ENGLISH

Mounting Instructions

FS62CSS, FS63CTS

Composite Strain and Temperature Sensors

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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

2 SENSOR INSTALLATION

2.1 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

2.2 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

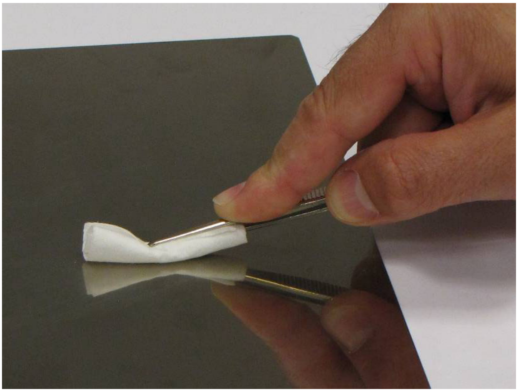

Fig. 2.4 Cleaning with nonwoven pad

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

2.3 Marking the measuring point

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

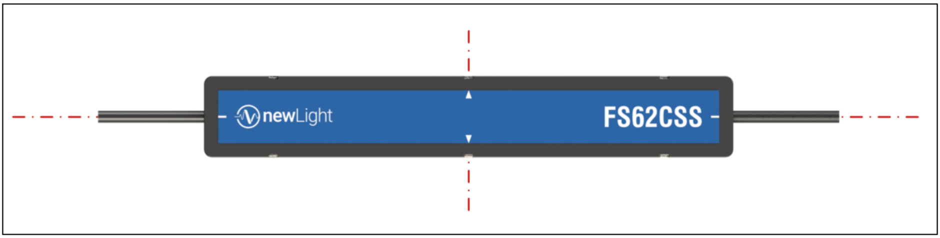

Fig. 2.5 Sensor alignment markings

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*.

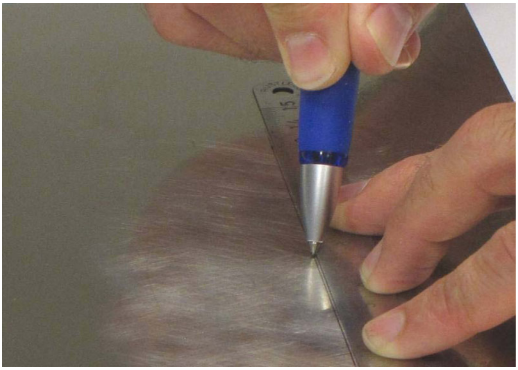

Fig. 2.6 Marking the marking lines

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.

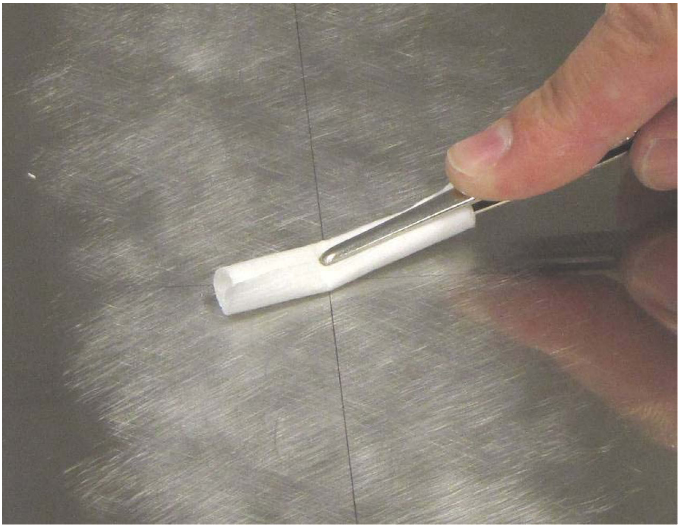

Fig. 2.7 Final cleaning of the installation point

2.4 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.

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. 2.8*).

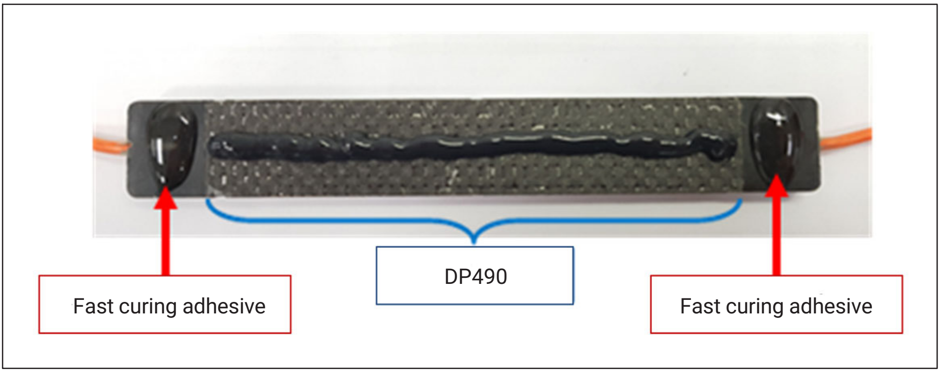

Fig. 2.8 Glue application

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.

2.5 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. 2.9*).

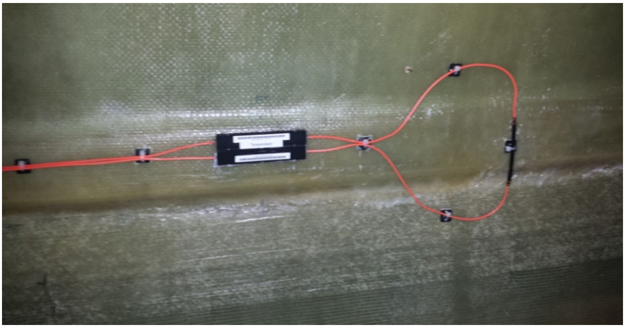

Fig. 2.9 Cable fixed with plastic clamps

Plastic corrugated tubes can also help routing the longer lead cables that will connect to the interrogator (*Fig. 2.10*).

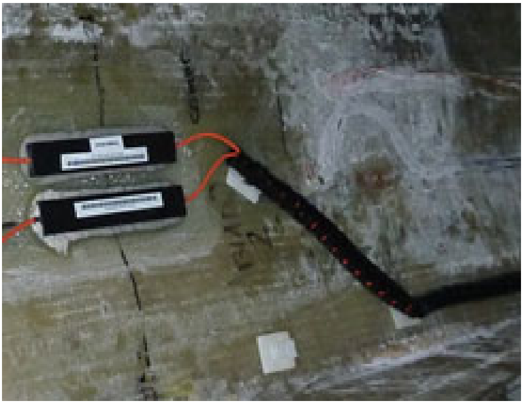

Fig. 2.10 Cable protected with corrugated tubes

Excess cable should be coiled and stored in a suitable IP case, so it can be used in case of network refurbishment (*Fig. 2.11*).

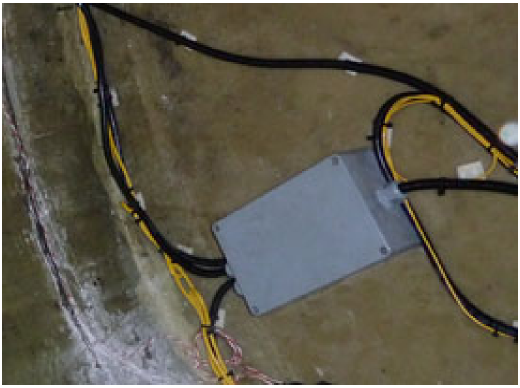

Fig. 2.11 Protection boxes for extra cable and connections

2.6 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 ºC
- 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 ºC
- S_1 is the first order sensitivity in ºC/nm
- S_2 is the second order sensitivity in ºC/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.

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. 3.2*.

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

Fig. 3.2 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. 3.3*.

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

Fig. 3.3 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. 3.4*.

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

Fig. 3.4 *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

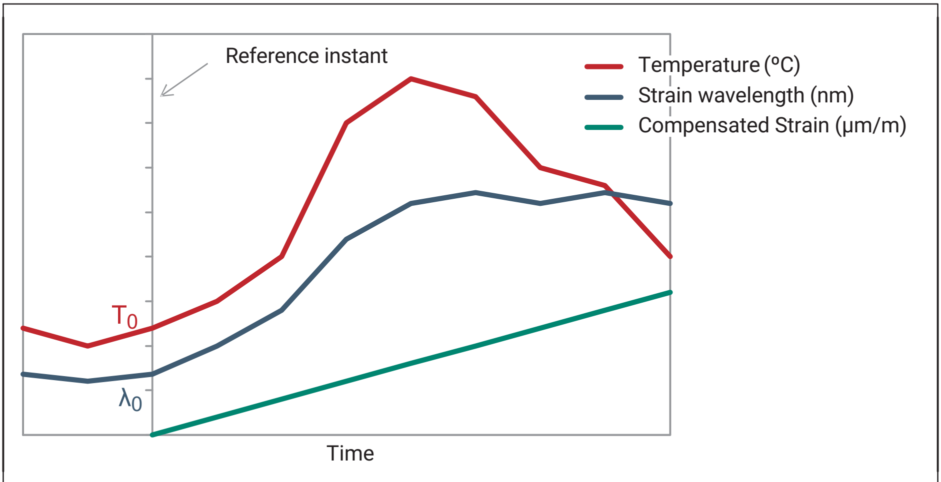

Fig. 3.5 *Reference instant for temperature compensated strain measurement when using a temperature sensor for compensation*

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. 3.6*.

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

Fig. 3.6 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
- λ_{0TC} 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. 3.7*.

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

Fig. 3.7 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

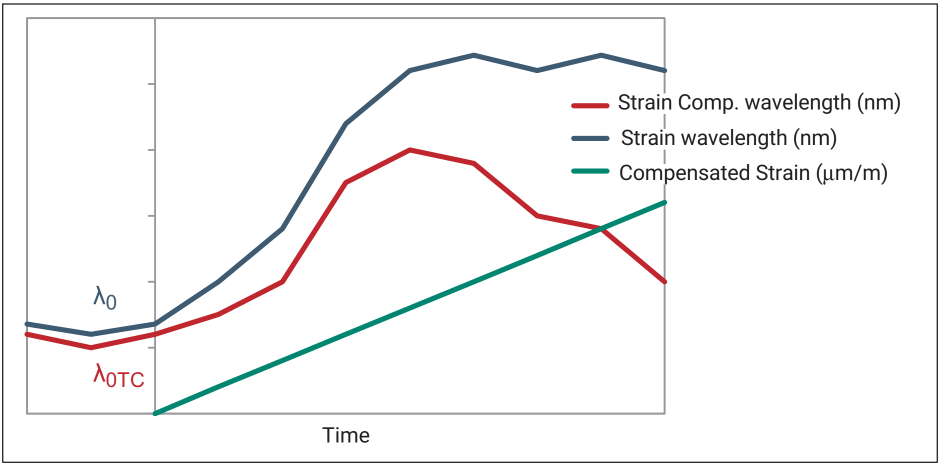

Fig. 3.8 *Reference instant for temperature compensated strain measurement when using an FBG compensation element*

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.

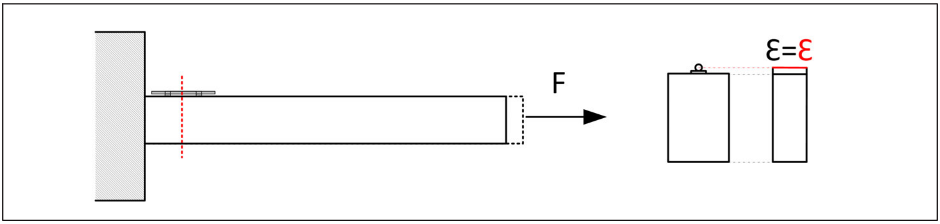

Fig. 3.9 *Strain on pure axial deformation*

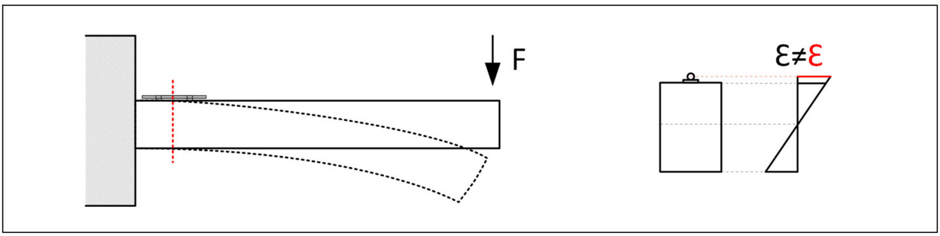

Fig. 3.10 *Strain on pure bending moment*

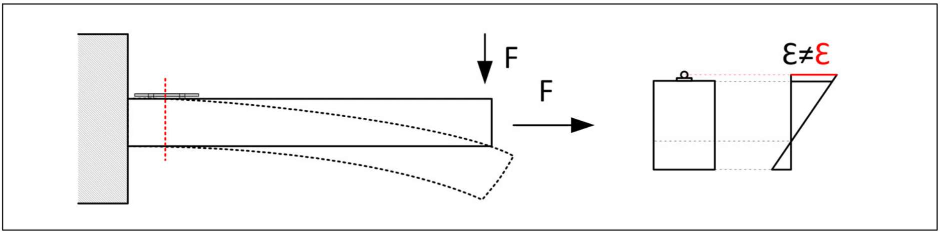

Fig. 3.11 *Strain on axial load and bending moment*

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. 3.11*).

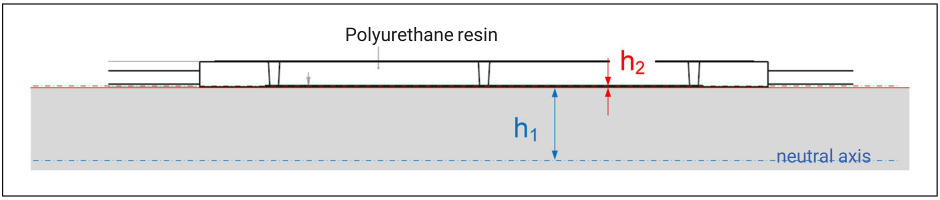

Fig. 3.12 *Distance of the FBG to the mounting surface on the FS62CSS*

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. 3.13 *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)

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