ORIGINAL RESEARCH PAPER

Physics

APPLICATION OF HOOKS LAW IN ELASTICITY

KEY WORDS:

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ABSTRACT

Stress and Strain relation is explained by Hooke's in his law. It states that the force (*F*) needed to extend or compress a spring by some distance X scales linearly with respect to that distance. $F = kX$, where *k* is a constant factor characteristic of the spring and its stiffness, and *X* is small compared to the total possible deformation of the spring. It is only a first-order linear approximation to the real response of springs and other elastic bodies to applied forces. It must eventually fail once the forces exceed some limit, since no material can be compressed beyond a certain minimum size, or stretched beyond a maximum size, without some permanent deformation or change of state. Many materials will noticeably deviate from Hooke's law well before those elastic limits are reached. In this article the relation between stress and strain is discussed elaborately.

INTRODUCTION:

The law is named after 17th century British physicist Robert Hooke, who sought to demonstrate the relationship between the forces applied to a spring and its elasticity. This can be expressed mathematically as F= kX, where F is the force applied to the spring (either in the form of strain or stress) X is the displacement of the spring, with a negative value demonstrating that the displacement of the spring once it is stretched and k is the spring constant and details just how stiff it is.

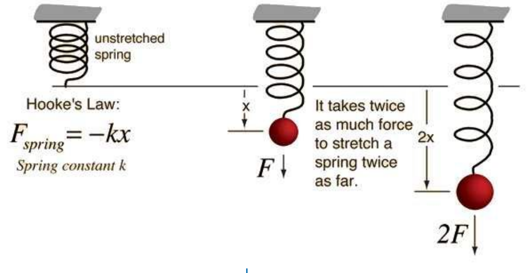
Hooke's law is the first classical example of an explanation of elasticity, which is the property of an object or material which causes it to be restored to its original shape after distortion. This ability to return to a normal shape after experiencing distortion can be referred to as a "restoring force". Understood in terms of Hooke's Law, this restoring force is generally proportional to the amount of "stretch" experienced. It is an accurate approximation for most solid bodies, as long as the forces and deformations are small enough. It is extensively used in all branches of science and engineering. And is the foundation of many disciplines such as seismology, molecular mechanics and acoustics. It is also the fundamental principle behind the spring scale, the manometer, and the balance wheel of the mechanical clock.

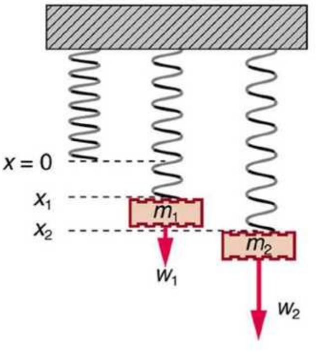
The modern theory of elasticity generalizes Hooke's law to say that the strain (deformation) of an elastic object or material is proportional to the stress applied to it. However, since general stresses and strains may have multiple independent components, the "proportionality factor" may no longer be just a single real number, but rather a linear map (a tensor) that can be represented by a matrix of real numbers. In this general form, Hooke's law makes it possible to deduce the relation between strain and stress for complex objects in terms of intrinsic properties of the materials it is made of. For example, one can deduce that a homogeneous rod with uniform cross section will behave like a simple spring when stretched, with a stiffness k directly proportional to its cross-section area and inversely proportional to its length. According to the Hooke's law, the elastic behavior of solids can be explained by the fact that the small displacements (of molecules, atoms or ions) from their normal positions are proportional to the force which causes the displacement. The deforming force is applied through compression, stretching, squeezing, twisting or bending a solid.

Hooke's law states that the applied force is equal to a constant times the change in length or displacement.

F= kx, Where, F is force, K is constant of proportionality and X is displacement.

PICTORIAL EXPLANATION





As an equation, it can be written as:

F = -kx

where ***F*** is the force applied to the spring (**N**).
where ***x*** is the displacement of the spring (**m**).
where ***k*** is the spring constant, the rate at which the spring is displaced (**N/m**).

Hooke's law applies, as long as the material is within it's elastic limit.

Once a sufficient amount of force has been applied, so as to extend the material beyond it's elastic limit, the material enters it's plastic region. With the material in it's plastic region, the force applied causes permanent displacement of the material.

STRAIN AND STRESS:

Strain is the deformation produced by the stress. And stress is the force on the unit areas within a material caused due to externally applied force.

Robert Hooke studied the springs and their elasticity and observed that the Stress vs Strain curve for a variety of materials has a linear region. Within its certain limits, the force applied or required to stretch an elastic object (eg. A metal spring) is directly proportional to that of the extension of that spring.

DIRECTION OF THE FORCE APPLIED:

Even though the direction of force isn't established, a negative sign is always added. It is because of the restoring force which causes the displacement (since the spring is already in the opposite direction). Pulling down a spring will make the spring extend downwards and the resulting force would be upwards. Thus, it is essential to make sure of the fact that the direction of the restoring force should be specified consistently while approaching elastic related mechanic problems.

HOOKE'S LAW: USES:

- Used in all branches of science and engineering

- Foundation for seismology, acoustics and molecular mechanics.
- Fundamental principle behind manometer, spring scale, balance wheel of the clock.

LIMITATIONS OF HOOKE'S LAW:

- The law isn't a universal principle and only applies to the materials as long as they aren't stretched way past their capacity.
- It ceases to apply past the elastic limit of a material. If the material is stretched past its elastic limit, it causes permanent deformation.
- The law is only accurate for most solid bodies only and if the forces and deformations are small.

SPRING:

A spring is an object that can be deformed by a force and then return to its original shape after the force is removed.

Springs come in a huge variety of different forms, but the simple metal coil spring is probably the most familiar. Springs are an essential part of almost all moderately complex mechanical devices, from ball-point pens to racing car engines. There is nothing particularly magical about the shape of a coil spring that makes it behave like a spring. The 'springiness', or more correctly, the elasticity is a fundamental property of the wire that the spring is made from. A long straight metal wire also has the ability to 'spring back' following a stretching or twisting action. Winding the wire into a spring just allows us to exploit the properties of a long piece of wire in a small space. This is much more convenient for building mechanical devices.

The response of a metal wire to stretching (axial load) and twisting (torsion) is governed by different physics and the design of a particular spring can exploit one kind of deformation over another. In addition, the elastic properties of metals depend strongly on their grain microstructure. This can be changed by stress and a controlled heating/cooling process known as annealing. If a metal wire was formed from a straight section into a coil then it is likely that it would need to be re-annealed to restore its original elastic properties.

WHEN A MATERIAL IS DEFORMED:

When a force is placed on a material, the material stretches or compresses in response to the force. We are all familiar with materials like rubber which stretch very easily.

In mechanics, the force applied per unit area is what is important; this is called the stress (symbol σ\sigma). The extent of the stretching/compression produced as the material responds to stress in called the strain (symbol ϵ\epsilonϵ). Strain is measured by the ratio of the difference in length ΔL\Delta LΔLdelta, L to original length L0L_0L0L, start subscript, 0, end subscript along the direction of the stress, i.e. ϵ=ΔL/L0\epsilon=\Delta L/L_0ϵ=ΔL/L0.

Every material responds differently to stress and the details of the response are important to engineers who must select materials for their structures and machines that behave predictably under expected stresses.

There are broadly two types of deformation:

1. **Elastic deformation.** When the stress is removed the material returns to the dimension it had before the load was applied. The deformation is reversible, non-permanent.
2. **Plastic deformation.** This occurs when a large stress is applied to a material. The stress is so large that when removed, the material does not spring back to its previous dimension. There is a permanent, irreversible deformation. The minimal value of the stress which produces plastic deformation is known as the elastic limit for the material.

Any spring should be designed and specified such that it only ever experiences elastic deformation when built into a machine under normal operation. The spring is a marvel of human engineering and creativity. For one, it comes in so many varieties – the compression spring, the extension spring, the torsion spring, the coil spring, etc. all of which serve different and specific functions. These functions in turn allow for the creation of many man-made objects, most of which emerged as part of the Scientific Revolution during the late 17th and 18th centuries.

As an elastic object used to store mechanical energy, the applications for them are extensive, making possible such things as an automotive suspension systems, pendulum clocks, hand sheers, wind-up toys, watches, rat traps, digital micro mirror devices, and of course, the Slinky.

Like so many other devices invented over the centuries, a basic understanding of the mechanics is required before it can so widely used. In terms of springs, this means understanding the laws of elasticity, torsion and force that come into play – which together are known as Hooke's Law.

In addition to governing the behavior of springs, Hooke's Law also applies in many other situations where an elastic body is deformed. These can include anything from inflating a balloon and pulling on a rubber band to measuring the amount of wind force is needed to make a tall building bend and sway.

However, like most classical mechanics, Hooke's Law only works within a limited frame of reference. Because no material can be compressed beyond a certain minimum size (or stretched beyond a maximum size) without some permanent deformation or change of state, it only applies so long as a limited amount of force or deformation is involved. In fact, many materials will noticeably deviate from Hooke's law well before those elastic limits are reached.

Still, in its general form, Hooke's Law is compatible with Newton's laws of static equilibrium. Together, they make it possible to deduce the relationship between strain and stress for complex objects in terms of the intrinsic materials of the properties it is made of. For example, one can deduce that a homogeneous rod with uniform cross section will behave like a simple spring when stretched, with stiffness (k) directly proportional to its cross-section area and inversely proportional to its length.

CONCLUSION:

Stress is used to express the loading in terms of force applied to a certain cross-sectional area of an object. From the perspective of loading, stress is the applied force or system of forces that tends to deform a body. From the perspective of what is happening within a material, stress is the internal distribution of forces within a body that balance and react to the loads applied to it. The stress distribution may or may not be uniform, depending on the nature of the loading condition.

Strain is the response of a system to an applied stress. When a material is loaded with a force, it produces a stress, which then causes a material to deform. Engineering strain is defined as the amount of deformation in the direction of the applied force divided by the initial length of the material.

Elasticity is the ability of a body to resist a distorting influence or deforming force and to return to its original size and shape when that influence or force is removed. Solid objects will deform when adequate forces are applied on them. If the material is elastic, the object will return to its initial shape and size when these forces are removed. Hooke's law is an accurate approximation for most solid bodies, as long as the forces and deformations are small enough. The modern theory of elasticity generalizes Hooke's law to say that the strain (deformation) of an elastic object or material is proportional to the stress applied to it.

Another interesting thing about Hooke's law is that it is perfect example of the First Law of Thermodynamics. It is concluded that according to Hook's Law any spring when compressed or extended almost perfectly conserves the energy applied to it. The only energy lost is due to natural friction. In addition, law contains within it a wave-like periodic function. A spring released from a deformed position will return to its original position with proportional force repeatedly in a periodic function. The wavelength and frequency of the motion can also be observed and calculated by using this law.

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