NON DESTRUCTIVE INVESTIGATION TOOLS: VALUE CREATION FOR STRUCTURAL TEST MONITORING

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Keywords: *test monitoring, full-field*

Abstract

The common application of non-destructive testing (NDT) techniques is the detection of defects in structures, internal or external, during the production or maintenance phases. However, the increasing value of structural testing led EADS Corporate Research Centre to implement these methods in order to monitor structures during mechanical tests. Indeed available techniques allow to have more data at one's disposal and thus to draw more profit from individual test results.
Three main fields for using NDT techniques have been identified and implemented from the sample scale to the full structure:
- damage detection
- damage sizing
- full-field strain and stress measurement
The information and value provided by these techniques have been now clearly assessed.

1 Introduction

Gains in weight are an important objective in new aircraft programmes in order to improve the global performances. Many actions have been undertaken that led to an increased ratio of composite materials in primary structures. It appears also important to get more precise sizing of structures. Possible axes of progress are:

- better understanding of structure behaviour under the range of loads
- better understanding of damage mechanisms

The tools conventionally used for mechanical test monitoring are mostly point probes and the number of measurements is greatly limited. This situation led us to investigate new techniques, offering a better value to testing. In this respect, the potential of NDT techniques and other derivative methods appeared mostly interesting.

2 Potential of Non Destructive Techniques

NDT methods are commonly used for the detection and characterisation of defects in structures, either for production or maintenance quality insurance purposes. Characterisation implies in most cases that it is possible to size a defect, and even to evaluate its geometry in auspicious conditions.

The range of methods is quite large. A quick overview of their potential shows their possible application in mechanical test monitoring. Ultrasonic waves suit the detection of cracks or delaminations, eddy current are sensitive to cracks or fibre rupture while acoustic emission or infrared thermography have a potential for detecting microdamages.

Optical methods have known a significant growth in the last years. Main uses in NDT concern the detection of debonding or delamination damages. However, most techniques enable to achieve a quantitative measurement. Among available techniques, projection Moiré or fringe projection enable to characterise out-of-plane deformation. Other methods based equally on triangulation enable to get in-plane deformation, and possibly in complement out-of-plane deformation. Photogrammetry but preferably image correlation techniques offer this potential.

Hence it is possible to identify two ranges of application. Direct applications of NDT methods enable:

- the monitoring of defect initiation, through microdamage analysis,
- the monitoring of defect growth and consequently the possibility to adjust the defect characteristics that the mechanical model takes into account.

More, acoustic emission is used on a regular basis to ensure the safeguarding of high value structures.

Besides, optical methods enable to characterise globally the behaviour of a part and consequently to adjust the parameters of mechanical models.

3 Application to Structural Testing

The applicability of NDT methods to structural test monitoring has first been assessed on small-scale tests. To that end, extensive validation tests have been conducted, using records from conventional gauges.

In a second phase, the methods have been developed when necessary, in order to fit the size or geometry of the structure for instance, then have been applied to larger scale parts. A significant range of use is running currently. Representative examples illustrate below the capabilities of these tools. The complementary aspects of the various techniques will be addressed through application to a notched composite sample submitted to tensile test.

3.1 Identification of damage mechanism

Acoustic emission is a powerful method for detecting and localising micro- and macro-damages in materials. When used during a test, it makes it possible to connect damage initiation and propagation phases with specific loading steps. One dedicated application is the safeguarding of high value parts and as such acoustic emission is commonly used during certification tests of aircraft components.

The diagrams in Fig. 1 reproduce results obtained on the notched composite sample. They illustrate the occurrence of small damages during most of the loading (energy lower as 10^3) while major damages appear in the last loading phase, accumulating quickly and leading to the ruin of the sample.

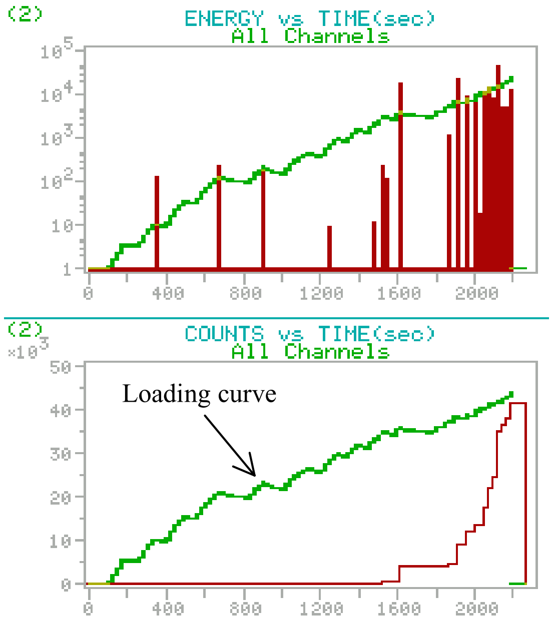

Fig. 1: Damage occurrence in a notched composite sample

3.2 Characterisation of defect growth

Specific systems based on ultrasonic or electro-magnetic techniques have been developed in order to provide maps of the damage at regular intervals during mechanical tests.

One very first application aimed at better understanding the fatigue behaviour of longitudinal joints. Indeed the respective influences of initiation and propagation phases on fatigue resistance are not well known. A better understanding would help in selecting the most favourable properties of joints to improve the life. An in-situ system based on ultrasounds has been developed to record the crack profile for all joint holes during a fatigue test. The analysis and exploitation of the records are much easier than it would be using a destructive approach and cycle counting. The profile of the crack for rivet n°10 is shown below in Fig. 2. The results present a good correlation with destructive examination.

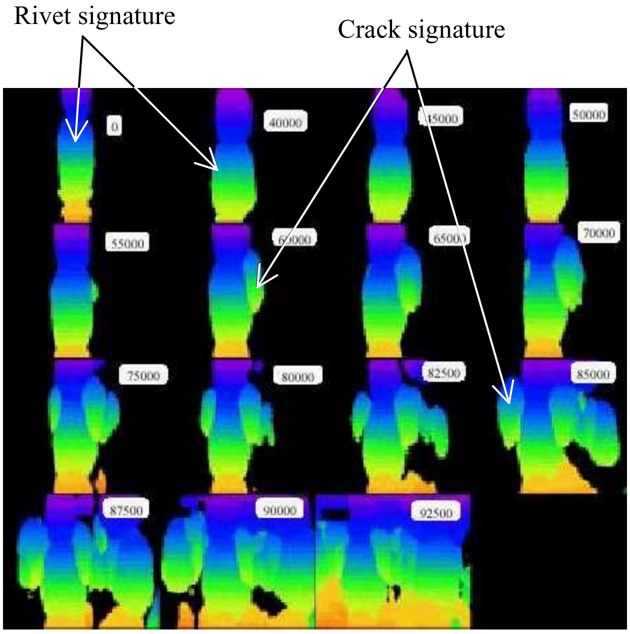

Fig. 2: Crack propagation around rivet n°10

Having the possibility to automatically monitor the crack propagation during fatigue enables to compare technical solutions and see which properties are favourable to fatigue resistance.

The second example presented for this type of application concerns the notched composite sample. The 4 successive ultrasonic C-Scans presented in Fig. 3 illustrate the delamination process at each notch tip. Quantitative information on delamination depth and area is available.

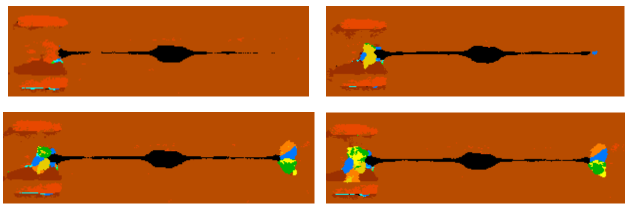

Fig. 3: Delamination progress at notch tips

3.3 Deformation and strain measurement

Optical methods offer the unique ability to provide with a full-field map of part deformation, both in plane and out of plane. This potential is highly interesting for the adjustment of model parameters. More, contrary to the situation when using conventional displacement or strain gauges, it is not necessary to have a good knowledge of the structure behaviour before positioning adequately the gauges. The behaviour can be identified with the very first test.

This is illustrated in Fig. 4 and Fig. 5 below that display the out-of-plane deflection of a fuselage panel submitted to a compression load. In this case, the efficiency of full field data for model adjustment and validation can be appreciated.

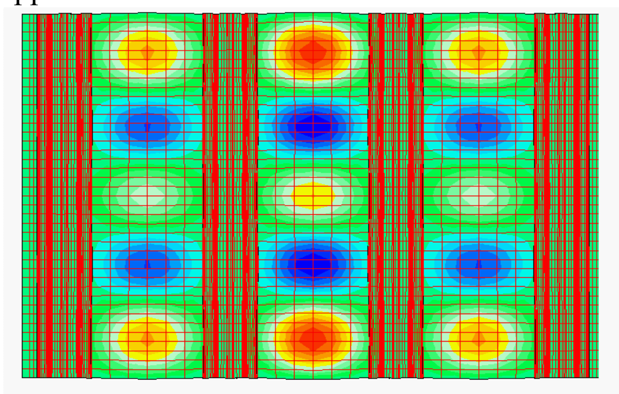

Fig. 4: Finite element prediction

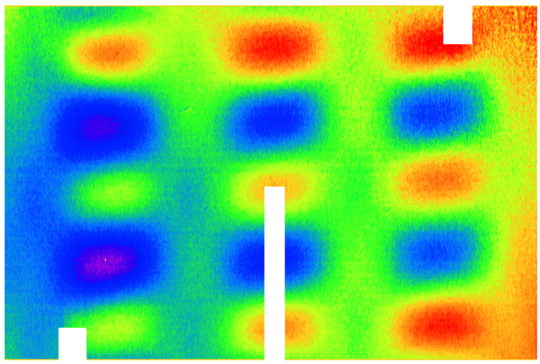

Fig. 5: Projection Moiré recording

The global information provided by these techniques is especially powerful when it comes to the tuning of mechanical models and the understanding of complex part behaviour.

Similar tools are available to provide global strain measurement on structures. The strain map calculated on the notch composite sample in Fig. 6 illustrate this feature.

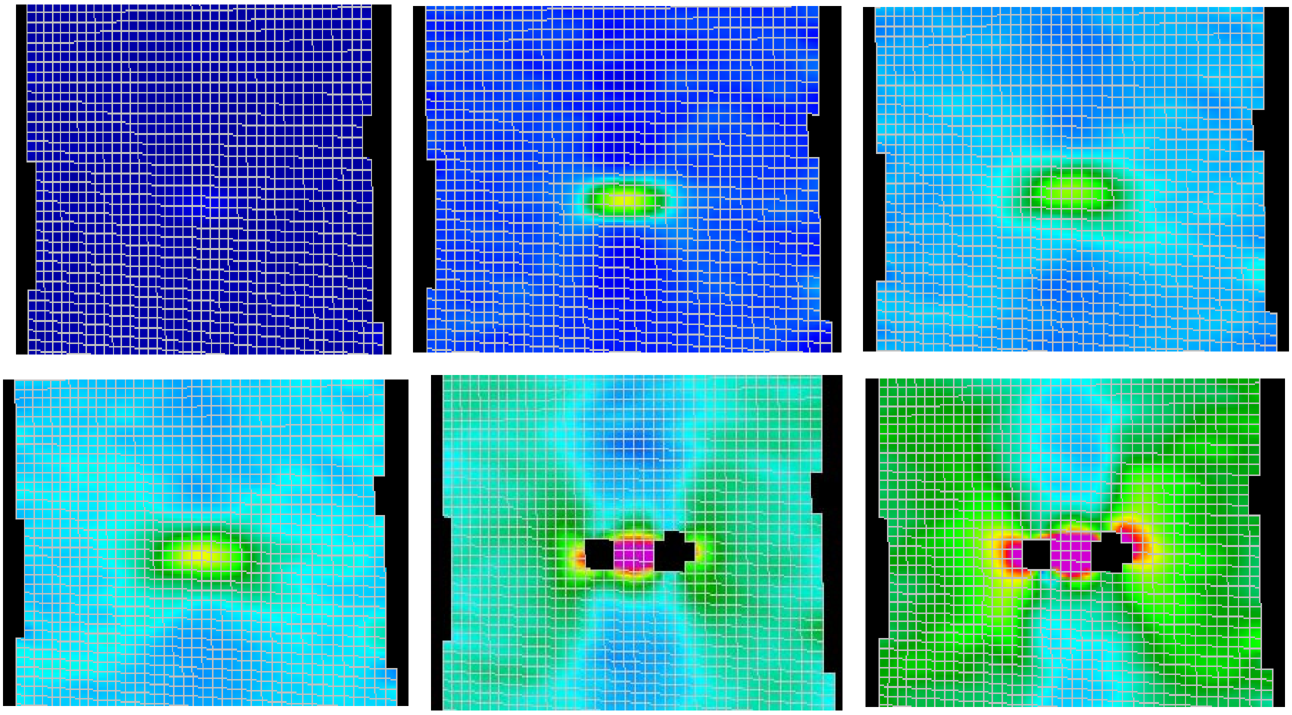

Fig. 6: Strain field during tensile test on a notched composite sample

4 Conclusion

The extension of conventional NDT techniques to test monitoring allows improving in a significant way the information, both qualitative and quantitative, derived from the tests. Considerable advances are expected in a better understanding of damage mechanisms, defect propagation or structure behaviour of complex parts. The increased use of these tools shall be a valuable asset in the search for tighter sizing.

After the initial implementation phase in the corporate research centre, the spreading has began in several business units.