IN-SITU IMPREGNATION BY FFF PROCESS OF CONTINIOUS TEXTILE FLAX/PA6 COMPOSITES

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Abstract

Over the past few years, the advancements of process and material development in Fused Filament Fabrication (FFF) technology have been achieved to show significant potential for different applications, varying from small scale prototype to large scale industrial applications. With wide variety of thermoplastic materials and composites (continuous, discontinuous, nano…) that could be printed requiring only modifications of the printer itself, FFF process became one of the most widely used AM technologies. Recently, continuous synthetic (carbon, glass, or aramid) fiber-based composites are increasingly studied due to their high level of mechanical performance compared to the discontinuous ones. Two 3D printing approaches exist: (i) printing with pre-impregnated filaments [1–2] and, (ii) printing with simultaneous impregnation of polymer and fiber in the one cylindrical channel of print head [3]. In addition, more and more attention has been paid to reinforcing plastics with plant fibers [2-3]. Interest in the latter is associated with economic factors, since they are a renewable resource, very light, and their cost is lower compared to all other fibers. They have also got another important advantage - the possibility of processing and reuse.

In this context, the considered work highlights a simple and customized in-nozzle impregnation method by FFF process for the development of novel green composites at relatively high temperature (~230°C). These composites are based on PA6 matrix reinforced by continuous bleached flax fibers issued from textile industry. The considered reinforcement were first introduced in the FFF process due to its low linear density (26 tex) (lower than fiberglass and namely, flax fibers (68 tex) traditionally used during the FFF of composite) and thus, good homogeneous distribution in the printed composite. It is interesting by its renewability, recyclability, low-cost, availability at high quality and large range in industry, and its potential use in the widespread applications. The use of PA6 matrix is also considered thanks to its excellent mechanical and chemical properties, but also long-term resistance in fatigue [4].

In this work, the continuous twisted flax yarn and PA6 filament were fed via two separate channels followed by mixing in the small heated zone before extruding from a conic flat-head nozzle of 0.6 mm diameter (Fig. 1a). The advantages of this method, regarding to in-nozzle impregnation with two printing separate heads "side by side", are: (i) ensure the mixing the fiber flax and PA resin in the one heated zone allowing thus, both better fiber distribution and impregnation, (ii) prevent specially flax fiber degradation due to short-stay time in the small heated zone of the conic nozzle, (iii) print composite in one-shot permitted gain time for the industrial applications.

The main ideas of this work are to study preliminary the feasibility of the customized in-situ impregnation by the FFF process dedicated for the new considered composites. The influence of some processing parameters such as: layer height, hatch distance, and number of layers on the variation of

the fiber volume ratio of the printed unidirectional textile flax/PA6 composite, and thus, on its mechanical performance will be shown. Additionally, the effect of fiber orientation was studied to assess the transversal tensile properties.

(a) *(b)*

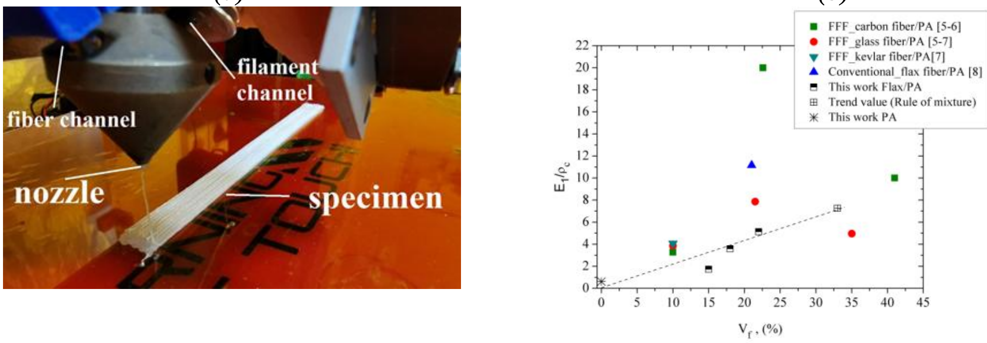

Fig. 1a – Magnification view of the 3D printing of a continuous textile flax/PA6 composite; b - Comparison of specific tensile modulus versus volume fiber fraction of considered composite with literature review.

Conclusions

Three filling patterns (0°, 90° and ±45°) strategies relative to the tensile loading were adopted to investigate the mechanical properties of continuous textile flax/PA6 composites. The tensile tests resulted in the best properties obtained for the unidirectional considered composites. It has been highlighted that void content and inter-layer delamination decreased with increasing volume fiber fraction. The transversal tensile properties remained at their weakest point. The novel composite and customized for its purpose method led to competitive specific elastic properties compared to continuous glass fiber/PA printed composites, given by the literature review (Fig. 1b). Furthermore, the flax fibers have the potential to replace glass fibers in considered composite for infrastructure, automotive industry, and consumer applications. This is possible if only composite void content is controlled, and its yarn/matrix adhesion is improved.

References

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