Real-time Monitoring of a Full-scale Fatigue Test

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The full-scale fatigue test is one of the major tests in the process of certification and qualification of a new aircraft type. Additional airframe fatigue tests may be also conducted in life extension programs. In both cases, setting-up the test facility can take up to one year of implementation, while the test itself can last for several years.

The experiment is based on a fatigue spectrum representative of the number of flight hours and the usage statistics expected during the service life of the airframe. The spectrum is applied by several actuators introducing a discretized load on the structure. By definition, the spectrum is divided in "units" that have to be executed multiple times.

During the test, three signals are constantly recorded: the command signal (CMD) set by the spectrum, the feedback signal (FDBK) corresponding to the real strength applied by the hydraulic jacks and the measured signal (MES) detected by strain gauges implemented close to the critical points. An algorithm was developed to process and compare those three signals. Thanks to an experimental matrix, the actuators involvement in the stress at a critical point and supposedly measured by a strain gauge is defined by a linear combination. Therefore, three damage values can be calculated from the CMD, the FDBK and the MES signals for each strain gauge at any time and more judiciously, after one unit has been entirely played. Most of the monitoring indicators lean on those values.

Indeed, the first goal of a real-time monitoring is to improve the knowledge and the compliance of the loading applied to the airframe. According to Basquin's law of fatigue, a relevant indicator has been built from the calculated damage values induced by the CMD and the FDBK signals, showing the actual difference of severity in terms of stress observed at the critical points. When necessary, the adequate adjustment of one or several hydraulic jacks can be made during the test, mostly to prevent an overloading or an underloading of a critical component.

A second indicator was also created to ensure the global stability of the structural damage following each application of a unit. Until now, this indicator was only verifying the good reproducibility of a unit, by appreciating the difference in the damage values for all the critical points. For future tests, it will be improved and sharpened to guide and determine the visual inspection steps, which are currently set by the number of flight hours and not by the remaining potential of the components.

Ultimately with the real-time monitoring, the fatigue data can be processed and verified during the test and not exclusively when the test is over. The damage calculations produced throughout the tests can be compared to the simulated ones, enabling the deviations to be flagged and handled before the occurrence of any structural damages. Adjustments and modifications can be conducted at a suitable time and for instance, an irrelevant or malfunctioning strain gauge can be relocated or replaced to optimize the test.

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