Prognostic of flight control actuators

XXXII PhD Cycle

DIMEAS – Mechatronics and Servosystems Group

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WHAT IS PROGNOSTIC?

Prognostic means monitoring a component, **recognize** if **a fault** occurred and estimate the **remaining useful life** before the failure.

WHY?

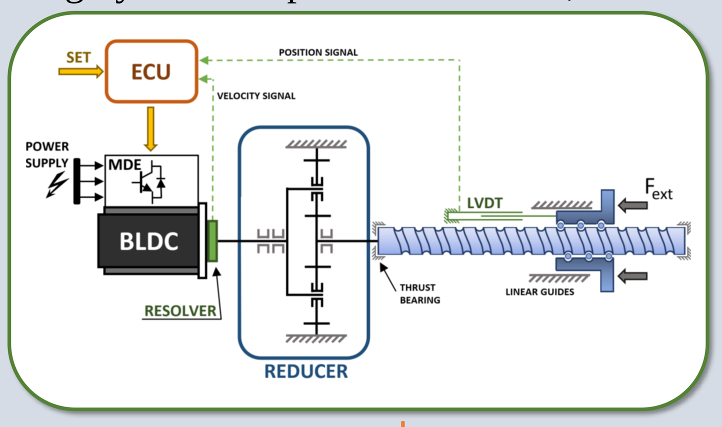
It allows the **maintenance** to become **predictive** instead of scheduled, saving money and time, and enables the use of new technologies.

HOW?

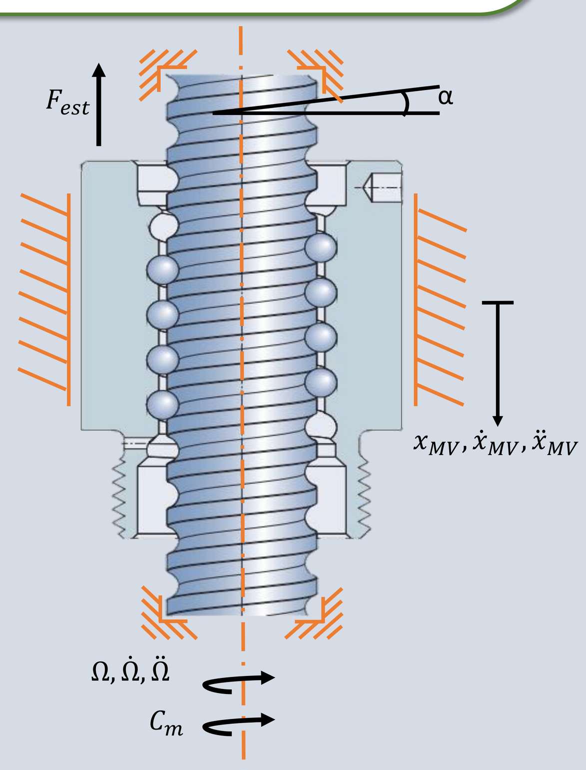
Features need to be extracted from data and to be correlated with the different faults in order to recognize them and track their evolution. This approach can be *data-driven* or *model-based*. To use the second one a **high-fidelity model** is paramount: it is used as **virtual bench** on which inject artificial defects to investigate their effect on the global performance and on the selected features.

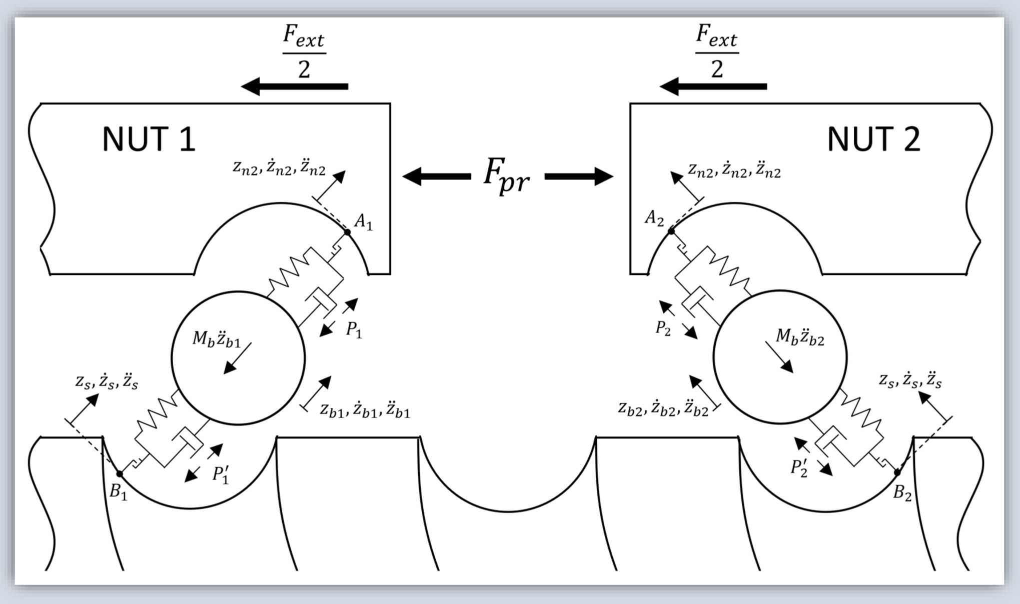
ELECTRO-MECHANICAL ACTUATORS

Flight-control systems of civil aircraft have undergone huge developments in the last decades. The increasing size and speed of civil aircraft led to higher control loads. This evolution forced the introduction of hydraulically powered flight-control systems. However, recent advantages in high-performance magnetic materials, miniaturized and highly efficient power electronics, and gear technology have made electromechanical actuators (EMAs) increasingly competitive compared to hydraulic actuators, in particular closing the gap on power-to-weight ratio, while considering the whole flight-control system.

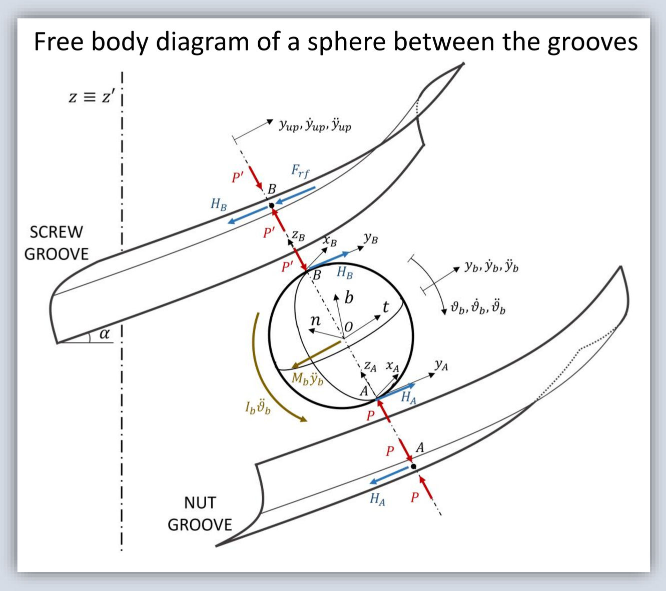


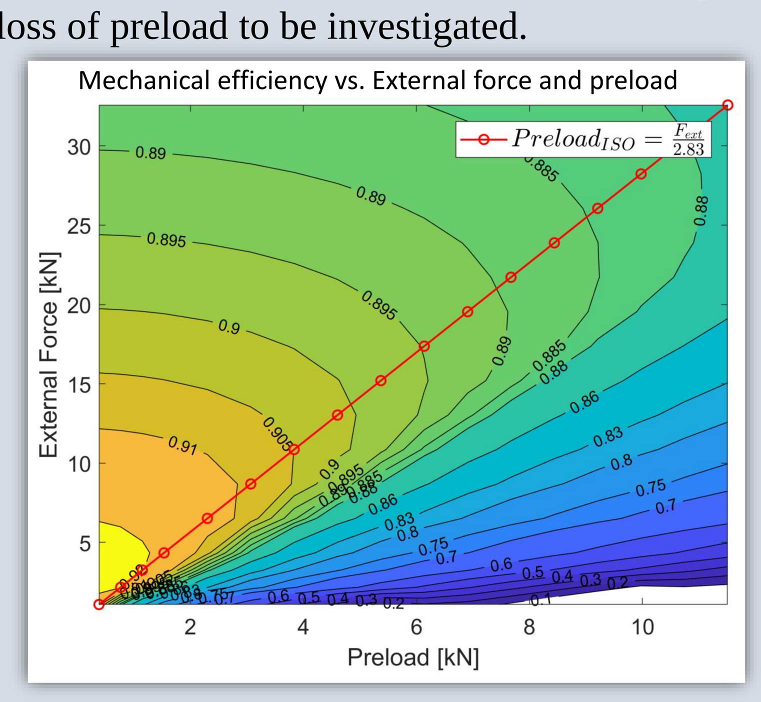
Attention has been paid to the mechanical components of the system, particularly to the **ball screw**. An **high-fidelity dynamic numerical model** of this component has been developed to understand which roles the several parameters play with regards to the mechanism's efficiency as well as the possible influence and propagation of defects.

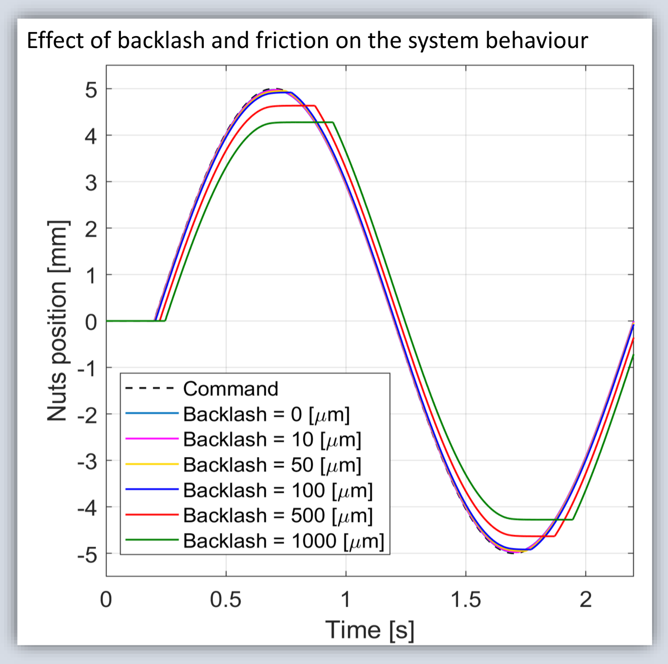




A **single-cycled preloaded double-nut ball screw** has been considered. The model has a low computational cost and it can accurately describe the kinematics and dynamics of each element within the mechanism. **Contact deformations, backlash, rolling/sliding behavior and friction** are considered. The influence of these parameters on the mechanical efficiency has been analyzed by means of mono and **multi-variate sensitivity analysis**. The influence of backlash and friction on the dynamic performances has been investigated. The results of the sensitivity analysis agree with the prescription of the ISO standards and allow the influence and consequences of loss of preload to be investigated.

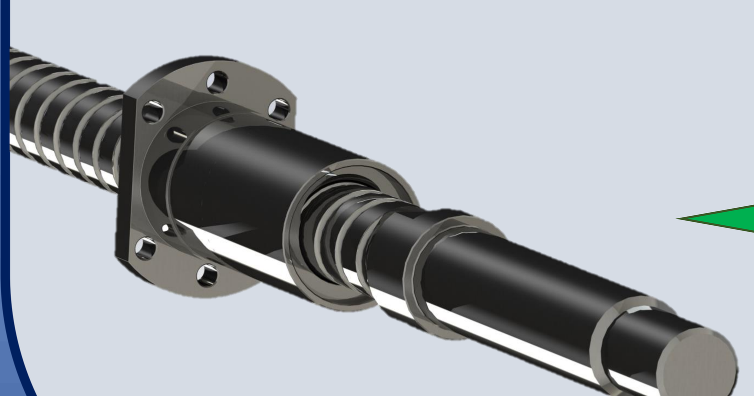




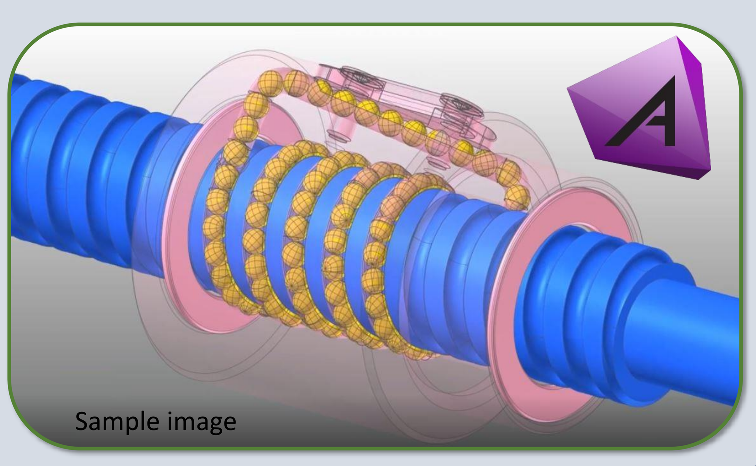


MBD model

In order to better describe the interaction of the spheres with the screw and the nuts and to take into account the **recirculation system**, starting from a CAD model a multi-body model is being developed, in the *MSC Adams* environment.

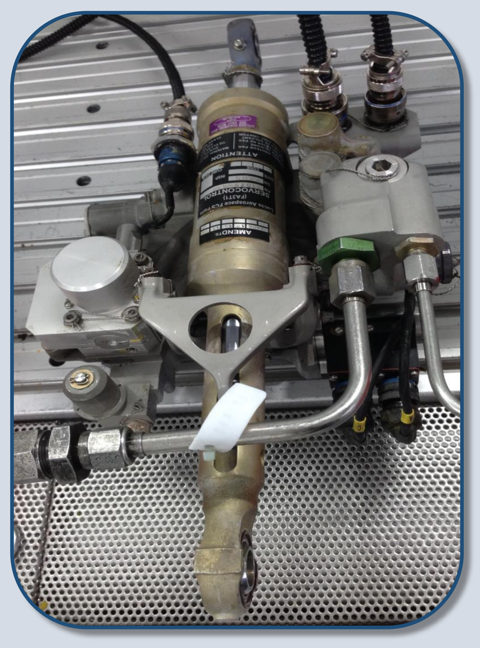


CAD model



MBD model

ELECTRO-HYDRAULIC ACTUATORS

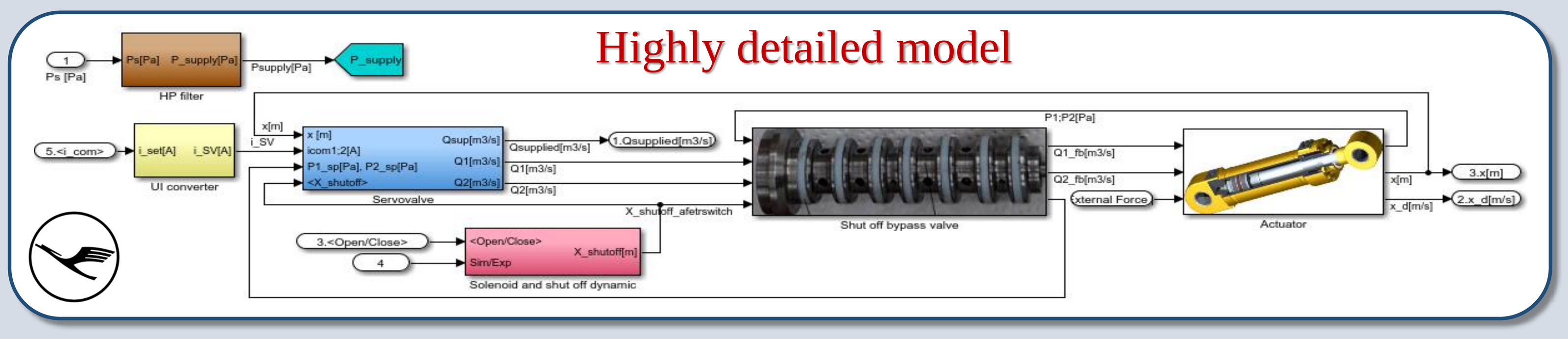


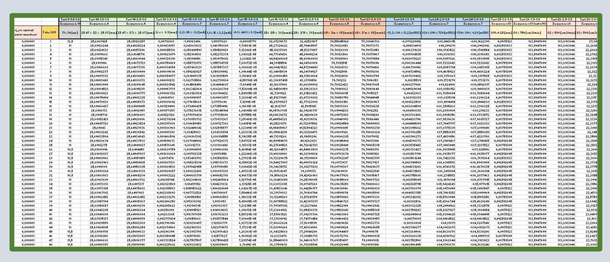
This type of actuators is nowadays the most widespread in the aviation industry, since that they guarantee an extremely low jam probability (about 10^{-9} occurrences/flight hour).

Currently, when an actuator is unloaded and sent to the maintenance shop, a standard procedure to repair it must be followed; several parameters are analysed and compared with a specified range. The aim of this work is to develop a **command sequence** for the actuator from which **extract** some **feature to understand its health status** and to identify the nature of the arisen alarm alert.

From a **high-fidelity model**, several simulation campaigns have been performed with **different parameter combinations**. The model response has been tuned on the real data coming from the test rig.

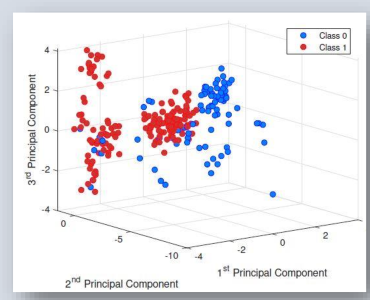
Highly detailed model



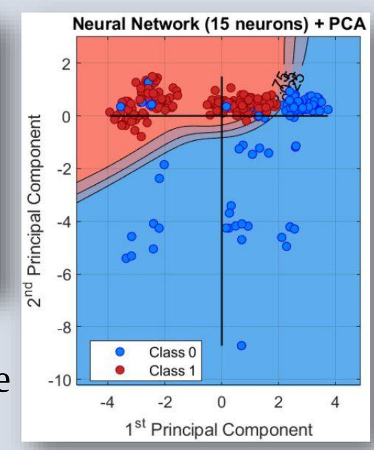


Feature extracted from the simulations

PCA analysis

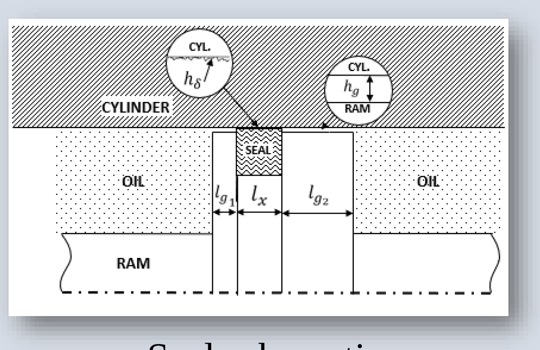


Machine Learning techniques to recognize fault patterns

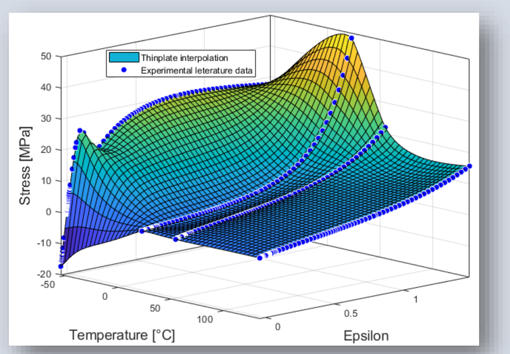


Seals dynamic degradation model

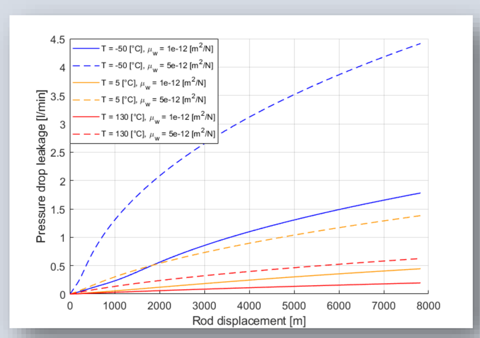
Dynamic seals on the rod are needed to reduce the leakage between the chambers. This **leakage** increases with time due to **wear**. A model of the degradation of the seals in time has been developed, taking into account the **hyperelastic material model**, the **temperature** and the **sliding speed**. Feature have been extracted from the actuator response to track the seals' health conditions.



Seal schematic representation



Hart-Smith model



Leakage vs. time and temperature

PUBBLICATIONS AND COURSES

Publications

- A.C. Bertolino, G. Jacazio, S. Mauro, M. Sorli, High fidelity model for efficiency calculation of ball screws for flight control actuators, in: Recent Adv. Aerosp. Actuation Syst. Components, Tolouse, France, 2018: pp. 153–163.
- A.C. Bertolino, M. Sorli, G. Jacazio, S. Mauro, Modelling of the Ball Screw Drive for Flight Control EMAs, Mech. Mach. Theory. Under review (2018).
- O. Ritter, G. Wende, R. Gentile, F. Marino, A.C. Bertolino, A. Raviola, Intelligent diagnostics for aircraft hydraulic equipment, in: Eur. Conf. Progn. Heal. Manag. Soc., Utrecht, 2018.
- A.C. Bertolino, R. Gentile, G. Jacazio, F. Marino, M. Sorli, EHSA Primary Flight Controls Seals Wear Degradation Model, in: IMECE2018, ASME, Pittsburgh, PA, USA, 2018: pp. 1–12.
- Bertolino, A.C., Jacazio, G., Mauro, S., Sorli, M. (2017) *High Fidelity Model of a Ball Screw Drive for a Flight Control Servoactuator*. Proceedings of the ASME 2017 International Mechanical Engineering Congress and Exposition. November 3-9, Tampa, FL, USA.

Courses

Hard skills

- Experimental modeling: costruzione di modelli da dati sperimentali
- Machine learning for pattern recognition
- Strumenti e tecnologie per lo sviluppo del prodotto
- Sviluppo dei comandi di volo fly-by-wire
- Tecniche di modellazione numerica
- LabVIEW core 1 (National Instrument Customer Education)

8th October 2018