



Choosing the Right Materials with Low Compression Set: Considerations, Testings and Recommendations

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I. Introduction of Compression Set:

Compression set is a term commonly used in materials science and engineering, particularly in the context of elastomers (rubber-like materials), plastics, and other polymers. It refers to the permanent deformation or "set" that occurs in a material after it has been subjected to compression for a prolonged period and then released.

Compression set is typically measured as the percentage of the original thickness or height that the material fails to recover after being compressed for a specified time period under certain conditions, such as temperature and pressure. It is an important property to consider in applications where materials are subjected to sustained compression, such as gaskets, seals, O-rings, and other sealing applications.

High compression set can indicate that a material will not maintain its sealing or cushioning properties over time, as it fails to recover its original shape after being compressed. Therefore, materials with low compression set are often preferred for such applications. Factors that can influence compression set include the type of material, its formulation, processing conditions, environmental factors, and the duration and magnitude of the compression.

II. How to Measure the Compression Set of a Material?

Measuring the compression set of a material typically involves the following steps:

2.1. Sample Preparation:

Cut or prepare specimens of the material according to the relevant standards or testing protocols. Ensure specimens are of uniform size and shape.



2.2. Initial Thickness Measurement:

Measure the initial thickness or height of each specimen using a precise measuring instrument, such as a micrometer or caliper. Record this measurement as the starting point for the test. For example, let's say the initial thickness is measured to be 10 mm.

2.3. Compression:

Apply a specified compressive load or strain to each specimen for a predetermined time period using a compression testing machine or specialized compression set apparatus. Let's assume the material is compressed under a load of 100 N for 24 hours at room temperature.

2.4. Relaxation Period:

After the compression period, remove the load and allow the specimens to relax for a specified recovery period. This allows the material to attempt to recover its original shape. Let's say the relaxation period is also 24 hours.

2.5. Final Thickness Measurement:

Measure the thickness or height of each specimen again using the same measuring instrument used in step 2. Record these final measurements. For example, let's say the final thickness is measured to be 7.5 mm.

2.6. Calculation:

Calculate the compression set for each specimen using the following formula:

$$\begin{aligned}\text{Compression Set (\%)} &= [(\text{Initial Thickness} - \text{Final Thickness}) / \text{Initial Thickness}] \times 100 \\ &= [(10 \text{ mm} - 7.5 \text{ mm}) / 10 \text{ mm}] \times 100 \\ &= (2.5 \text{ mm} / 10 \text{ mm}) \times 100 \\ &= 25\%\end{aligned}$$

2.7. Analysis:

Analyze the compression set data obtained from multiple specimens to determine the average compression set and assess the material's performance. Lower compression set values indicate better recovery properties.



2.8. Reporting:

Report the compression set results along with relevant testing parameters (e.g., temperature, duration of compression) for documentation and comparison purposes. For example, the compression set of the rubber material tested under a load of 100 N for 24 hours at room temperature is 25%.

By following these steps and integrating the example data, you can conduct compression set testing and evaluate the performance of rubber or elastomeric materials.

III. Why Compression Set Testing is crucial?

3.1. Quality Control:

It helps manufacturers ensure that the materials they produce meet the required standards and specifications for applications where compression set resistance is essential, such as in seals, gaskets, and O-rings. By testing the compression set, manufacturers can verify the consistency and reliability of their materials.

3.2. Product Performance:

Compression set testing provides valuable information about how a material will perform over time under compression. Materials with low compression set are more likely to maintain their sealing or cushioning properties over extended periods, ensuring the durability and reliability of products.

3.3. Predictive Maintenance:

In industrial settings where seals and gaskets are critical for equipment operation, monitoring compression set over time can help predict when maintenance or replacement is necessary. A significant increase in compression set may indicate that the material is no longer functioning as intended and needs to be replaced to prevent equipment failure or leaks.

3.4. Material Selection:

Engineers and designers use compression set data to select the most suitable materials for specific applications. By comparing the compression set performance of different materials



under similar conditions, they can choose materials that offer the best combination of properties for their intended use, balancing factors like cost, performance, and longevity.

3.5. Research and Development:

Compression set testing is also valuable in the research and development of new materials or formulations. It helps scientists and engineers understand how changes in material composition, processing methods, or environmental conditions affect the material's ability to recover from compression, leading to the development of improved materials with enhanced performance characteristics.

IV. What Factors May Affect Compression Sets?

Several factors can influence the compression set of a material. These factors include:

4.1. Material Composition:

The composition of the material, including the type of polymer, filler materials, cross-linking agents, and additives, can significantly affect its compression set properties. Different polymers and additives have varying levels of elasticity, resilience, and resistance to permanent deformation.

4.2. Temperature:

Temperature plays a crucial role in the compression set behavior of materials. Elevated temperatures can accelerate the relaxation process, leading to increased deformation and higher compression set values. Conversely, lower temperatures may slow down recovery and increase the material's stiffness, affecting its ability to recover from compression.

4.3. Compression Duration:

The duration of compression, or the time that the material is subjected to a compressive load, can impact its compression set. Longer compression times typically result in greater permanent deformation as the material may undergo more extensive relaxation and creep processes.



4.4. Compression Stress/Pressure:

The magnitude of the compressive stress or pressure applied to the material can influence its compression set behavior. Higher stress levels may cause greater deformation and lead to higher compression set values, especially if the material approaches its elastic limit or undergoes plastic deformation.

4.5. Environmental Factors:

Environmental conditions such as humidity, exposure to chemicals, UV radiation, and other environmental factors can affect the material's compression set properties. Certain environmental conditions may accelerate degradation or alter the material's mechanical properties, leading to changes in compression set behavior over time.

4.6. Material Age and History:

The age and history of the material, including any prior deformation or exposure to compression, can impact its compression set performance. Materials that have undergone repeated compression cycles or prolonged use may exhibit higher compression set values due to accumulated damage or fatigue.

4.7. Processing Conditions:

The processing conditions used during manufacturing, such as curing temperature, pressure, and time, can affect the material's microstructure and mechanical properties, including its compression set behavior. Variations in processing conditions can lead to differences in material performance and compression set resistance.

4.8. Filler Type and Loading:

The type and loading level of fillers added to the material, such as carbon black, silica, or other reinforcing agents, can influence its compression set properties. Fillers can improve stiffness, strength, and wear resistance but may also affect the material's ability to recover from compression.

By considering these factors and conducting comprehensive testing under relevant conditions, manufacturers and researchers can better understand and optimize the compression set performance of materials for specific applications.



V. What Are the Common Materials with Lower Compression Set?

Materials with lower percentage compression set typically exhibit better elastic recovery and resilience after compression. Some common materials known for their low compression set properties include:

5.1. Fluoroelastomers (FKM/Viton):

Fluoroelastomers are known for their excellent resistance to heat, chemicals, and compression set. They are often used in demanding sealing applications where low compression set and long-term performance are essential, such as in automotive seals and gaskets.

5.2. Perfluoroelastomers (FFKM):

Perfluoroelastomers offer even higher temperature and chemical resistance compared to fluoroelastomers and typically have very low compression set values. They are used in extreme environments where conventional elastomers would fail, such as in semiconductor manufacturing and aerospace applications.

5.3. Silicone Rubber:

Silicone rubber exhibits good resistance to compression set, especially at elevated temperatures. It is commonly used in medical devices, food-grade applications, and automotive seals where flexibility and durability are required over a wide range of temperatures.

5.4. Polyurethane (PU):

Polyurethane elastomers can have low compression set values, particularly if formulated with high-quality raw materials and additives. They are used in various applications, including industrial seals, suspension bushings, and footwear, where resilience and abrasion resistance are critical.

5.5. Ethylene Propylene Diene Monomer (EPDM):

EPDM rubber has good resistance to compression set, weathering, and ozone exposure. It is commonly used in outdoor applications, such as automotive weatherstripping, roofing membranes, and seals, where durability and long-term performance are important.



VI. How to Determine the Best Material with Lower Compression Set?

To determine the best material option with the lowest compression set for a specific application, several factors should be considered:

6.1. Performance Requirements:

Consider the operating conditions, including temperature, pressure, exposure to chemicals, and expected mechanical stresses. Choose a material that can withstand these conditions without significant deformation or loss of sealing ability.

6.2. Material Properties:

Evaluate the mechanical properties of different materials, including compression set, tensile strength, elongation at break, and hardness. Compare these properties to the requirements of the application to ensure compatibility and performance.

6.3. Cost and Availability:

Consider the cost-effectiveness and availability of the materials, taking into account factors such as material cost, manufacturing processes, and supply chain reliability.

6.4. Testing and Validation:

Conduct thorough testing and validation of candidate materials under simulated or real-world conditions to assess their performance and reliability. This may involve compression set testing, accelerated aging tests, and field trials to confirm suitability for the application.

6.5. Regulatory Compliance:

Ensure that the chosen material complies with relevant industry standards, regulations, and safety requirements for the intended application.

By carefully considering these factors and selecting a material with the lowest compression set that meets the specific requirements of the application, you can ensure optimal performance, durability, and reliability over time.



VII. Does the Thermoplastic Elastomers Have a Low or High Compression Set?

Thermoplastic elastomers (TPEs) can exhibit a wide range of compression set values, depending on their specific formulation, molecular structure, and processing conditions. In general, TPEs can offer both low and high compression set properties, depending on factors such as:

7.1. Chemical Composition:

The specific polymer(s) used in the TPE formulation can influence its compression set behavior. Some TPEs, such as certain types of styrenic block copolymers (e.g., styrene-butadiene-styrene or SBS), may have relatively low compression set values due to their elastic properties and ability to recover after compression. Other TPEs, such as some thermoplastic polyurethanes (TPUs) or thermoplastic vulcanizates (TPVs), may have higher compression set values depending on their molecular structure and composition.

7.2. Cross-Linking:

Some TPE formulations may include cross-linking agents to improve their mechanical properties and reduce compression set. Cross-linking enhances the material's ability to recover its shape after deformation, resulting in lower compression set values. However, not all TPEs are cross-linked, and the presence or absence of cross-linking can significantly impact compression set behavior.

7.3. Processing Conditions:

The processing conditions used during TPE manufacturing, such as temperature, pressure, and cooling rate, can affect the material's molecular structure and mechanical properties, including compression set. Proper processing techniques can help minimize compression set by optimizing material properties and ensuring uniformity throughout the TPE product.

7.4. Filler Content:

The addition of fillers or reinforcing agents to TPE formulations can influence compression set properties. Fillers may improve mechanical strength and stiffness but can also affect the



material's ability to recover from compression. Proper selection and optimization of filler content can help balance these competing factors and achieve desired compression set performance.

Overall, while some TPE formulations may offer low compression set values comparable to traditional elastomers, others may exhibit higher compression set depending on their specific characteristics and intended applications. It's essential to evaluate TPE materials carefully and conduct testing under relevant conditions to determine their compression set behavior and suitability for specific applications.

VIII. Conclusion

This comprehensive article offers expert guidance on selecting materials with low compression set, vital for applications requiring resilience and long-term performance. Beginning with an overview of common materials renowned for their low compression set properties, including fluoroelastomers, perfluoroelastomers, silicone rubber, polyurethane, and EPDM, it delves into the multifaceted factors affecting compression set behavior. These factors encompass material composition, temperature, compression duration, stress/pressure, environmental conditions, material age, processing conditions, and filler type/loading.

The article underscores the significance of standardized compression set testing to accurately assess material performance. Recommendations for material selection encompass thorough consideration of performance requirements, material properties, cost-effectiveness, availability, testing protocols, and regulatory compliance. By integrating these critical considerations, engineers and manufacturers can make informed decisions to identify the most suitable material with low compression set for their specific application requirements.

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