# Determine the thermal expansion coefficient

Technical information

When there is a change in temperature, each SG quarter bridge registers a measurement signal, the "apparent strain". The apparent strain of an SG measuring point exposed to a temperature difference $\Delta\vartheta$, can be described as follows:

$$\varepsilon_s = \left(\frac{\alpha_r}{k} + \alpha_b + \alpha_m\right) \times \Delta\vartheta / \qquad (1)$$

The following applies here:

| | |
|---|---|
| $\varepsilon_s$ | Apparent strain of the SG |
| $\alpha_r$ | Temperature coefficient of the electrical resistance |
| $\alpha_b$ | Thermal expansion coefficient of the measurement object |
| $\alpha_m$ | Thermal expansion coefficient of the measuring grid material |
| $k$ | K factor of the SG |
| $\Delta\vartheta$ | Temperature difference that triggers the apparent strain |

On all of their strain gage packs, HBM shows the apparent strain as a function of temperature in a chart and also as a polynomial.
Of course, these data only ever give useful results if the thermal coefficient of linear expansion of the material to be tested matches the data on the strain gage pack.

The following then applies:

$$\varepsilon_a = \varepsilon_m + \varepsilon_s \qquad (2)$$

### Determining the thermal coefficient of linear expansion α

But the apparent strain can also be used perfectly well for measurement purposes, if the coefficient of thermal expansion αm is to be determined. In this situation, the following formula can be used.

$$\varepsilon_a = \varepsilon_m + \varepsilon_s + (\alpha_b - \alpha_{DMS}) \cdot \Delta\vartheta \qquad (3)$$

Transposed, this produces:

$$\alpha_b = \frac{\varepsilon_a - \varepsilon_s}{\Delta\vartheta} + \alpha_{DMS} \qquad (4)$$

| | |
|---|---|
| $\varepsilon_a$ | Strain indicated at the amplifier |
| $\varepsilon_b$ | The strain triggered by the mechanical load |
| $\alpha_{DMS}$ | Thermal coefficient of linear expansion as per the SG pack |

In a practical test, four HBM SGs of the LG11-6/350 type, adapted to steel (α=10.8 10-6/K), were installed on an aluminum workpiece.
A four-wire circuit was used to eliminate cable influences. According to the data supplied by the manufacturer for the material, α=23.00 *10-6/K for T= 0 … 100°C.

| ϑ (°C) | $\varepsilon_a$(*$10^{-6}$) | $\varepsilon_s$(*$10^{-6}$) | $\varepsilon_a$-$\varepsilon_s$(*10-6) | $\alpha_b$(*$10^{-6}$)/K |
|---:|---:|---:|---:|---:|
| -10 | -396.9 | -38.017 | -358.883 | |
| 0 | -254.35 | -16.9 | -237.45 | 22.9433 |
| 10 | -122.5 | -5.003 | -117.497 | 22.7953 |
| 20 | 0 | -1.084 | 1.084 | 22.6581 |
| 30 | 118.75 | -3.901 | 122.651 | 22.9567 |
| 40 | 232.4 | -12.212 | 244.612 | 22.9961 |
| 50 | 344.32 | -24.775 | 369.095 | 23.2483 |
| 60 | 453.27 | -40.348 | 493.618 | 23.2523 |
| 70 | 562.12 | -57.689 | 619.809 | 23.4191 |
| 80 | 671.6 | -75.556 | 747.156 | 23.5347 |
| 90 | 781.82 | -92.707 | 874.527 | 23.5371 |

| $\vartheta$ (°C) | $\varepsilon_a$(*$10^{-6}$) | $\varepsilon_s$(*$10^{-6}$) | $\varepsilon_a$-$\varepsilon_s$(*10-6) | $\alpha_b$(*$10^{-6}$)/K |
|---|---|---|---|---|
| 100 | 894.07 | -107.9 | 1001.97 | 23.5443 |
| 110 | 1010.45 | -119.893 | 1130.343 | 23.6373 |
| 120 | 1132.32 | -127.444 | 1259.764 | 23.7421 |

*Tab. 1.1 Measurement results for an SG adapted for ferritic steel, installed on aluminum*

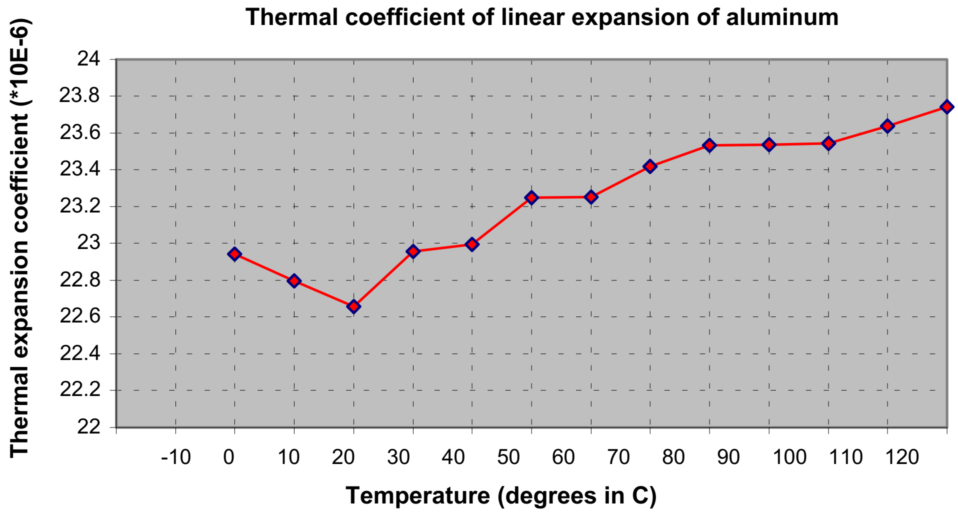


*Fig. 1 Determining the thermal coefficient of linear expansion of aluminum*

If you calculate αm for the specified interval, you obtain 23.19 *$10^{-6}$/K, which corresponds to a deviation from the theoretical value of 0.19 *$10^{-6}$/K (0.84%).

To run the experiment, it is first necessary to install several SGs on the object under investigation (to attain experimental reliability). The sample must be flat in the direction of the measuring grid.

In the next step, the strains are determined subject to the temperature. Care must be taken to ensure that thermal equilibrium is established.

First εa-εs is calculated. To determine the thermal coefficient of linear expansion, you subtract the two calculated values (εa-εs ) from each other and divide this by the corresponding temperature interval. The coefficient of thermal expansion $\alpha_{DMS}$ as per the pack data must then be added to this.

Example:

In the interval from 20 to 40 degrees, the coefficient of thermal expansion is calculated as follows (using calculation (4)).

$$\frac{(232,4 \cdot 10^{-6} - (-12,212 \cdot 10^{-6} - 1,084 \cdot 10^{-6}))}{(40 - 20)K} + 10,8 \cdot 10^{-6}/K = 23,08 \cdot 10^{-6}/K$$

During this measurement, the SG creep is an undesirable effect. So in the interest of maximum accuracy, it is advisable to use HBM series G strain gages, which have three different creep adjustments as standard and of these, use the strain gage with the greatest end loop length.

Also, when the measuring temperatures are over 60 °C, it is advisable to use hot curing adhesives for installation.



**Hottinger Baldwin Messtechnik GmbH**
Im Tiefen See 45 · 64293 Darmstadt · Germany
Tel. +49 6151 803-0 · Fax +49 6151 803-9100
E-Mail: info@hbm.com · www.hbm.com



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