Development of a defect/damage propagation modelling for launcher composite structures pre-sizing

The use of composite materials in the space field has led to great weight improvements. For instance, important structural parts, like solid motor cases, inter-stage structures, fairings, etc. are made from filament winding, fiber placement or manual lay-up with monolithic or sandwich composite structures. Classical sizing methods for these structures set the ultimate load threshold before the apparition of any damage and take into account manufacturing and operational defects with knock-down factors on material's allowables to ensure the damage tolerance. Other more complex methods exist to better take into account impacts of defects but they are used at the end of a development (once the architecture is set) to finalize the qualification and to know the validity scope of the structure. These methods are not adapted to quick sizing loop realized during a project to compare and chose the best architecture solution (geometry, material, lay-up, etc.) by taking into account damage effects from the beginning of a development.

These damages are various (matrix cracking, delamination, fibre breakage, etc.)[1], sometimes can be barely detectable (during manufacturing or operations) and they can induce a decrease of the mechanical properties and a loss of the strength. Moreover, when the structure is loaded, and especially in a reutilisation scenario, these damages can propagate and lead to the final failure having dramatic consequences. For all these reasons, understanding and characterizing the behaviour of damaged composite structures, that is to say the growth of the damages, is important:

- at sizing level, to improve the performance of the structures, challenging the mass and the cost by entering the damage domain while avoiding the loss of integrity.
- at safety level to be able to confidently predict the extension of damage and characterize the shape and size of fragments after an accidental event or after the neutralization of the launcher.

This problematic is all the more important in the space field as more and more parts are aimed to be reusable (sizing level) by launcher return to the ground (safety level). In addition, new applications are under development like composite cryogenic tanks, for which permeability is an issue and whose behaviour under defects is even more important.

The objective of this thesis work will be to define a simplified methodology to well take into account damages for sizing and for safety from the beginning of a development by understanding the damage propagation generically.

In a first step, the mechanisms responsible for the propagation of the defects in composite structures will be identified through a large literature review and a complementary experimental campaign if necessary. In parallel, a Finite Element Modelling strategy will be developed to represent these phenomena. It will be based on the modelling strategies that has been developed at ICA [2,3], and it will be adapted in order to be used during the pre-sizing phase. A special focus will be done on the better compromise between modelling scale and calculation time. Local / global approaches could be considered to reduce calculation time.

This research work will be applied to the general case of defect/damage propagation in unidirectional composite structures with an application on launcher at sizing and safety levels.

This three-year doctoral work will be organized as follows. During the first year the PhD student will make a large state of the art of the composite defect/damage propagation issues. She/he will analyse and identify the key phenomena that drive the damage propagation. This analysis will be completed, if necessary, with the set-up of some experimental tests. In parallel some ingredients of the future modelling will be formulated and tested. The second year will be focused on the development of the finite element modelling. A special attention will be paid on the choice of the modelling scale and the damageable material laws keeping in mind that the model will be used during pre-sizing phases. The parameters will be identified with several experimental tests at the coupon scale. During the third year, the numerical results will be compared to the results provided in the literature and to what observed experimentally in order to validate the modelling strategy. At the end of the last year, the PhD student will write the thesis manuscript.

[1] S. Abrate. Impact on composite structures. Cambridge University Press (1998)
[2] A. Rogani, Pablo Navarro, Steven Marguet, Jean-François Ferrero, C. Lanouette. Tensile post-impact behaviour of thin carbon/epoxy and glass/epoxy hybrid woven laminates – Part I: Experimental study. Composite Structures, Elsevier, 230, p.111508
[3] A. Rogani, Pablo Navarro, Steven Marguet, Jean-François Ferrero, C. Lanouette. Tensile post-impact behaviour of thin carbon/epoxy and glass/epoxy hybrid woven laminates – Part II: Numerical study. Composite Structures, Elsevier, 230, p.111455

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