Effect of the drying methods in the process of impregnation of carbon fibers with cellulose microfibrils

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Abstract

Unsized carbon fiber fabrics (CFF) were impregnated with three different concentrations of an aqueous suspension of microfibrillated cellulose (MFC), 0,1; 0,2, and 0,4 %wt. Vacuum-assisted impregnation made the suspensions penetrate and deposit the cellulose on carbon fiber (CF) surfaces. The effect of drying of two plies of carbon fiber fabrics impregnated with cellulose was evaluated for three concentrations of cellulose in aqueous suspension. Resin infusion under flexible tooling was used to manufacture multi-scale MFC-CF-Epoxy composites. 0.1 % MFC resulted in higher flexural strength and modulus of elasticity. The drying of the two plies together resulted in a higher modulus of elasticity due to the entanglement of MFC between CFF plies.

Keywords: multi-scale composites, nano-cellulose, MFC, vacuum-assisted infusion.

Introduction

Damages in fiber-reinforced polymers (FRP) generally occur by starting as a matrix crack or transverse cracking. Consequently, interfacial fiber-matrix debonding, delamination between layers, and finally, fiber fracture [1]. Thus, the volumetric region between the reinforcement and the matrix, known as the interphase, determines the interaction and the FRP mechanical response to loads [2].

In the last decade, it was identified that micro/nanofibrils of cellulose (MFC) might increase fibers' choices in composites and expand their use because of their excellent mechanical properties [3]. Furthermore, coating continuous fibers through impregnation with MFC aqueous suspensions has proven to be an effective, simple, and low-cost method for improving
the mechanical properties of composites [4]. In carbon fiber reinforced polymers (CFRP) has been determined that adhesion between MFC and carbon fibers occurs by van der Waals interaction[5] and that it also depends on CF roughness, improving the toughness of epoxy matrix composites MFC-CF-EP [6].

Previous works in GECoM group published by Uribe et al. [6] show that immersing of CFF in MFC pools may improve stiffness (+20.1%) and the ultimate flexural strength (+49.2%) [7].

This work proposes vacuum-assisted infusion as a route for adding MFC that coat CFF and provide the deepest penetration of MFC into them, therefore, better mechanical properties of MFC-CF-EP composites.

Experimental Procedure

- Infusion of Cellulose process

MFC water paste was transformed into 0,1; 0,2; and 0,4 wt. % of MFC/water suspensions by dispersing 10 wt.% MFC in distilled water. Those suspensions were used to coat CFF using a vacuum-assisted MFC infusion process, similar to the vacuum-assisted transfer molding process.

The schematic of the molding for the penetration of suspensions through the carbon fiber fabrics using vacuum-assisted impregnation of MFC is shown in Figure 1.

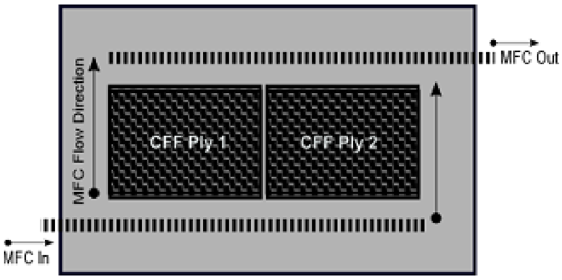


Figure 1 – Schematic upper view of side-to-side carbon fiber fabrics plies during infusion of MFC.

MFC suspensions were infused through the CFFs using a vacuum of -40 kPa at 25°C, flowrate of 100 mm/min, the volume of infusion of 50 ml. After infused, CF-MFC were dried for 3 hours at 100°C.

Two different methods for drying were tested after CFF were impregnated with MFC:

1. CFF were dried by separated (Sep).
2. CFF were stacked while wet and dried together (Tog).

- Manufacturing of composites.

Resin infusion process under flexible tooling [9] was used to permeate the preforms containing the non-coated CFF and CFF-MFC coated. Under a vacuum pressure of −80 KPa, filling time for the entire preform was 10 min. Cured for 24 h at room temperature and post cured for 5 h at 70 °C.

- Flexural Properties

Three-point loading tests were performed according to the ASTM D7264-15 standards. The testing machine was 5969 Universal Material Testing by INSTRON (load cell: 5 kN). The samples were two-ply laminates with dimensions close to 60x15x0.5 mm^3 and a span to thickness ratio of 40:1.

Results and Discussion

- Effect of MFC concentration and drying.

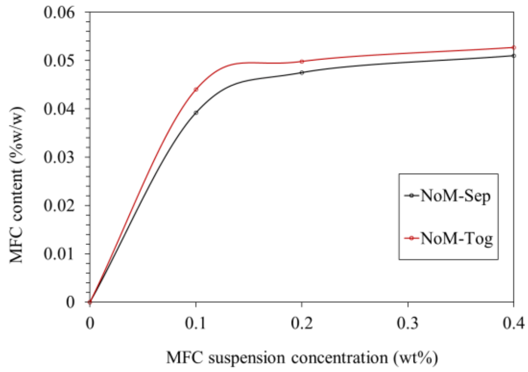


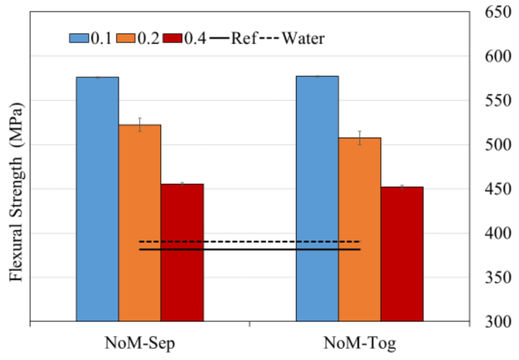
Figure 2 - Content of deposited MFC on CF-related after drying to the drying method used and MFC concentration.

Figure 2 shows that the mass gain (MG) increases according to the concentration, fulfills that: MG%0,4 > MG%0,2 > MG%0,1. The drying process shows similar curves, not affecting the mass gaining.

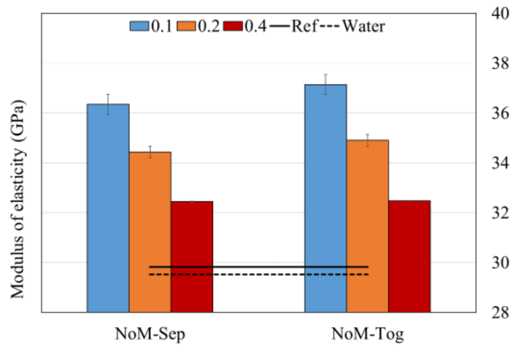
- Flexural Properties.

The Figure 3. shows that the modulus of elasticity values improved with the addition of MFC compared to reference and water infusion, it is observed that 0.1 wt.% presents the highest values for both drying process. However drying CFF together resulted in a higher modulus.

Flexural strength also increase with the coating of CFF with MFC, obtaining values close to 600 MPa for both drying methods when 0.1% MFC was used.



(a)



(b)

Figure 3 - Effect of the MFC deposition on MFC-infused/CF/Epoxy composites on flexural properties and drying methods, (a) Flexural Strength and (b) Modulus of Elasticity

Conclusions

The infusion method was effective for MFC penetration into CFF, forming a 3D network between CF and serving as a node at the intersection of 0-90 bundles. Dry together CFF impregnated with MFC allows MFC of different plies of CFF links each other, transferring the stress between them better than when dried by separated.

Acknowledgments

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