INTERLAMINAR SHEAR STRENGTH OF UNAGED AND AGED CARBON FIBER REINFORCED ROSIN-BASED EPOXY COMPOSITES

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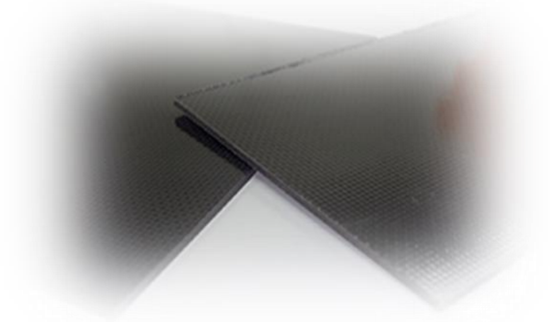
Introduction

- In **aircraft structures** carbon-fiber reinforced plastics have extensively replaced the classic materials such as aluminum or titanium. Eco-materials such as bio-resins have been for a long time under investigation primarily for their use in composites, but they have not been introduced into a modern aircraft in noticeable amounts yet, mainly due to both their **low mechanical properties** as well as the **lack of experience** and confidence regarding their durability**.**

- Bio-Resins as **rosin** is plentiful and available naturally in the pines and conifers. The rigidity of rosin acid is comparable with the petroleum-based compounds. The rosin-based fused ring endowed the materials with good thermal properties, water and acetone resistance, as well as satisfactory mechanical properties such as **tensile strength**.



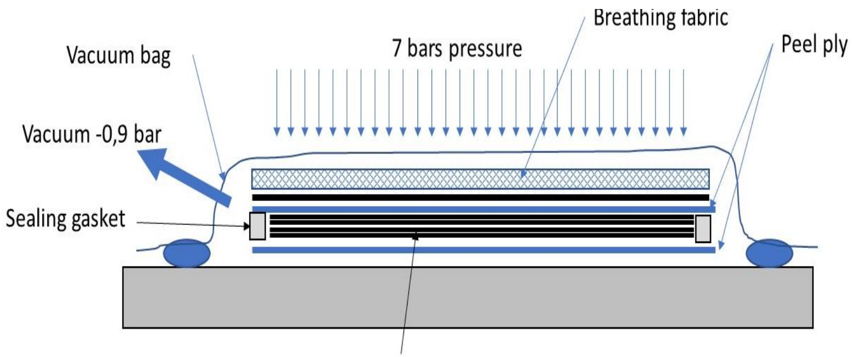
Objective

The purpose of this research is investigate **experimentally**, the effect of **hygrothermal ageing** on the interlaminar shear strength (**ILSS**) of the carbon fibre-reinforced rosin-based epoxy resin composite and assess if the rosin-based epoxy resin materials reinforced with carbon fibers, have a good prospect as an alternative choice to the commercial fossil-based ones.

Materials

The material investigated was **carbon fiber**-reinforced **rosin-based epoxy** resin composite.

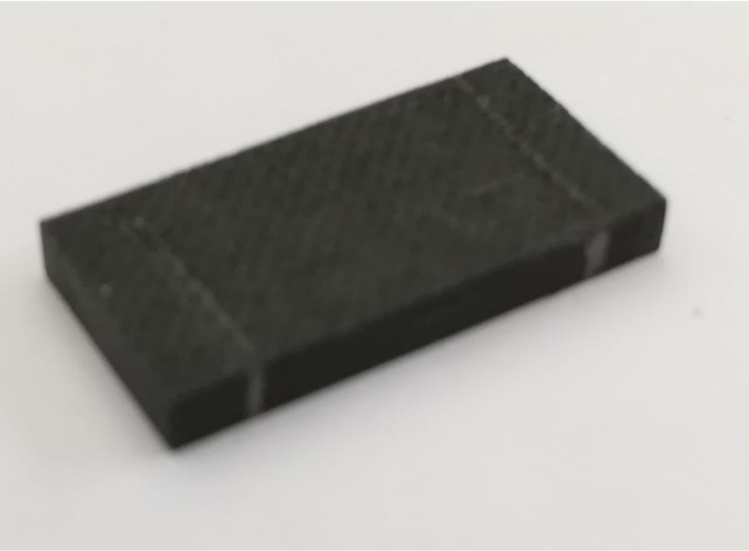
- The prepreg was manufactured from carbon/rosin epoxy, namely from the **rosin sourced** two component epoxy system and **2.2 twill carbon** woven fabric.
- The rosin film impregnation with carbon fabric was done at **85 ˚C to 90 ˚C** with a gap of 400μm between the rollers.
- The composite panels were manufactured in **10 plies of prepreg layup** and fully cured using autoclave molding, with a curing cycle of **3 hours** at **130 ˚C** with **2 ˚C/min** heating /cooling rate and a pressure of **7 bars** on the vacuum bag(-0.9 bars) by **DRL**.



Interlaminar shear strength tests

For the evaluation of the **hydrothermal aging** effect of on the interlaminar shear strength (**ILSS**) of the composite material, ILSS tests on unaged (reference) and aged specimens were conducted according to **EN 2563:1997** standard.

- Nominal **dimensions** of the specimen **: 20mm** × **10mm** × **2mm**
- Temperature**: 25 ˚C**
- Testing machine: Tinius Olsen H5KT
- Experimental set up: **3-point bending** mode / **10 mm** distance between the supports
- Load: constant displacement rate of **1 mm/min**.



Hydrothermal Ageing

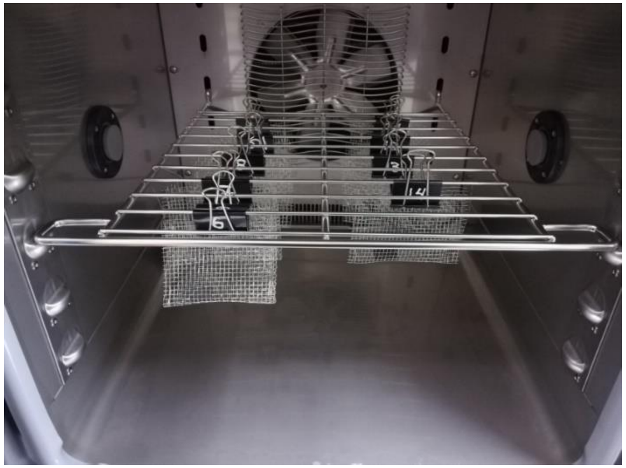
Ageing tests:

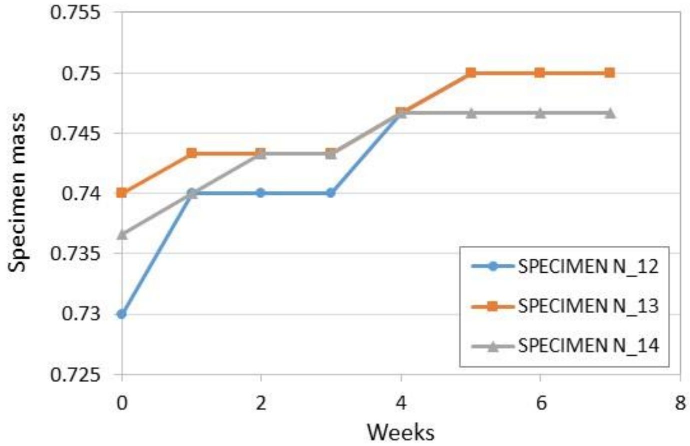
- **8** specimens were exposed to a temperature of **70˚C** and a **humidity of 85%** until saturation according to the EN 2823:1998 standard.

- Saturation is considered to have been achieved when the difference of three successive weightings carried out at an interval of **168 h** (7 days) on the traveler specimens are in conformity with the formula below:

$$\frac{|M_{J-2} - M_J|}{M_J} \leq 5x10^{-4}$$

- The traveler specimens had a mass increment from 1.3% up to 2.7%.



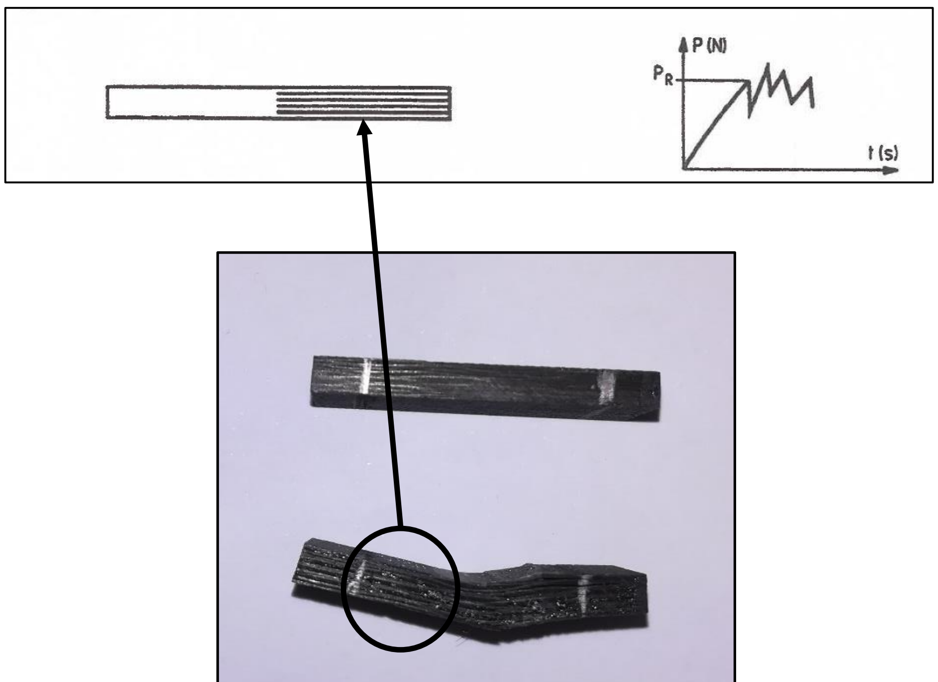


Results

Comparing the reference specimen performance to the aged the ones, both types of specimens failed approximately at their **neutral axis** due **to multiple shear failure**.

No flexural or **plastic** deformations were **observed** after the mechanical testing under a LEICA DMLM microscope

Validity
Multiple Shear Failure



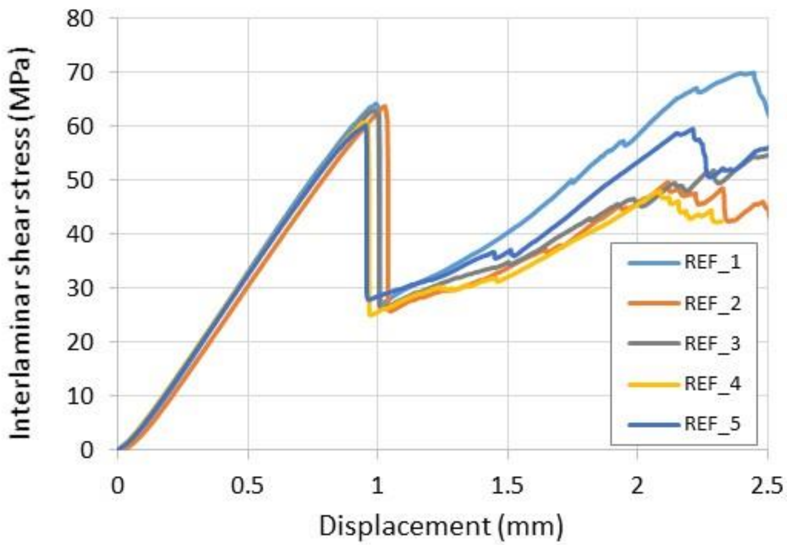
Results

The interlaminar shear stress of the **reference specimens** (set as reference point for the aged ones) is plotted against the applied displacement.

Reference specimens:

- Interlaminar shear strength: **62.3 MPa**
- Standard deviation: **1.79 MPa**

while commercial ones exhibit lower values up to **52 MPa** and other studies have shown still low up to **46.4MPa** (with the same 2.2 twill woven fabric).



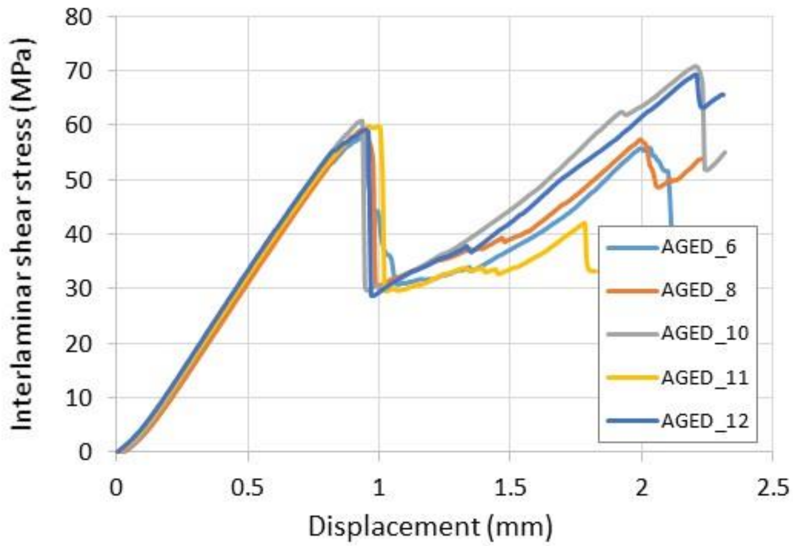
Results

The interlaminar shear stress of the **aged specimens** is plotted against the applied displacement.

Reference specimens:

- Interlaminar shear strength: **59.33 MPa**
- Standard deviation: **1 MPa**

The results show that there is a slightly decrease in the mechanical strength of the aged specimens as compared to the ones that were not exposed to hydrothermal ageing. More specifically, the specimens under humidity and elevated temperature exposure show a ILSS strength **reduction up to 4.81%.**

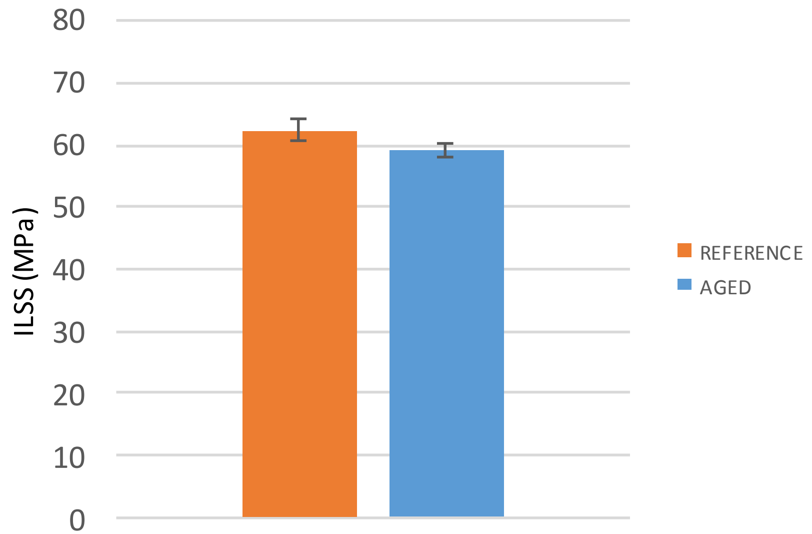


Results

Mechanisms that lead to the reduction of the interlaminar shear strength and shear failure:

- Moisture absorption (swelling of the matrix which lead to internal stresses).
- Plasticization of the matrix.
- Creation of extra hydrogen bonds.

The ILSS strength **reduction up to 4.81%** shows that the moisture absorption does not seem to affect the physical properties of the material and that the mechanical properties exhibit a slightly decrease due to the swelling of the matrix.



Conclusions

The aim of this study was to investigate the effects of hygrothermal ageing on the interlaminar shear strength for the bio-based carbon/rosin epoxy 2.2 twill woven material.

ILSS results exhibit a slight decrease (**4,81%)** in mechanical strength of the aged samples as compared to the ones that were not exposed to ageing, possibly due to an increase of internal stresses.

- The swelling of the material due to water absorption lead to internal stresses of the polymeric matrix.
- Plasticization of the polymeric matrix.
- Hydrolysis of the polymeric matrix.
- Creation of extra hydrogen bonds.

The ILSS for reference specimens is **62,33 MPa** while at the other hand, for the aged specimens is **59,33 MPa**.

(Interlaminar shear strength of commercial epoxy-twill carbon fibre: 52MPa).

The results of this research lead to the conclusion that the rosin-based epoxy resin materials reinforced with carbon fibers, have a good prospect and need to be investigated thoroughly, as **they could be used as an alternative choice to the commercial fossil-based ones.**

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THANK YOU FOR YOUR ATTENTION