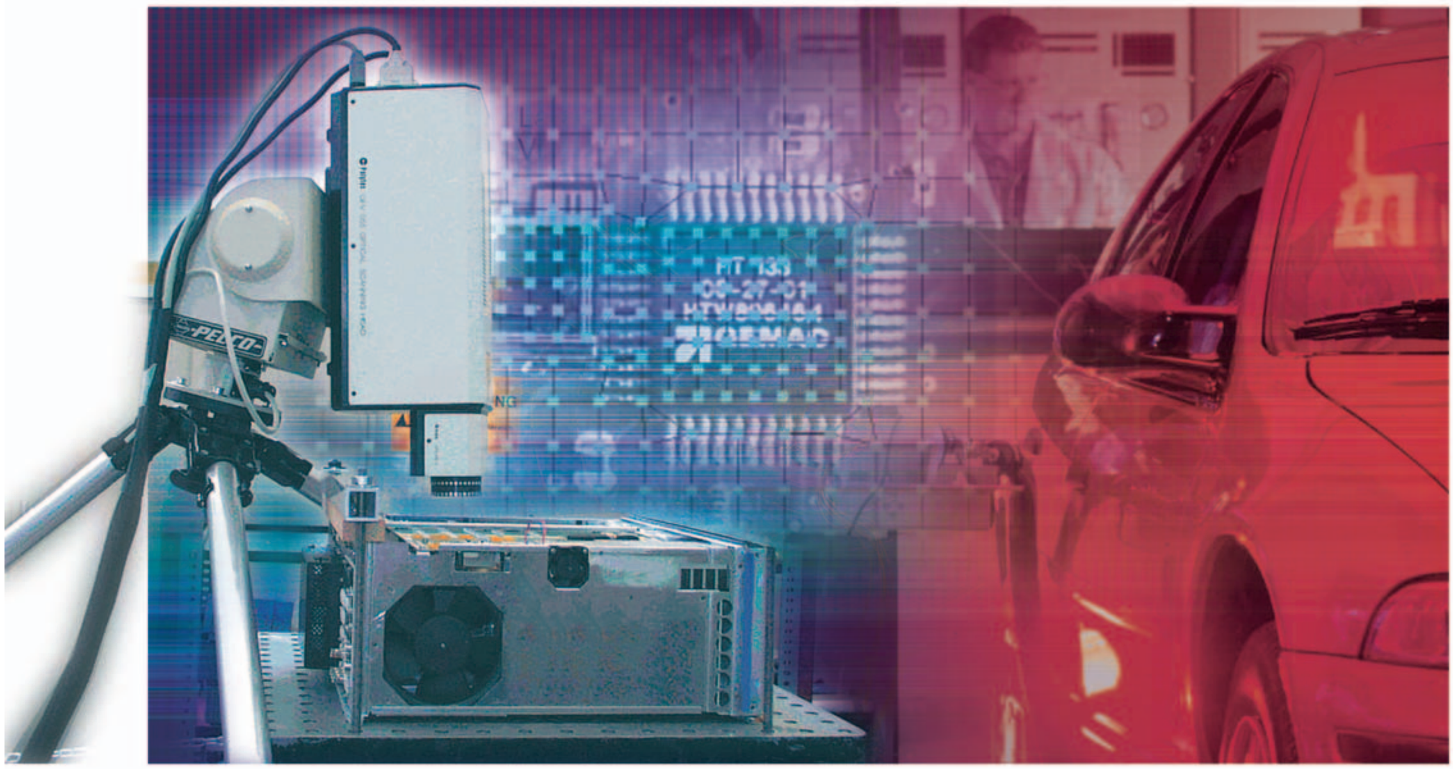
Long-term *Reliability*



Characterizing the Thermomechanical Properties of Sensors Using Laser Vibrometry

Over the last few years, micromechnical sensors have become ubiquitous in every day technology. Their failure-to-perform can adversely affect simple products as well critical, safety-related automobile technology. The long-term reliability of sensors is of increasing importance through all stages of development and production and is characterized using sophisticated measurement procedures

Thermomechanical Sensor Properties

Depending on the application, micromechanical sensors are designed with different superstructures, materials and joining technologies.

Integrated together to form the sensor, these components determine the device's elastic, dynamic and thermomechanical properties.

Specific deformation under thermal and static load as well as mode structure, vibration amplitude and resonance spectra are also a direct result of these components. The long-term stability of these components is critically important for the long-term reliability of the sensor.

Measurement Procedure

The thermomechanical properties are measured using various non-contact methods and tools. To measure deformation, ESPI methods or image-correlation methods are used.

The vibration characteristics of micromechanical sensors can be identified with the aid of laser vibrometry.
For this purpose, AMITRONICS uses a single point vibrometer and a scanning vibrometer. The lateral resolution of these vibrometers and thus the smallest measurable structural size is defined by the size of the laser focus of approx. 30 µm. The scanning vibrometer is particularly good for thermomechanical characterization of electronic subassemblies because it shows the results as animated 2-dimensional vibrations.

Basics

Characterization of the dynamic behavior of a subassembly is based on the spectral position of significant eigenfrequencies, the associated deflection shapes and the amplitudes measured. If for example the properties of the joints change as a result of aging, fatigue or environmental influences, then the dynamic properties of the sensor often show a change which can be measured by the vibration characteristics.
For example, if vibration-relevant structural elements get "softer", then

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the eigenfrequencies become lower (Figure 2). Alternatively, if the stiffness increases, then the eigenfrequencies become higher. Tears and fractures not only reduce the frequency but also change the deflection shapes, particularly in the upper frequency range.

Typical Sequence of a Characterization

Characterization begins with a properly designed measurement setup. Components can be self-excited or externally excited. Switching sensors, for example, are self-excited and do not require any external excitation. In contrast, acceleration sensors are excited externally using piezo ceramic elements. The title illustration shows the measuring setup with the PSV Scanning Vibrometer equipped with a close-up unit. The measurement grid is defined for scanning the surface of the sensor and follows the geometry of the component, taking into consideration vibration-relevant stiffness steps. Based on significant peak amplitudes or coupled eigenfrequencies, the measurement results can show possible vibrational weak points. This is a useful approach to characterize a variety of parts and samples for defects and potential failure points.

Applications

The tilt sensor shown in Figure 1 was examined before and after thermal cycling tests between – 40° C and 150° C (500 cycles). In Figure 2, the frequency response function of an undamaged tilt sensor is compared to a damaged sensor, both under external excitation.

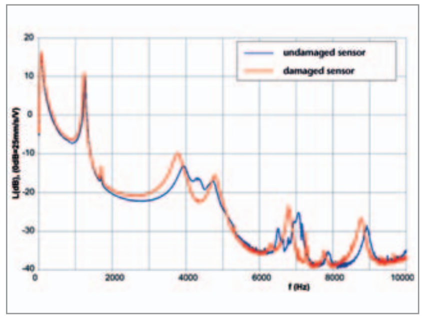

Figure 2: Frequency response function for the tilt sensor

The frequency shift to lower frequencies is clearly visible.

The vibration characteristics of a HF-MEMS switch were also examined (Figure 3). The switching process (electrostatic) is identified by self-excitation. The sensor can also be excited externally using a piezo shaker. The behavior of the bridge structure is of particular interest for thermo-mechanical characterization.
The initial results from this kind of investigation are plotted in Figure 4 and can be used to validate an FE model.

Sensor Properties and Long-term Reliability

The vibration characteristics of an intact sensor measured across a wide frequency range forms a baseline response. By sampling the sensor's vibration characteristics over time and comparing them back to the baseline, early changes in the sensor can be detected often prior to any functional impairment. The long-term reliability of sensors can be correlated to these changes and thus checked through suitable monitoring of the sensor itself or subassemblies critically related to reliability. Hence monitoring can be done externally or by observing the self-excitation through driving the actual sensor function (for example the switching function).

Summary

Non-contact laser vibrometry makes it possible to characterize the thermo-mechanical behavior of sensors through the spectral position of significant eigenfrequencies, the corresponding deflection shapes and amplitudes. Tears and fractures not only cause a frequency shift but also change the deflection shapes. The long-term stability of the thermomechanical behavior of sensors can be monitored through external measurements as well as by monitoring the self-excitation, for example with switching functions.

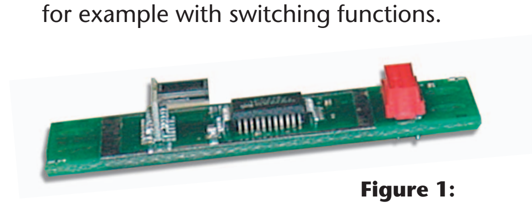

Figure 1: Tilt sensor (GEMAC mbH)

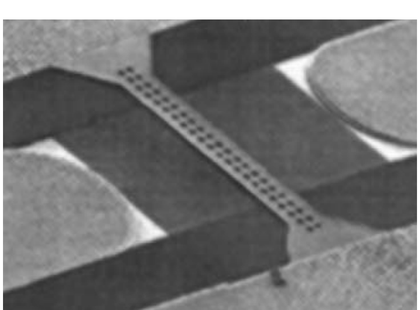

Figure 3: HF-MEMS switch (Picture: R. Bosch GmbH)

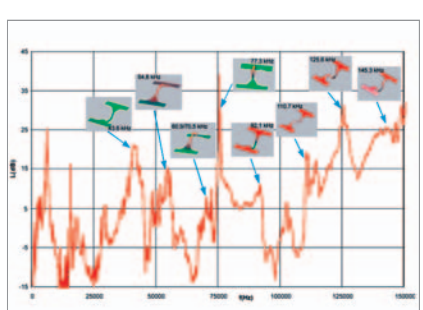

Figure 4: Frequency behavior and corresponding mode shapes

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