

Lecture 38 - Polymer testing-03

Let's delve into the discussion on conditioning, mass density measurement, and rheological properties in polymer testing.

Conditioning: The moisture content of the specimen plays a critical role in ensuring the repeatability of test results. Even slight fluctuations in factors such as loading rate, ambient temperature, or humidity can impact characteristic values. Therefore, maintaining a consistent and controlled test climate is essential for reliable and reproducible data.

Separators for Conditioning: Several separators are used to control the conditions for testing. These may include:

1. **Air Conditioners:** Regulate ambient temperature.
2. **Enclosures:** Provide controlled environments for testing.
3. **Hydrometers:** Measure the moisture content in the air.
4. **Thermometers:** Monitor and regulate temperature during testing.

Bulk Material Properties - Mass Density Measurement: Mass density is a fundamental property of materials, including polymers. It refers to the mass of a substance per unit volume. Accurate measurement of mass density is crucial for understanding and characterizing polymer materials. Various techniques and instruments, such as balances and density meters, are employed for this purpose.

Rheological Properties: Rheological properties involve the study of how materials deform and flow under the influence of an applied force. In the context of polymers, this is particularly important as it provides insights into their flow behavior, viscosity, and response to different conditions.

Understanding the rheological properties of polymers is vital for applications such as processing, molding, and predicting material behavior under different manufacturing conditions.

Feel free to provide more specific details or ask questions if there's a particular aspect you'd like to explore further!

Absolutely, standardizing testing conditions is crucial to ensure reproducibility and comparability of results in polymer testing. Let's explore further.

Standard Atmosphere: Testing conditions are often defined under a standard atmosphere to simulate real-world situations and provide a basis for comparison. This

standard atmosphere typically satisfies average climatic parameters, allowing for consistent testing conditions. It is essential to conduct tests under specified conditions to obtain reliable and meaningful results.

Simulating Real-World Conditions: Simulating real-world conditions becomes necessary when the testing environment needs to deviate from standard atmospheric conditions. For example, if the intended application involves a temperature different from the standard room temperature (e.g., 25 degrees Celsius), it is important to replicate those conditions during testing. This ensures that the material properties are characterized under relevant circumstances.

Standards Compliance: Various standards, such as ISO 291, provide guidelines for specimen preparation and testing under specific conditions. Adhering to these standards is essential for achieving consistency and comparability of results across different testing laboratories and studies.

ISO 291: ISO 291 is a standard that likely provides detailed specifications for the atmosphere under which testing should be conducted. It sets parameters such as temperature to create a standardized testing environment. Following such standards ensures that the material properties are assessed in a controlled and repeatable manner.

In summary, adherence to standardized testing conditions, whether under a standard atmosphere or conditions simulating real-world scenarios, is crucial for obtaining reliable and comparable results in polymer testing. If there are specific aspects or standards you'd like more information on, feel free to let me know!

Certainly, the classification of standard atmospheres into different classes based on temperature and relative atmospheric humidity (RH) deviations plays a crucial role in ensuring controlled and reproducible testing conditions. Let's delve into the details:

Standard Atmosphere Classes:

1. Class 1:

- *Temperature Deviation:* ± 1 degree Celsius
- *RH Deviation:* ± 5 percent

2. Class 2:

- *Temperature Deviation:* ± 2 degrees Celsius
- *RH Deviation:* ± 10 percent

Specimen Adjustment: The adjustment of specimens to the appropriate test climate is a critical step in obtaining accurate and reliable data on polymers, especially in short-term tests. Specimens are conditioned to bring them into balance with the specified atmosphere. This conditioning process ensures that the material properties are characterized under controlled and standardized conditions.

Test Duration: The test duration can vary based on factors such as the initial temperature of the specimen and its geometrical characteristics, particularly thickness. Conditioning the specimen under the specified atmospheric conditions for a defined duration allows for stabilization and ensures that the material's response is consistent.

Ambient Air Temperature: During the conditioning phase, specimens are assumed to be under the influence of ambient air temperature. This helps create a controlled environment, aligning with the specified class of standard atmosphere. Achieving this balance is crucial for the reliability and repeatability of test results.

In summary, the classification of standard atmospheres into different classes, along with the adjustment and conditioning of specimens, contributes to the accuracy and reproducibility of polymer testing. The duration of conditioning and the specifics of the atmosphere help create a standardized testing environment. If you have further questions or if there's anything specific you'd like to explore, feel free to let me know!

Certainly, maintaining the proper moisture content in specimens is crucial for achieving accurate and reliable testing results, and it involves considerations of equilibrium, storage conditions, and the use of environmental chambers. Let's break down the key points:

Equilibrium Moisture Content:

1. **Dependence on Polymer Type:** The equilibrium moisture content of specimens is influenced by the polymer's coefficient of diffusion and its specific characteristics. Different polymers may require varying durations for their moisture content to reach equilibrium.
2. **Storage Duration:** The storage time required for specimens can vary, even for the same relative humidity, depending on the type of polymer. Achieving equilibrium with the surrounding air is essential for consistent results.

Storage in a Normalized Atmosphere:

1. **Surface Exposure:** Specimens should be kept in a normalized atmosphere where as much of their surface as possible is exposed to atmospheric conditions. This exposure helps in achieving equilibrium moisture content.

2. **Temperature Stability:** While maintaining a steady storage temperature is usually manageable, achieving the required humidity level can be more challenging. Desiccators or environmental chambers are often used for preconditioning.

Relative Humidity over Saturated Salt Solutions:

Table; Relative humidity over saturated salt solutions at various temperatures

Salt	Relative humidity in % at									
	5(°C)	10(°C)	15(°C)	20(°C)	25(°C)	30(°C)	35(°C)	40(°C)	50(°C)	60(°C)
Potassium hydroxide	14	13	10	9	8	7	6	6	6	-
Lithium chloride	14	14	13	12	12	12	12	11	11	11
Magnesium chloride	35	34	34	33	33	33	32	32	31	30
Sodium bichromate	59	58	56	55	54	52	51	50	47	-
Ammonium nitrate	-	73	69	65	62	59	55	53	47	42
Potassium chloride	88	88	87	86	85	85	84	82	81	80

Source; Wolfgang Grellmann, Sabine Seidler, Paul I. Anderson Polymer testing, 2nd edition, Hanser Publications Cincinnati (2013), E-Book ISBN 978-1-56990-549-4.

1. **Humidity Conditions:** The table provides relative humidity values over saturated salt solutions at various temperatures. Different salts such as potassium hydroxide, lithium chloride, magnesium chloride, etc., are used to create specific humidity conditions.

Testing Facilities and Environmental Chambers:

1. **Temperature Chambers:** Testing facilities may incorporate environmental chambers, and the test equipment should fit entirely inside the temperature apparatus.
2. **Reference vs. Characterization Temperature:** If polymer characterization is performed at a temperature different from the reference temperature, both the reference and characterization temperatures need to be accommodated in the testing facility.
3. **Preheating Specimens:** To avoid thermal shock, specimens need to be preheated at each tested temperature to achieve a suitably constant cross-sectional temperature.

4. **Avoiding Surface Contact:** Specimens should be stored to avoid direct surface contact, ensuring sufficient air circulation around them.

In summary, controlling and maintaining the moisture content and environmental conditions of specimens are critical aspects of polymer testing to ensure accurate and reproducible results. If you have any specific questions or if there's more you'd like to explore, feel free to let me know!

Polymer Testing: Conditioning and Long-Term Experiments

1. Time Duration for Multipurpose Specimens:

- For multipurpose specimens with a thickness of around 4 mm, a time duration of 30 minutes is considered quite adequate for achieving equilibrium in the environmental chamber.

2. Utilization of Environmental Chamber:

- An environmental chamber is utilized for conditioning, especially when changing the temperature. It ensures a specific humidity level is maintained, which is crucial for some testing scenarios.

3. Media Resistance Testing:

- In certain tests, specimens may be exposed to various media (e.g., oil, water, detergent solutions) for extended periods (e.g., up to 2000 hours). The exposure is carried out at different temperatures, and the resulting values are compared with the initial state to assess degradation.

4. Variety of Atmospheric Conditions:

- Long-term experiments involve exposing specimens to a variety of atmospheric conditions, ranging from, for example, 25°C to 47°C or 2°C to 47-48°C. This helps simulate real-world scenarios and assess the effects of different environments on polymers.

5. Storage Separation in Long-Term Experiments:

- Strict separation of polymer types during storage in recirculating heating cabinets and media chambers is essential. This separation minimizes the potential for reciprocal interactions and influences from aging-related breakdown products.

Apparatus for Conditioning:

1. Air Conditioned Room:

- An air-conditioned room is a fundamental requirement for the test laboratory. It provides a controlled environment with tight temperature regulation for polymer testing techniques.

2. Air Conditioning Chamber:

- The air conditioning chamber must maintain proper temperature and relative humidity levels. These conditions need to be sustained consistently, even over extended periods, such as weekends or nights when there might be no lab staff present.

3. Temperature and Humidity Control:

- The air conditioning chamber should have the capability to control temperature and relative humidity effectively, meeting the requirements of specific testing standards.

4. Tolerant Level Maintenance:

- Tolerant levels need to be maintained throughout the testing period to ensure the reliability and repeatability of results.

In summary, the conditioning of polymer specimens is a critical step in polymer testing, requiring controlled environments, precise temperature and humidity control, and separation of polymer types during storage in long-term experiments. The use of environmental chambers and proper testing apparatus ensures the accuracy and reliability of test results. If you have further questions or if there's anything specific you'd like to explore, feel free to let me know!

Ensuring reliable automatic control is imperative for the efficient operation of an air conditioning system. This consideration becomes crucial when incorporating a heating system into the setup, as the design must prioritize achieving optimal temperature uniformity throughout the working space. The dual aspect of this requirement is noteworthy—especially when dealing with data collection spanning from, for instance, 2 degrees Celsius, common in certain regions, to temperatures reaching 45-46 degrees Celsius. In such cases, the inclusion of a heating mechanism becomes essential to normalize the chamber temperature to the desired level, such as 25 degrees Celsius.

For environments demanding controlled humidity and temperature, it is advisable to position the room within another room, minimizing windows and doors to prevent


atmospheric contamination. Now, let's explore the significance of enclosures in the context of polymer testing.

Enclosures in Polymer Testing:


Enclosures play a pivotal role in polymer testing, particularly for studies involving controlled humidity and temperature. Cabinets equipped with regulated humidity and temperature settings are frequently employed for conditioning and moisture aging studies. Two prevalent forms of humidity control cabinets are moisture injection cabinets and salt tray cabinets.



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- ✓ Despite being intended specifically for plastics, ISO 483 offers helpful information on the use of such cabinets that also applies to all polymeric materials.
- ✓ A suitable moisture sensor, such as a capacitive sensor or a wet and dry bulb hygrometer, measures the humidity and controls how much moisture is injected into the chamber.



Enclosure for humidity and temperature maintenance



  <https://www.google.com/search?q=Enclosures+to+regulate+humidity+and+temperature&tbn> 17

Moisture injection cabinets and salt tray cabinets are instrumental in maintaining controlled environmental conditions essential for precise polymer testing. These enclosures provide a controlled space where variables like humidity and temperature can be manipulated according to testing requirements.

In conclusion, the integration of reliable automatic control, heating systems, and strategic enclosure placement are integral considerations when establishing testing environments for polymers. These elements collectively contribute to the efficacy and accuracy of polymer testing methodologies.

Humidity Control Cabinets in Polymer Testing:

Humidity control cabinets are a fundamental component in polymer testing, serving as controlled environments where saturation salts or standard solutions maintain the required humidity at a specified control temperature. The hygroscopic nature of these salts ensures a constant moisture content in the ambient air when placed over a tray.

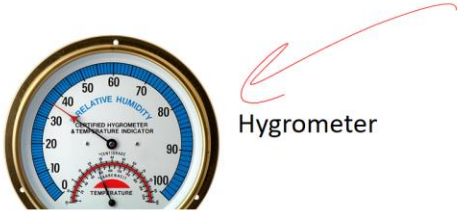
Designing these cabinets is critical, especially when maintaining humidity within necessary tolerance levels throughout the working area. Considerations such as the depth of the salt and the tray's size play pivotal roles, with ISO standards providing dimensions and valuable information for their use with various polymeric materials.

In the image provided, we see an enclosure designed for humidity and temperature maintenance. The design of such enclosures requires careful attention to detail, and the use of suitable moisture sensors, such as capacitive sensors or wet/dry bulb hygrometers, is essential. These sensors measure humidity levels and control the injection of moisture into the chamber.

Hygrometers in Polymer Testing:

Hygrometers are indispensable tools in polymer testing, with wet and dry bulb thermometers, as well as capacitance impedance instruments, commonly used for everyday applications in equipment and enclosures. In the context of humidity control, dew point hygrometers serve as reference standards for measuring relative humidity, ensuring accurate and reliable results in polymer testing environments.

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✓ Hygrometric tables are provided by BS 4833 for use with wet and dry bulb thermometers, while ISO 4677 details how to measure relative humidity (RH) using aspirated or whirling psychrometers, sometimes known as hygrometers.

Source; <https://www.google.com/search?q=hygrometer&rlz>


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In summary, the meticulous design and implementation of humidity control cabinets, coupled with the utilization of appropriate hygrometers, contribute significantly to the precision and effectiveness of polymer testing procedures. These considerations are vital for maintaining consistent and controlled testing conditions.

Temperature Measurement in Polymer Testing:

In polymer testing, precise temperature control and measurement are crucial. Platinum-resistant thermometers are highly recommended due to their extreme stability and durability. These thermometers often necessitate an air flow of around 3 meters per second for accurate readings, emphasizing the importance of maintaining proper circulation. While electronic versions of temperature-measuring devices gain popularity, traditional mercury or alcohol thermometers in glass remain common. Electronic thermometers typically employ thermocouples or platinum resistance thermometers as sensing components. Each type has its characteristics, with thermocouples offering large temperature ranges by altering the metal combination. Digital thermometers are increasingly favored, and ASTM and ISO manuals provide guidelines for their use, with British standards offering comprehensive advice on selection and application.

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Digital thermometer

✓ There is also an ASTM manual on the use of thermocouples, and the various sections of BS 1041 provide guidelines on the selection and usage of thermometers of various sorts.

Source; <https://www.google.com/search?q=Thermometers&tbn>

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Hygrometers and Humidity Control:

Humidity control is integral in polymer testing environments. Platinum-resistant thermometers ensure stability, and hygrometers play a crucial role in measuring and maintaining humidity levels. Standard hygrometer tables, such as those in BS48, British Standard 4833, and ISO 4677, are referenced for hygrometric data. Psychrometric charts and various hygrometer types, including aspirated and building psychrometers, contribute to accurate humidity measurement. Proper circulation is essential, and platinum-resistant thermometers are ideal for this purpose. Electronic alternatives, especially digital thermometers, are gaining popularity, and guidelines provided by standards assist in their selection and application.

Bulk Material Properties in Polymer Processing:

Handling and transporting palletized or powder molding materials in polymer processing depend on bulk material properties. To understand and predict the behavior of these materials during processing, properties such as pourability and bulk density must be determined. Key parameters for precise characterization include bulk material density, bulk material strength, internal angle of friction, and wall friction angle. These properties play a crucial role in designing feeding apparatus and mold cavities, ensuring efficient and controlled polymer processing.

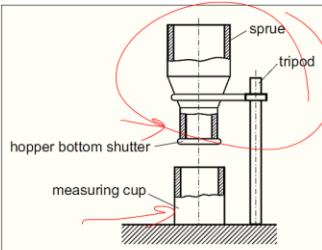
Bulk Density Measurement:

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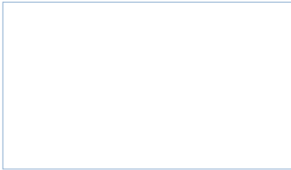
- **Bulk density**
- ✓ Bulk density is determined by the mass-to-volume ratio of a heap of bulk material under specific circumstances.


$$\rho_{SG} = \frac{m_{SG}}{V_{SG}}$$

- ✓ In this kind of equipment, a predetermined volume of moulding material passes through a hopper with a particular geometry.



Figure; Apparatus for determining Bulk density (ISO 60)




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Bulk density, a critical parameter in polymer processing, is determined by the mass-to-volume ratio of a heap of bulk material under specific conditions. The formula for bulk density (ρ_{SG}) is given by the ratio of mass (M) to volume (V). The measurement apparatus, as defined by ISO 60 standards, involves a hopper with specific geometry, including a hopper bottom shutter, measuring cup, screw, and tripod. Loose bulk material falls into the measuring vessel positioned underneath when the hopper bottom shutter is open. Bulk density (ρ_{SG}) is calculated as $(M1 - M0) / V$, where $M0$ is the mass of the empty vessel, $M1$ is the mass of the vessel filled with bulk material, and V is the vessel volume. For molding materials with long fibers and slices, bulk density is calculated according to ISO standard 61.

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- ✓ The loosely packed bulk material in the hopper falls into the measuring vessel that is positioned underneath it when the hopper bottom shutter is opened.

$$\rho_{SG} = \frac{m_1 - m_0}{V}$$

Where,
M0 is mass of empty vessel
M1 is mass of vessel filled with bulk material
V is vessel volume



Fill Factor (F) in Polymer Processing:

The fill factor (F), denoted as the relationship between the volume of piled or compacted material (VSG) and the volume of compact molding material after processing (VFS), is a crucial parameter. Fill factor is also represented by the ratio ρ_{FS} / ρ_{SG} . Understanding the fill factor is essential for designing storage, transport, and feeding equipment for molding materials, whether in pallet or powder form. This parameter guides the efficient handling and processing of materials throughout various stages of polymer manufacturing.

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➤ Fill Factor 'F'

The fill factor F describes the relationship between the volumes of the piled or compacted material VSG and the volume of the compact moulding material after processing VFS.

$$F = \frac{V_{SG}}{V_{FS}} = \frac{\rho_{FS}}{\rho_{SG}}$$

- ✓ Designing storage, transport, and feeding equipment requires an understanding of the moulding material parameters bulk density, compacted apparent density, or fill factor, whether in pellet or powder form.



Bulk Density and Its Significance:

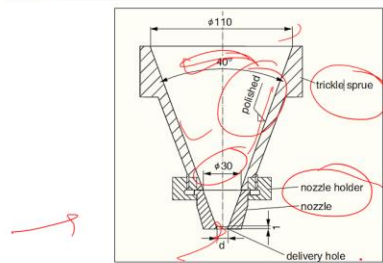
Bulk density serves as a crucial parameter in polymer processing, influencing pressure build-up in the solid conveying sections of extruders or injection molding machines. Understanding bulk density is pivotal for managing pressure within processing equipment, ensuring smooth operations in various stages of polymer manufacturing.

Pourability, Angle of Repose, and Slide Angle:

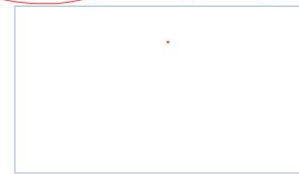
Pourability, along with the angle of repose and slide angle, plays a significant role in the transportation of bulk materials through hoppers, containers, and pipelines in polymer processing equipment. The granulometric and viscoelastic properties of polymers are essential factors in comprehending the rheological behavior of bulk polymer materials. Pourability is affected by surface moisture, electrostatic interactions between particles, and interactions with vessel walls, all of which can impact the flow characteristics.

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- ✓ Additionally, surface moisture and electrostatic interactions between bulk material or particle particles and vessel walls can have a negative impact on pourability.
- ✓ It makes sense to distinguish between cohesive, free-flowing, and non-cohesive bulk materials for this reason.
- ✓ According to ISO 6186, the pourability of pelletized polymers is determined.



Figure; Showing apparatus for determining pourability of polymer bulk material According to ISO 6186



Pourability Testing and ISO Standard 6186:

The determination of pourability in polymer bulk materials is a standardized process, as outlined by ISO standard 6186. The apparatus used for this determination involves specific components such as a delivery hole, nozzle, nozzle holder, sprue, and polished surfaces with defined angles. The distinction between cohesive, free-flowing, and non-cohesive bulk materials is crucial for effective polymer processing. The polishing of the apparatus's inner core ensures accurate measurements of pourability, contributing to the overall efficiency of polymer manufacturing processes.

Angle of Repose and Pourability:

Pourability in both palletized and powdered molding materials is quantified through the angle of repose. This angle signifies the slope at which pelletized molding material initiates sliding off a surface with defined quality. Influenced by factors such as surface moisture, liquid adsorption, density, and aeration forces between particles, the angle of repose plays a pivotal role in designing hopper slopes and feeding machines. Geometric characteristics of pellets or powder also contribute to determining the angle of repose.

Mass, Dimension, and Significance:

Mass, dimension, and density play crucial roles in cost determination and overall product quality. Ensuring dimensional accuracy is a fundamental quality control measure, influencing the cost of production. Mass, a determining factor in ingredient usage, is vital for recipe optimization. It's essential to differentiate between weight and mass, with mass being a critical parameter in various testing techniques. Daily measurements, especially dimensions, should not be taken for granted to avoid unnecessary errors.

Mass Measurement and Equipment Selection:

For mass measurement, a proper balance or scale is utilized to weigh the test piece or object accurately. The selection of the weighing device must align with the requirements for magnitude and accuracy, ensuring reliable data for subsequent processing or testing. Understanding the significance of mass in different applications is essential for precise and effective manufacturing processes.

Balances and Precision:

Balances, characterized by graduations such as 1 milligram accuracy, are crucial instruments in various applications. Precision requirements are often specified, and standards may vary, making it imperative to clarify the intended accuracy. Measurement errors or uncertainties in balances directly impact test results, emphasizing the need for accurate instruments in manufacturing processes.

Dimensional Measurements and Stress Calculation:

Dimension measurements, particularly for components like tensile dumbbells, directly influence stress calculations. Any error or uncertainty in these measurements translates directly into the test result. Categorizing test component dimensions into large and small helps choose appropriate measuring tools, including rulers, tape measures, micrometers, dial gauges, and calipers for larger dimensions.

Methods for Small Measurements:

For smaller measurements, various methods are employed, including both contact and non-contact approaches. Contact methods involve dial gauges, while non-contact methods utilize tools like travelling microscopes. Non-linear measurements, encompassing angles, surface roughness, dispersion, extensometer, and thermal expansion, are essential for comprehensive testing.

Standard Laboratory Procedures:

Standard laboratory procedures distinguish between measurements for dimensions less than 30 mm, dimensions between 30 and 100 mm, dimensions over 100 mm, and non-contact measurements. Each category follows specific protocols to ensure accurate and reliable data collection during testing processes.

Dimensional Measurements Protocol:

In laboratory procedures for dimensions over 100 mm, a tape or rule with a maximum accuracy of 1 mm is utilized. For measurements between 30 and 100 mm, calipers are employed with a maximum accuracy of 1 percent. Dial gauges, with an accuracy of not more than 1 percent or 0.01 mm, are used for measurements under 30 mm. It's crucial to avoid stressing the test piece during measurements.

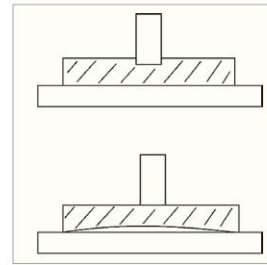
Caliper Usage and Considerations:

In the 30 to 100 mm range, calipers are used, requiring careful handling, especially with soft materials. Calipers are deemed risk-free for stiff plastics as there is no danger of stretching the test piece. However, for obtaining the dumbbell width from die dimensions, calipers may not be ideal for thin sections.

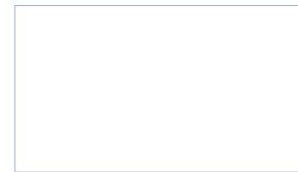
Dial Gauge Application:

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- **Under 30 mm**
- ✓ There is Use of dial gauge. ↩
- ✓ On soft materials, foot pressure must be taken into account.
- ✓ According to ISO 4648, the recommended method is to administer 22 ± 5 kPa through a circular foot that is smaller than the test piece.
- ✓ Below 35 IHRD 10 ± 2 kPa is utilized for very soft materials.
- ✓ The dial gauge measurement of a soft material and a stiff substance to show potential variations from the true thickness.



Figure; Showing possible deviations from True thickness



For measurements under 30 mm, dial gauges come into play. Soft materials demand consideration of foot pressure, following ISO 4648 recommendations to apply 20 ± 5 kilo Pascals through a smaller circular foot. In cases involving very soft materials, 10 ± 2 kilo Pascals may be applied. Dial gauge measurements on both soft and stiff materials reveal potential variations in true thickness.

Non-Contact Methodology:

The non-contact method, involving a moving or projecting microscope, is tailored for specific forms such as O-rings, coating thickness, dumbbell cutter profiles, impact notches, and rip nicks. This method offers versatile applications in scenarios where direct contact measurements might not be suitable.

Micrometer and Sliding Caliper Precision:

For measuring small dimensions in stiff materials, micrometers are the tool of choice. The accuracy requirements for micrometers and sliding calipers typically stand at 0.05 mm for dimensions under 10 mm and 0.1 mm for dimensions exceeding 10 mm. While travelling microscopes are fine for precision, they can be tedious in operation.

Travelling Microscope in Dimensional Stability Testing:

In dimensional stability testing, a travelling microscope might be the most practical approach for measuring changes in lateral dimensions between marked spots on a surface. The accuracy is determined by the thickness of the marked lines, making it a limiting factor.

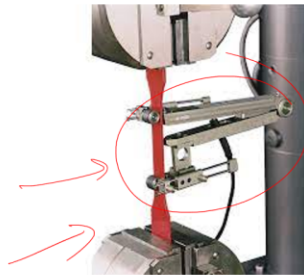
Contact Methods for Test Item Measurement:

Contact methods, such as dial gauges and digital microscopes, are predominantly employed for the majority of test item dimension measurements. These methods are favored due to their affordability, speed, and ease of use, making them practical for routine measurements.

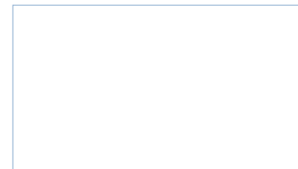
Extensometry in Strain Measurement:


Extensometry is a scientific technique utilized to measure the change in length or strain of an object under the application of stress or force. The extensometer, depicted in the accompanying photograph, serves as a critical tool in understanding how materials respond to stress and strain.


- **Extensometry**
 - ✓ Extensometry is a scientific technique used to measure changes in the length or strain of an object under the application of stress or force.
 - ✓ It is commonly employed in materials testing, engineering, and research fields to assess the mechanical properties and behavior of materials.
 - ✓ The device used in extensometry is called an extensometer, which typically consists of a measuring frame or arms that attach to the specimen being tested.
 - ✓ The extensometer is designed to accurately measure the elongation or contraction of the specimen as it is subjected to tension, compression, or bending forces.




Extensometer









<https://www.google.com/search?q=extensometry&tbm>

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Extensometry in Material Testing:

Extensometry plays a crucial role in material testing, engineering, and research to evaluate the mechanical properties and behavior of materials. The key device used for this purpose is the extensometer, consisting of measuring frames or arms attached to the specimen under test.

Types of Extensometers:

1. Mechanical Extensometer:

- Utilizes mechanical mechanisms to measure specimen displacement.

- Often employs gauges or reference marks that move with specimen deformation.
- Enables measurement of strain during tension, compression, or bending.

2. **Electrical Resistance Strain Gauge Extensometer:**

- Utilizes strain gauges made of fine wire or foil.
- Changes in electrical resistance during strain are measured and correlated to specimen deformation.

3. **Laser Extensometer:**

- Relies on laser beams to measure specimen displacement.
- Directs laser onto the specimen surface, and the reflected beam is captured by a detector.
- Changes in the reflected beam provide information about specimen deformation.

4. **Optical Extensometer:**

- Utilizes optical principles such as interferometry or image analysis.
- Provides highly accurate measurements.
- Commonly used in research and precision engineering applications.

These variations in extensometers cater to specific applications and measurement accuracy requirements, offering flexibility in experimental setups and ensuring precise assessments of material deformation.

Rheological Properties in Polymer Systems:

Rheological properties are fundamental in the context of polymer processing, particularly in understanding the behavior of fluids, both Newtonian and non-Newtonian. The discussion primarily revolves around viscosity and its implications.

Importance of Rheological Properties:

The rheological properties of polymer systems play a pivotal role, especially when subjected to heating. At elevated temperatures, polymer chains become unentangled, exhibiting flow behavior. Understanding these properties becomes critical during various processing techniques like molding, injection molding, or extrusion. The rheological

characteristics, including viscosity, are essential considerations to ensure proper processing conditions, preventing issues related to temperature and solvent effects.

Shear Viscosity:

Shear viscosity is a key parameter defining the internal resistance of a fluid to an externally acting load. It distinguishes between shear and elongational viscosity. The absolute shear viscosity (τ_{yx}) is defined as the ratio of shear stress (τ_x) to shear rate ($\dot{\gamma}_x$). In a scenario where a plate moves at a velocity (v) over a fluid lying on a fixed plate, the relationship is expressed as

$$\tau_{yx} = \frac{F}{A_0} = \eta \frac{dv_x}{dy} = \eta \dot{\gamma}_x$$

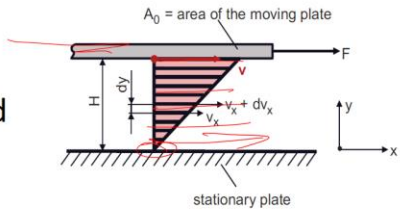
Here, η represents the Newtonian viscosity.

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- **Shear viscosity**
- ✓ The absolute shear viscosity can be defined as;

$$\tau_{yx} = \frac{F}{A_0} = \eta \frac{dv_x}{dy} = \eta \dot{\gamma}_x$$

- ✓ τ_{yx} is the resulting shear stress when a plate with surface A is moved at velocity v over a fluid lying on a fixed plate.
- ✓ $\frac{dv_x}{dy} = \dot{\gamma}_x$ and τ_{yx} are directly proportional and η is the Newtonian viscosity.



Figure; showing velocity profile of a Newtonian fluid 2-D shear flow (Two-plate model)

Understanding shear viscosity is crucial for assessing the flow behavior during different processing phases, helping to optimize conditions for successful polymer processing.

Newtonian and Non-Newtonian Fluid Behavior:

Understanding fluid behavior is crucial in polymer processing, distinguishing between Newtonian and non-Newtonian fluids. This distinction significantly impacts processes like extrusion and injection molding, where shear rates vary, and melts exhibit high viscosity.

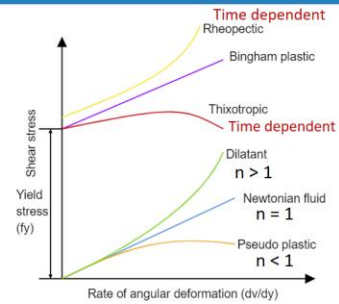
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➤ Newtonian fluids

- ✓ Water, solvents, mineral oil, and thin polymer solutions are among the fluids whose viscosity doesn't change when the shear rate does.
- ✓ Newtonian behavior in polymer melts typically only appears at very low shear rates.

➤ Non-Newtonian fluids

- ✓ Shear stress and shear rate are not directly related since viscosity is no longer constant.
- ✓ The flow is non-Newtonian in actual processing techniques like extrusion or injection moulding, where relatively large shear rates happen in highly viscous melts.



Figure; Newtonian and Non-Newtonian behavior



Newtonian Fluids:

Newtonian fluids, such as water, mineral oils, and certain thin polymer solutions, maintain a constant viscosity regardless of shear rate variations. However, Newtonian behavior in polymer melts is observed only at very low shear rates.

Non-Newtonian Fluids:

In contrast, non-Newtonian fluids exhibit a non-linear relationship between shear stress and shear rate, and viscosity is not constant. This behavior is prominent in processing techniques like extrusion or injection molding, involving relatively large shear rates in highly viscous melts.

Ostwald and De Waele Model:

The Ostwald and De Waele model, also known as the power law or flow behavior index model, serves as a mathematical model to describe the flow behavior of non-Newtonian fluids, especially those showcasing shear-thinning behavior. The model correlates shear stress (τ) and shear rate ($\dot{\gamma}$) using the equation:

$$\tau = K\dot{\gamma}^n$$

➤ Ostwald and de Waele Model

- ✓ Also known as Power law model or flow behaviour index model.
- ✓ It is a mathematical model frequently used to describe the flow behavior of non-Newtonian fluids, particularly those exhibiting shear-thinning behavior.
- ✓ The Ostwald de Waele model relates the shear stress (τ) to the shear rate ($\dot{\gamma}$) in a fluid using the following equation:

$$\tau = K * \dot{\gamma}^n$$

Where; τ is the shear stress, $\dot{\gamma}$ is the shear rate, K is the consistency coefficient, and n is the flow behavior index.



Here, τ is shear stress, $\dot{\gamma}$ is shear rate, K is the consistency coefficient, and n is the flow behavior index. The flow behavior index (n) indicates the degree of non-linearity in the relationship between shear stress and shear rate. For $n = 1$, the fluid behavior follows Newtonian flow, where shear stress is directly proportional to shear rate. Understanding these models is essential for optimizing processing conditions in polymer melts with varying viscosity.

Shear and Elongational Viscosity:

Exploring the rheological properties of polymer melts involves understanding shear and elongational viscosity, vital factors in polymer processing.

Shear Thinning and Shear Thickening:

- **Shear Thinning Behavior ($n < 1$):** When n is less than 1, the fluid exhibits shear-thinning behavior. With increasing shear rate, the fluid's viscosity decreases, resulting in a reduction in shear stress. This behavior is commonly observed in many polymer solutions and suspensions.
- **Shear Thickening Behavior ($n > 1$):** Conversely, when n is greater than 1, the fluid displays shear-thickening behavior. As the shear rate increases, the fluid's viscosity rises, leading to an increase in shear stress. Although less common, this behavior can occur in certain colloidal suspensions and concentrated emulsions.

Understanding these behaviors is crucial for optimizing processing conditions in various polymer applications.

Elongational Viscosity:

Elongational viscosity measures a material's resistance to deformation when subjected to an elongational or stretching force. This property is vital in processes involving extensional flow, where a material is stretched or extended. Processes like fiber spinning, film blowing, blow molding, and other deformation processes rely on elongational viscosity to understand how materials respond to stretching forces and deformation.

In summary, a comprehensive understanding of shear and elongational viscosity is essential for tailoring processing conditions and achieving desired material properties in polymer applications.

Elongational Viscosity and Fluid Behavior:

Understanding the behavior of polymer melts under elongational forces is crucial in processes like fiber spinning, film blowing, and blow molding.

Elongational Viscosity:

- **High Elongational Viscosity:** Indicates a higher resistance to extensional deformation. This characteristic is essential for processes where complex stretching or elongation is required, ensuring the material responds as intended.
- **Low Elongational Viscosity:** Suggests simpler stretching or elongation. This property is valuable when a material needs to undergo straightforward deformation.

Newtonian Fluids:

For Newtonian fluids, elongation (ϵ) is defined as

$$\eta_E = \frac{\sigma}{\dot{\epsilon}} \text{ with } \dot{\epsilon} = \frac{dv_x}{dx}$$

$\dot{\epsilon}$ is the elongation and defined according to Hencky as a natural logarithm of the draw ratio as;

$$\epsilon = \ln \left(\frac{l}{l_0} \right)$$

Elongation viscosity is independent of elongational rate, equals shear viscosity, and is denoted by the following formula:

$$\eta_E = 3\eta$$

Cont...

For Newtonian fluid it can be defined as;

$$\eta_E = \frac{\sigma}{\dot{\epsilon}} \quad \text{with} \quad \dot{\epsilon} = \frac{dv_x}{dx}$$

$\dot{\epsilon}$ is elongation and defined according to Hencky as a natural logarithm of the draw ratio.

$$\epsilon = \ln(l/l_0)$$

Elongation viscosity is independent of elongational rate, equals shear viscosity, and is denoted by the following formula:

$$\eta_E = 3\eta$$



Non-Newtonian Fluids:

- In the realm of non-Newtonian flow, the elongational viscosity of non-Newtonian fluids at low deformation rates is influenced by shear viscosity and can be described with decimal powers lower than the elongational viscosity.

Effective Viscosity:

- Effective viscosity refers to the viscosity assumed by a fluid in a spatially constant shear field. Unlike Newtonian viscosity, it varies under different deformation conditions, correlating with the specific structure of the fluid. Various factors, including temperature, pressure, concentration, molecular weight, additives, and the presence of particles, can impact effective viscosity.

Apparent Viscosity:

- Apparent viscosity is determined when there is no spatially constant shear field, providing a mean value derived from effective viscosities. It offers insights into the overall viscosity of the fluid under varying conditions.

In summary, elongational viscosity and related parameters play a crucial role in predicting and controlling the behavior of polymer melts in different processing scenarios. The complex interplay between molecular structure and external factors determines the overall viscosity characteristics of the material.

Apparent Viscosity and Conclusion:

Apparent Viscosity as a Test-Specific Measure:

- **Mean Viscosity vs. Apparent Viscosity:** The mean viscosity, not being an inherent material parameter, is referred to as apparent viscosity. Apparent viscosity is highly dependent on the specific test method and conditions used for measurement.
- **Test Method Sensitivity:** Different experimental setups or test geometries can yield varying apparent viscosities for the same fluid. This sensitivity underscores the importance of clearly specifying the experimental conditions and test methods employed when reporting or comparing apparent viscosity values.

Conclusion:

In conclusion, this segment has delved into various conditioning aspects and the intricacies of viscosity relevant to polymer testing. The significance of understanding and specifying experimental conditions for accurate viscosity measurements has been highlighted. For further exploration and reference, we have provided a list of resources. Thank you for your attention and participation in this discussion on polymer testing.