TMA evaluation

In thermomechanical analysis (TMA), dimensional changes of a sample under very small sample loading (dilatometry mode) are measured as a function of temperature or time. The deformation of a sample under a higher load (penetrometry mode) can also be recorded. Depending on the type of sample and the selected measurement program, the curve profile can be used to help characterize the substance.

This software option offers you the following evaluations specific to TMA:

- **Glass transition temperature:** Intersection point of the tangents to the expansion curve before and after the effect or to the TMA curve before and after incipient deformation (softening temperature).
- **Linear coefficient of expansion:** local value α, in tabular or graphical form.
- **Linear coefficient of expansion:** mean value α, in tabular or graphical form.
- **Conversion:** Ratio of the partial length change to the total length change over a temperature or time interval, e.g. in thermal decomposition of a surface coating.

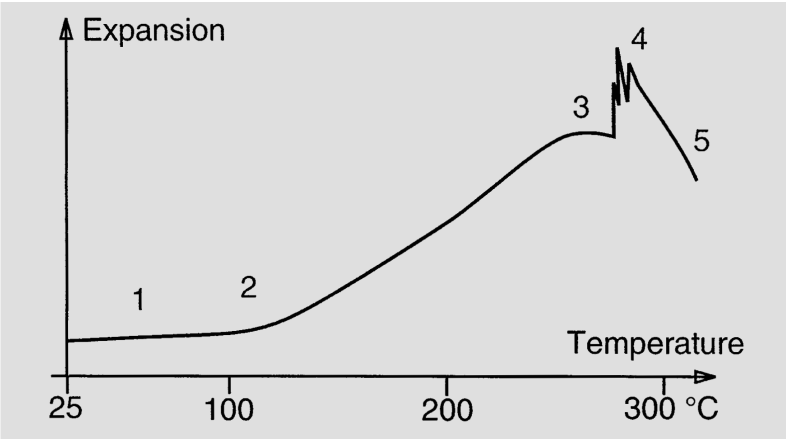
Theory

A typical TMA curve of a glass-fiber reinforced epoxy resin demonstrates the most important effects. In addition to the glass transition determined from the intersection point of the tangents, calculation of the coefficients of expansion is of importance. A distinction is made between:

Local coefficient of expansion $\alpha = \frac{dL}{dT} \cdot \frac{1}{L_o} = \frac{dL}{dt} \cdot \frac{1}{\beta \cdot L_o}$

Mean coefficient of expansion $\alpha = \frac{\Delta L}{\Delta T} \cdot \frac{1}{L_o}$

dL = Infinitesimal lenght change
dT = Infinitesimal temperature change
dt = Infinitesimal time change
L_o = Initial lenght
ΔL = Lenght change of the sample
ΔT = Temperature change
β = Heating rate in the sample



1 = Linear expansion
2 = Glass transition
(change in the coefficient of expansion)
3 = Softening, penetration
4 = Degassing, Delamination
5 = Plastic deformation

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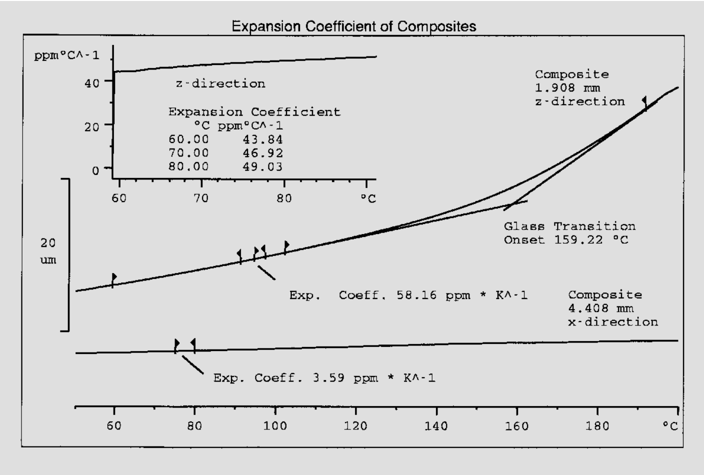
Application examples

Coefficient of expansion of a glass-fiber reinforced plastic

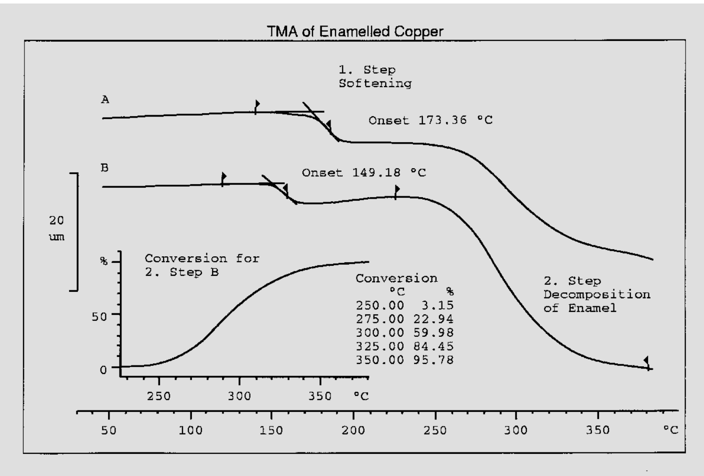
The expansion behavior is a decisive quantity especially with composites as it defines the possible application field.



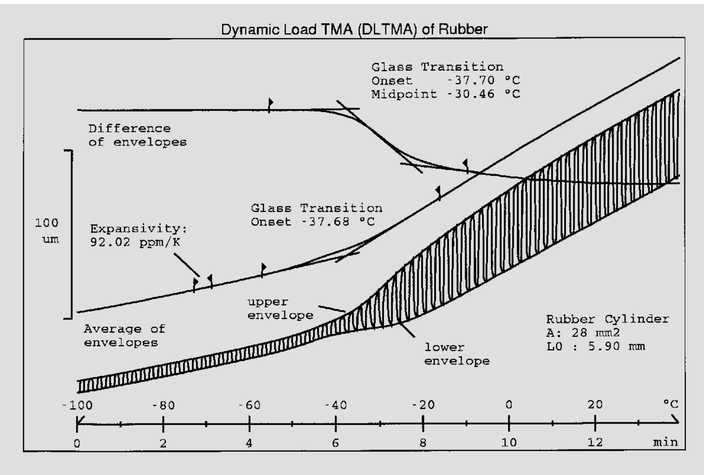
The diagram shows the expansion behavior of a glass-fiber reinforced epoxy resin sample recorded at a heating rate of 10 K/min. The sample was first measured in the fiber direction (x direction) and then across the fibers (z direction). These curves were blank corrected and used to calculate the local coefficients of expansion at 75 and 95 °C. In addition, the mean coefficient of expansion between 60 and 90 °C was displayed graphically and in tabular form for the z direction. As expected, the coefficient of expansion in the fiber direction is much less than its counterpart at right angles. It is also clear that detection of the glass transition is possible only at right angles to the fiber direction.

TMA curve of a copper wire insulated by enamel

The thermal and mechanical stability of copper wire insulations is an important quality characteristic for the resulting coils. The diagram shows the experimental curves of two copper wires (A and B) insulated with different enamels. In principle, the same behavior is apparent, namely softening of the insulation recognizable from the 1st step at around 150 °C and the subsequent thermal decomposition as the 2nd step.



The conversion can be calculated for the entire process and shown in tabular or graphical form. Both effects are shifted to higher temperatures with sample A thus demonstrating the greater thermal stability of this enamel. The thickness of the particular enamel coating can also be determined as an overall step divided by two.



Thermoelastic behavior of rubber

DLTMA (dynamic load TMA) can be used to determine the elastic behavior of materials such as rubber. During heating, the applied force of the probe is varied every 6 s between 0.1 and 0.5 N. The evaluation of the experimental curve using the envelope curves provides both the expansivity (the mean value of the envelope curves) and a value inversely proportional to the modulus of elasticity (the difference between the envelope curves). In addition, the glass transition temperature of the rubber, here –37 °C, can be determined from the intersection point of the tangents to the expansion curve.

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