Enhanced hybrid prognostic approach applied to aircraft on-board electromechanical actuators affected by progressive faults

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ABSTRACT

In the last generation aircrafts, the architecture of the powered flight control system is radically changing, since the hydraulic systems are gradually replaced by electromechanical actuators (EMAs), according to the More Electric Aircraft paradigm [1-2]. Being some onboard actuators safety critical (in particular those related to primary flight controls), the practice of monitoring their behavior (through the electrical acquisition of relevant parameters) to determine their health condition is a task of growing importance within the system engineering. This discipline is often referred to as Prognostics & Health Monitoring (PHM) [3-4] and has the purpose of predicting the remaining useful life of the components, until they are no more compliant to their required performances and specifications. Among the several possible approaches that could be employed to this purpose, the choice of the best one is driven primarily by their effectiveness in correctly identifying the health conditions of the system, since each technique might be more or less useful in a given situation. The approach usually adopted consists in the use of a model-based identification of the health condition of the system, to identify the precursors of failures while they do not affect significantly the actuator performances. Then, a statistical extrapolation is employed to estimate the remaining useful life of the system. Authors propose a Genetic Algorithm (GA) based fault detection tool [6-7], relying on a model-based approach to directly compare the system output to that of a monitor model (MM), which is able to reproduce accurately the dynamic response of the actual EMA in terms of position, speed and equivalent current, even under the effects of different failure modes while keeping a reasonably low computational cost [5]. The proposed FDI algorithm [8] has been extended to seven progressive failures, introducing the proportional gain drift fault, which models the effect of an electrical failure of the PID controller or the feedback position and current sensors. To test the algorithm, a dedicated simulation test environment was developed: two Simulink models representing the real EMA and the corresponding MM have been respectively used to simulate progressive faults and to evaluate the accuracy of this prognostic algorithm. Results showed an adequate robustness and a suitable ability to early identify malfunctions with low risk of false alarms or missed failures. Moreover, the effect of a failure different from those considered was studied, to avoid safety concerns related to the missed identification of an incipient failure, hidden by another unknown failure mode.

Keywords: Aircraft Primary Flight Controls, BLDC Motor, Electromechanical Actuator (EMA), Fault Detection and Identification (FDI) Technique, More-Electric Aircraft, Prognostics, Genetic Algorithm.

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