

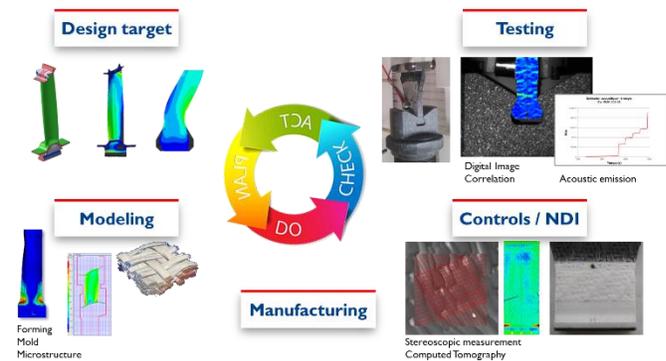
## ENGINEERING FRAMEWORK FOR SAFRAN INTERLOCKED CERAMICS COMPONENTS

David Marsal, Safran Ceramics  
david.marsal@safrangroup.com  
Eric Bouillon, Safran Ceramics  
Nicolas Laval, Safran Ceramics

Key Words: co-engineering tools, multiscale, multidiscipline, component testing, digital image correlation.

CMC technologies, emerging for civil aircraft engines, require to adapt designers and manufacturers rules, which mainly come from metal experience. Many aspects should be rethought: strain criteria are low compared to metal, dimensions are small compare to PMC, and geometrical requirements for aerodynamic performance are very challenging compare to spatial and brakes applications.

To cope with these engineering stakes, it's priceless to integrate the sound knowledge of CMC's specific relationships across scales and disciplines built by the scientific community.



First, a co-engineering framework is briefly described. It enables to go from 3D part design to thermo-mechanical testing and analysis, including material and process modelling at the appropriate scales.

Second, based on this framework, recent achievements are presented like ARCOCE nozzle certification and commercial flight experience, and blade dovetail performance fitting now with Low Pressure Turbine requirements.

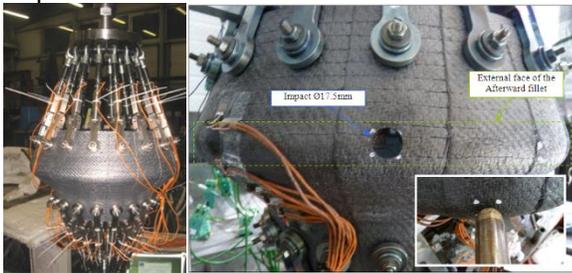


Figure 1 – Scale One demonstration of ARCOCE nozzle for commercial flight agreement

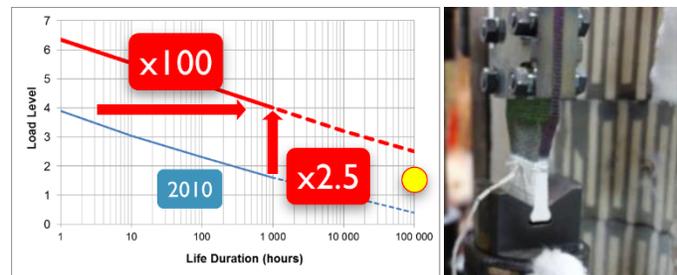


Figure 2 – Dovetail performance improvement fitting Low Pressure Turbine requirement

Finally, different levels of interaction between Digital Image Correlation and finite element modelling will be discussed, in 2D situation with thermal and displacement imaging, and 3D situation with X-ray micro-tomography.

- C. Chateau, L. Gélébart, M. Bornert, J. Crépin, E. Boller, C. Sauder, W. Ludwig, In-situ X-ray microtomography characterization of damage in SiC/SiC minicomposites, Composites Science and Technology (71) (2012) 916–924.
- S. Roux, F. Hild, P. Viot, D. Bernard, Three Dimensional Image Correlation from X-ray computed tomography of solid foam, Composites A : Applied Science and Manufacturing (39) (2008) 1253–1265.
- G. Morscher, N. Gordon, Acoustic emission and electrical resistance in SiC-based laminate ceramic composites tested under tensile loading, Journal of the European Ceramic Society (2017)
- A. Haboub, HA Bale, JR Nasiatka, BN Cox, D. Marshall, RO Ritchie, AA MacDowell, Tensile testing of materials at high temperatures above 1700 °C with in situ synchrotron X-ray micro-tomography. Rev Sci Instrum. (2014)