Introduction to Life Prediction Methodologies for Materials and Structures

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In his book "Citadelle» Antoine de Saint Exupéry wrote "Intelligence examines the material while the mind only sees the ship". Such a quote sets the context of this issue of ONERA's Aerospace Lab Journal entitled "Life Prediction Methodologies for Materials and Structures" very well. In order to predict the mechanical integrity and lifetime of complex components and structures, it is essential to understand the physical mechanisms that control local deformation and damage phenomena at the relevant scales in the material. This issue of the Aerospace Lab Journal addresses this problem by providing a forum for some of the leading members of the mechanics of materials community to report on recent theoretical and computational modeling approaches to describe the mechanics of materials at scales ranging from the atomistic, through the microstructure, and up to the continuum. A broad range of materials and physical phenomena are addressed, including metallic and composite materials, dislocation behavior, crystallographic slip, fatigue and damage, and other macroscopic and structural behavior.

This issue contains the eleven invited contributions that have successfully gone through the standard review process of the journal. They reflect the strong interactions between universities, research institutes and industry in the topic of this issue, and underline the importance and challenging nature of the scientific issues addressed.

The various topics covered range from the defect and microstructural scales (dislocations in Articles 1 and 2, and individual grains in Articles 3 and 9) to the structure scale (Article 6), including intermediate scales described by various continuum mechanics approaches (Articles 4, 5, 7, 8 and 11). Furthermore, Article 10 deals with the thermodynamic aspects governing the evolution of superalloy microstructures. Two articles discuss approaches developed to predict the deformation, damage and fatigue behavior of composite materials. This includes topics that have not been widely reported in the literature, such as the behavior of composite materials subjected to dynamic and crash loads, addressed in Article 4, or the treatment of fatigue damage discussed in Article 6.

Contributions to this issue scan the entire life prediction workflow of a structure, which can be broken down into the following steps:

- Observations and characterization of the material microstructure.
- Measurements and prediction of the local strain and stress fields, which control local deformation and damage phenomena.
- Determination of the component and/or structure behavior through the stress redistributions within the structure.
- Identification, through adequate fatigue damage laws, of the number of cycles for crack initiation.
- Determination of either stable or unstable crack growth behavior, including catastrophic failure.

While these steps are consistent with current practices, there are still challenges to be addressed in the coming years. Indeed, it would be unrealistic to propose a structural analysis today where the material behavior is described at, for instance, the defect level by discrete dislocation dynamics, or by explicitly accounting for all of the heterogeneities in a composite material even though theoretical tools are available for some idealized cases. Despite such challenges, the scientific community continues to work towards developing closer integration of the various modeling and life prediction approaches.

Finally, we would like to thank all of the authors for their contributions to what we hope will be an important reference in the field, as well as the reviewers who spent a considerable amount of time commenting on the scientific merits of the manuscripts. It is hoped that this collection of overview articles will provide readers with the current state-of-the-art in some of the key modeling approaches required to predict the mechanical integrity of components and structures on the basis of physical principles ■

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