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Acoustic Emission Localization in the Dynamic Fatigue Testing of a Composite Wing

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Abstract: Acoustic emission (AE) is current trend of non-destructive monitoring methods. It suits perfectly for supporting of fatigue tests. Method is also applicable in monitoring of quasi-static tests. AE helps the engineers to understand the degradation process in the tested object and also keep track of the failures. Article offers an insight into the practical experience with acoustic emission. Tests of three different composite structures (wing, fuselage and hull panel) were chosen to illustrate the application of AE monitoring system during fatigue and quasi-static tests. These tests have shown that accuracy of localization is sufficient to identify damaged areas. Moreover the system may offer an early warning of upcoming failure.

Method used and described in this article is the *"passive acoustic emission detection"*. This means, that the sensors, attached to the tested structure, were "listening" to the emissions produced (emitted) by component due to the external loading. This external force builds the level of elastic energy in the structure, which is released afterwards as the sound and heat energy. The released energy travels through the structure with certain speed, specific to each material.

Gain the experiences

The most important aspect of using acoustic emission for monitoring is about experience. Using AE for different test, conducted at the Institute of Aerospace Engineering (IAE), led to different applications. Important steps prior each test is to measure the speed of sound (speed of wave propagation), damping characteristics and accuracy. Choosing the type of localizations is important decision. For some tests the linear localization is sufficient, some tests will benefit from planar localization. The type of localization depends on the experience and requested results. In fatigue tests, linear localization is used for preliminary measuring and identifying the most critical areas. These critical areas can be monitored in more detail by additional sensors (both types of localization are possible: denser linear, or planar).

Clearly, the luxury of identifying the critical areas belongs to fatigue tests only. Considering static strength tests is different case.

Quasi - static test

Acoustic emission analysis has been used for a quasi-static test of the in-house built VLA category airplane, the VUT 061 Turbo. In this case, the results were huge success, because the AE identified the same problematic area as the finite element analysis has predicted. Acoustic emission analysis has proven to be really accurate in identifying the areas, where the foam core collapsed. Moreover it discovered the exact point of the final failure initiation and linked this event with the loading level.

Fatigue test

Fatigue tests are recognized by international authorities as a proof, that the tested product ensures either safe life or provides time to discover any problems without endangering the user. The object of these tests can be whole assemblies, such as wings or fuselage, or just single parts or representation of parts (laboratory samples).

A total of four wing segments were tested at the IAE since 2008. These tests were an inspiration for using the acoustic emission analysis for monitoring of the test process. There was a hope that it would be possible to predict and track failures in the composite structural parts.

The acoustic emission is easily applicable on the composite wing under fatigue tests. It offers quite accurate structural-health monitoring. The drawbacks are mostly in the need for experienced personnel and – in case of long fatigue tests – huge data storage and computer processing capacity.

As it turned out, it takes a very experience engineer to immediately recognize the upcoming failure. Some indications of upcoming failure are easily hidden in the amount of data. Other failures, like loosened bolts are very easily detectible even for a novice.

The series of four wings fatigue tests was preceded by a series of 5 static tests as a part of airworthiness certification (first in 2004). First fatigue test (specimen #6) ran in period from September 2007 till April 2008. As it was the first fatigue test of its kind at the institution, all parameters had to be defined and the experience to be gained. After two segments were tested, other changes in the design were made and sample #8 has been tested under static loading in February 2010 (sample #8 was a full scale wing). AE has been involved in this static test; however the results were inconclusive for unpredicted area of failure.

Since January 2013 until august 2014, wing segment #9 has been tested. This test will be discussed further in this article.