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The Springas a Simple Machine

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Abstract: *The spring was studied and proven to be a simple machine. This is an addition to the six simple machines. The two concepts of the spring were compression and tension. The applicationsof the string ranged from protecting objects to creating a stored force. Examples of the springs were given.It may also serve as an inductor, a prime requirement of motors and generators.*

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Ductility
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Spring
Strength of materials

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I. Introduction

A simple machine is a mechanical device that changes the direction or magnitude of a force. (Paul et al., 2005) In general, they can be defined as the simplest mechanisms that provide mechanical advantage (also called leverage)to multiply force. (Asimov, 1988) The idea of a "simple machine" originated with the Greek philosopher Archimedes around the 3rd century BC, who studied the "Archimedean" simple machines: lever, pulley, and screw. (Asimov, 1988 and Osdiek et al., 2005) Simple machines are needed to make complex machines. It has been part of our life to make hard tasks easier. There are six recognized simple machines namely lever, pulley, wheel and axle, inclined plane and screw.

A spring is an elastic body or device that recovers its original shape when released after being distorted. (Anonymous, 2018a)Spring is a twisted or coiled strip of material (as metal) that recovers its original shape when it is released after being squeezed or stretched. (Anonymous, 2018a)

Springs are mechanical devices that are capable of storing mechanical energy because of their elasticity. Springs are often made of coiled, hardened steel, although non-ferrous metals such as bronze and titanium and even plastic are also used. There are various types of springs, the designs of which take advantage of different energy storage management. (Anonymous, 2018b)

Machine, device, having a unique purpose, that augments or replaces human or animal effort for the accomplishment of physical tasks. This broad category encompasses such simple devices as the inclined plane, lever, wedge, wheel and axle, pulley, and screw (the so-called simple machines) as well as such complex mechanical systems as the modern automobile.

The operation of a machine may involve the transformation of chemical, thermal, electrical, or nuclear energy into mechanical energy, or vice versa, or its function may simply be to modify and transmit forces and motions. All machines have an input, an output, and a transforming or modifying and transmitting device.

Machines that receive their input energy from a natural source, such as air currents, moving water, coal, petroleum, or uranium, and transform it into mechanical energy are known as prime movers. Windmills, waterwheels, turbines, steam engines, and internal-combustion engines are prime movers. In these machines the inputs vary; the outputs are usually rotating shafts capable of being used as inputs to other machines, such as electric generators, hydraulic pumps, or air compressors. All three of the latter devices may be classified as generators; their outputs of electrical, hydraulic, and pneumatic energy can be used as inputs to electric, hydraulic, or air motors. These motors can be used to drive machines with a variety of outputs, such as materials processing, packaging, or conveying machinery, or such appliances as sewing machines and washing machines. All machines of the latter type and all others that are neither prime movers, generators, nor motors may be classified as operators. This category also includes manually operated instruments of all kinds, such as calculating machines and typewriters.

In some cases, machines in all categories are combined in one unit. In a diesel-electric locomotive, for example, the diesel engine is the prime mover, which drives the electric generator, which, in turn, supplies electric current to the motors that drive the wheels.(Anonymous, 2018c)

The concept is also applied in stretchable items like bows and rubber bands though there is one or two partsstretched or have seen visible changes.

II. Methodology

Information were gathered and evaluated.

Objectives of spring

The objectives of a spring when used as a machine member are as follows.

Cushioning, absorbing, or controlling of energy due to shock and vibration. Examples are car springs, railway buffers, vibration dampers etc.

Control of motion – A spring control the motion by maintaining contact between two elements. In a cam and a follower arrangement, widely used in numerous applications, a spring maintains contact between the two elements in this way primarily controls the motion.

Creation of the necessary pressure in a friction device (a brake or a clutch). For example, in a car a brake or a clutch is used for controlling the car motion. A spring system keep the brake in disengaged position until applied to stop the car. The clutch has also got a spring system (single springs or multiple springs) which engages and disengages the engine with the transmission system.

Restoration of a machine part to its normal position when the applied force is withdrawn. A typical example is a governor for turbine speed control. A governor system uses a spring controlled valve to regulate flow of fluid through the turbine, thereby controlling the turbine speed.

Storing of energy – An example of storing of energy by springs is winding clocks. The clock has spiral type of spring which is wound to coil and then the stored energy helps gradual recoil of the spring when in operation.

Measuring forces – Examples are spring balances, and gauges etc.

Commonly used spring materials

One of the important considerations in spring design is the choice of the spring material. Some of the common materials used for the springs are given below.

Hard-drawn wire – Cold drawn steel wires are the cheapest materials used for the making of springs. Springs made from cold steel wires are generally used for low stress and static loads. This material is not suitable for springs to be used at sub-zero temperatures and at temperatures above 120 deg C.

High carbon blue tempered and polished spring steel- It is a standard material for conventional springs. It is a low cost material and best suited for applications that have a protected environment, as carbon steel corrodes if not lubricated or atmospherically sealed.

Oil tempered wire – Oil tempered wires are cold drawn, quenched, and tempered. These spring steel wires are used for general purpose springs. Springs made from these wires are not suitable for fatigue or sudden loads as well as at sub-zero temperatures and at temperatures above 180 deg C.

Alloy steels containing chromium and vanadium – Springs made from alloy steels containing chromium and vanadium are used for high stress conditions and at high temperature up to 220 deg C. These springs are good for fatigue resistance and long endurance for shock and impact loads.

Alloy steels containing chromium and silicon – This material can be used for making of highly stressed springs. The material is suitable for springs requiring for long life and shock loading. Springs made from these alloy steels are suitable for temperature up to 250 deg C.

Piano wire – Piano wire is also known music wire and is made from tempered high carbon steel. Piano wire is normally the most widely used material for springs. This spring material is generally used for small springs. Springs made from this material are the toughest and have highest tensile strength. These springs can withstand repeated loading at high stresses. However, springs made from piano wires cannot be used at sub-zero temperatures as well as temperatures above 120 deg C.

Stainless steel – These are alloy steels containing at least 10 % chromium and offer much improved corrosion resistance over plain or alloy steels. Springs made from stainless steels stain and corrode very slowly in severe environments such as seawater. These springs have improved resistance to high temperature and can be used for temperatures up to 288 deg C. Springs made from stainless steels of 18-8 composition can be used for sub-zero temperatures.

Spring materials other than steels – Usually phosphor bronze and brass are used as spring materials. Springs made from these materials have good corrosion resistance and electrical conductivity. They are normally used for contacts in electrical switches. Springs made from brass can be used at sub-zero temperatures.

Classification of springs

There are several methods used for the classification of the springs.

Springs can be classified depending on how the load force is applied to them. As per this classification method there are the following types of springs.

Tension/extension springs – These springs are designed to operate with a tension load and hence the spring stretches as the load is applied to it.

Compression springs – These springs are designed to operate with a compression load and hence the spring becomes shorter as the load is applied to it.

Torsion spring – As compared to the tension and compression springs where the applied load is an axial force, the load applied to a torsion spring is a torque or twisting force, and the end of the spring rotates through an angle as the load is applied.

Constant spring – In this type of spring, the supported load remains the same throughout deflection cycle.

Variable spring – In this type of spring the resistance of the coil to load varies during the compression.

The springs can also be classified according to their shape. As per this classification method the springs are of the following type.

Coil springs- A coil spring is made of a coil or helix of wire.

Flat springs – A flat spring is made of a flat or conical shaped piece of metal.

Machined springs – This type of spring is produced by machining a steel bar with a lathe and/or milling operation rather than coiling wire. Since it is machined, the spring may incorporate features in addition to the elastic element. Machined springs can be made in the typical load cases of compression/extension, torsion, etc.

The most common types of spring are as follows.

Cantilever spring – This is a type of spring which is fixed only at one end.

Coil spring – It is also known as helical spring. It is made by winding a wire around a cylinder or a cone. In case wire is wound on a cone then the spring is called a conical spring. Coil springs are usually of two types. The first type consists of a compression spring which is designed to become shorter when loaded. Their turns (loops) are not touching in the unloaded position, and they need no attachment points. A volute spring is also a compression spring in the form of a cone, designed so that under compression the coils are not forced against each other, thus permitting longer travel. The second type consists of tension or extension springs which are designed to become longer under load. Their turns (loops) are normally touching in the unloaded position, and they have a hook, eye or some other means of attachment at each end.

Hairspring or balance spring – It is a delicate spiral torsion spring used in watches and galvanometers, and places where electricity is to be carried to partially rotating devices such as steering wheels without hindering the rotation.

Leaf spring – It is a flat spring used in vehicle suspensions, electrical switches, and bows.

V spring – V springs are used in antique firearm mechanisms such as the wheel lock, flint lock, and percussion cap locks.

The other types of springs which are commonly used are as given below.

Belleville washeror Belleville spring – It is a disc shaped spring normally used to apply tension to a bolt. It is used in the initiation mechanism of pressure activated landmines.

Constant force spring – It consists of a tightly rolled ribbon which exerts a nearly constant force as it is unrolled.

Gas spring – The spring action is provided by a volume of gas which is compressed.

Ideal spring – In reality this spring does not exist. It is the notional spring used in physics and it has no weight, mass, or damping losses.

Mainspring – it is a spiral ribbon shaped spring used as a power source in watches, clocks, music boxes, wind-up toys, and mechanically powered flash lights.

Negator spring – It is a thin metal band slightly concave in cross-section. When coiled it adopts a flat cross-section but when unrolled it returns to its former curve, thus producing a constant force throughout the displacement and negating any tendency to re-wind. The most common application is the retracting steel tape rule.

Progressive rate coil spring – It is a coil spring with a variable rate, usually achieved by having unequal pitch so that when the spring is compressed one or more coils rests against its neighour.

Rubber band – It is a tension spring where energy is stored by stretching the material.

Spring washer – It is used to apply a constant tensile force along the axis of a fastener.

Torsion spring – it is a spring which is designed to be twisted rather than compressed or extended. This spring is used in torsion bar vehicle suspension systems.

Wave spring – It is a thin spring washer into which waves have been pressed.

Spring design

Different mathematical equations have been developed to describe the properties of springs, based on such factors as wire composition and size, spring coil diameter, the number of coils, and the amount of expected external force. These equations are used while designing springs for a particular application.

The process of manufacturing

The process for the production of coil springs made of steel is given below.

Coiling – it can be done either by cold winding or hot winding. In case of cold winding the steel wire (usually up to 18 mm diameter) is coiled at room temperature using one of two basic techniques. One consists of winding the wire around a shaft called an arbour or mandrel. This can be done on a dedicated spring-winding machine, a lathe, an electric hand drill with the mandrel secured in the chuck, or a winding machine operated by hand cranking. A guiding mechanism, such as the lead screw on a lathe, is required to be used to align the wire into the desired pitch (distance between successive coils) as it wraps around the mandrel. In the second technique, the wire may be coiled without a mandrel. This is generally done with a CNC machine. The wire is pushed forward over a support block towards a grooved head that deflects the wire, forcing it to bend. The head and support block can be moved relative to each other in as many as five directions to control the diameter and pitch of the spring that is being formed. For extension or torsion springs, the ends are bent into the desired loops, hooks, or straight sections after the coiling operation is completed. In case of hot winding, thicker wire or round bar can be coiled into springs by heating the steel to make it flexible. Standard industrial coiling machines can handle steel bar up to 75 mm in diameter, and custom springs have reportedly been made from bars as much as 150 mm thick. The steel is coiled around a mandrel while red hot. Then it is immediately removed from the coiling machine and plunged into oil to cool it quickly and harden it. At this stage, the steel is too brittle to function as a spring, and hence it is to be subsequently tempered.

Hardening – It is done by heat treatment. Whether the steel has been coiled hot or cold, the process has created stress within the material. To relieve this stress and allow the steel to maintain its characteristic resilience, the spring is to be tempered by heat treatment. The spring is heated in an oven, held at the appropriate temperature for a predetermined time, and then allowed to cool slowly. For example, a spring made of piano wire is heated to 260 deg C for one hour.

Finishing – If the design calls for flat ends on the spring, the ends are ground at this stage of the production process. The spring is mounted in a jig to ensure the correct orientation during grinding, and it is held against a rotating abrasive wheel until the desired degree of flatness is obtained. When highly automated equipment is used, the spring is held in a sleeve while both ends are ground simultaneously, first by coarse wheels and then by finer wheels. An appropriate fluid (water or an oil-based substance) may be used to cool the spring, lubricate the grinding wheel, and carry away particles during the grinding. After this the spring is subjected to shot peening. This process strengthens the steel to resist metal fatigue and cracking during its lifetime of repeated flexings. The entire surface of the spring is exposed to a barrage of tiny steel balls that hammer it smooth and compress the steel that lies just below the surface.

Setting and coating – setting is done to permanently fix the desired length and pitch of the spring, it is fully compressed so that all the coils touch each other. Some production plants carry out this process several times. Coating is done to prevent corrosion, the entire surface of the spring is protected by painting it, dipping it in liquid rubber, or plating it with another metal such as zinc or chromium. One process, called mechanical plating, involves tumbling the spring in a container with metallic powder, water, accelerant chemicals, and tiny glass beads that pound the metallic powder onto the spring surface. Alternatively, in case of electroplating, the spring is immersed in an electrically conductive liquid that will corrode the plating metal but not the spring. A negative electrical charge is applied to the spring. Also immersed in the liquid is a supply of the plating metal, and it is given a positive electrical charge. As the plating metal dissolves in the liquid, it releases positively charged molecules that are attracted to the negatively charged spring, where they bond chemically. Electroplating makes carbon steel springs brittle, so shortly after plating (less than four hours) they are to be baked at 160 deg C to 190 deg C for four hours to counteract the embrittlement.

Quality control – Various testing devices are used to check completed springs for compliance with specifications. The testing devices measure such properties as the hardness of the metal and the amount of the spring's deformation under a known force. Springs that do not meet the specifications are discarded. (Anonymous, 2018d)

Hooke's Law

Hooke's Law is a principle of physics that states that the force needed to extend or compress a spring by some distance is proportional to that distance. 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. He

first stated the law in 1660 as a Latin anagram, and then published the solution in 1678 as uttensio, sic vis – which translated, means "as the extension, so the force" or "the extension is proportional to the force").
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.(Williams, 2018)

III. Results

The spring was studied and the concepts of a spring are

1. When a spring is compressed or stretched, the force it exerts is proportional to its change in length.
2. It uses force in proportion
3. The resultant force is in a particular direction and concentration.
4. It uses the tensile or compressive strength of a material.

Note: These factors make the spring a simple machine.

IV. Discussions

1. The strengthsof the materialsto be used are considered when making a spring.
2. The taken load must be considered when using a spring.

V. Conclusion

The materials use their ductility, malleabilityand melting pointto create a spring; another factor is the strength of the materials. We have many uses for a spring ranging from tension spring to compression spring. Rubber bands are also springs.

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