Diagnostic and prognostic of airplane motor equipments towards an adaptive maintenance

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1. Problematic treated:

The maintenance of the airplane motors equipments is nowadays based on reliability on ground tests, which provide the components MTBF (Mean Time Between Failures). The maintenance is programmed accordingly with those statistical results. The problem found with that programmed maintenance is its lack of flexibility in front of flight variables, since each motor could be submitted to different flight conditions. As a result, over programmed maintenance operations as well as unexpected motor failures carry out expensive direct operation costs for airlines.

2. Objectives and framework

The PhD work is developed within the framework of European project TATEM (Techniques And Technologies for nEw Maintenance concepts) in collaboration between the LAAS, Hispano-Suiza and TechspaceAero (Group Safran). The objective is to provide diagnostic methods for motor carburant and oil systems health monitoring, as well as the introduction of aging and failure prognostic towards an adaptive maintenance.

3. Context

The diagnostic has been focused in the context of non-linear complex systems and piecewise linear systems, which are those who affect the whole system dynamics intermittently, as the actuators do. The methods applied are related to the system continuous and discrete parameter estimation in the framework of hybrid complex system, by linearization in function of system operating points. Concerning the data analysis used in diagnostic methods, the information theoretic entropy has been introduced for the input-output data validation in terms of information provided by the data. Considering the existing prognostic methodologies, the trended-based methodologies are found to be the most appropriate for the problem studied. These methodologies are based in the a priori knowledge of the system combined with the on-line data treatment to update system reliability in order to evaluate aging.

4. Work progress:

Trending-based approaches

Evolutionary prognostics may be implemented on systems that experience conditional or slow degradation faults related to loss efficiency. This approach requires sufficient data available and parametric conditions that would allow system performance mode identification. The trend-based techniques use indicators extracted form sensed data that are identified to be correlated with faults or anomalies. Once these indicators are obtained, they can be tracked and trended over the system life so as to provide degradation information.

A key concept in this framework is the remaining useful life, represented by the probability distribution function (PDF). The PDF is a mathematical expression of the failing probability of a system. The most commonly PDF used are the Weibull distribution when expressing a failure probability model. Furthermore, a PDF is actually a conditional PDF that changes as time advances.

So, the conditional distribution function is recomputed at each current instant actualized with the information provided by system features tracking. Among evolutionary techniques the state estimator prognostics is stressed since it is based on estimation and prediction techniques as the Kalman filter or the ARMAX models.

Bench tests data analysis for degradation estimation

Figure below shows a sample of data recorded following the typical cycle:
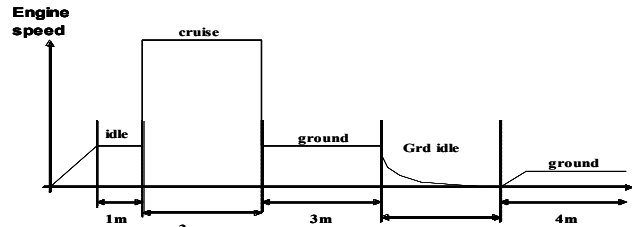
Typical airplane engine cycle in life tests

The data sets used in this study correspond to the equivalent 2000 actuator cycles. Data sets correspond to four consecutive periods: A-November'06, B-December'06, C-January 2007 and D-February'07

Aging indicators

Using the data provided by the sensors, many possible aging indicators candidates can be proposed: difference between signals provided by the redundant sensors, difference between input and output, reconstructed variables by sequential estimation and their standard deviation.

Aging indicators results

The figures below show the time evolution of the mean and standard deviation corresponding to the redundant sensor difference. Same analysis has been carried out with other indicators as the servovalve current. Both distribution parameters show an increasing tendency from initial cycles to the end of available data.
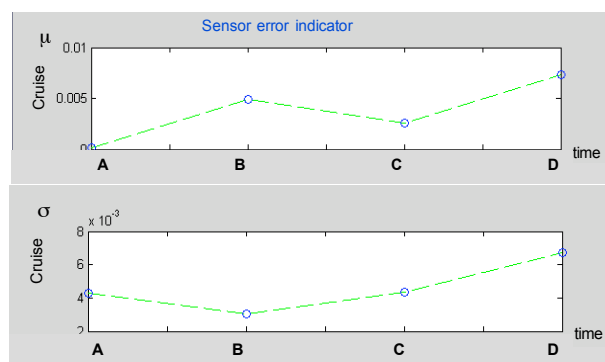
Sensor error indicator mean and standard deviation vs time

The figure below shows the deviation, due to aging, of the system estimated parameter set (blue and red points) related to the original point (round) in the parameter space partition
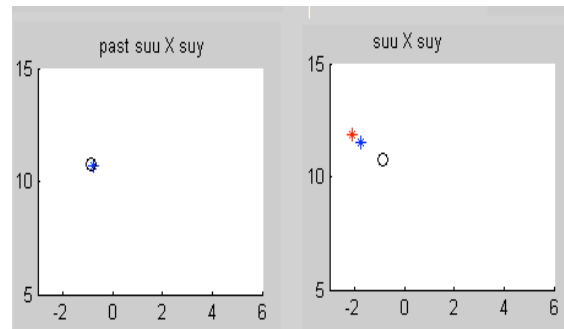
Aging indicator monitoring by means of estimated parameters space partition

5. Publications

- E. Diez-Lledó, Aguilar-Martin, Joseph. *Oil system degradation monitoring*. Internal contract rapport in collaboration with TechspaceAero.
- C.ISAZA NARVAEZ, E.DIEZ LLEDO, T.KEMPOWSKY, J.AGUILAR MARTIN, M.V.LE LANN. *System operation modes identification by means of finite time window pseudo-inverse estimation and learning parameter space partition*. Submitted to review
- E.DIEZ LLEDO, J.AGUILAR MARTIN, J.R.MASSE, A.SIF, E.GRIFUL. *Hydraulic actuation loop degradation diagnosis and prognosis*. 1st CEAS European council of aerospace and security. Berlin, Sept'07
- C.ISAZA NARVAEZ, E.DIEZ LLEDO, H.HERNANDEZ DE LEON, J.AGUILAR MARTIN, M.V.LE LANN. *New decision method for functional states validation in a drinking water plant monitoring*. CAB, June'07, IFAC congress.

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