MULTI-CRITERIA APPROACH FOR THE DESIGN OF COMPOSITE STRUCTURES MADE BY ADDITIVE MANUFACTURING

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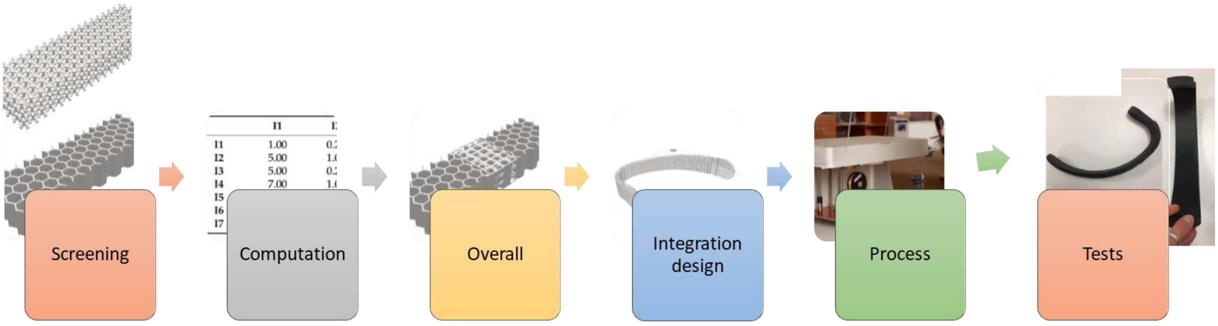
Abstract

The purpose of the design activity is to define a product that performs these functions as well as possible within the constraints of cost, (development) time and performance (quality), and the design problem to be solved is how to accomplish this. During the design process the design team must continuously check whether the chosen design implementation meets the requirements from the user's point of view. To be able to do this, product characteristics must be linked back to the functions the product has to perform. Also, when choosing between design alternatives the key functions, in addition to the major constraints the product has to comply with, again deliver the criteria to screen and rank the alternatives. In the area of additive manufacturing (AM) technology shows opportunities and challenges, to improve product characteristics. AM technology can be used to develop and create a new smart path in different composite applications. Some of these opportunities have been investigated by different researchers [1–3]. However, there is effectively deal to develop with structural composite materials. If several criteria are required and different optimal material mesostructure are fund, a methodology is needed to assemble them.

First, the framework is a systematic process [4], even if it presents its specificities. It can be applied both in the case of new design or redesign of an already existing product. A decision-making process has been defined to select feasible candidates and then progressively move on to further analysis, only if the previous phase has succeeded. The process moves from a collection of basic facts and main design requirements of the product under analysis. A selection of possible data can be gathered, many of them being optional depending on the application such as loads, constrains, targets, size, time-to market etc… Generic numbers and information are sufficient at this stage, also in the form of expected values or possible ranges. More precise parameters and requirements will be defined or refined in successive evaluation steps.

Following design phase, the next step of the process is the Preliminary Analysis, which is a rough examination of main manufacturing constraints to exclude unfeasible applications. Three aspects have been identified as overwhelming limitations that could impede the usage of AM. Even if the three evaluations can be regarded as subjective and depending on the evolution of the technologies, it is reasonable to evaluate them early and to skip the process from the beginning if one of them cannot be surely met by the application. In Figure below, the sub-steps of the Preliminary Analysis are presented:

1. Screening of materials/mesostructure compatible with the given constraints (i.e., minimum stiffness, minimum strength, minimum electric conductibility, etc.);
2. Computation of a set of indices according to Ashby [5] or other method for each compatible material;
3. Definition of index weights and computation of Compliant Index (CI) for each material through adaptative mesostructure;
4. Materials/mesostructure integration in 3D Model;
5. Selection of possible printers proceeding (materials and shape dependence);
6. Check of printer capabilities and printed parts versus specifications.



Therefore, the first step is to identify suitable materials out of a list. The materials database is built from data provided by technology suppliers, mostly available on the web [6], where the value range of properties of available materials is reported. It is possible that only a few or no materials are compatible if numerous and strict constraints are imposed, making AM an impractical solution for the imposed requirement. However, it is possible then to generate 'metastructure' (mesostructure assembly) that will enable to optimize specific properties for composite application.

In this paper, the authors propose to evaluate this approach through the design of a sandwich beam. The first objective was to develop a stiffness-based design of a lightweight honeycomb core for a composite sandwich beam subjected to 3-point bending loading. The geometric parameters of the core unit cell were chosen to maximize the shear stiffness and minimize the density while accounting for the AM constraint. Both the homogenized honeycomb stiffness and the density are computed using analytical approximations. Several sandwich beams were manufactured and tested during a student project at the University of Bordeaux. Theorical and practical evaluations were well correlated. Then, we investigated a second objective by adding in the design a strength requirement to avoid core crushing. This requirement leads to take advantage of FA versatility by designing honeycomb cores and lattice structure with graded properties using evolutive mesostructures. Finally, a case study on a prosthetic foot was develop and manufactured to apply the strategy with several criteria on a complex shape following specifications. It is demonstrated that AM, taken into DFAM rules, can open multi-objective and multi-constraints development.

References

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