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Analyzing & Testing


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Motivation

Material innovation leads to extended requirements on the measuring instruments, which are increasingly not fulfilled by state-of-the-art.

In the following, this need for action is shown by means of a dilatometer with focus on the measuring cell.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Conventional Measuring Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measuring range of the length change</td>
<td>5 mm</td>
</tr>
<tr>
<td>Resolution of the length change</td>
<td>1.25 nm</td>
</tr>
<tr>
<td>Detection of the contact force</td>
<td>No detection</td>
</tr>
<tr>
<td>Constancy of contact force</td>
<td>Not constant</td>
</tr>
<tr>
<td>Adjustment of the contact force</td>
<td>Manual adjustment</td>
</tr>
<tr>
<td>Range of contact force</td>
<td>0.15 N – 0.45 N</td>
</tr>
<tr>
<td>Friction influence on sample</td>
<td>Friction of guidance</td>
</tr>
<tr>
<td>Realisation of different initial sample length</td>
<td>Different pushrods needed</td>
</tr>
<tr>
<td>Detection of the initial sample length</td>
<td>Manually by using a caliper</td>
</tr>
</tbody>
</table>
The aim of Dilatometry is:
- measurement of the length change
- during a temperature change
- under a negligible load

Calculation of the mean CTE (coefficient of thermal expansion):

$$\bar{\alpha}(T_0; T) = \frac{1}{L_0} \cdot \frac{\Delta L}{\Delta T} = \frac{1}{L_0} \cdot \frac{\Delta L}{T - T_0}$$
Key Figures of a Measuring Cell

- Range of length change
- Resolution of length change
- Uncertainty of length change
- Detection of sample load (contact force)
- Constancy of sample load (contact force)
- Range of sample load (contact force)
- Influence of friction
- Range of initial sample length
- Detection of initial sample length
- Uncertainty of initial sample length detection

influence the
- variety of materials
- variety of sample dimensions
- the quality of results
Conventional Measuring Cell of a Dilatometer – Technical Principle

Measurement uncertainty influenced by
- Undefined sample load (contact force) (1)
- Friction influence (2)
- Limited range of sample length (3)
- Limited length change and resolution (4)
- Manual detection of initial sample length (3, 4)
NanoEye

Achieved goals:
- Defined small & constant sample load (contact force)
- No influence by friction due to force control circuit
- Nearly unlimited range of initial sample length & length change at higher resolution
- Automatic detection of initial sample length

...enabled by the use of
- Incremental encoder for detection of $\Delta L$ and $L_0$
- Sample load detection and force control circuit
- Nearly unlimited piezo drive and guidance
Metrological Advantage of *NanoEye* – Length Change

Influence of the sample load (contact force) on the length change

Small and constant contact forces required

⇒ only realizable with a force-controlled measuring cell: *NanoEye*
Metrological Advantage of *NanoEye* – Detection of $L_0$

**Influence of the sample load on the initial sample length**

![Graph showing the influence of contact force on $L_0$.](image)

**Insulation material (Styrodur®, BASF):**
- $L_0$ is influenced by contact force (up to 5%)
- Manual Measurement:
  - Standard deviation higher
  - Variation of the contact force $\sim 0,3N$

**Advantages of the force-controlled measuring cell:**
- Defined contact to the sample
- Conditions of $L_0$ determination comparable with later length change measurement
Length Change of Reference Samples: platinum and tungsten

Results in the range of uncertainty of the expansion values of the references

Use of the force-controlled measuring cell for determination of thermally induced length changes possible
**Comparison of Key Figures: Conventional vs. NanoEye**

**NanoEye: Overcoming the restrictions of established DIL measuring cells**

<table>
<thead>
<tr>
<th>Properties</th>
<th>Conventional Measuring Cell</th>
<th>NanoEye</th>
<th>Achieved improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principle of length measurement</td>
<td>LVDT</td>
<td>Incremental displacement encoder</td>
<td>✓</td>
</tr>
<tr>
<td>Measuring range of the length change</td>
<td>5 mm</td>
<td>50 mm</td>
<td>~ ·10</td>
</tr>
<tr>
<td>Resolution of the length change</td>
<td>1.25 nm</td>
<td>0.10 nm</td>
<td>~ ·10</td>
</tr>
<tr>
<td>Detection of the contact force</td>
<td>No detection</td>
<td>Detection by force sensor</td>
<td>✓</td>
</tr>
<tr>
<td>Constancy of contact force</td>
<td>Not constant, the spring preload is changed</td>
<td>Definable (control deviation ± 0.25 mN)</td>
<td>✓</td>
</tr>
<tr>
<td>Adjustment of the contact force</td>
<td>Manual adjustment of the spring preload</td>
<td>Electronic / software controlled</td>
<td>✓</td>
</tr>
<tr>
<td>Range of the contact force</td>
<td>0.15 N – 0.45 N</td>
<td>0.01 N – 3.00 N</td>
<td>~ ·10</td>
</tr>
<tr>
<td>Friction influence on sample</td>
<td>Friction of guidance</td>
<td>Eliminated within the force control circuit</td>
<td>✓</td>
</tr>
<tr>
<td>Realization of different initial sample length</td>
<td>Different pushrods or extension pieces</td>
<td>Measuring range sufficient</td>
<td>✓</td>
</tr>
<tr>
<td>Detection of the initial sample length</td>
<td>Manually by using a caliper</td>
<td>Automatically by incremental displacement encoder</td>
<td>✓</td>
</tr>
</tbody>
</table>
New Product Series Based on the New Measuring Cell

DIL 402 Expedis Classic
DIL 402 Expedis Select
DIL 402 Expedis Supreme
DIL 402 Expedis Supreme HT
DIL 402 Expedis Supreme Glovebox
Conclusion

We provide the most advanced measuring cell – *NanoEye*

Advantages:

- Expanded measuring range of the length change at a higher resolution
- Defined small & constant contact force
- Impact-free and reproducible movement of the pushrod due to force control circuit
- Use of the entire range of initial sample length without operator intervention
- Automatic detection of the initial sample length

**Patented in US, CN, DE, FR, GB, IT, CH, NL, JP**

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