TECH NOTE :: Temperature compensation of FBG

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Temperature compensation of Fiber Bragg Grating strain sensors

When performing strain measurements with FBG based sensors care must be taken on the effects of temperature on the measurement.

Temperature influence on the strain of the specimen

The measured strain on a mechanically loaded specimen that is also subjected to a temperature change is affected by the load (ε_{load}) and the thermal expansion of the specimen material (ε_{CTE})

$$\varepsilon_{Real} = \varepsilon_{Load} + \varepsilon_{CTE}$$ **Equation 1**

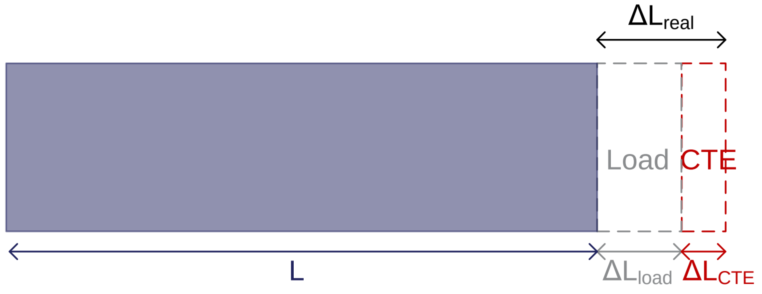

Figure 1

Temperature influence on the FBG measurement

Because the reflected wavelength shift on an FBG depends both on the applied strain and on the temperature variation, when using an FBG for strain measurements there is a parcel of the measured wavelength shift that is does not correspond to strain. The thermally induced wavelength shift can be removed from the measurement by calculation.

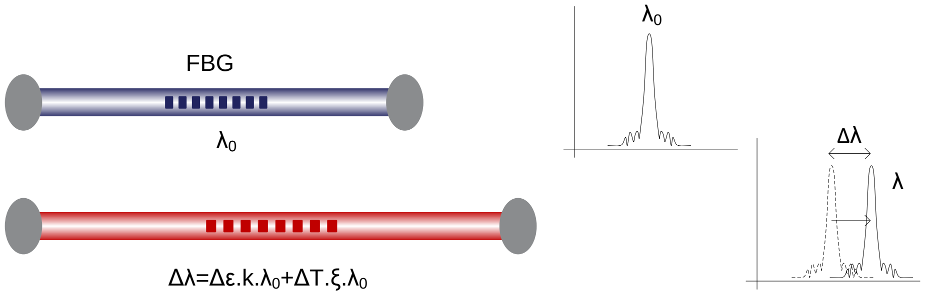

Figure 2

Temperature compensation of both thermal effects

The complete strain-temperature signal of the installed optical strain sensor is given by:

$$\frac{\Delta\lambda}{\lambda_0}.\frac{1}{k} = \varepsilon + TCS.\Delta T + CTE.\Delta T$$ **Equation 2**

where

- CTE is the coefficient of thermal expansion of the measuring body onto which the strain sensor is installed (also known as α of the material). CTE is expressed in µm/m/°C.
- k is the dimension-less strain sensitivity of the sensor (also known as gauge factor or k factor). It is indicated on the data sheet.
- ε is the pure mechanical strain, distinguished from the temperature-influenced strain signal.
- TCS is the thermal cross sensitivity of the strain sensor, indicated on the data sheet. It is given by the thermo-optic coefficient ζ divided by the k factor, TCS=ζ/k. The TCS is expressed in µm/m/°C.

In order to obtain the temperature-compensated strain signal ε, the latter two summands need to be subtracted.

$$\varepsilon = \frac{\Delta\lambda}{\lambda_0}.\frac{1}{k} - TCS.\Delta T - CTE.\Delta T$$ **Equation 3**

There are several possibilities to achieve that upon a measurement. For example by using:

A temperature measurement

With a temperature measurement on the same location of the strain sensor, the thermal cross sensitivity of the sensor (as stated on the data- and calibration sheets) and the thermal expansion of the base material, the strain measurement can be corrected. With a temperature measurement of the sensor location, one can define the reference temperature (T_{ref}) at the moment of zero strain, and compute the pure mechanical strain ε by using the measured temperature from the temperature sensor at each instant.

An optical compensation element

For some strain sensors, a fiber Bragg grating sensor specifically designed for temperature compensation effects can be used. This is realized by using a temperature compensation (TC) sensor next to the strain sensor, which only measures the temperature shift ΔT. Its temperature compensation factor (TCF) is indicated on the data sheet.

A compensation FBG sensor

If an optical strain gauge is applied to the same material and is under the same temperature change but not subjected to strain, the strain measured by this sensor is the temperature induced strain. The compensation FBG measures strain, but since the pure mechanical strain is zero, the measured strain corresponds only to thermally induced strain and can be used directly to compensate the strain sensor measurement by subtracting.

An optical strain gauge with the opposite deformation

When two strain gauges are installed in opposite surfaces of a bending beam, strain has the same value but a different signal. With sensors operating in this push-pull configuration the effect of temperature can be cancelled by combining both strain measurements. When the sensors are under the same temperature influence we can calculate mechanical strain as the difference between the two divided by 2.

HBM catman software supports you on getting temperature corrected mechanical strain by embedding the calculation algorithms. The used option can be easily selected and only the correct coefficients need to be inserted.