ON THE PERFORMANCE OF CAR DOOR LIMITER MADE OF POLYMER/GLASS FIBER COMPOSITE PA12HST: TOPOLOGY OPTIMIZATION AND SLS ADDITIVE MANUFACTURING

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Abstract

Some ways to enhance mechanical performances of additively manufactured components is to add fibers as reinforcement to the base material, and by designing adequate shapes (e.g., using topology optimization). This research work deals with analysis of the performance of a car door limiter (CDL), as a case study, made of a polymer/fiber composite. The component, solicited mainly in tension, is redesigned using topology optimization (TO) and printed by SLS AM process from composite powder of polyamide and glass fiber (PA12HST). Both numerical and experimental mechanical responses (force vs. displacement, and stress state) are analyzed. It is shown that the variability of the material behavior, induced the by the SLS process as well as printing orientation, affect the force/displacement response and the stress state. This study raised the question about what behavior model of resulted material (i.e., after AM process) to introduce in the design of components (e.g., using TO) to obtain safe components based on imposed specifications (e.g., stress/strain limits or strength resistance).

Keywords: PA12HST composite; SLS AM, TO; Case study; Variability behavior; Mechanical performance

Introduction

AM processes are widely used in prototyping components, mainly to validate designs and some functionalities. In recent years, in service components are additively manufactured in small series for various products. In the automotive industry, vehicle weight reduction has become a major issue. Few studied are conducted to enhance performances of solicited components. Cavazzuti et al. [1] carried out a TO design of a blank body to reduce its mass while maintaining the required performance, just like Mantovani et al. [2] but using a lattice structure approach. Verge et al. [3] is one of the rare studies where an existing automotive component (rod link) is designed by TO, then fabricated by FDM, to finally perform experiments and analyze the difference with simulations. As FDM is done layer by layer, they introduced in a FE code a behavior of a composite material to be as close as possible to reality.

It is shown from literature studies that, in majority, there is few comparisons between experimental and predicted performances of automotive components obtained by AM processes. In this context, the proposed study concerns the analysis of the performance of a CDL made of polymer/fiber composite and fabricated by SLS AM process. Both experimental and modelling approaches are conducted, with comparison of mechanical responses. This is done to highlight the contribution of SLS AM process with TO design to the development of functional and safe components that can be integrated in automotive.

Outline of the study

The polymer/short fibers composite, named PA12HST, in the form of powder before SLS printing, is chosen to realize a vehicle component solicited mainly in tension. This composite in its initial form contains the polyamide PA12, with particle size around 50µm, and about 30% of short glass fibers with length range of 40 to 300µm. The microstructure of this composite (reconstructed by tomography and then segmentation) is shown in Fig. 1(a).

The chosen case study is the arm of a CDL of Ford C-Max vehicle (Fig 1(b)). This arm is mainly solicited in tension and should presents a good mechanical resistance. It is decided to print with SLS AM process various designs of this arm: an initial design, one without design space, two TO designs, and lattice design (see Fig.1(c)). The main steps, including TO modeling and tests are indicated in Fig.1(d).

Tension tests on each design are performed. Two cameras are used to detect the fracture of each component and the force/displacement responses are recorded. The comparison with numerical predictions is shown in Fig.1(e).

As results, the variability of the behavior due to the SLS AM process explains the difference between experimental data and simulations. The printing orientation has also a clear effect on the mechanical response. Since, in the FE modeling, with or without TO, an average stress/stain response is introduced, the variability of the behavior due to the SLS process is not captured. However, a safe range for the material behavior can be defined to find safe designs of the component before SLS printing.

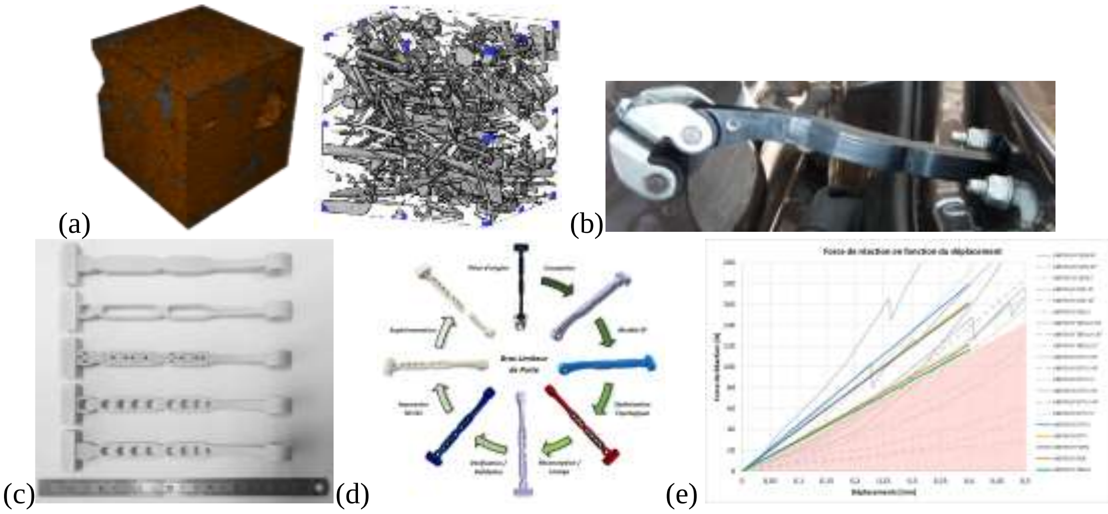

Fig. 1 – (a) Microstructure of polymer/short fibers composite PA12HST, (b) CDL of Ford C-Max, (c) printed designs (b) main steps of the study, and (c) experimental vs. predicted force/displacement responses.

Conclusions

The main concluding remarks are as follow:

(1) The obtained polymer/fiber composite by SLS AM process presents a good mechanical resistance, making it adequate for some solicited automotive components.

(2) The printing orientation has a clear effect on the mechanical response of CDL arm.

(3) The induced variability of mechanical behavior by the SLS AM process affects the mechanical response of fabricated components.

(4) Although the TO designs gives better mechanical performance than the initial design, tension tests on fabricated TO designs shows low mechanical resistance.

(5) Indeed, the variability of the behavior should be included in the TO modelling to obtain safe components, mainly including induced low mechanical resistance behavior.

References

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