Investigation of Elastomer Seal Behavior for Transport and Storage Packages

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Summary

- Elastomers are highly complex materials
- Properties are strongly influenced during:
  - Compounding
  - Processing
  - Application
- The application conditions encountered in transport/storage containers are challenging:
  - Regarding temperature range
  - long time scale of use
  - continuous irradiation
• Elastomer production
• Seal function
• Application in containers
• Important topics
  – e.g. behavior at low temperatures
• Summary
At the beginning
Elastomer production
Function / Influencing factors

leakage rate $Q$:

$Q = Q_{\text{perm}} + Q_{\text{trans}}$

$Q_{\text{perm}} = P \cdot A/d \cdot (p_1 - p_2)$

$Q_{\text{trans}} = f(\text{material contact, pressure difference})$
Container application

• Application in containers
  – broad temperature range
  – long time
  – continuous irradiation
  – static conditions, but with possibility of highly dynamic events

• Comparison with other applications of seals
  – piping / pipelines
  – aviation/automotive
Container application

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Identified important topics

• General sealing process
  – How does the molecular and/or micro-structure correlate with the properties
  – Which properties are mainly responsible for the function
    • Common requirements for material selection: hardness, tear strength, elongation at break
    • Really needed: low Compression Set and Stress Relaxation

• Temperature dependence of several properties

• Aging behavior over extended times
  – Property change due to e.g. chain scission, plasticizer loss or additional crosslinking
    • standard criterion 50% drop of tear strength
    • better 80% Compression Set?
Thermal Analysis: glass rubber transition

- DMA: $E'$-onset -26°C
- DMA: $E'$-inflection point -20°C
- DMA: $E'$-offset -14°C
- DMA: $\tan \delta$-peak -8°C
- DMA: $E''$-peak -18°C
- DSC: Heat flow-onset -23°C
- DSC: Heat flow-inflection point -19°C
- DSC: Heat flow-offset -15°C

The glass-rubber transition temperature ($T_g$) has to be defined: conditions and method of measurement, analysis method.

So far no direct correlation between the glass-rubber transition temperature and seal failure is known.

Additional tests are required:
- Compression Set / Component Tests

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Compression Set (CS) according to ISO 815

Initial state

Compression by 25% at room temperature

Heating/Cooling to test temperature and subsequent storage

Release and Recovery

Two ways of analysis:
- a single value after a fixed time span (30 minutes) after release of the compression force
- continuous measurement over a certain time after release of the compression force

\[
CS = 100\% \frac{(h_0 - h_2)}{(h_0 - h_1)}
\]
Comparison with standardized test:

- similar results are obtained
- only slight differences between the standardized and the new method (~2-3 % CS)
- measurement is much faster and shows a higher resolution
- is performed automatically
- allows a quick overview of the recovery behavior of a material at different temperatures

“Compression Set” with DMA

Graph shows the change in compression set (CS) as a function of time at various temperatures. The graph is labeled with the following temperatures: -39 °C, -34 °C, -29 °C, -24 °C, -19 °C, -14 °C, -9 °C, -4 °C, 1 °C, 6 °C, and 11 °C. The x-axis represents time in minutes, ranging from 0 to 60, and the y-axis represents the CS DMA as a percentage, ranging from 100 to 0.
$y = y_\infty + \sum_i A_i e^{-\frac{t}{t_i}}$
Component test

- at critical temperature, drastic increase in leakage rate
- continuous reduction followed by faster decrease in the range of the glass rubber transition
- closure much lower than opening of leakage path
- hysteresis like behavior observed

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THANK YOU FOR YOUR ATTENTION