Processes and EngIneering in Mechanics and Materials Laboratory (PIMM)

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POST-DOCTORAL RESEARCHER POSITION OPENING

Title: *Hybrid twin concept to Structural Health Monitoring 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: 1st semester 2022 **Duration**: 18-24 months

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. Looking to maintenance workload, engine aerofoils components play an important role. These components are **complex, high-value** and technology intensive, subject to **harsh environmental** and operational conditions, such as temperature, fatigue, vibration, and **bird strikes**. Hence, monitoring their **structural health** in a robust and automated way is an important challenge in their development and exploitation.

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**[1] 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 sensors are fed to the hybrid twin which adapts online during its whole life cycle.

This PostDoc 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.

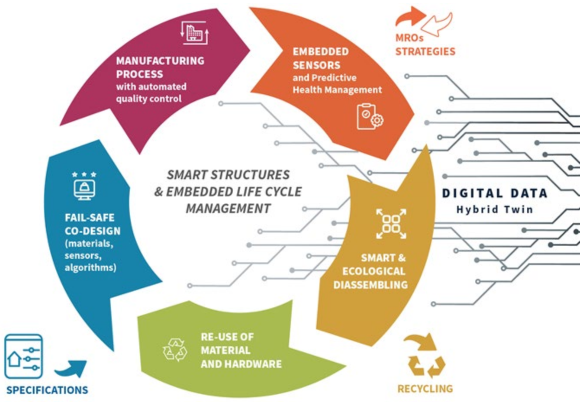

Fig. 1: MORPHO general concept

[1] 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).

Objectives and research work:

The PostDoc 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.

Monitoring in real -time and autonomously the health state of aeronautic structures is referred to as Structural Health Monitoring (SHM). SHM process is classically decomposed into four steps: damage detection, localization, classification, and quantification. An increasingly useful tool in SHM is machine learning (ML). Machine learning is employed because of its efficiency in classification, function interpolation and prediction using data. Data-driven models are built and used to serve SHM purposes. **Transfer learning**[2] is a subfield of machine learning that aims to improve a learner from one domain by transferring knowledge from a related domain Hence, in the SHM context this means that diagnostic information from one structure (or a hybrid twin) can be used in aiding damage identification on a different structure[3].

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[4,5] that have to be elaborated within this work to predict the remaining useful life (RUL) of the structure. In order to have reliable and versatile monitoring tool, **model reduction** and **machine learning** algorithms will be developed to decrease computational complexity to quantify the smart blade performances within the aircraft engine.

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 develop specific SHM algorithms from damage detection to RUL prediction based on **transfer learning method**.
- **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 PhD degree in **Mechanical Engineering** with a Signal processing, Multivariate Statistical Analysis or Machine learning component. You can also hold a PhD 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 **PhD's thesis**
4) **recommendation letter**s
5) a list of **referees** we can contact.

[2] S.J. Pan and Q. Yang. "A survey on transfer learning", *IEEE Trans. on Knowledge and Data Eng.*, 22:1, 2010.

[3] P.Gardner, L.A. Bull, N.Dervilis & K. Worden. "On the application of kernelised Bayesian transfer learning to population-based structural health monitoring", *MSSP journal,* 2022

[4] 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.

[5] 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