superior drying, curing and handling characteristics.

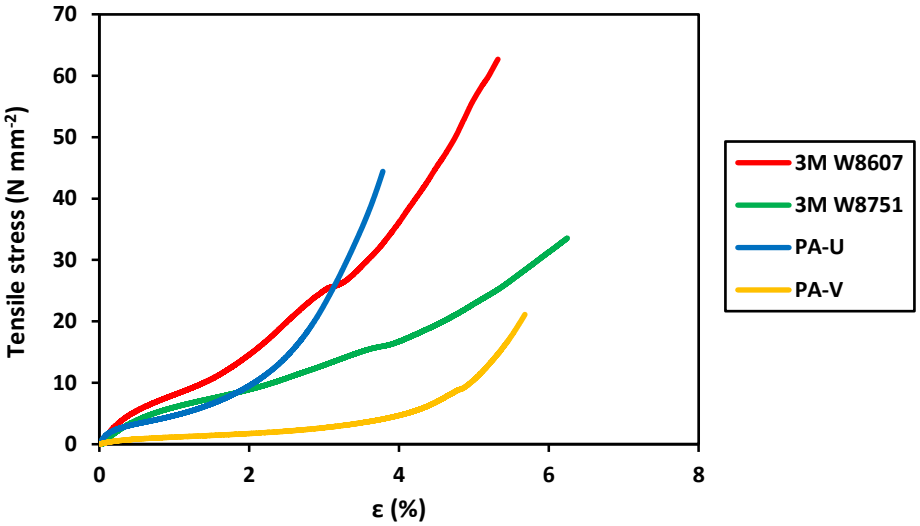

Figure S1. Tensile stress-strain curves of 3M Wind Protection Tapes (W8751 and W8607) in comparison to candidate polyaspartate binder formulations.

Table S1. Tensile properties of 3M Wind Protection Tapes (W8751 and W8607) in comparison to candidate polyaspartate binder formulations.

LEP Product	3M W8607	3M W8751	PA-U	PA-V
Ultimate tensile strength (MPa)	63.5 ± 1.6	33.6 ± 0.9	39.4 ± 1.3	19.8 ± 3.5
Elongation to break (%)	537 ± 6	626 ± 1	374 ± 8	554 ± 23

S2. Creep recovery experimental procedure by DMA

The general procedure for performing creep recovery testing by DMA is herein described and outlined in Figure S2. In the first step of this method, a constant force was applied to each sample for a creep time of 2 minutes. The resulting strain, ε, which may consist of (i) recoverable and reversible elastic strain; (ii) time-dependent viscoelastic strain; and (iii) inelastic viscous strain, is then measured as a function of time [28]. Upon the initial application of stress, the sample exhibits an instantaneous elastic deformation prior to viscoelastic and viscous flow occurring at a decreasing rate until a steady-state deformation is reached. The applied stress is then removed, which initiates instantaneous elastic recovery in the sample. Time-dependent viscoelastic recovery then proceeds at a slower rate until the end of the experimental procedure, which was defined by a recovery time of 10 minutes. Any remaining strain may be defined as non-recoverable and indicates that permanent plastic deformation has occurred within the sample. The equilibrium recoverable compliance, J_{er}, may be subsequently calculated using Equation S1 [29]:

$$J_{er} = \left(\frac{\gamma_c - \gamma_r(t)}{\sigma}\right) \quad \text{(S1)}$$

where γ_c is the maximum compression strain determined in the creep zone, $\gamma_r(t)$ is the time dependent recoverable compression strain, and σ is the applied stress in the creep zone.

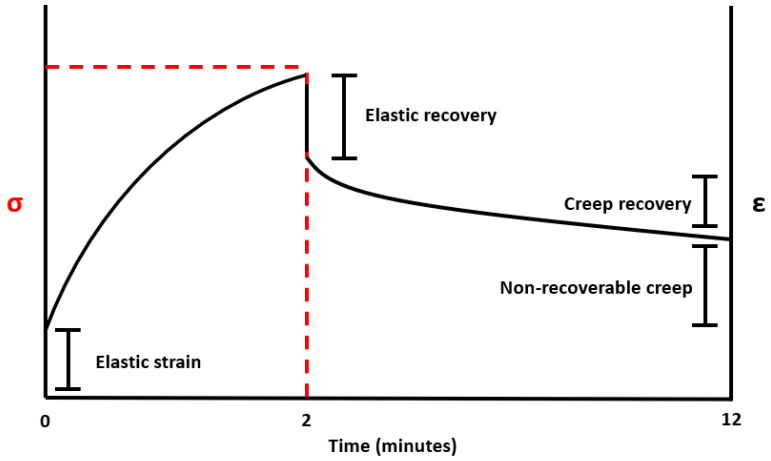

Figure S2. Representative DMA creep recovery curve where applied stress = dashed line; and resulting strain curve = solid line.

References

14. Hoksbergen, N.; Akkerman, R.; Baran, I. The Springer model for lifetime predictions of wind turbine blade leading edge protection systems: A review and sensitivity study. *Materials* **2022**, *15*, pp. 1170.
16. Schmitt Jr, G.F. Materials parameters that govern the rain erosion behaviour of polymeric coatings and composites at subsonic velocities, Technical Report AFML-TR-71-197, **1971**.
24. DIN 53504:2017-03: Testing of rubber – Determination of tensile strength at break, tensile stress at yield, elongation at break and stress values in a tensile test, DIN **2017**.
28. Daver, F.; Kajtaz, M.; Brandt, M.; Shanks, R.A. Creep and recovery behaviour of polyolefin-rubber nanocomposites developed for additive manufacturing. *Polymers* **2016,** *8*, pp. 437.
29. Musilova, L.; Mracek, A.; Kovalcik, A.; Smolka, P. Minarik, A.; Humpolicek, P.; Vicha, R.; Ponizil, P. Hyaluronan hydrogels modified by glycinated Kraft lignin: Morphology, swelling, viscoelastic properties and biocompatibility. *Carbohydr. Polym.* **2018**, *181*, pp. 394-403.