PHD POSITION OPENING

Title: *Hybrid twin concept to embedded life-cycle management of smart multi-material structures*

Laboratory and/or research group: PIMM / DYSCO Team

Supervisors and contact: Nazih mechbal (nazih.mechbal@ensam.eu), Eric Monteiro (eric.monteiro@ensam.eu) and Marc Rébillat (marc.rebillat@ensam.eu):

Funding: EU H2020 MORPHO Project– Embedded Life-Cycle Management for Smart Multimaterials Structures: Application to Engine Components.

Starting date: Autumn 2021

Topic Description

Context:

Hybrid material has gained attention and interest in engine design. For some current engines, the core body of the fan blades is composed of 3D woven composite material, while the leading edge is made up of titanium. **The manufacturing** of these complex composite aerofoils usually involves long processes that proceed by injecting a resin into a mold initially filled with a reinforcement preform (**RTM** process– Resin Transfer Molding). The associated forming process simulation, used to optimize and control the process, generally greatly differs from the reality because of the important variability in the input matter material parameters in both space and time that is not (or badly) considered into simulation. Currently, Airbus and as well as Boeing are working hard to enhance the robustness and reliability of the composite manufacturing process through monitoring technology and modeling & simulation of the RTM process [1].Therefore, in order to be able to control the process and to ensure high quality part forming, the manufacturing system (namely the injection process) should adapt in real time to these changing conditions in the input matter characteristic but also to any change in the factory and even to the customer needs.

Furthermore, providing the structure with **cognitive** capabilities (data from sensors and digital models) involves strategically adding sensors within it. These sensors can then enable the monitoring of the structure health throughout its service life and to push towards a "**sustainable eco-friendly manufacturing**" philosophy promoted by engine manufacturing companies, by developing original concepts for **disassembling, reuse and recycling.**

The digital twin is a standard multi-physical simulation model. The concept of **hybrid twin**[2] goes beyond the digital one, by combining physics-based and data-driven models. It makes use of Model Order Reduction (MOR) techniques (also called surrogate model) to provide real-time solution of physically based models that have been calibrated through physical sensors data and on-the-fly data-driven models (estimation and machine learning approaches) and to correct any observed deviation or mismatch between data and model prediction. The data provided by the printed and embedded sensors are fed to the hybrid twin which adapts online during its whole life cycle.

This PhD position is part of the H2020 project MORPHO where the overall goal is to enable efficient, profitable, and environmental-friendly manufacturing, maintenance, and recycling of these next-generation smart engine fan blades. MORPHO consortium is built up with multiple partners across several European universities and companies and close collaboration with them is expected.

[1] S. Chatel, F. Chinesta. Recent Advances and New Challenges in the Simulation of RTM Processes at EADS. *Composite Magazine*, 2010, pp.60-73.
[2] Chinesta, F., Cueto, E., Abisset-Chavanne, E. et al. Virtual, Digital and Hybrid Twins: A New Paradigm in Data-Based Engineering and Engineered Data. *Arch. Comput. Methods Eng.*, 27, 105–134 (2020).

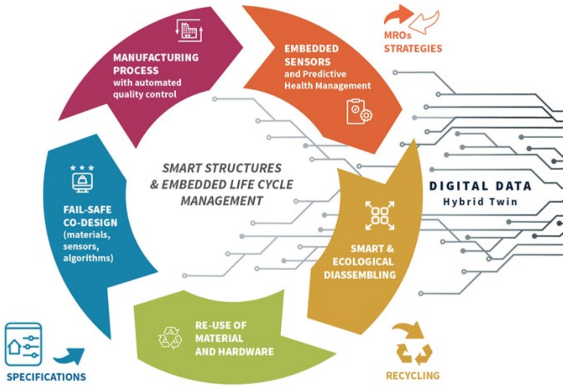

Fig. 1: MORPHO general concept

Objectives and research work:

The PhD candidate will be in charge of developing a **hybrid twins platform** merging physics-based and data-driven models for **monitoring the in-service life** of a smart fan blade. Model reduction and **machine learning** algorithms will be used to decrease computational complexity to quantify the smart blade performances within the aircraft engine.

In addition to the FBG sensors that will be included during the RTM manufacturing process, the hybrid structure will be embedded with printed sensors (PZT, temperature or humidity). The generated data will then be used for digitalization purposes and for feeding robust structural health monitoring algorithms[3,4] that have to be elaborated within this thesis to predict the remaining useful life (RUL) of the structure.

Among the main objectives, we can highlight the following:

- To elaborate an **interactive hybrid twin platform** allowing to provide feedback regarding specifications, to assess the smart fan blade performances.
- **To quantify smart fan blade performances within the aircraft engine and its environment** by developing a reduced parametric smart fan blade model that will be included in complex system simulation tools.

Candidate profile

You are expected to hold a master's degree in **Mechanical Engineering** with a Signal processing, Multivariate Statistical Analysis or Machine learning component. You can also hold a master's in **Electrical Engineering**, **Signal Processing, or Machine Learning** with links with the field of Mechanical Engineering. We expect a demonstrable **interest for numerical activities and industrial project management**.

Interested candidates should send to **Mr. Monteiro** (eric.monteiro@ensam.eu) an application containing:

1) a **personal motivation letter** (max. 1 A4 page) describing why you apply and how the position fits into your career plans,
2) **a full CV** showing how your profile fits the requirements (max 4 pages),
3) an electronic copy of your **Master's thesis**
4) **recommendation letter**s
5) a list of **referees** we can contact.

[3] M Rebillat & N Mechbal "Damage localization in geometrically complex aeronautic structures using canonical polyadic decomposition of Lamb wave difference signal tensors", *Structural Health Monitoring journal* 19 (1), 305-321, 2019.
[4] A. Rahbari, M. Rébillat, N. Mechbal and S. Canu, "Unsupervised damage clustering in complex aeronautical composite structures monitored by Lamb waves: An inductive approach", *Eng. Applications of Artificial Intelligence,* vol. 97, 2021