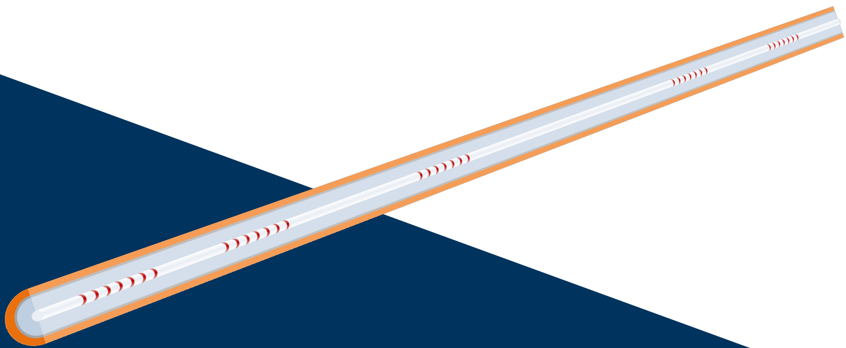
ENGLISH

Mounting Instructions



FS70PKF

Array of FBG in PEEK coated fiber

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TABLE OF CONTENTS

1 GENERAL INFORMATION

The following instructions refer to the installation procedure of the FS70PKF Array of FBGs in PEEK coated fiber.

Material Numbers
K-FS70PKF

2 SENSOR INSTALLATION

2.1 List of materials

Included material
FS70PKF Array of FBG in PEEK coated fiber

Needed material
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
Glue Recommended Third Party: DP490 from 3M
Glue (for strain relief – optional) Recommended HBK: 1-X60
Protection Recommended HBK: 1-ABM75 and/or 1-AK22
Rounded tweezers
Foam tape (optional) Recommended: TESA POWERBOND 5MX19MM
Small spatula (optional)

2.2 Preparation of the installation area

The surface of the measurement object must first be cleaned and be flat before installing the FS70PKF fiber.

Fig. 2.1 Spraying the measuring point with 1-RMS-SPRAY

- Clean around the measuring point thoroughly. Use the RMS1 cleaning agent and non-woven tissues.

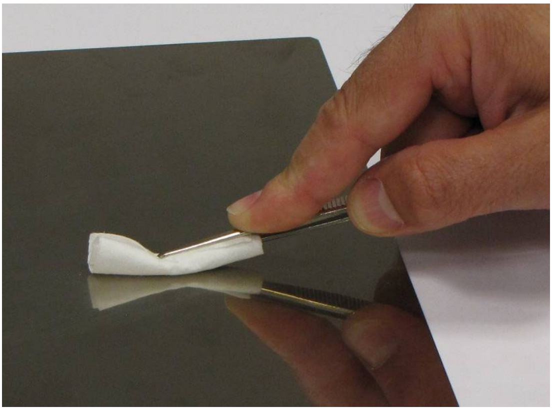

Fig. 2.2 Thorough cleaning of measuring point using a non-woven pad

- Perform repeated linear movements always on the same direction.

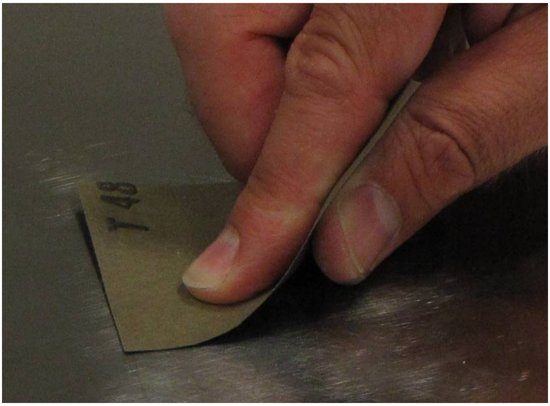

Fig. 2.3 Roughening the surface of the measuring body

- Roughen the surface around the measuring point using the sanding sheets.

Fig. 2.4 Cleaning the roughened installation surface

- Clean the roughened installation surface again with RMS1 and non-woven pads.

2.3 Marking the measuring point

Define the alignment of each FBG considering the measurement direction. The FBG is positioned centered between the two dark markings.

This following step is particularly important as the fiber positioning dictates the measurement direction.

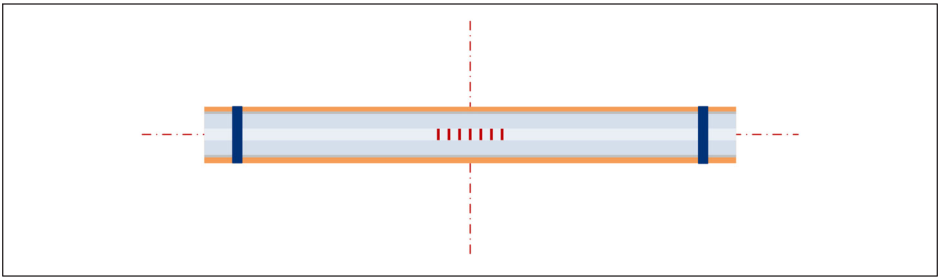

Fig. 2.5 FBG alignment markings

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. 10 cm in the measurement direction. A vertical marking line, approx. 2 cm long, must be drawn starting at the center of the measuring point (*Fig. 2.6*).

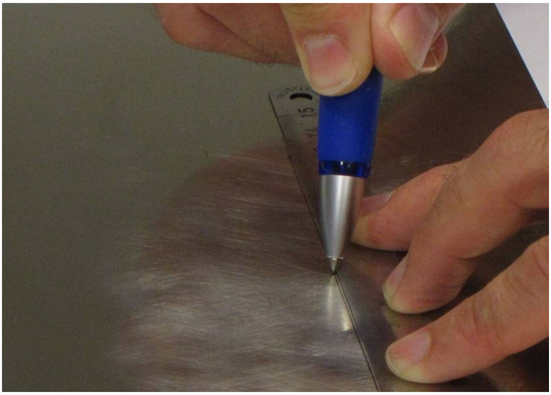

Fig. 2.6 Marking the marking lines

Once the area is marked out, the installation point must be cleaned very thoroughly (*Fig. 2.7*).

Important

Use a new non-woven pad each time the point is wiped to prevent re-contamination of the measuring point. The cleaning process is complete when no residues can be recognized on the non-woven pad.

Fig. 2.7 Final cleaning of the installation point

2.4 Gluing the sensor with epoxy adhesive

2.4.1 Limiting the gluing area (optional)

For a better-looking finishing, it is advisable that a frame is created around the gluing area using a foam tape (recommended TESA Powerband).

Fig. 2.8 Gluing frame created using foam tape (optional).

2.4.2 Glue application

Apply the adhesive (recommended DP490 from 3M) evenly over a length of at least 90 mm along the marking line centrally to the marking cross. The mixing nozzle must be positioned vertically to the surface during application (*Fig. 2.9*).

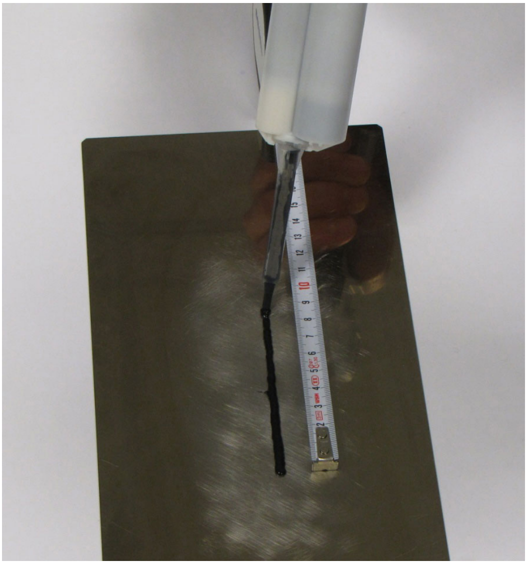

Fig. 2.9 Applying the epoxy adhesive

- Slightly tension the fiber with both hands so that it is as straight as possible.
- Align it with the marked measuring direction and the FBG area centered on the marked cross.
- Move it towards the adhesive.

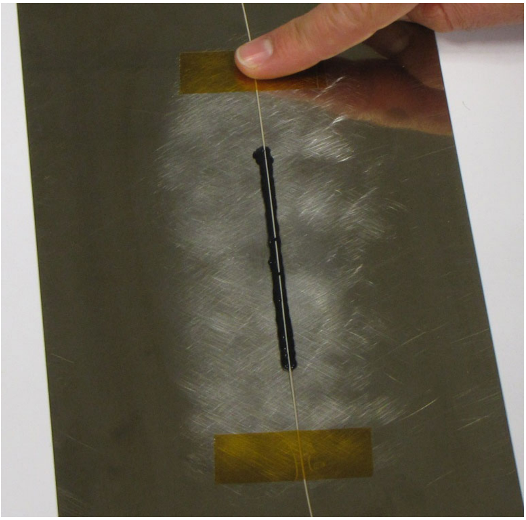

Fig. 2.10 Fixing the embedded optical sensor fiber FS70PKF

- Fix the fiber in this position using adhesive strip (recommended polyimide tape 1-KLEBEBAND) on each side of the gluing area (*Fig. 2.10*).

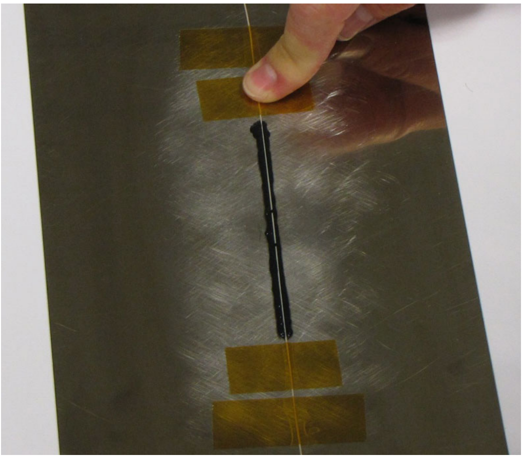

Fig. 2.11 Application of two further adhesive strips at the ends of the adhesive

- Apply two further adhesive strips directly at the end of the adhesive area (*Fig. 2.11*).

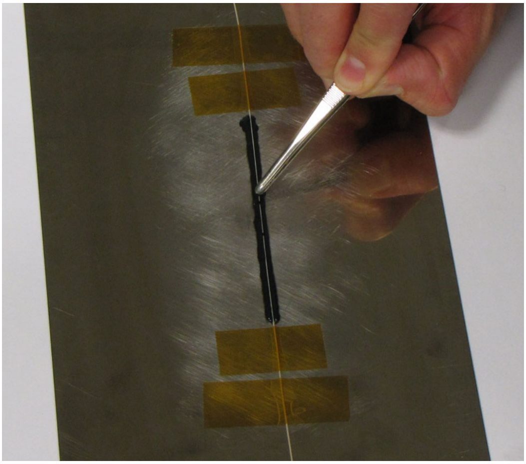

Fig. 2.12 Pressing down the optical sensor fiber FS70PKF with rounded tweezers

- Press the optical fiber gently to the epoxy adhesive, ensuring a full embedment of the fiber into the glue and that the fiber stays as close as possible to the component surface using rounded tweezers (*Fig. 2.12*).

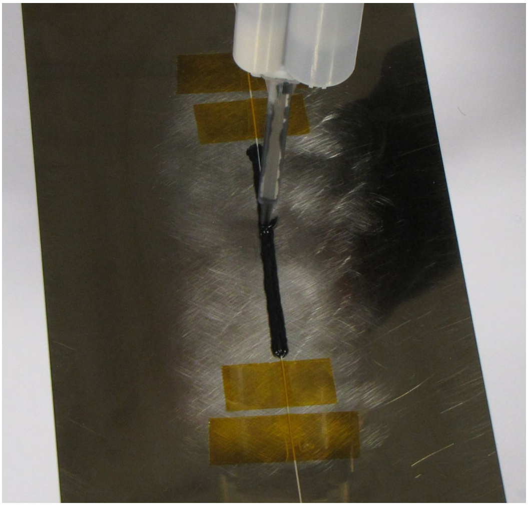

Fig. 2.13 Covering the optical fiber with the epoxy glue

- Apply a second layer of epoxy adhesive over the embedded fiber to fully cover it. To avoid air inclusions, move the mixing nozzle closely over the fiber and orthogonally to the component surface (*Fig. 2.13*).

2.4.3 Finishing the glue surface (optional)

If a gluing frame has been prepared, the surface of the gluing area can be leveled by swiping the gluing area with a spatula, using the foam tape as a guide.

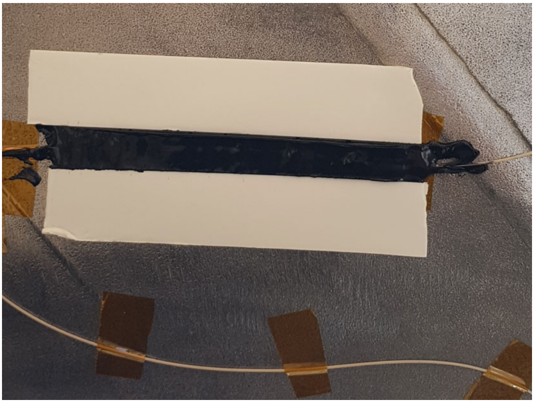

Fig. 2.14 Smoothening the gluing area (optional).

- Slightly pressure a straight surface of the spatula against the foam tape, at one end of the gluing area, with a small tilt towards the center of the sensor.
- Slowly swipe it in one direction over the created groove.

2.4.4 Glue curing

Allow the glue to cure before proceeding with the measurements. The suggested adhesive takes a long time to cure at environmental temperatures (at 20 °C [68 °F] curing time is of 40 h) but the process can be highly improved for higher temperatures (2 h for curing at 65 °C [149 °F]). This means that, whenever needed and possible, heat should be applied to speed up the process.

For more information on the characteristics of the glue, please refer to its documentation.

2.5 Protecting the sensor

The suggested DP490 glue is a rough protecting coating to the sensing area. However, it might be advisable to further protect the sensors and glue against moist or mechanical damage.

- Remove the foam tape from the sensor area.

Fig. 2.15 Gluing area after removing the tape.

Fig. 2.16 Protecting the sensor with AK22.

- Apply a layer of AK22 putty on top of the sensor pressing against the component surface.
- Cover the area with ABM75.

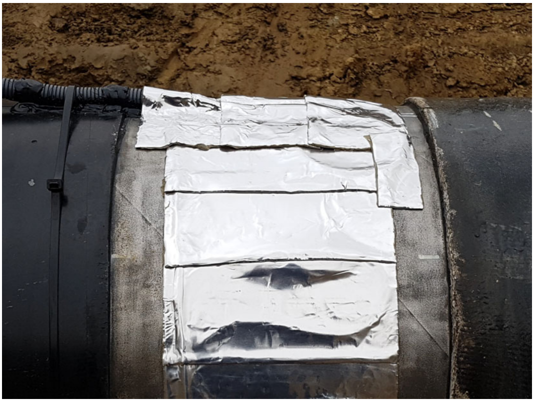

Fig. 2.17 Protecting with ABM75.

2.6 Routing and protecting the fiber

The fiber length of the FS70PKF between the FBG positions should be deployed with care so that curvatures are not tighter than the specified.

Because the length between FBG is fixed, there could be the need to coil some of the extra fiber length.

Fig. 2.18 Coiling the extra fiber length.

One easy and effective option for protecting the fiber between measuring points is covering it with the epoxy adhesive.

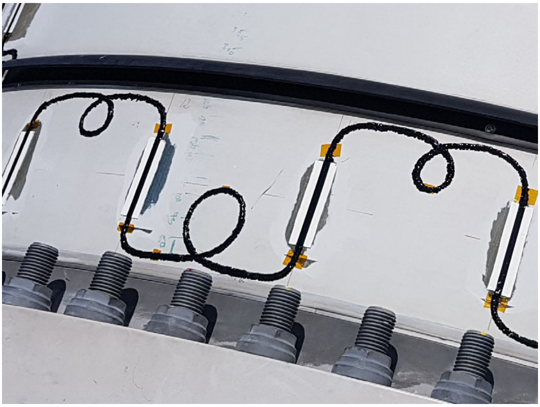

Fig. 2.19 Protecting extra fiber length with epoxy adhesive (optional)

- Apply a covering coat of epoxy on top of the fiber (optional).

In case no further protection on the fiber is needed, it is recommended that a strain relief is used close to the sensor area.

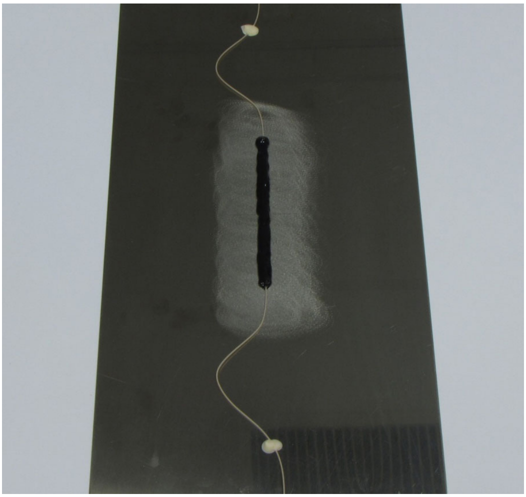

Fig. 2.20 Strain relief for the FS70PKF fiber.

- Position the fiber at the ends of the gluing area with a gentle loop and fix them to the component surface using a fast curing adhesive (e.g. X60 adhesive).

2.7 Routing and protecting the cables

FS70PKF sensor can be delivered with or without cable, and with different types of cables.

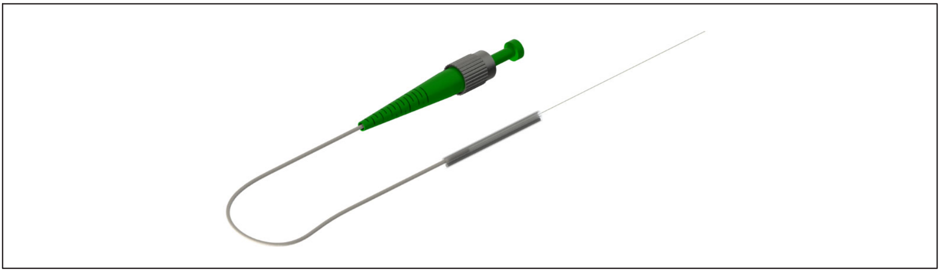

Fig. 2.21 Braided cable termination

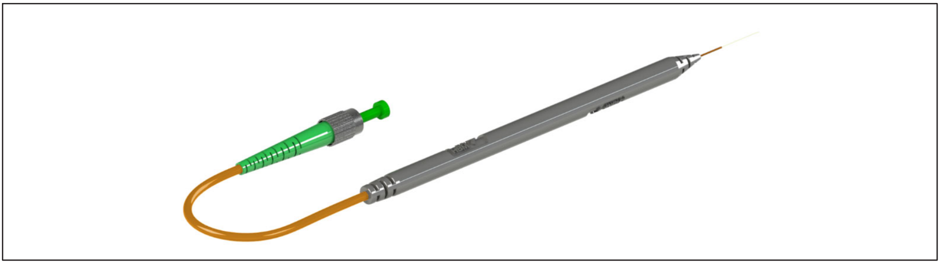

Fig. 2.22 Aramid cable termination

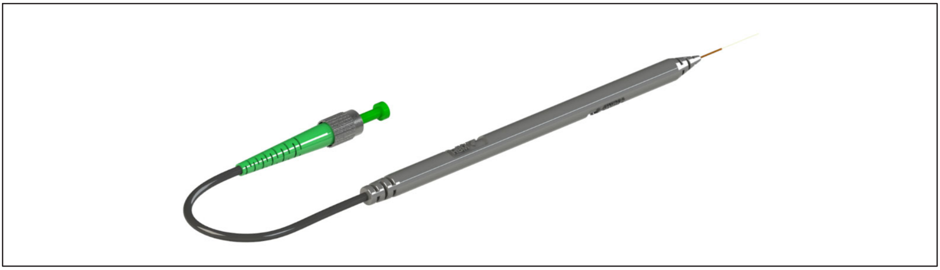

Fig. 2.23 Armor cable termination

Sensor cable should be routed without being left hanging. The cable should be fixed by means of plastic clamps, for example (*Fig. 2.24*).

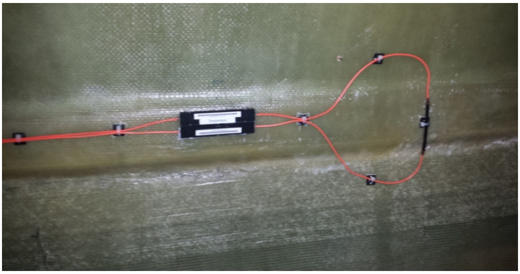

Fig. 2.24 Cable fixed with plastic clamps

Plastic corrugated tubes can also help routing the longer lead cables that will connect to the interrogator (*Fig. 2.25*).

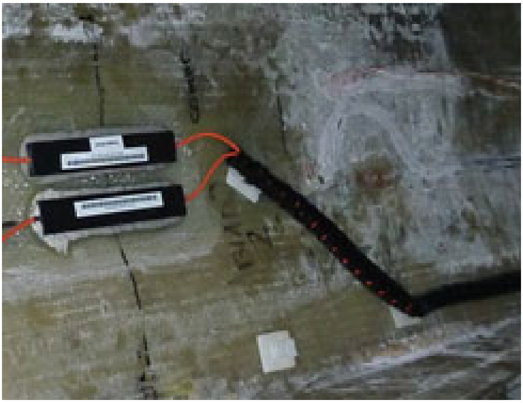

Fig. 2.25 Cable protected with corrugated tubes

Excess cable should be coiled and stored in a suitable IP case, so it can be used in case of network maintenance (*Fig. 2.26*).

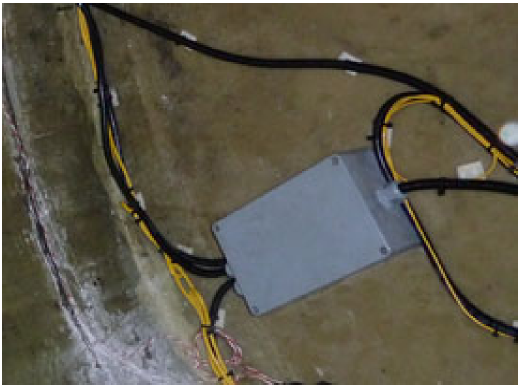

Fig. 2.26 Protection boxes for extra cable and connections

Splice protections must also be well fixed. The splice interface between the peek fiber and the splice protection is a fragile location due to the difference of rigidities. This is especially true when considering the 3 mm cables (aramid or armor).

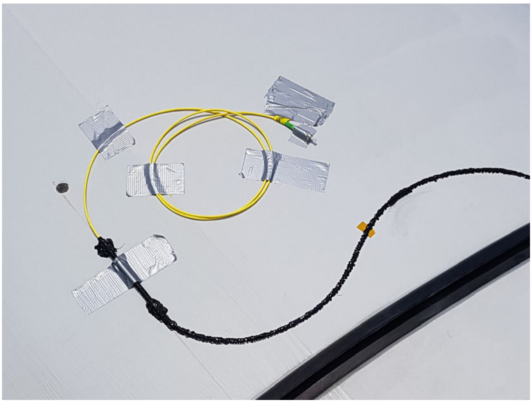

Fig. 2.27 Glued splice protection

3 SENSOR CONFIGURATION

3.1 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. 3.1*.

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

Fig. 3.1 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)/°C
- *CTE* is the thermal expansion of the material of the specimen the strain sensor is attached to in (µm/m)/°C
- T-T_0 is the temperature variation since the reference instant to the measurement instant in °C

Measurement with no compensation

If no temperature compensation is required the strain computation can be done as shown in *Fig. 3.2*.

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

Fig. 3.2 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. 3.3*.

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

Fig. 3.3 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 thermal expansion of the material of the specimen the strain sensor is attached to in (µm/m)/°C
- T is the measured temperature of the used temperature sensor in °C
- T_0 is the temperature from the temperature sensor at the reference instant in °C

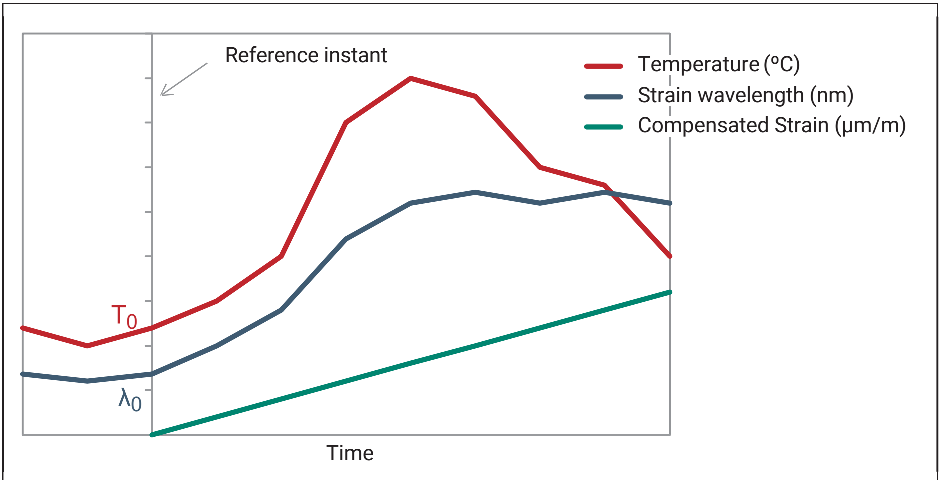

Fig. 3.4 Reference instant for temperature compensated strain measurement when using a temperature sensor for compensation

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. 3.5*.

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

Fig. 3.5 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 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. 3.6*.

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

Fig. 3.6 Temperature compensation factor computation

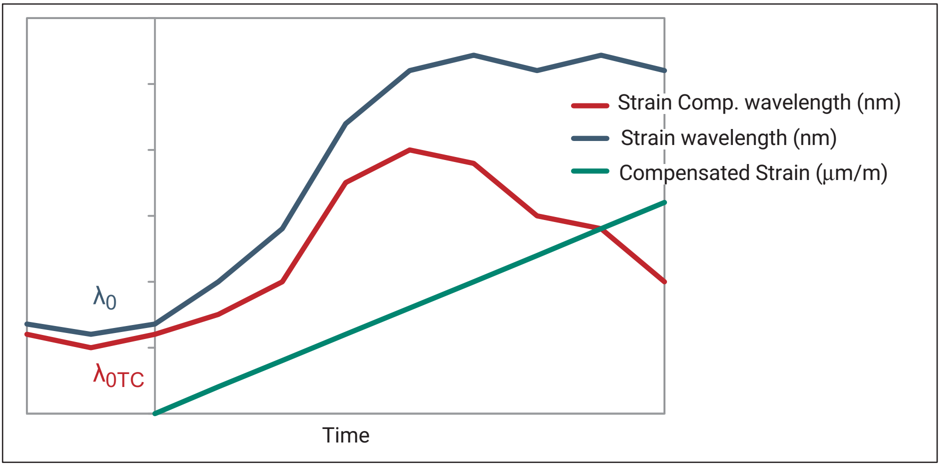

Fig. 3.7 Reference instant for temperature compensated strain measurement when using an FBG compensation element

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.

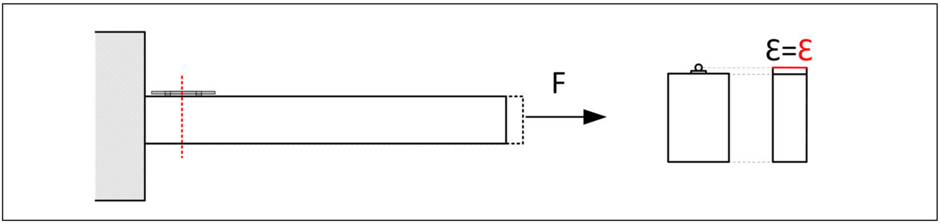

Fig. 3.8 Strain on pure axial deformation

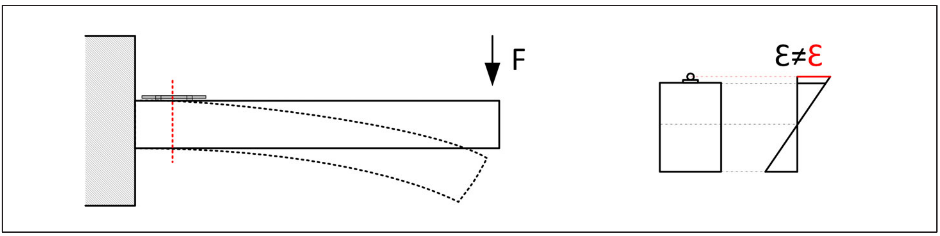

Fig. 3.9 Strain on pure bending moment

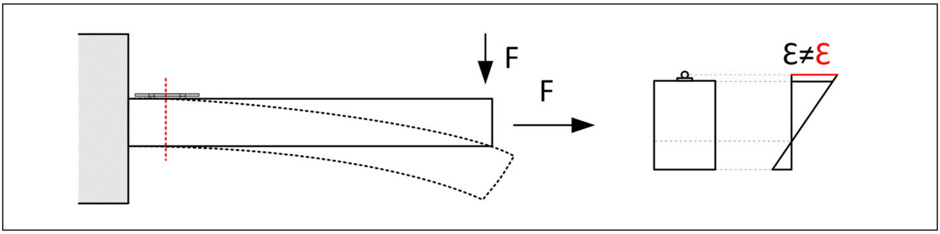

Fig. 3.10 Strain on axial load and bending moment

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 FS70PKF Peek Coated Strain Sensor is 0.35 mm (h_2 on *Fig. 3.11*).

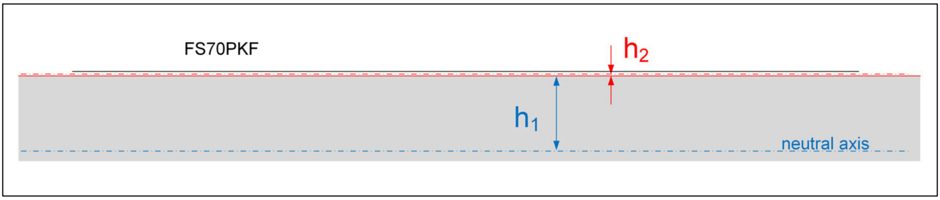

Fig. 3.11 Distance of the FBG to the mounting surface on the FS70PKF

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. 3.12 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 (0.35 mm for the FS70PKF)

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