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Analisys of the Temperature Response of a Strain Gage

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Abstract

This paper presents briefly the experimental approaches regarding the sensitivity of strain gages, the change of resistance to a strain and the temperature dependence of the strain gages with sensitivity. The study has been accomplished using semiconductor strain gages .

Key words: *strain gage, sensitivity, temperature, rezistance, expansion.*

Factors Affecting the Temperature Response

This heading refers to the change in the measurement signal due to temperature under conditions where the mechanical loading of the measurement object is zero or constant.

A response to temperature can occur if during the observation period, i.e. between zeroing or recording of the reference value and the taking of the measurement itself, the measurement object's temperature or that of its environment changes. The response to temperature is reversible and the temperature effects disappear when the original temperature conditions at the measuring point return. In the literature the response to temperature is often called "apparent strain", which is a term giving no indication as to its cause.

There are many factors affecting the temperature response ε_t :

a. the component material's thermal expansion, α_C;
b. the thermal expansion of the material of the strain gage's measuring grid, α_M ;
c. the temperature coefficient of the grid material's electrical resistance, α_R ;
d. the temperature change Δt as the variable causing the effects.

In addition the temperature response of the electrical resistance of the wiring, which is connected in series with the strain gage, can also contribute to the overall temperature response. The temperature response should not be confused with thermal drift, which is a non-reversible process, but which is also superimposed on the temperature responses.

An approximate calculation of a strain gage's temperature response can be made using the equation:

$$\varepsilon_t = \left(\frac{\alpha_R}{k} + \alpha_c - \alpha_M \right) \Delta t \tag{1}$$

where: C – component; M – measuring grid.

The figure 1 can only be used as a guideline value for a limited temperature range, because the parameters α_C, α_R, α_M and k are temperature dependent.

Therefore representation of the temperature response is more correct in diagrammatic form. If strain gages with identical parameters are bonded to component materials having different values for α_C, then different curves of ε_t are obtained. Examples are shown in Fig. 1.

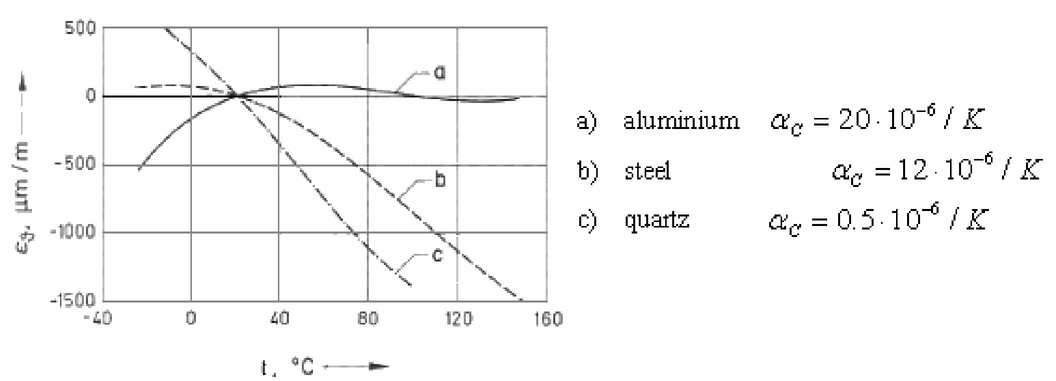

Fig. 1. Examples of temperature responses of strain-gage measuring points for the mounting of the same types of strain gage on different component materials.

Sufficient rigidity in the measurement object is assumed for the validity of the diagram, so that the forces originating from the strain gage and the adhesive have no effect. This assumption is always valid for metal objects apart from extremely thin components. A measurement, during which the measurement object experiences both a temperature change and mechanical loading, gives as a result the sum of the mechanical strain and the thermal strain. The thermal portion of the indicated strain is therefore an error. This unsatisfactory result can be remedied by the use of self-temperature compensating strain gages [1].

Temperature Compensated Strain Gages

Through the adoption of certain production methods, it is possible to influence the strain gage such that its temperature response within a limited temperature range is minimized. Here, the advantage is taken of being able to change the temperature coefficient of electrical resistance of the measuring grid's material.

This can be achieved by adding corrective alloying ingredients to the constantan which is the main alloy used and also by heat treatment.

The following requirements must be fulfilled for the correct mounting of strain gages:

- on flat application surfaces the strain gage closely follows the component's thermal expansion, i.e. the component's strain and that of the strain gage are identical; equation (1) describes this case and fig. 2, exaggerated for clarity, illustrates the conditions.

For the sake of simplicity the measuring grid and the adhesive are taken to be one material.

As a result of the change in temperature Δt , the component's original length l_C alters by the amount $l_C + \Delta l_{\vartheta C}$. The strain gage is compelled to follow this change in length.

The length of the measuring grid l_M, which was equal to the component section l_C under consideration, has altered by the amount $\Delta l_{\vartheta M}$.

If $l_C = l_m$, $\Delta l_{\vartheta 0} = \Delta l_{\vartheta M}$

Consequently the strains are also the same:

$$\frac{\Delta l_{\vartheta C}}{l_C} = \varepsilon_{\vartheta C}; \qquad \frac{\Delta l_{\vartheta M}}{l_M} = \varepsilon_{\vartheta M}; \qquad \varepsilon_{\vartheta C} = \varepsilon_{\vartheta M} \tag{2}$$

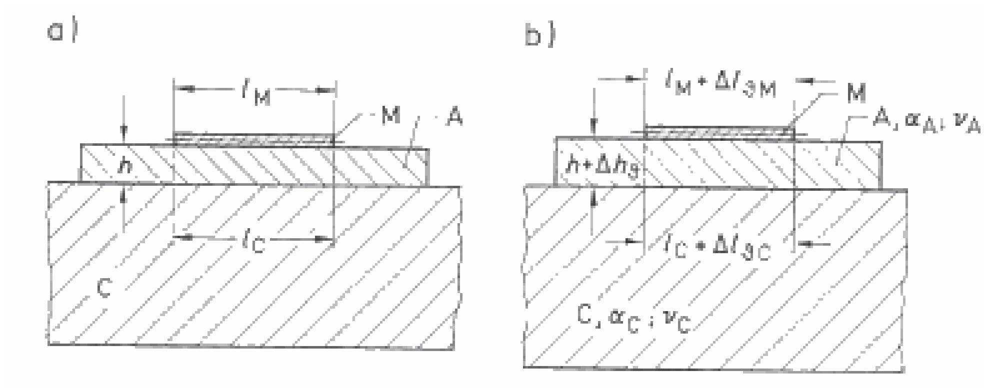

Fig. 2. Influence of a temperature change on the bonding of a strain gage mounted to a flat surface: A – intervening layer made up of adhesive and measuring grid carrier; h – thickness of the layer A;
a) initial condition at temperature t_0
b) condition at temperature $t_0 + \Delta t_0$;

The increase in the thickness of the layer h by Δh_{ϑ} has no influence on the strain conditions, because a correctly mounted strain gage closely follows the longitudinal strain on a flat surface.

Now the relationship on a curved surface will be examined. A section of a roller is considered as an example, see fig. 3. The thermal expansion in the axial direction along a surface layer is the same as with a flat section, i.e. $\varepsilon_{\vartheta C} = \alpha_C \cdot \Delta t$, according to [2].

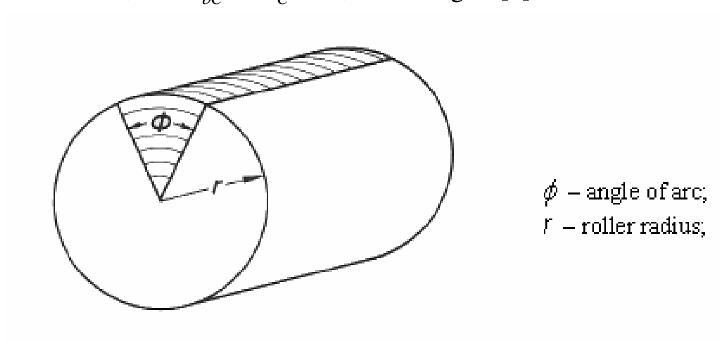

Fig. 3. Section of roller

The section of the roller under consideration is shown in cross-section in fig.4 including the bonding layers; the thicknesses are again markedly exagerated for clarity.

The thermal expansion of the measuring grid in the region of its neutral plane i.e. on the line $s/2$, is described by the expression (3):

$$\varepsilon_{\vartheta M} = \frac{\{r\alpha_C + h[\alpha_A 2\nu_A(\alpha_A - \alpha_C)]\} + s/2[\alpha_M + 2\nu_M(\alpha_M - \alpha_C)]}{r + h + s/2}\Delta t \qquad (3)$$

Whereas the strains $\varepsilon_{\vartheta C}$ and $\varepsilon_{\vartheta M}$ ere equal for the flat plate, here there is a difference.Therefore the temperature responses of the measuring points are different. Two examples have been calculated to give some idea of the extent of the variation in temperature response[3]. Technical data and the results are in table 1.

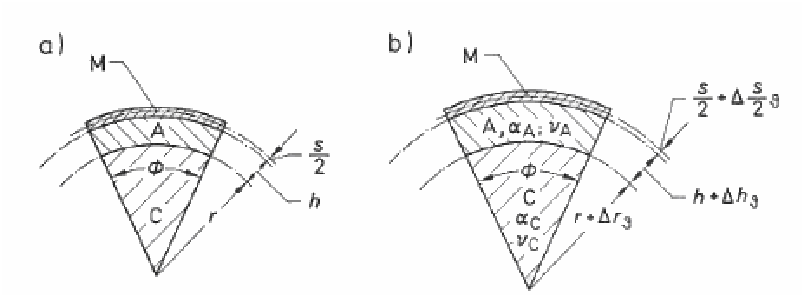

Fig. 4. Section of a roller with a strain gage bonded to the surface layer
a) initial condition at temperature t_0
b) condition at temperature $t_0 + \Delta t_0$

Table 1. Data and results for the temperature response

r	h	s	α_C	α_A	α_M	ν_A	ν_M	$\varepsilon_{\vartheta M}$	$\varepsilon_{\vartheta C}$	ε^*
mm	µm	µm	/K	/K	/K			/K	/K	/K
5	100	5	$12\cdot10^{-6}$	$70\cdot10^{-6}$	$15\cdot10^{-6}$	0.4	0.3	$14.05\cdot10^{-6}$	$12\cdot10^{-6}$	$2.05\cdot10^{-6}$
10	100	5	$12\cdot10^{-6}$	$70\cdot10^{-6}$	$15\cdot10^{-6}$	0.4	0.3	$13.04\cdot10^{-6}$	$12\cdot10^{-6}$	$1.04\cdot10^{-6}$

References

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Analiza răspunsului la temperatură al unui traductor

Rezumat

În cadrul acestui articol sunt prezentate aspecte importante legate de răspunsul la temperatură al unui traductor. Răspunsul la temperatură al unui punct de măsură cu marcă tensometrică(traductor) este dependent de conturul suprafeței pe care se aplică. Aplicațiile în care deformația grilei de măsurare urmează tangențial curba suprafeței, au răspunsuri la temperatură care diferă față de cele în care direcția activă a grilei este dreaptă.