Using strain gages in automotive and aerospace applications

Greg Reed - March 07, 2007

Strain is defined as the amount of deformation an object undergoes in response to an applied force. While it is easy to observe the results of strain—a stretch or a compression, for example—measuring the force that produced the deformation often presents a challenge.

In a recent interview, Dirk Eberlein, product manager for strain gages and experimental analysis at Hottinger Baldwin Messtechnik (HBM) in Darmstadt, Germany, discussed the use of strain gages in test and measurement applications in the automotive and aerospace industries.

Q: How do strain gages ensure structural integrity for aerospace or automotive applications?

A: Today, millions of strain gages are used in the field of experimental stress analysis. Testing newly developed components using strain gages has become a standard, particularly in the automotive and aerospace industry. Measuring strain with strain gages and computing mechanical stress on the basis of known material properties has been an established method over the past few decades. Already in 1941, first investigations were made using a large number of strain gages—50,000 strain gages were used in two months.

At that time, the American aerospace industry had been particularly interested in employing strain gages, because of their ease of use. This situation has not changed. In the field of experimental stress analysis, strain gages are the sensors that are used most often.

Q: Why have composites and irregular-shaped parts changed traditional strain-gage testing procedures?

A: Strain-gage installations on fiber-reinforced plastics feature some properties that distinguish them from "standard" installations. The mechanical properties of fiber-reinforced plastics are directionally dependent. Therefore, the standard theoretical approach of Hooke’s Law cannot be applied anymore. Only if the directionality of the modulus of elasticity (Young’s modulus) of the material is known, can and may the stress in fiber-reinforced plastics be computed. This is one of the main distinguishing features.

Furthermore, it is essential to consider some special characteristics when selecting the strain gages and preparing the measuring point. Using fiber-reinforced plastics, however, opens up a wide range of new and as yet unknown applications in test and measurement. For example, HBM developed a patented strain gage that can be embedded into structures during manufacturing. This enables strain to be measured at points that normally are no longer accessible with classical surface installations.
These strain gages offer more advantages when used in applications with components in a flow—for example, in wind tunnels. By embedding the strain gages into structures, they no longer affect the test result, which is the case, for example, with sensors that are installed on the surface and may cause turbulences.

At HBM, we recently published a free brochure entitled "Structural integration of strain gages" that provides more information on how to correctly embed strain gages.

Q: Are there special problems associated with mounting strain gages for auto/aero applications?

A: Fiber-reinforced plastics are used ever more often. It is a well-known fact that Boeing (for example with “Dreamliner”) and Airbus increasingly rely on fiber-reinforced plastics in the new generation of their airplanes.

In particular, when preparing the measuring point, test engineers need to consider some special properties of fiber-reinforced plastics. For example, it is essential to be very careful when treating plastics with solvents that might cause moisture expansion or etching of the material. Roughening the measuring spot with emery cloth is prohibited very often. Fibers might be damaged or destroyed by roughening. The strength properties of the structure might be affected. With "classical" materials such as steel or aluminum, the above mentioned factors may be neglected.

Q: What is the best method for data acquisition from strain-gage test setups?

A: Distributed data acquisition has become established, especially in the field of aerospace where up to 20,000 channels are simultaneously tested. Test data are acquired and digitized on site, in as close proximity to the strain gages as possible. An appropriate bus system is used for data transfer to the data servers.

Powerful software, suited to client/server architectures, completes the data-acquisition system. Our proprietary enterprise software meets these requirements and has been tried tested by different users over past years, for example with the JSF F-35 Lightning II Joint Strike Fighter, where ultimately 20,000 channels were used for data acquisition.

Q: What are some guidelines for strain-gage evaluation and eventual selection?

A: As mentioned above, the theoretical approach of Hooke’s Law cannot be applied anymore with fiber-reinforced plastics, because the mechanical properties are directionally dependent. If the directionality of the modulus of elasticity of the material is not known, computing mechanical stress is not possible or would provide incorrect results—possibly with fatal consequences for the design of the components.

On principle, the same rules apply to strain-gage selection as to other inhomogeneous materials, such as concrete. The strain gage should be longer than the distance of the fibers by at least a factor five. Meanwhile, the width of the strain gage should bridge several fibers.

Using 350-ohm strain gages also has proved successful. Because of the inevitably higher current flow, low-impedance strain gages tend to cause “self-heating” at the measuring point.

Q: Do you have additional guidelines for engineers conducting strain-gage test and measurement?

A: Especially in the field of strain-gage measurements, I am of the opinion that you should measure
as precisely as required—and not as precisely as possible!

I often wonder why, in experimental stress analysis, users want to measure "very precisely," although they have little or no information about the material properties of the component to be tested, such as its modulus of elasticity. The result of experimental stress analysis—the mechanical stress—can only be as precise (or imprecise) as the individual influence factors—for example, the modulus of elasticity.

Also see:

- The case of the resistor turned strain gauge
- Tips for better strain-gage measurements