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ASSESSING THE EFFECTS OF VARYING TEMPERATURE AND RELATIVE HUMIDITY LEVELS ON THE FATIGUE PERFORMANCE OF FLAX FRP COMPOSITES

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ABSTRACT

This study investigates the effects of hygrothermal conditions on the fatigue performance of flax FRP composites. Cross-ply laminates were tested in tension-tension fatigue in five different hygrothermal conditions. Humidity was initially expected to enhance fatigue life at 30% RH and reduce it at 90% RH relative to the reference 50% RH, based on the modulus variations observed in quasi-static tests. However, experimental results indicated the opposite trend, with a remarkable ~10-fold increase in fatigue life under high-humidity conditions. Temperature effects were also found to have a significant impact but only at high temperature and high stresses displayed by a change of the S-N curve slope.

INTRODUCTION

Flax fibres have a lignocellulosic nature combined with a hierarchical microstructure. Moreover, Flax fibres, unlike synthetic counterparts (carbon and glass), have a viscoelastic behaviour. These characteristics make flax FRP composites and structures made of them particularly susceptible to environmental hygrothermal (different temperature and relative humidity levels) conditions. Water absorption and desorption can alter viscoelastic properties, as well as the cellulosic microfibrillar organization within flax fibres, impacting the fibres mechanical properties [1]. Moreover, change in moisture level causes swelling and shrinkage of the flax fibres, and subsequently induces damage within the composite microstructure (e.g. fibre/matrix debonding) [2]. Temperature variations also affect these properties, particularly between 20 and 60°C where the single fibre strength and stiffness evaluated in the final deformation stage is approximately reduced by half [1]. Consequently, the mechanical performance of flax FRP composites, can degrade or improve under variable humidity and temperature conditions. Understanding these effects is essential for ensuring the reliability and performance of structures made of flax fibre composites, notably when subjected to combination of extreme environmental conditions and mechanical cyclic loading (fatigue).

Laminates with a $(0/90/0)_S$ lay-up were manufactured with non-dried fibres, and each laminate was conditioned in a 50°C climate chamber to one of the three tested in-service relative humidities, 30%, 50%, or 90% RH, and equilibrated to -20°C, +20°C, or +50°C in the

climate chamber enclosing the tensile testing area. The specimens were then tested at the equilibrate T and RH in fatigue at a frequency of 5 Hz and a 0.1 R ratio.

RESULTS AND CONCLUSIONS

The isolated effects of temperature and relative humidity on fatigue life are shown with S-N curves in Fig. 1. Increasing temperature from 20°C to 50°C was observed to enhance sensitivity to stress levels, resulting in a significant reduction in fatigue life under high load conditions. In terms of moisture, it was found that increasing the RH (from 30 to 90%), despite decreasing stiffness of the laminates results in an increase of fatigue life.

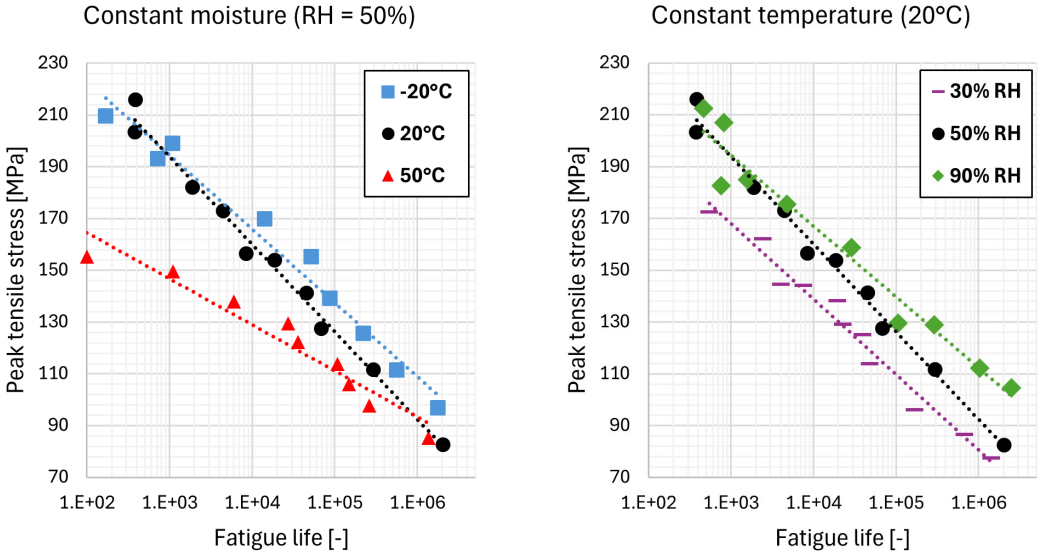

Fig.1 Isolated effects of temperature (left) and relative humidity (right) on fatigue life

This study demonstrates that the fatigue properties of flax fibre-reinforced polymer (FRP) composites are significantly influenced by in-service hygrothermal conditions. This influence on fatigue properties was found not directly predictable based on quasi-static tests as the changes of modulus are accompanied by changes in the material viscoelasticity or brittleness. Those conditions can simultaneously result in lower stiffness suggesting shorter fatigue life by accelerating damage progression and increase of strength suggesting slower damage progress thus longer fatigue life. This is exemplified by 90% RH conditions inducing a 38% stiffness decrease and 14% strength increase in quasi-static testing resulting, in fatigue, in a general increase of fatigue life, particularly at low stress levels.

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