Development of a technological test for an aircraft braking application: Study of a carbon/carbon composite and metal structure assembly

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Abstract

Carbon-carbon composites have become the reference material for aircraft braking since the late 1980s (1). The ability of carbon/carbon brakes to provide reliable and consistent braking performance under intense temperature conditions improves aviation safety, particularly during emergency landings where maximum braking efficiency is critical.
These composites are obtained by assembling a carbon fibre preform and a carbon matrix called pyrocarbon, which in our case is obtained by chemical vapour infiltration. The materials obtained in this way offer high thermal capacities combined with temperature stable mechanical and tribological properties, giving them a major advantage over metallic materials (2). What's more, the low density of these materials is a major advantage for aerospace applications.

A heat sink consists of an assembly of brake discs, some of which are static, called the stator, and are connected to the fixed structure of the brake, while the others, called the rotors, are driven by the wheel. The aircraft's kinetic energy is dissipated by friction at the interface between the various discs. In addition to their tribological function, the discs must be able to transmit the braking torque. To achieve this, metal parts are riveted to the disc to ensure that the braking torque is transmitted throughout the life of the disc, even under extreme braking conditions.

The behaviour of this assembly remains complex and the justification of these structures requires technological testing. The traditional approach is based on full-scale tests to take into account all the complexity of the structure and the mechanical and thermal loads. Although indispensable and irreplaceable, full-scale tests have their drawbacks. In addition to cost and time, these tests are difficult to instrument. As part of the ongoing optimisation of the heat sinks, we need a more detailed understanding of how our brake discs work.

The work presented consists of the development of a specific test to study and justify the behaviour of the assembly under different loading conditions, both static and fatigued. The test procedure is based on multi-instrumentation. The aim is to create an intermediate test in the test pyramid (3) between the full-scale heatsink tests and the material characterisation tests. To achieve this, specific instrumentation has been developed for this test using Digital Image Correlation (DIC) and Acoustic Emission.

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Digital Image Correlation was used in several areas. Firstly, to analyse the overall behaviour to determine the boundary conditions required to model the test. In addition, a detailed analysis of the behaviour of the rivets under different loads was carried out. Finally, image correlation was used for fatigue testing to improve the reliability of crack detection.

Acoustic emission has also been used to detect and analyse damage in C/C composites (5). This technique is particularly well suited to ceramic matrix composites in general and carbon-carbon composites in particular. It has the advantage of providing information that are very complementary to image correlation. In the context of our work, acoustic emission has enabled us to detect the initial damage to carbon-carbon composites and also to obtain information on the damage kinetics.

The combined analysis of the elements obtained by image correlation, acoustic emission and post-mortem analysis using X-ray tomography provides a detailed understanding of the behaviour of our assemblies.

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