

An Extensible Wire That Obeys Looks Low It Stands By 5.00 Mm When It's Elastic Potential Energy Is 50j.

An Extensible Wire That Obeys Looks Low It Stands By 5.00 Mm When It's Elastic Potential Energy Is 50j. Understanding the properties of extensible wires is crucial in various engineering and scientific applications, from constructing flexible electronics to designing resilient structural components. This article delves into the fascinating world of elastic wires, focusing on their deformation characteristics, energy storage capabilities, and the implications of their physical properties, all while providing insights into how to analyze and optimize such materials for practical use.

Introduction to Elastic Wires and Their Significance

Elastic wires are slender, flexible materials that can undergo deformation under applied forces and return to their original shape once the force is removed. These materials are fundamental in numerous fields, including mechanical engineering, materials science, and electronics. Their ability to store elastic potential energy makes them invaluable in applications requiring energy absorption, dampening vibrations, or controlled movement.

In the context of the specific problem statement—an extensible wire that disobeys looks low and stands by 5.00 mm when its elastic potential energy is 50 J—we are dealing with a wire exhibiting elastic deformation behavior characterized by Hooke's Law. To analyze such a wire comprehensively, it is essential to understand the relationship between force, extension, and energy stored during deformation.

Fundamental Concepts of Elasticity and Energy Storage

Hooke's Law and Elastic Deformation

Hooke's Law states that, within the elastic limit, the force (F) required to extend or compress a wire is proportional to the displacement (x) :

$$F = kx$$

where:

- (k) is the spring constant or stiffness of the wire,
- (x) is the extension or compression length.

This linear relationship simplifies the analysis of elastic deformation, enabling the calculation of various properties such as the elastic potential energy and the wire's stiffness.

Elastic Potential Energy

The elastic potential energy (U) stored in a wire when stretched by a displacement (x) is given by:

$$U = \frac{1}{2} k x^2$$

This formula indicates that the energy stored depends on the stiffness of the wire and the amount of extension. When the energy is known, such as the 50 J in our scenario, it provides a means to determine the extension or other properties of the wire.

Analyzing the Given Scenario

The problem states that the wire stands by 5.00 mm (which is 0.005 meters) when its elastic potential energy is 50 J. To analyze this, we need to find the wire's stiffness (k) , and possibly other properties like the tension force and the original length of the wire if available.

Calculating the Spring Constant (k)

Using the elastic potential energy formula:

$$U = \frac{1}{2} k x^2$$

Plugging in the known values:

$$50 = \frac{1}{2} k (0.005)^2$$

Solving for (k) :

$$50 = \frac{1}{2} k \times 25 \times 10^{-6}$$

$$50 = 12.5 \times 10^{-6} k$$

$$k = \frac{50}{12.5 \times 10^{-6}}$$

$$k = 4 \times 10^6 \text{ N/m}$$

This high stiffness indicates a very rigid wire relative to its extension.

Interpreting the Results

The calculated spring constant suggests that the wire resists extension strongly, which aligns with the small extension (5 mm) for a relatively large stored energy (50 J). This information can be used to determine the tension force in the wire at maximum extension:

$$F = kx = 4 \times 10^6 \times 0.005 = 20,000 \text{ N}$$

This force is substantial, indicating the wire's capacity to withstand high tension without permanent deformation.

Implications for Material Selection and Design

Understanding the elastic properties of wires is vital when designing components that require specific deformation characteristics. Factors such as material type, cross-sectional area, length, and elastic modulus influence the wire's behavior significantly.

Material Properties Affecting Elastic Behavior

- Elastic Modulus (Young's Modulus): Determines the material's stiffness.
- Yield Strength: The maximum stress before permanent deformation.
- Tensile Strength: The maximum stress the material can withstand while being stretched.

Choosing a material with appropriate properties ensures that the wire performs reliably within its elastic limits.

Design Considerations for Extensible Wires

- Cross-sectional area: Larger areas increase the wire's stiffness.
- Length of the wire: Longer wires tend to be more extensible but less stiff.
- Pre-stress or pre-tension: Applying initial tension can influence the elastic behavior.
- Environmental factors: Temperature, corrosion, and fatigue impact performance over time.

Applications of Extensible Wires with High Elastic Energy Storage

Such wires are used in various practical applications:

- **Spring Mechanisms:** For absorbing shocks or providing controlled motion in machinery.
- **Vibration Dampers:** To reduce oscillations in structures or electronic devices.

- **Medical Devices:** Wires in stents or surgical tools that require flexibility and resilience.
- **Electronics:** Flexible connectors and flexible printed circuit boards (FPCBs).
- **Robotics and Actuators:** Providing controlled movement and energy storage.

Designing wires for these applications requires balancing stiffness, energy capacity, and durability.

Testing and Characterization of Extensible Wires

To ensure the wire meets desired specifications, rigorous testing is conducted:

Mechanical Testing

- Tensile Testing: Measures the force-extension relationship.
- Fatigue Testing: Assesses performance under repeated loading.
- Elastic Limit Determination: Identifies the maximum extension within elastic behavior.

Material Analysis

- Stress-Strain Curves: Plotting stress versus strain to analyze elastic and plastic regions.
- Elastic Modulus Calculation: Derived from the initial linear portion of the stress-strain curve.
- Energy Absorption Capacity: Determined through cyclic loading tests.

Such tests inform engineers about the safety margins and lifespan of the wire.

Conclusion: Optimizing Extensible Wire Design

Designing an extensible wire that can store significant elastic potential energy while maintaining durability involves understanding and balancing multiple factors. The example scenario illustrates how to calculate key properties like stiffness and tension from given energy and extension data. By selecting appropriate materials, adjusting geometrical parameters, and thoroughly testing, engineers can develop wires tailored for specific high-performance applications.

The ability to precisely analyze and predict the behavior of such wires enhances their utility across industries, leading to innovations in machinery, electronics, biomedical devices, and beyond. As technology advances, the development of new materials and fabrication techniques will further expand the capabilities and applications of extensible wires with high energy storage potential.

Keywords: elastic wire, elastic potential energy, Hooke's Law, spring constant, tensile force, material properties, energy storage, mechanical testing, design considerations, high-performance materials, applications

Frequently Asked Questions

What does it mean when an extensible wire 'stands by 5.00 mm' in the context of elastic potential energy?

It indicates that the wire's original or equilibrium length is 5.00 mm longer than its unstretched length, serving as the initial extension before additional deformation occurs.

How is the elastic potential energy related to the extension in a wire?

Elastic potential energy is proportional to the square of the extension (stretching), following the relation $PE = (1/2) k x^2$, where k is the spring constant and x is the extension.

Given an elastic potential energy of 50 J, how can we determine the extension of the wire?

Using the formula $PE = (1/2) k x^2$, solving for x gives $x = \sqrt{2 PE / k}$. Knowing the spring constant k allows calculation of the extension x .

What is the significance of the wire obeying 'looks low' in the context of elastic deformation?

The phrase suggests the wire appears less stretched or less extended than its maximum capacity, indicating it is within elastic limits and not permanently deformed.

How does the wire's low extension of 5.00 mm relate to its elastic potential energy of 50 J?

The low extension indicates the wire is only slightly stretched; however, if the elastic potential energy is 50 J at this extension, it implies a high stiffness or spring constant in the wire.

What factors influence the elastic potential energy stored in an extensible wire?

Factors include the wire's material properties (like Young's modulus), its length, cross-

sectional area, and the amount of extension or deformation applied.

Can the wire's elastic potential energy of 50 J be exceeded without causing permanent deformation?

Yes, as long as the extension remains within the elastic limit of the wire. Exceeding this limit would cause plastic deformation, where energy is no longer stored elastically.

Additional Resources

An Extensible Wire That Obeys Hooke's Law It Stands By 5.00 mm When Its Elastic Potential Energy Is 50 J

Introduction

In the realm of materials science and mechanical engineering, understanding the behavior of elastic materials under various forces is fundamental. The intriguing phrase "An extensible wire that obeys Hooke's Law it stands by 5.00 mm when its elastic potential energy is 50 J" hints at a complex interaction between the wire's elastic properties, deformation, and energy storage capabilities. This article aims to dissect this statement comprehensively, exploring the physical principles behind elasticity, the relationship between deformation and energy, and the practical implications of such a material in engineering applications.

The Significance of Elasticity in Materials

Understanding Elastic Behavior

Elasticity refers to a material's ability to return to its original shape after deformation when the applied force is removed. For many materials, this behavior is described by Hooke's Law, which states that the force needed to extend or compress a spring is proportional to the displacement, provided the elastic limit is not exceeded.

Mathematically:

$$F = k \Delta L$$

where:

- F is the applied force,
- k is the stiffness or spring constant,
- ΔL is the extension or compression from the equilibrium length.

The elastic potential energy stored in such a material during deformation is given by:

$$U = \frac{1}{2} k (\Delta L)^2$$

This quadratic relationship implies that energy storage increases with the square of the extension, which is crucial for understanding the behavior of the wire in question.

Elastic Limit and Material Integrity

While Hooke's Law provides a simplified model, real materials have an elastic limit beyond which permanent deformation occurs. For the wire discussed, the parameters suggest it operates within its elastic regime, allowing for predictable deformation and energy storage.

Deciphering the Statement: Breaking Down the Components

"Obeys Hooke's Law"

This phrase appears to be a typographical or interpretative anomaly. It likely intends to communicate that the wire "obeys Hooke's Law" or "obeys elastic behavior," implying its deformation is proportional to the applied force within the elastic limit.

"Stands By 5.00 mm"

The 5.00 mm refers to the extension or elongation of the wire under the applied load. This displacement is a key parameter for calculating the elastic properties and energy stored.

"When Its Elastic Potential Energy Is 50 J"

The stored elastic potential energy directly relates to the deformation and the wire's stiffness. Knowing the energy and extension allows us to infer the material's spring constant or stiffness.

Analytical Breakdown of the Physical Parameters

Applying Hooke's Law and Energy Equations

Given:

- Extension, $(\Delta L = 5.00 \text{ mm} = 0.005 \text{ m})$
- Elastic potential energy, $(U = 50 \text{ J})$

The elastic potential energy stored in the wire:

$$U = \frac{1}{2} k (\Delta L)^2$$

Rearranged to solve for (k) :

$$k = \frac{2U}{(\Delta L)^2}$$

Substituting the known values:

$$k = \frac{2 \times 50}{(0.005)^2} = \frac{100}{0.000025} = 4,000,000 \, \text{N/m}$$

This indicates an extremely stiff wire, with a spring constant of 4 million N/m, which is characteristic of high-strength, elastic materials.

Implications of the Calculated Stiffness

Material Characteristics

A spring constant of this magnitude suggests the wire is made of a material with high elastic modulus and strength, such as certain alloys or advanced composites. Such a wire can withstand significant elastic energy storage with minimal deformation, making it suitable for high-precision applications.

Energy Storage and Mechanical Performance

The ability to store 50 J of energy with just 5 mm of extension indicates a highly efficient elastic system. This has potential applications in:

- Energy harvesting devices where elastic materials store and release energy cyclically.
- Precision actuation systems requiring minimal deformation under large energy loads.
- Vibration damping where elastic elements absorb and dissipate energy.

The Role of Material Extensibility and Safety Limits

Extensibility and Load Limits

While high stiffness is beneficial for energy storage, it also demands materials capable of resisting the high forces involved. The maximum force (F) can be inferred from Hooke's law:

$$F = k \times \Delta L$$

$$F = 4,000,000 \times 0.005 = 20,000 \, \text{N}$$

This force (20 kN) is substantial, indicating the wire must be engineered to withstand such loads without yielding or permanent deformation.

Elastic vs. Plastic Deformation

Ensuring the wire remains within the elastic regime is critical. Exceeding the elastic limit would lead to plastic deformation, permanently altering its length, compromising energy storage capabilities, and potentially causing failure.

Practical Applications and Engineering Considerations

Material Selection and Design

Designing a wire with such properties involves selecting materials with high elastic modulus, tensile strength, and fatigue resistance. Common candidates include:

- High-strength steel alloys
- Shape memory alloys like Nitinol
- Advanced composites with tailored elastic properties

Manufacturing and Quality Control

Manufacturing processes must ensure uniformity in cross-sectional area and material composition to achieve predictable elastic behavior. Quality control measures, including tensile testing and fatigue analysis, are essential for reliability.

Safety Factors and Operational Limits

Engineers typically incorporate safety factors to account for uncertainties and material imperfections. For a wire designed to store 50 J at 5 mm extension, safety considerations might limit operational loads to below the calculated maximum to prevent accidental plastic deformation or failure.

Broader Context and Future Directions

Innovations in Elastic Materials

Research continues into novel materials with exceptional elastic properties, enabling more efficient energy storage, damping, and actuation mechanisms. The theoretical understanding of such wires informs these innovations.

Integration in Modern Technologies

Extensible wires with high energy storage capacities are integral to various fields, including aerospace (deployable structures), robotics (elastic actuators), and renewable energy systems (elastic energy harvesting).

Conclusion

The statement about "An extensible wire that obeys Hooke's law it stands by 5.00 mm when its elastic potential energy is 50 J" encapsulates a fascinating interplay of material science, mechanical design, and energy dynamics. By analyzing the parameters, we see that achieving such a combination of extension and energy storage requires a highly stiff, elastic material capable of withstanding significant forces within its elastic limit. These insights are not only academically intriguing but also practically vital for advancing engineering solutions across multiple high-performance applications. As materials science

progresses, the development of such extensible, energy-efficient wires promises to unlock new horizons in technology and innovation.

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