Modeling of Fracture Across Scales and Time

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Flying is today one of the safest ways to spend our time. In the United Kingdom, for example, it is 33,000 times more likely to die from a clinical error than from an air crash. This is probably the consequence of over a century of experience building, starting with the Wright brothers at the beginning of the 20th century to the most recent aerospace developments culminating in technological giants such as the Airbus A380 and the Boeing Dreamliner, through the enlightening catastrophic events of the "Comet Aircraft," ``Liberty Ships," and many others.

Yet, with the increasing urge to increase flight efficiency, decrease costs and Carbon emissions, airlines have been pushed to drive down the weight of aircraft, whilst guaranteeing their safety. This push for lighter aircraft has progressively seen a reduction in the use of metallic components which have been slowly replaced by composite materials. Such composite materials are made up of two or more phases of which they exploit the mechanical complementarity. For some applications, such as thermal barrier coatings, thermal complementarity is also leveraged.

Yet, these novel materials, and especially their failure mechanisms and durability have proven difficult to understand, both through physical and virtual, in silico, experiments. One of the reasons for this is the large ratio between the size of the smallest constituent relevant in the description of failure mechanisms (e.g. 5-10 micron diameter carbon fibres) and the size of the structure (79m wingspan A380).

In this presentation, we will briefly review advances in modeling and simulation of failure across the scales. We will discuss non exhaustively some of the recent advances in this field, ranging from adaptive atomistic modeling of fracture to algebraic model reduction methods for severely non-linear problems, including homogenization. We will also discuss the relevance of such simulations in daily engineering practice and claim that devising interactive simulators able to let engineers interact with the composite structure of interest and thus develop intuition about these advanced and complex materials.

We will conclude by making a parallel between the difficulties encountered in modeling complex aerospace components and those met in personalized medicine, by discussing briefly the concept of Digital Twin.

Key Words
- multi-scale simulation of fracture
- damage tolerance analysis
- model reduction for fracture and non-linear problems
- the digital twin paradigm
- possible parallels with digital twins in personalized medicine