ENGLISH

Mounting Instructions

FS62CSS, FS63CTS

Composite Strain and Temperature Sensors

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Mat.:
DVS: A05021 03 E00 00
02.2025

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1 GENERAL INFORMATION

The following instructions refer to the installation procedure of FS62CSS Composite Strain Sensors and FS63CTS Composite Temperature Sensors.
These sensors can be delivered individually or in arrays of sensors preassembled in HBK FiberSensing facilities.

Material Numbers	
Strain Sensors	**Temperature Sensors**
K-FS62CSS	K-FS63CTS
1-FS62CSS-ARM/1510	1-FS63CTS-ARM/1515
1-FS62CSS-ARM/1520	1-FS63CTS-ARM/1525
1-FS62CSS-ARM/1530	1-FS63CTS-ARM/1535
1-FS62CSS-ARM/1540	1-FS63CTS-ARM/1545
1-FS62CSS-ARM/1550	1-FS63CTS-ARM/1555
1-FS62CSS-ARM/1560	1-FS63CTS-ARM/1565
1-FS62CSS-ARM/1570	1-FS63CTS-ARM/1575
1-FS62CSS-ARM/1580	1-FS63CTS-ARM/1585
1-FS62CSS-ARM/1590	1-FS63CTS-ARM/1595
Sensor Arrays	
K-FS76ARD	K-FS76ARM

1.1 Environment Considerations

1.1.1 Packaging Disposal

The packaging of this equipment is designed to protect it from damage during transportation and storage. It is also made of materials that can be recycled or reused, in accordance with the European Union's waste management regulations to minimize its environmental impact.

If you plan to move your equipment to different locations it is advisable that you keep the original package for reuse. This will not only grant proper protection for transportation, but also ensure the reduction of waste creation.

Packing boxes include a label with information on the materials used on that specific package.

Fig. 1.1 Packing label example

Please follow the instructions below to dispose of the packaging properly and responsibly and contribute to the preservation of our planet. Thank you!

To dispose of packaging, you should:

- Remove any labels, adhesives, nails, staplers or caps that are not part of the same material.
- Rinse the packaging with water to remove any residues or dirt.
- Flatten or fold the packaging to reduce its volume and save space (except for glass that should not be crushed).
- Separate the packaging by material and place it in the appropriate recycling bin or bag.

Most of our packing are made of paper and plastic and aimed to be reused or recycled, but they are not appropriate for food containing. Please consult the chapter "Packing Symbols" for more detailed information about the packing materials used by HBK FiberSensing, marked in the packing label of each product delivered to customers.

Packaging Symbols

Packing materials are marked with the correspondent symbol for guidance.

Not appropriate for food

Recyclable

The recycling symbols for the different materials include numbers and letters that identify the material type. For example, PET (polyethylene terephthalate) is marked also with the number 1, and PE-HD (high-density polyethylene) is marked with the number 2. For paper (PAP) 20 corresponds to corrugated cardboard and 22 to paper as seen in newspapers, books,…

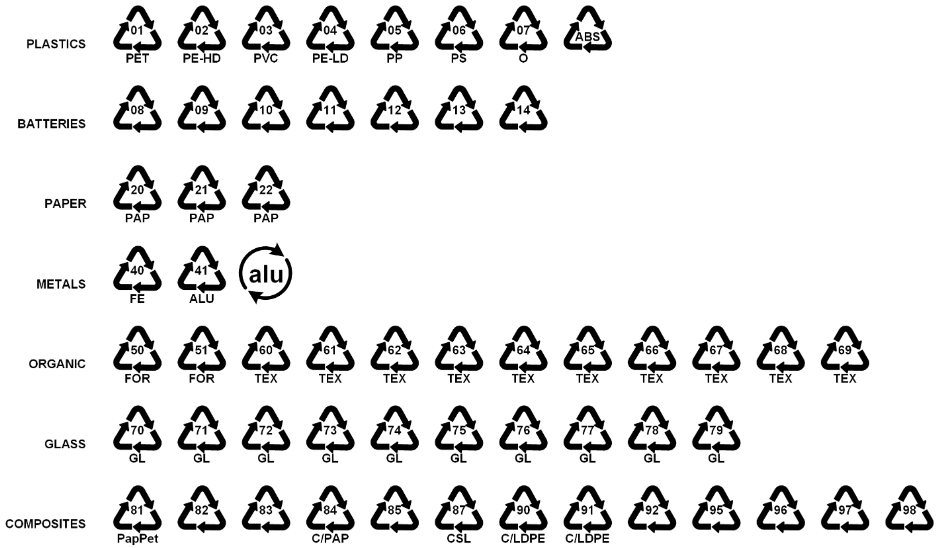

Fig. 1.2 Recycling symbols

Plastics

Plastic packaging materials are commonly bags, films, trays, blisters or containers.

Batteries

Batteries are not part of the packaging, but they may be included in the equipment or its accessories. HBK FiberSensing sensors do not include batteries.

Paper

Paper packaging materials are commonly boxes, cartons, envelopes, or labels.

Metals

Metal packaging materials are commonly cans, foils, caps, or wires.

Organic

Organic packaging materials could be wood, cork, or cotton and are made of natural or biodegradable materials that can be composted or reused.

Glass

Glass packaging materials are bottles, jars, or vials.

Composites

Composite packaging materials are made of layers of different materials, such as paper, plastic, and aluminum. They are marked with a recycling symbol and a letter that indicates the composition of the packaging. For example, PAP is for paper and plastic, and ALU is for aluminum.

1.2 Marking used in this document

Important instructions for your safety are specifically identified. It is essential to follow these instructions to prevent accidents and property damage.

Symbol	Significance
⚠ CAUTION	This marking warns of a *potentially* dangerous situation in which failure to comply with safety requirements *can* result in slight or moderate physical injury.
Notice	This marking draws your attention to a situation in which failure to comply with safety requirements *can* lead to damage to property.
! Important	This marking draws your attention to *important* information about the product or about handling the product.
Tip	This marking indicates application tips or other information that is useful to you.
i Information	This marking draws your attention to information about the product or about handling the product.
Emphasis *See …*	Italics are used to emphasize and highlight text and identify references to sections, diagrams, or external documents and files.
▶	This marking indicates an action in a procedure

2 SENSOR INSTALLATION

2.1 Introductory notes

When mounting FS62CSS and FS63CTS sensors, please pay attention to the following:

- Handle with care.

These are precision sensors and so their achievable accuracy highly depends on correct mounting.

- Do not overload the sensors.
- Avoid lateral forces or torque.
- Handle the cables with care before fixing to avoid damage. Do not hold the sensor by the cables.

Notice

The FS62CSS and FS63CTS sensors are precision measuring elements and need to be handled carefully. Dropping or knocking the sensors may cause permanent damage. Make sure that the sensors cannot be overloaded, including while they are being mounted.

2.2 List of materials

Included material
FS62CSS Composite Strain Sensor(s)
FS63CTS Composite Temperature Sensor(s)

Needed equipment
Deburring Machine (optional)

Needed material
Glue. Recommended HBK: 1-X60 (fast curing), 1-X280 Recommended Third Party: DP490 from 3M
Sanding sheets.
Surface cleaning agents. Recommended HBK: 1-RMS1 or 1-RMS1-SPRAY
Tissues. Recommended HBK: 1-8402.0026

Drafting tape. Recommended HBK: 1-KLEBEBAND
Protection. Recommended HBK: 1-ABM75 and/or AK22

2.3 Preparation of the installation area

If there are protection layers applied on the material, such as paint or rust, deburr (*Fig. 2.1*) or sand (*Fig. 2.2*) the surface to remove them ensuring that the surface does not become irregular.

Fig. 2.1 Deburring the surface to remove paint or rust

Fig. 2.2 Sanding the surface to remove remaining paint or rust

The surface needs then to be cleaned ensuring that no dust nor grease is present in the bonding area.

Clean the surface using RMS1 cleaner (*Fig. 2.3*) and the nonwoven tissues (*Fig. 2.4*), as recommended.

Fig. 2.3 Spraying 1-RMS on specimen

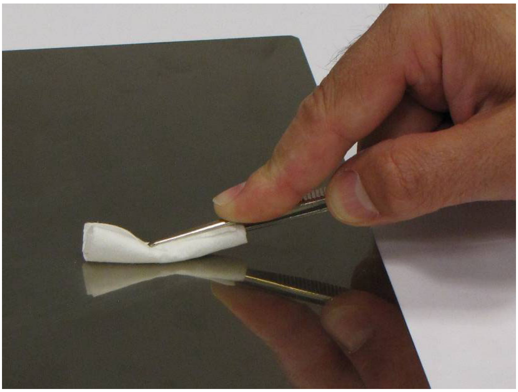

Fig. 2.4 Cleaning with nonwoven pad

The wiping movements should always be performed in the same direction until the last tissue comes out clean.

2.4 Marking the measuring point

Define the alignment of the sensor considering the measurement direction and the sensor's guides.

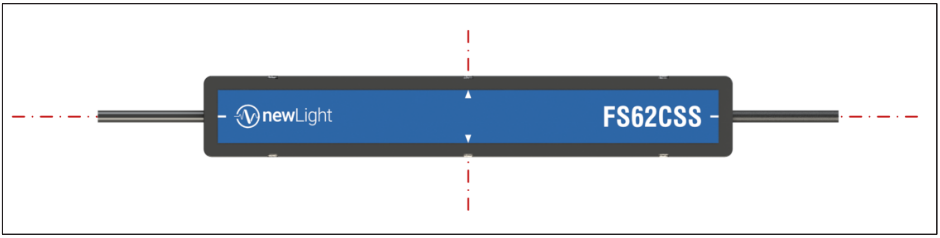

Fig. 2.5 Sensor alignment markings

In the ideal case, an empty ball point pen cartridge is recommended for marking the installation point. The length of the marking line should be approx. 150 mm in the measurement direction. A vertical marking line, approx. 50 mm long, must be drawn starting at the center of the installation point, *see Fig. 2.6*.

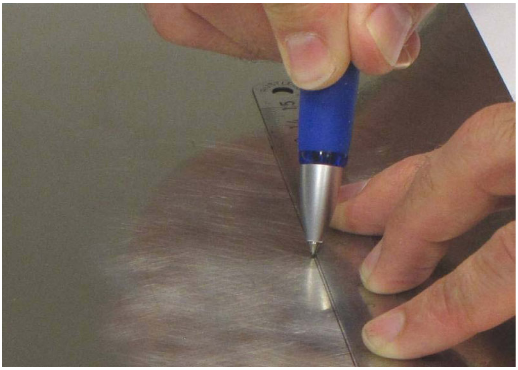

Fig. 2.6 Marking the marking lines

Once the area is marked out, the installation point must be cleaned very thoroughly, *see Fig. 2.7*. Please note that a new non-woven pad must be used each time the point is wiped. Repeat the cleaning process until no residues can be detected on the non-woven pad.

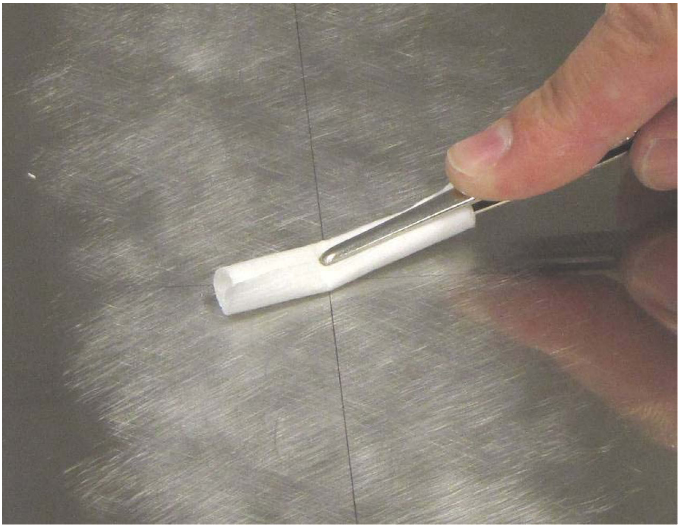

Fig. 2.7 Final cleaning of the installation point

2.5 Positioning and gluing the sensor

Remove the sensor from the box and prepare cablings so that the sensor movements are not constrained. Spread the selected adhesive homogeneously along the sensor and proceed accordingly to the selected adhesive instructions.

Tip

Strain and temperature sensors look very similar, which eases installation and pairing of both. They can easily be differentiated by the label and also by the base material. Strain sensors are built using a glass fiber composite and Temperature sensors using carbon composite.

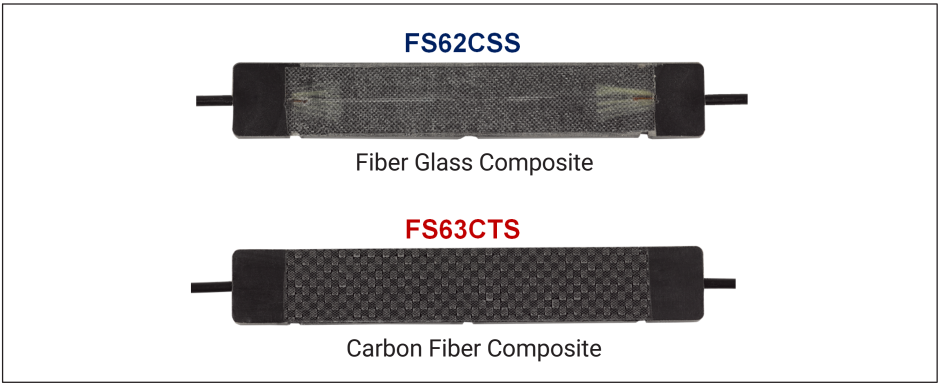

Fig. 2.8 Strain and temperature sensors difference

For the usage of adhesives that require long curing time (e.g. DP490) and in materials and/or positions where weights or magnets cannot be used, combine a fast curing epoxy with the selected bonding glue (*Fig. 2.9*).

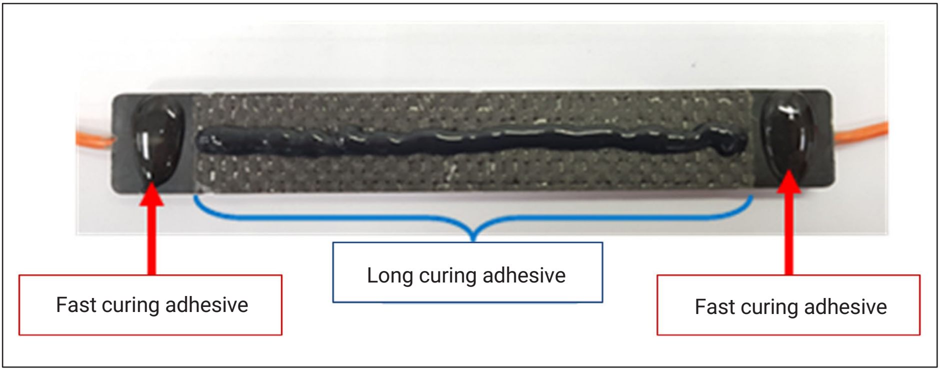

Fig. 2.9 Glue application

After fixing the sensor on its position and securing it, use the drafting tape to secure the cables as well to reduce the effect of their weight.

2.6 Routing and protecting the cables

Sensor cable should be routed without being left hanging. The cable should be fixed by means of plastic clamps, for example (*Fig. 2.10*).

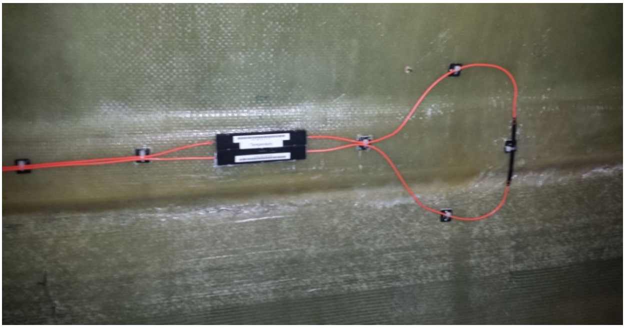

Fig. 2.10 Cable fixed with plastic clamps

Plastic corrugated tubes can also help routing the longer lead cables that will connect to the interrogator (*Fig. 2.11*).

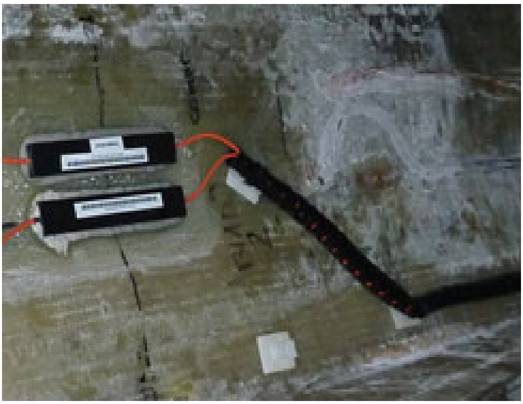

Fig. 2.11 Cable protected with corrugated tubes

Excess cable should be coiled and stored in a suitable IP case, so it can be used in case of network refurbishment (*Fig. 2.12*).

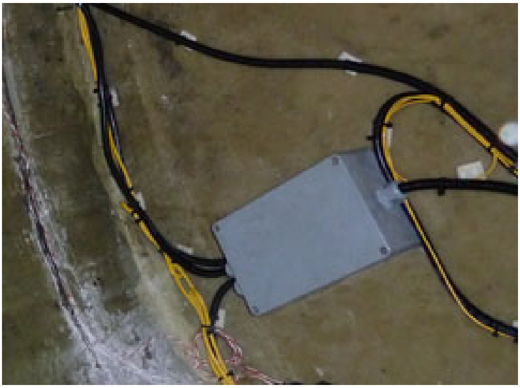

Fig. 2.12 Protection boxes for extra cable and connections

2.7 Protecting the sensor

The FS62CSS and FS63CTS sensors are ruggedized sensors designed with protection for mechanical and environmental actions, meaning that they do not need much more protection.

However, the adhesives may be exposed to moisture and environmental effects becoming prone to a faster degradation.

Recommendations for protection are the HBK AK22 putty adhesive and/or ABM75.

3 SENSOR CONFIGURATION

3.1 Sensors documentation

Calibrated HBK FiberSensing Sensors are delivered with a Calibration Sheet. Remaining sensors are delivered with a sensor Characteristic Sheet that contains important information for sensor configuration.

In the case sensors are delivered in arrays of pre-assembled sensors, a resume table with the relevant calibration information is provided in alternative.

Within the sensor's packing this installation instructions document is delivered in a printed version. Installation instructions can also be downloaded from our website.

3.2 Measurement computation

3.2.1 Temperature

The calculations that should be performed for converting a wavelength measurement into temperature are the shown in *Fig. 3.1*. The temperature value of a temperature sensor is given by a second order polynomial equation with coefficients obtained from the sensor calibration.

$$T = S_2(\lambda - \lambda_0)^2 + S_1(\lambda - \lambda_0) + S_0$$

Fig. 3.1 Temperature computation formula

Where

- T is the measured Temperature in °C
- λ is the measured Bragg wavelength of the temperature sensor in nm
- λ_0 is the Bragg wavelength of the temperature sensor at reference temperature in nm
- S_0 is the zero order sensitivity (reference temperature) in °C
- S_1 is the first order sensitivity in °C/nm
- S_2 is the second order sensitivity in °C/nm^2

When operating with catman® the values λ_0, S_0, S_1 and S_2 should be filled on the menu for temperature sensors configuration.

Measurement with Distance Effect Correction

When measuring with sweeping laser-based Optical Interrogators, such as the BraggMETER from HBK FiberSensing, the length of cabling between the interrogator and the sensor affects the measured reflected signal. This distance error is significant for sensors that rely on absolute wavelength values, such as temperature sensors.

The sweeping laser emits a varying wavelength over time. The method for measuring the reflected wavelength from the fiber Bragg grating (FBG) sensor identifies the wavelength being emitted at the time the reflected peak from the FBG is detected. As the acquisition rate increases, the delay caused by the distance the light travels both ways becomes more pronounced, reducing the accuracy of the absolute wavelength measurement. The same effect occurs with increasing distances.

The cable length effect manifests as a constant shift in the wavelength measurement, which depends on the sampling rate of the optical module and the distance between the sensor and the interrogator. The shift in the measured wavelength is negligible for low acquisition rates or short distances but becomes significant for high sampling rates or long distances.

$$\Delta\lambda_{error} = \frac{d \cdot 2 \cdot n \cdot RapRate \cdot FullRange}{SweepDirektion \cdot DutyCycle \cdot c}$$

Fig. 3.2 Wavelength shift due to sweeping laser speed

Where

- $\Delta\lambda_{error}$ is the wavelength "error", in nm
- *d* is the distance (in m) between the sensor and the measurement unit
- *n* is the refraction index of the fiber (1.446 for standard SMF28 fiber)
- *RepRate* is the optical module actual acquisition scan (for BraggMETER interrogators in the selected acquisition rate, in S/s)
- *FullRange* is the length of the range of measured wavelengths (102 nm for BraggMETER interrogators)
- *SweepDirection* is the signal of the sweeping direction: 1 for sweeping from the lowest to highest wavelengths and -1 for sweeping from the highest to lowest wavelengths
- *DutyCycle* is the sweeping portion of the cycle without flyback
- *c* is the speed of light ($3x10^8$ m/s).

A fixed temperature error caused by the distance can be calculated:

$$T_{error} = S_2 \times \Delta\lambda_{error}{}^2 + S_1 \times \Delta\lambda_{error}$$

Fig. 3.3 Temperature error induced by the distance effect

The error can be applied to the calibration formula for correction:

$$T = S_2(\lambda - \lambda_0)^2 + S_1(\lambda - \lambda_0) + S_0 - T_{error}$$

Fig. 3.4 Temperature computation formula with distance error correction

3.2.2 Strain

Strain sensors are not calibrated sensors. The characteristic sheet delivered with the sensor presents the sensor data for correct strain computation.

For the fiber Bragg grating strain sensors, wavelength variation including the effect of temperature is given by the equation as shown in *Fig. 3.5*.

$$\frac{(\lambda - \lambda_0)}{\lambda_0} = k \cdot \left(\varepsilon_{Load} + (TCS + CTE) \cdot (T - T_0)\right) \cdot 10^{-6}$$

Fig. 3.5 Wavelength variation of a strain FBG due to strain and temperature effects

Where

- λ is the measured Bragg wavelength of the strain sensor in nm
- λ_0 is the Bragg wavelength of the strain sensor at the reference instant in nm
- k is the strain k factor of the strain sensor, dimensionless
- ε_{Load} is the mechanical strain applied to the structure in µm/m
- *TCS* is the temperature cross sensitivity of the strain sensor in (µm/m)/ºC
- *CTE* is the thermal expansion of the material of the specimen the strain sensor is attached to in (µm/m)/ºC
- T-T_0 is the temperature variation since the reference instant to the measurement instant in ºC

Measurement with no compensation

If no temperature compensation is required the strain computation can be done as shown in *Fig. 3.6*.

$$\varepsilon = \frac{(\lambda - \lambda_0)}{k \cdot \lambda_0} \cdot 10^6$$

Fig. 3.6 Strain without temperature compensation computation formula

Where

- ε is the measured strain in µm/m
- λ is the measured Bragg wavelength of the strain sensor in nm
- λ_0 is the Bragg wavelength of the strain sensor at the reference instant in nm
- k is the strain k factor of the strain sensor, dimensionless

Measurement with temperature compensation using a temperature sensor

Calculating compensated strain, in µm/m, using a temperature sensor is straightforward as the output of a temperature sensor is a temperature value in °C. The calculation is the depicted in *Fig. 3.7*.

$$\varepsilon_{Load} = \frac{(\lambda - \lambda_0)}{k \cdot \lambda_0} \cdot 10^6 - (TCS + CTE)(T - T_0)$$

Fig. 3.7 Strain computation with temperature compensation using a temperature sensor

Where

- ε_{Load} is the mechanical strain applied to the structure in µm/m
- λ is the measured Bragg wavelength of the strain sensor in nm
- λ_0 is the Bragg wavelength of the strain sensor at the reference instant in nm
- k is the strain k factor of the strain sensor, dimensionless
- *TCS* is the temperature cross sensitivity of the strain sensor in (µm/m)/°C
- *CTE* is the coefficient of thermal expansion of the material of the specimen the strain sensor is attached to in (µm/m)/°C
- T is the actual measured temperature of the used temperature sensor in °C
- T_0 is the temperature measured by the temperature sensor used for compensation at the reference instant in °C

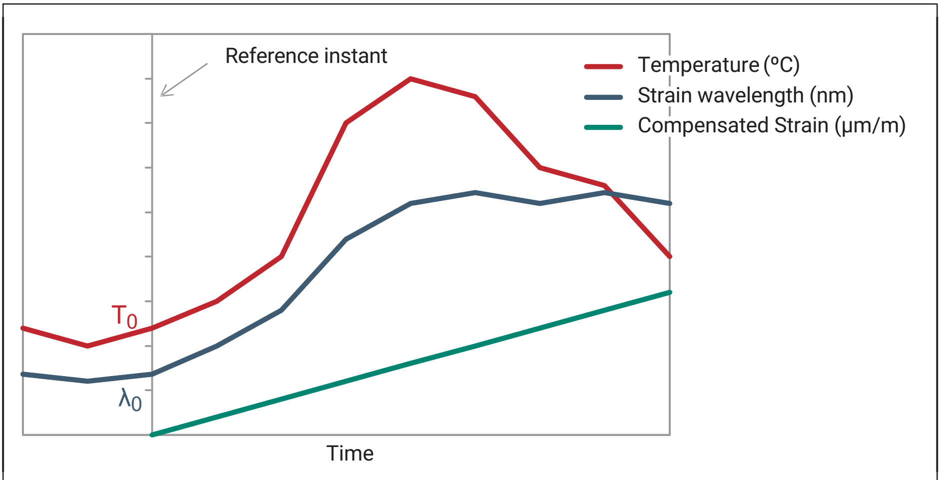

Fig. 3.8 Reference instant for temperature compensated strain measurement when using a temperature sensor for compensation

Measurement with temperature compensation using a compensation element

Strain measurement can also be correctly compensated using a compensation element based on FBG technology. Different approaches can be used:

- a temperature sensor without calibration certificate
- a strain sensor installed on a strain-free area of the same material
- a strain sensor installed on a strain-free material with a known CTE

The computation of strain can then be performed using the equation from *Fig. 3.9*.

$$\varepsilon_{Load} = \frac{\lambda - \lambda_0}{k \cdot \lambda_0} \cdot 10^6 - \frac{\lambda_{Tc} - \lambda_{0_{Tc}}}{\lambda_{0_{Tc}}} \cdot \frac{(TCS + CTE)}{TCF} \cdot 10^6$$

Fig. 3.9 Strain computation with temperature compensation using an FBG compensation element

Where

- ε_{Load} is the mechanical strain applied to the structure in µm/m
- λ is the measured Bragg wavelength of the strain sensor in nm
- λ_0 is the Bragg wavelength of the strain sensor at the reference instant in nm
- k is the strain k factor of the strain sensor, dimensionless
- λ_{TC} is the measured Bragg wavelength of the compensation element in nm
- $\lambda_{0\,TC}$ is the Bragg wavelength of the compensation element at the reference instant in nm
- *TCS* is the temperature cross sensitivity of the strain sensor in (µm/m)/°C
- *CTE* is the coefficient of thermal expansion of the material of the specimen the strain sensor is attached to in (µm/m)/°C
- *TCF* is the temperature compensation factor of the compensation element in (µm/m)/°C. For an uncalibrated temperature sensor the value is given on the sensor's characteristics sheet. For a strain sensor attached to a specific material TCF can be calculated as shown in *Fig. 3.10*.

$$TCF = (5.7 + k \cdot CTE_{TC})$$

Fig. 3.10 Temperature compensation factor computation

Where

- k is the strain k factor of the strain sensor attached to the temperature compensation element, dimensionless
- CTE_{TC} is the coefficient of thermal expansion of the material of the temperature compensation element in (µm/m)/°C

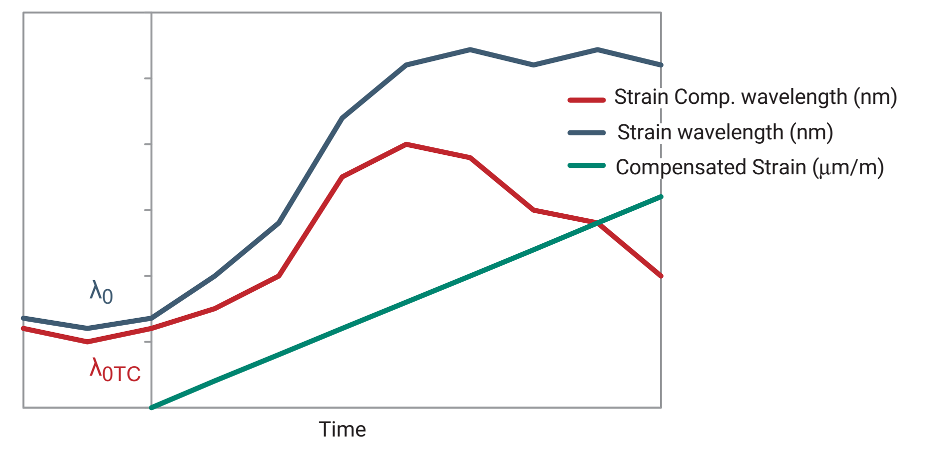

Fig. 3.11 Reference instant for temperature compensated strain measurement when using an FBG compensation element

Measurement with bending moment correction

When measuring on an element using a sensor that is far away from the attachment surface there may be an "error" on the measurement because the distance between the measuring point/alignment and the neutral axis is different to the distance between the installation surface and the neutral axis.

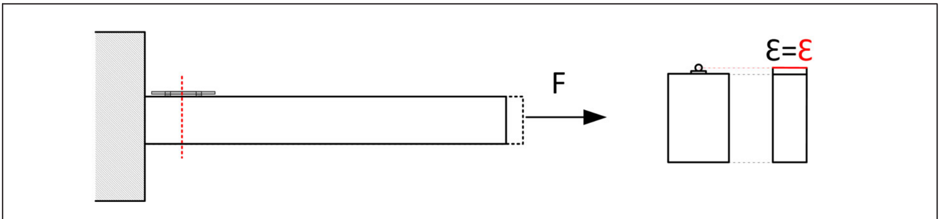

Fig. 3.12 Strain on pure axial deformation

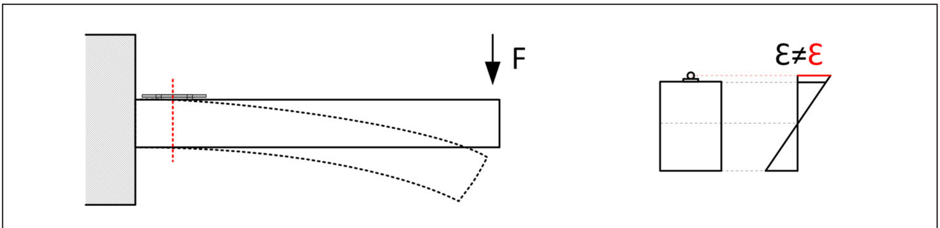

Fig. 3.13 Strain on pure bending moment

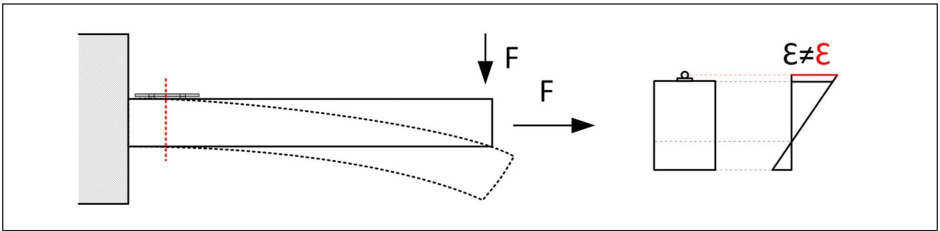

Fig. 3.14 Strain on axial load and bending moment

This becomes of high importance when the distance between the sensing element on the sensor to the attachment surface is relevant, or the measuring object is very thin. This distance on the FS62CSS Composite Strain Sensor is 0.143 mm (h_2 on *Fig. 3.14*).

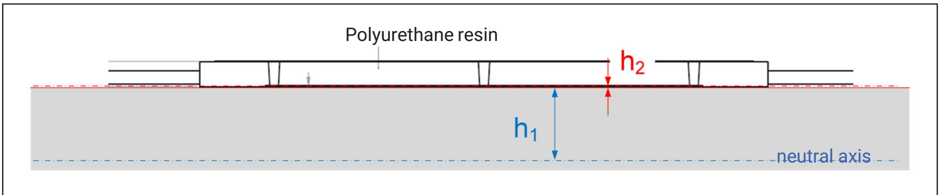

Fig. 3.15 Distance of the FBG to the mounting surface on the FS62CSS

However, knowing the distance to the neutral axis (h_1) the measured strain from the sensor can be corrected into strain on the surface by a geometrical factor:

$$\varepsilon_{surface} = \frac{\lambda - \lambda_0}{k \cdot \lambda} \cdot \frac{h_1}{h_2 + h_1} \cdot 10^6$$

Fig. 3.16 Strain computation bending effect correction

Where

- $\varepsilon_{surface}$ is the mechanical strain on the measuring surface in µm/m
- λ is the measured Bragg wavelength of the strain sensor in nm
- λ_0 is the Bragg wavelength of the strain sensor at the reference instant in nm
- k is the strain k factor of the strain sensor, dimensionless
- h_1 is the distance from the measuring surface to the neutral axis in mm
- h_2 is the distance from the measuring surface to the FBG in mm (0.143 mm for the FS62CSS)

4 SENSOR MAINTENANCE

4.1 Sensor

4.1.1 Strain Sensor

Gluable strain sensors, by principle, cannot be repaired after installation. If a strain sensor, whether linear or rosette, is damaged after installation, the solution is to completely replace the sensor. It is not expected that a strain sensor will be damaged under regular operating conditions. More commonly, damage occurs to the connections rather than the sensor itself.

4.1.2 Temperature Sensor

For temperature sensors, it might be possible to remove and reinstall the same sensor without causing damage, depending on the attachment method used. If glued, it is unlikely that the sensor can be removed without irreversible damage. However, if secured with polyimide tape or cable ties, it might be possible to retrieve the sensor without further damage.

Tip

Carefully remove any covering agents that may act as glue and damage the sensor during removal.

Temperature sensors can be completely damaged beyond repair in cases of severe incidents (mechanical shock, extremely high temperatures, etc.). However, recalibration may be necessary if the sensor has been subjected to temperatures higher than specified for short periods.

If it is possible to remove the installed sensor and an offset is observed, please contact HBK FiberSensing to discuss recalibration options. Note that recalibration performed by HBK FiberSensing may be subject to a fee.

4.2 Cables

If a cable is damaged during installation or use, a local repair might be possible. However, the feasibility of the repair depends on the location of the damage. If the damage is too close to the sensor, there may not be enough cable length available to use the splicing tools, making the repair unfeasible.

When a repair is feasible and there is sufficient cable length, you can cut the cable to remove the damaged section and perform a splice on the fiber cable. If there isn't enough cable length, you will need to insert an extension and perform two splices. Please contact HBK FiberSensing for support with the splicing procedures.

When sensors are delivered in an array and a cable is damaged between two sensors, you will lose signals from all sensors past the damage. Cables can be repaired as described above.

Tip

If no repair is possible, it might be possible to recuperate some signals when connection redundancy exists. If the fiber can be interrogated from both ends, ensure that there is no light propagation at the location of the damage (by fully cutting the fiber connection) and insert a splitter between the optical connector of the interrogator and the two ends of the sensor array.

4.3 Connectors

If a connector is damaged, it can be replaced either by performing a local splice or by returning the sensor for reconnection. Note that repairs performed by HBK FiberSensing may be subject to a fee.

HBK - Hottinger Brüel & Kjaer
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