What is Self-Temperature Compensated (STC) Strain Gauges

1. Zero-Temperature-Drift and its Correction by STC Strain Gauges

The zero-offset drift with temperatures (in short, zero-temperature-drift) of sensors is one of the key concerns in sensor applications. When sensors are operated within a wide temperature range, the zero-temperature-drift must be eliminated as much as possible, in order to have a real reading only proportional to the applied load without influence by temperature change.

Although the bondable resistors (e.g., ON-series, OB-series or OQ-series) from BCM SENSOR can be used to correct the zero-temperature-drift of sensors, the biggest part of this drift should be compensated already by making use of the so-called self-temperature compensated (STC) strain gauges.

Hereby is a brief discussion on how the zero-temperature-drift of sensors is corrected by the STC strain gauges from BCM SENSOR.

The zero-temperature-drift of sensors is mainly caused by thermal output of strain gauges which were bonded on the sensor body. The thermal output of the strain gauges is resulted from two concurrently and algebraically addable sources: one is the resistivity change with temperature of the metal foil from which strain gauges are made, and the other is the difference in LTEC (linear thermal expansion coefficients) between the strain gauges and the sensor body.

On one hand, to eliminate the change of the gauge resistivity with temperature, it is necessary to select metal foil of TCR (temperature coefficient of resistance) as low as possible. Both constantan foil and karma foil are such metal foils that their TCR is the lowest available which is about 20ppm/°C.

On the other hand, to eliminate the gauge resistance change due to the difference in LTEC between the strain gauges and the sensor body, a practical way is to modify the TCR of the metal foil, so that the change in gauge resistance due to the difference in the LTEC can be cancelled out by the change in gauge resistance resulted from the modified TCR.

The LTEC of constantan gauges is about 15ppm/°C while that of karma gauges is about 13.3ppm/°C. As the LTEC of sensor body materials can be either lower or higher than that of strain gauges, two scenarios will be discussed below by taking constantan gauges in discussion.

> Scenario-1: LTEC of Strain Gauge > LTEC of Sensor Body Material
> If the constantan gauge (i.e., its LTEC about 15ppm/°C) is bonded on the sensor body made from mild steel which has its LTEC of about 11ppm/°C, when the temperature of the sensor body increases (decreases), the sensor body will exhibit a thermally-induced elongation (shortening) which is less than that of the strain gauge. Therefore, the strain gauge is compressed (stretched) and its resistance decreases (increases). To cancel out such the resistance change, one can modify the TCR of the constantan foil to have a positive value.
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> Scenario-2: LTEC of Strain Gauge < LTEC of Sensor Body Material
> If the constantan gauge is bonded on the sensor body made from aluminum with its LTEC of about 23ppm/°C, when the temperature of the sensor body increases (decreases), the sensor body will thermally elongate (shorten) itself more than that of the strain gauge. Therefore, the strain gauge is stretched (compressed) and its resistance increases (decreases). To cancel out such resistance change, the TCR of the constantan foil must be modified to have a negative value.

These two scenarios are simplified situation, as the LTEC of the backing layer and the glue-line is not considered. In practice, the TCR of the strain gauge is mostly modified into the range from around -25 ppm/°C to +4ppm/°C for sensor applications. Thanks to the thermal property modulation technique, the TCR of both constantan foil and karma foil can be modified to a negative value down to -40ppm/°C, to compensate the

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gauge resistance change induced by the difference in LTEC between the strain gauge and the sensor body. The strain gauges of such compensation function are called STC (self-temperature compensated) strain gauges.

In addition, to eliminate the gauge resistivity change due to temperature, one can set up on the sensor body a full-Wheatstone-bridge circuit. The full-bridge circuit contains four identical strain gauges of the same TCR. If these four strain gauges are exposed to a same temperature when the sensor is operated, the gauge resistivity change with temperature will be cancelled out. Unfortunately, it is hard to have the four strain gauges identical with the same TCR, and it is also hard to have them exposed exactly to the same temperature. Therefore, one can still observe a limited zero-offset drift with temperatures in sensor applications.

2. Availability of STC Strain Gauges

All the strain gauges from BCM SENSOR for sensor applications are STC gauges. These STC gauges are available for the most common sensor body materials, as indicated by their STC numbers in the Ordering Information on each datasheet of BCM SENSOR strain gauges.

Listed in the Tab. 1 below are the most commonly used metals from which the sensor bodies are made, and the most matched STC numbers of strain gauges from BCM SENSOR:

Tab. 1: STC Number of Commonly Used Metals

Metals	STC Numbers
mild steel	11
martensitic stainless steel	11
austenitic stainless steel	16
coper	16
beryllium copper	16
aluminum	23

Furthermore, some additional spring materials are listed in Tab. 2, which can be used to produce sensor bodies and be bonded with the strain gauges of the right matched STC number. In the table the linear thermal expansion coefficient (α) of these spring materials is given and associated with the mostly matched STC number of the STC gauges from BCM SENSOR.

Tab. 2: [Materials] vs [STC number] vs [α (ppm/°C)] vs [α (ppm/°F)]

Material	STC Nr.	α @ 20°C (in ppm/°C[(1)])	α @ 68°F (in ppm/°F)
aluminium 2024-T4	23	24.7	13.7
aluminium 7075-T6	23	23.4	13.0
beryllium	11	12.1	6.7
beryllium copper	16	16.7	9.3
brass	23	19.8	10.6
copper	16	16.8	9.3
glass, soda lime	9	9.2	5.1
glass, crystal	11	12.9	6.7
gold	16	14.0	7.8
inconel	11	12.1	6.8
iron	11	11.7	6.5
lead	27	28.4	16.1
magnesium	27	26.5	14.6

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monel cast iron	11	13.5	7.5
nickel	11	12.7	6.7
pine	27	34.0	18.9
platinum	9	8.9	4.9
plexiglass	65	65.2	36.2
PVC	65	52.0	28.9
sapphire	9	5.2	2.9
silicon carbide	9	2.7	1.5
silicon	9	3.1	1.7
silver	16	18.0	10.0
selenium	27	26.3	14.5
stainless steel 304	16	17.4	9.7
stainless steel 310	16	14.7	8.1
stainless steel 316	16	16.0	8.9
stainless steel 410(2)	11	10.2	5.7
stainless steel 15-7PH(2)	9	9.0	5.1
stainless steel 17-4PH(2)	11	10.8	6.1
stainless steel 17-7PH(2)	11	10.5	5.8
stainless steel 17-9PH(2)	11	10.7	5.9
steel 1008 & 1018(2)	11	12.1	6.7
steel 4340(2)	11	11.4	6.3
tin	23	23.1	13.0
titanium	9	8.5	4.7
titanium 6Al-4V	9	8.9	4.9
tungsten	9	4.5	2.5

Notes:

(1) 1 ppm/°C = 10^{-6}/°C = 10^{-2}%/100°C.

(2) The sensor body has to be made from non-magnetic materials so as to avoid any influence of magnetic field. Stainless steel (SS) and mild steel (MS) are the most common candidates to be used to produce sensor bodies. The SS may be classified by its crystalline structure into three types: austenitic, ferritic, and martensitic. Austenitic steel is non-magnetic SS, while both ferritic and martensitic steels are magnetic SS. Some MS can be magnetic steel too. Therefore, both the martensitic SS and the MS as listed in the table 2 have to be demagnetized first before they can be used to produce sensor bodies.

3. Application Notes

For precision sensor manufacturing of ±0.02%fs accuracy class (e.g., load cells), it is necessary to use the STC gauges. By utilizing the STC gauges of the right STC number, as indicated in Tab. 1 or 2, one can reduce the zero-temperature-drift of sensors to a scale of about ±0.005%fs/°C. The further correction can be made by means of the bondable resistors (ON-series, OB-series or OQ-series) from BCM SENSOR so as to reduce the zero-temperature-drift to and within a tolerance of ±0.002%fs/°C.

When manufacturing the high precision sensors (like load cells), it is crucial as mentioned above to use the STC gauges of the right STC number, by which the linear thermal expansion coefficient (α) of the STC gauges matches to that of the sensor body material.

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In case of manufacturing force sensors and pressure sensors where there is not enough space to bond the bondable resistors (e.g., ON-series, OB-series or OQ-series) one must use the STC gauges of the right STC number so as to reduce the zero-temperature-drift of the sensors.

For detailed engineering advice on utilizing the STC gauges, one can contact BCM SENSOR.

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