Thermomechanical characterisation and linear viscoelastic modelling of ETFE membranes

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ABSTRACT

ETFE (ethylene-tetra-fluoroethylene) is a polymer employed in membrane structures as a tensioned foil or shaped into inflated cushions. Its relevance arises from its exceptional features, which include high stiffness, ductility, recyclability, durability, light transmission and self-extinguishing properties [1]. Although the material's mechanical properties strongly depend on both time and temperature effects [2-4], the lack of a comprehensive understanding of the mutual influence of these variables prevents an optimal design and a wider exploitation of ETFE in sustainable lightweight construction [5].

In the first phase of the study, an experimental characterisation was performed using a quasi-static universal electromechanical machine coupled with digital image correlation, and a Dynamic Mechanical Analyser (DMA). Uniaxial properties were investigated across a range of temperatures spanning from -20 to 60° C, at different displacement rates. Additionally, cyclic and creep tests were performed on the DMA. ETFE revealed a peculiar response that strongly depends on temperature, while the strain rate dependence is less pronounced. Two inflection points have been identified from the stress-strain response, the first of which was found to be associated with the onset of yielding. The polymer is proven to be in a glassy phase in the range of temperature of interest.

The study's second phase was devoted to linear viscoelastic modelling, in which a compliance master curve was built from the creep data through the time-temperature superposition principle. Rheological modelling of the master curve was performed through a single integral representation, expressing the time dependence with a Prony series. A recursive integration algorithm was used to implement the constitutive relation in a MATLAB script [6]. The model obtained is proven to accurately predict the effects of time and temperature on ETFE, as it was validated against independently acquired data.

The implemented model has a high potential in obtaining an accurate prediction of the ETFE behaviour, resulting in better and safer structural designs. Further improvements in capturing the nonlinear viscoelastic and biaxial responses are planned as future research efforts.

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