Prognostic of flight control actuators

XXXII PhD Cycle

DIMEAS – Mechatronics and Servosystems Group
PhD student: **Antonio Carlo Bertolino**
Supervisor: **Prof. Massimo Sorli**

WHAT IS PROGNOSTIC?

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

WHY?

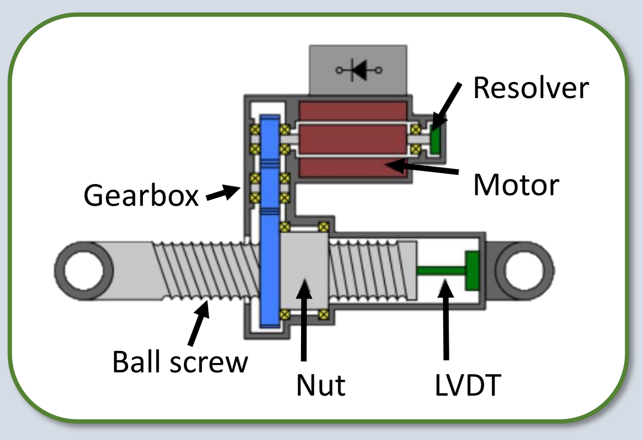
It allows the **maintenance** to become **predictive** instead of scheduled, saving money and time.

HOW?

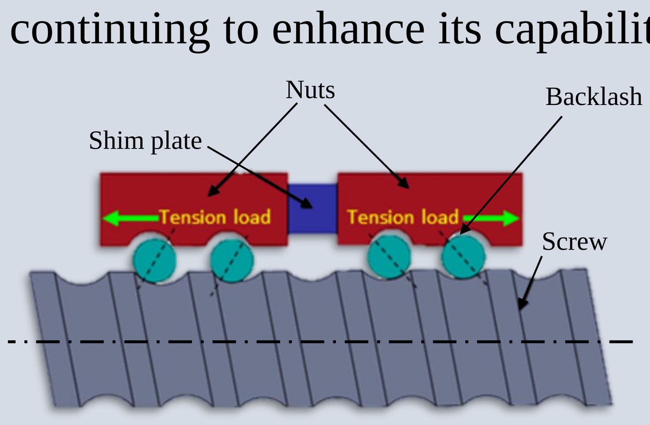
Build a **virtual bench** to predict performance aspects of the servo-system as well as to evaluate its behavior correlating it with small variations of some indicators, associated with the operational life. The need for a **high-fidelity model** is then paramount.

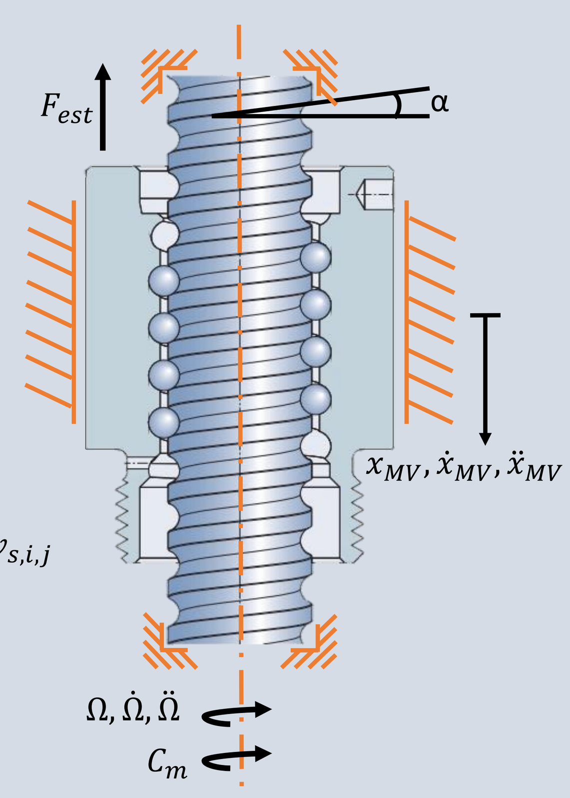
ELECTRO-MECHANICAL ACTUATORS

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.



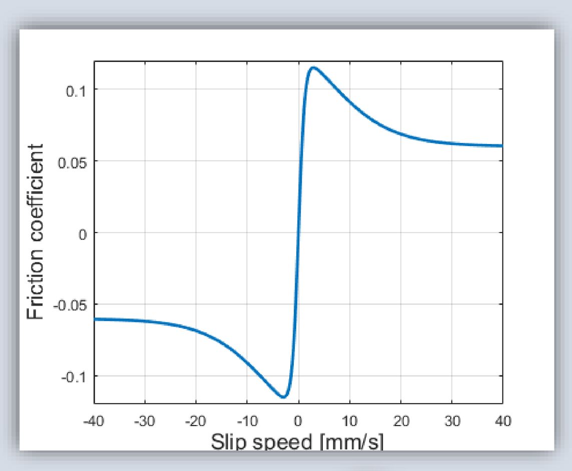
EMAs are typically composed of a brushless electric motor (BLEM), with its Motor Drive Electronics (MDE) and a resolver, mounted on a reduction gear and a linear ball screw, to which end an external load is applied. The Electronic Control Unit (ECU) receives the position feedback signal from and LVDT attached to the screw. Attention has been paid to the mechanical components of the system, particularly to the **ball screw**. An **high-fidelity numerical model** of this component is being developed to understand which roles the several parameters play with regards to the mechanism's efficiency as well as the possible propagation of defects.
A double-nut preloaded ball screw model has been built, and development is continuing to enhance its capabilities.





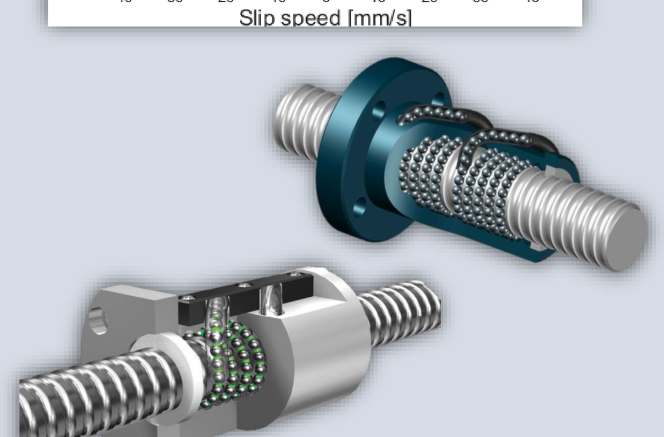
Tangential forces between spheres and grooves:

$$F_t = g_1(\tanh(g_2 v_{s,i,j}) - \tanh(g_3 v_{s,i,j})) + g_4 \tanh(g_5 v_{s,i,j}) + g_6 v_{s,i,j}$$



Efficiency cleaned of the inertia effects:

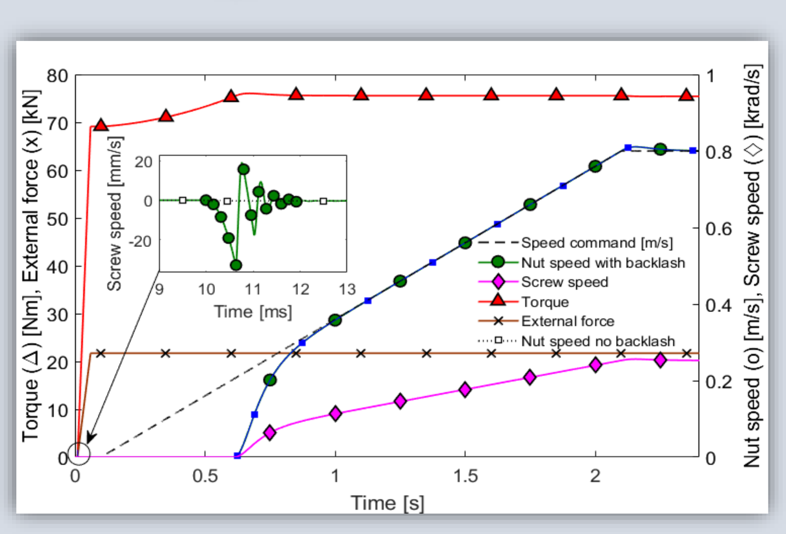
$$\eta = \frac{[F_{ext} + M_n(\ddot{x}_{n,1} + \ddot{x}_{n,2})]\dot{x}_n}{(C_m - I_S\ddot{\Omega})\Omega}$$

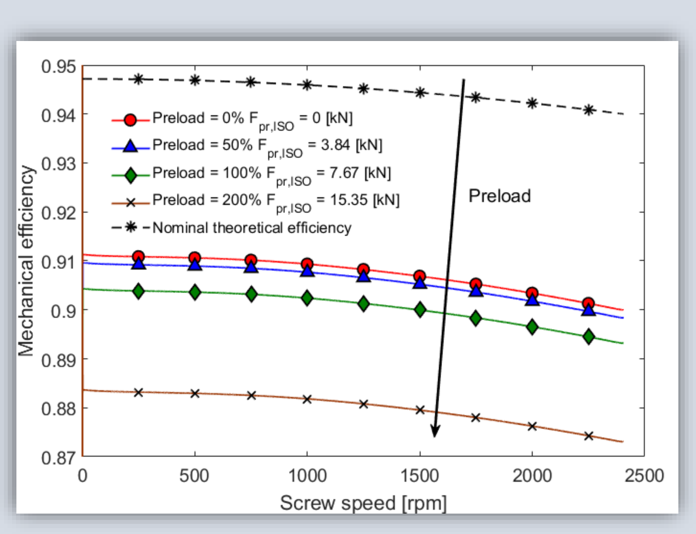


A procedure to rapidly evaluate the efficiency at different speed values has been defined.

A sensitivity analysis on the following parameters has been carried out:

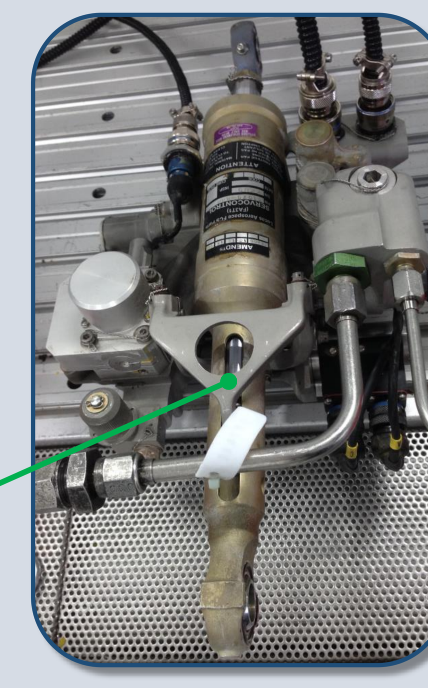
- Preload
- Rolling friction parameter
- External force



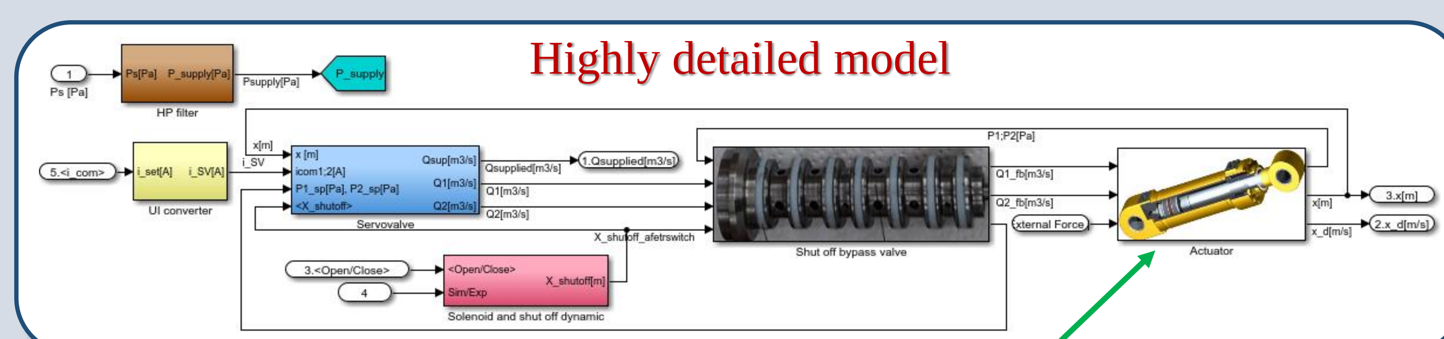


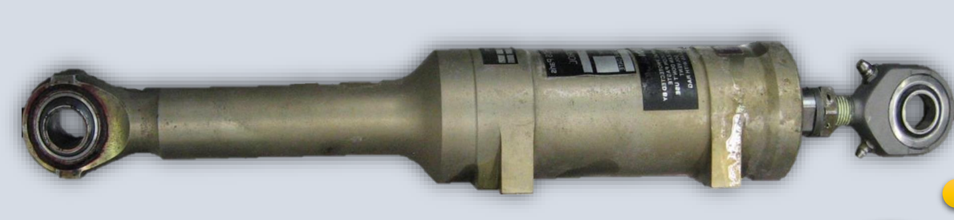
ELECTRO-HYDRAULIC ACTUATORS

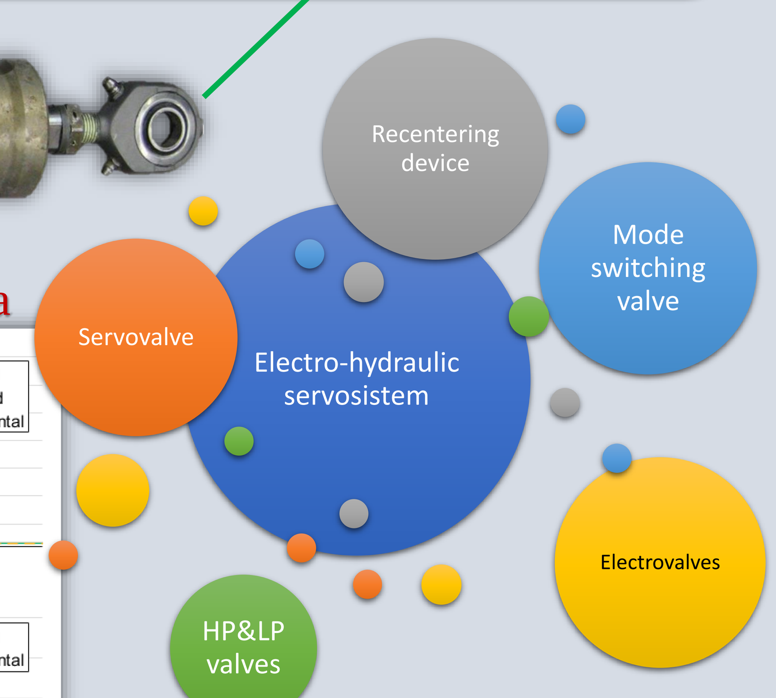
This type of actuators is nowadays the most widespread in the aviation industry. This is due to the fact that they guarantee an extremely low jam probability (about 10^{-9} occurrences/flight hour). Currently, when an actuator is unloaded and sent to the maintenance shop, a standard procedure to repair it must be followed; several parameters are analysed and compared with a specified range.

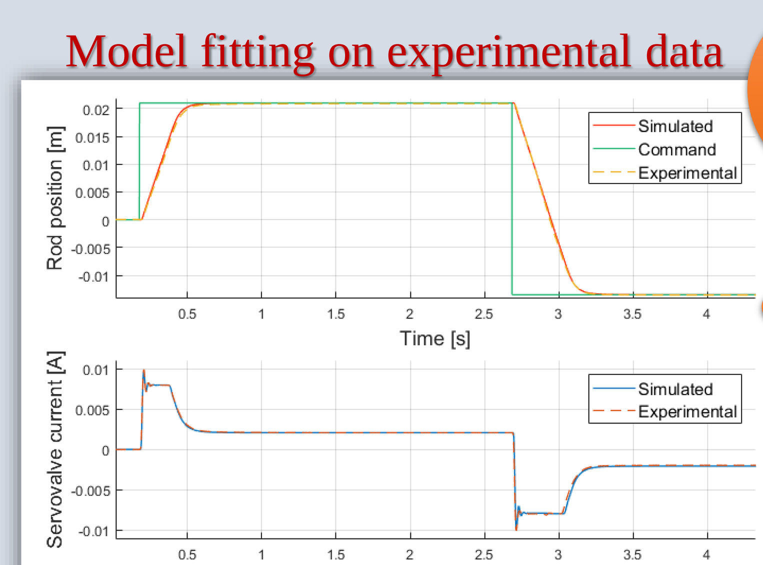


Aim of this study is to develop a command sequence for the actuator from which extract some feature to understand its health status and to perform an investigation on several parameters variation effect, that allows the various parts of that range to be classified w.r.t. the actuator's condition.









PUBBLICATIONS AND COURSES

Pubblications

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

- Tecniche innovative per l'ottimizzazione
- Il metodo Monte Carlo
- Introduzione alla lubrificazione a film sottile: modelli ed esempi applicativi
- Pattern recognition and neural networks (HQC)
- Servosistemi meccanici
- Wear of materials
- Soluzioni esatte del moto del corpo rigido e loro utilizzo in ambito Aerospaziale e Meccanico (HQC)

Soft skills

- Writing Scientific Papers in English
- Lean startup e lean business for l'innovation management

4th October 2017