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Title

Model-based comparative evaluation of stability performance of hydraulic servo actuators and electro mechanical actuators for flight controls

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Abstract

Hydraulic servo actuators (HSAs) using fly-by-wire technology are widely used in today's aviation for flight controls, landing gear, and thrust vector control systems. With the development of greener, cleaner, and cheaper aerospace technologies, the aerospace industry has developed the concepts of "more electric aircraft" and "all electric aircraft" [1]. The HSAs have been widely used in the aerospace industry for many years. The power-by-wire actuators of electro-hydrostatic actuators (EHA) and electromechanical actuators (EMA) are developed and used in many latest generation unmanned aerial vehicles (UAVs) and civil aircraft, such as A350 and B787, for the backup function of primary flight control and active function of spoilers and wheel brakes [2]. However, compared to the conventional hydraulic actuators, the electric actuators have great performance and could be used for more sustainable aviation. In particular, EMA eliminates all hydraulic units to avoid the risk of leakage and improve maintainability [3].

Although EMAs have not yet achieved a breakthrough in safety-critical flight controls for civil aircraft, EMAs are preferred over HSAs in UAV and spacecraft applications. Conventional HSAs consist of a servo valve, hydraulic blocks and a cylinder. However, there is a significant difference in power conversion and flow transfer in the EMA, which generally uses an electric motor to convert electric power into mechanical power and drive the air load through a gearbox and a nut. Therefore, the mathematical models should be developed for high-precision servo control. In addition, the EMA has nonlinearities such as hysteresis, saturation, friction, backlash, stiffness, signals sampling and etc., which are completely different with mature HSA in characterizing flight control dynamic behavior.

This communication aims to the key flight control HSAs subsequently replaced by the EMAs. A model-based virtual prototyping approach is proposed to compare the similarities and specifications in terms of stability control performance. To overcome the complex engineering requirements and reduce the hierarchical topology of physical effects, the bond graph modeling theory is introduced to facilitate the analysis of power flow and signal flow transmission in the actuation system. Finally, this research formulates the principle of evaluating functional and behavioral stability permanence, and preserve the constancy of representability of flight control characteristics during the consistency of actuation system modeling space.

References

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