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Design and Development of Spring testing machine

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ABSTRACT :

The Design and Development of a Spring Testing Machine aims to create a mechanical system capable of evaluating the mechanical properties of springs, such as stiffness (spring constant), load capacity, and deflection under applied forces. Springs are fundamental components in various mechanical systems, where they function to absorb shocks, store energy, and maintain force between contacting surfaces. Hence, testing their performance characteristics is essential for ensuring durability and functionality in real-world applications.

This project focuses on building a cost-effective, accurate, and user-friendly testing machine suitable for both educational and industrial use. The design integrates a robust mechanical frame, a manually or motor-driven loading mechanism, and precise measurement instruments including a load cell and a displacement sensor. These sensors are interfaced with a digital microcontroller or display unit to capture and present force and deflection data in real-time. Using these readings, the spring constant is calculated in accordance with Hooke's Law ($F = kx$).

The development process includes conceptual design, CAD modeling, selection of appropriate materials, fabrication of the machine frame, integration of sensors, and calibration of the system for reliable measurements. Extensive testing was conducted on different types and sizes of springs to verify the functionality and repeatability of the device.

The resulting machine successfully demonstrates its ability to measure spring behavior with high accuracy and repeatability. It serves as a valuable tool for engineering students and professionals, providing hands-on experience in mechanical testing and quality assurance of spring components.

1. INTRODUCTION

Springs are widely used in various industries, and their performance is characterized by the spring constant, which defines the relationship between the force applied and the resulting displacement. The Digital Spring Constant Testing Machine aims to automate and enhance the process of measuring this critical parameter. The main objective of this project is to determine the stiffness which is commonly known as spring constant of a compression spring under various load. The kit which has been built into a machine to stretch or compress test springs, while measuring load and displacement is called spring testing kit. It tests springs and finds their properties – good for mechanical workshops use. It includes a set of different springs to compare spring rates and effect of different spring sizes. It has wide range and variety of experiments. Easy-to-use, compact instrument that fits on a small bench or desktop and as a spring force constant determination as a learning tool for graphing and modeling. Compression of a spring in a spring constant testing machine is an example of a loading that can be treated as a combination of a direct shear load and a torsional load. This project is just a prototype which can be improved for implementation in industrial work..

Spring rolling industry is a large and growing industry. There are many special purposes machines used in this industry to-day. The proper selection of the machines depends upon the type of the work under-taken by the particular industry. There are many examples of spring, which can be seen in our everyday lives. The metals generally used for spring rolling work include iron, copper, tin, aluminium, stainless and brass. Our project the "SPRING TESTING MACHINE" finds huge application in all spring manufacturing industry. A spring is an elastic body used to store mechanical energy. When a spring is compressed or stretched from its mean position, it exerts an opposing force approximately proportional to its change in length. Spring is used in hydraulic valves, ball point pens, in a round hole or anywhere a pushing or compressing force needs to be applied. It is also used in brakes, clutches, spring balance, shock absorber, toys and watches etc. The most common application of spring is in vehicle suspension.

1.1. Introduction to spring cocnstant testing machine

Springs play a fundamental role in numerous mechanical systems, serving as essential components that store and release energy in response to external forces. The performance of springs is characterized by a critical parameter known as the spring constant, a measure of the stiffness of the spring. The accurate determination of this spring constant is crucial for ensuring the optimal functionality of springs in various applications, including automotive, aerospace, and manufacturing.

The Spring Constant Testing Machine addresses the need for a precise and efficient tool to quantify the spring constant of different types and sizes of springs. This sophisticated testing apparatus is designed to provide engineers, researchers, and manufacturers with a reliable means of assessing the mechanical characteristics of springs, enabling them to make informed decisions regarding design, quality control, and performance optimization.

1.2. Significance of Spring Constant Testing

Understanding the spring constant is essential in engineering applications where springs are employed. This parameter directly influences the behavior of a spring under load, impacting factors such as deflection, stress, and overall system dynamics. Accurate knowledge of the spring constant ensures that springs are appropriately selected for their intended purpose, contributing to the efficiency, safety, and longevity of mechanical systems.

1.3. Challenges in Traditional Testing Methods

Traditionally, determining the spring constant involved manual and often subjective methods that were prone to errors and inconsistencies. The Spring Constant Testing Machine addresses these challenges by providing an automated and highly accurate means of assessing the spring constant. By incorporating advanced sensors, precision mechanics, and digital controls, this machine streamlines the testing process and delivers reliable results, reducing the reliance on subjective judgments.

1.3.1. Objectives of the Spring Constant Testing Machine:
1.3.2. Accuracy: To provide precise measurements of the spring constant, ensuring the reliability of the data obtained.
1.3.3. Versatility: To accommodate various types and sizes of springs, allowing for a wide range of applications across different industries.
1.3.4. Efficiency: To streamline the testing process, minimizing human intervention and potential sources of error.
1.3.5. User-Friendly Operation: To incorporate an intuitive interface that allows users to input parameters, monitor the testing process, and interpret results with ease.

1.4. Anticipated Impact

The Spring Constant Testing Machine is expected to significantly contribute to advancements in spring-related research, development, and manufacturing. By offering a standardized and accurate method for measuring the spring constant, this machine has the potential to enhance the quality and performance of products across diverse industries, ultimately improving the reliability and safety of mechanical systems. In the subsequent sections of this report, we will delve into the detailed design, development, and functionalities of the Spring Constant Testing Machine, showcasing its capabilities and the innovations it brings to the field of spring testing.

1.5. Introduction to spring

Springs are ubiquitous mechanical components that play a pivotal role in a multitude of applications across various industries. Their fundamental function is to store mechanical energy when subjected to a force and release it when the force is removed, making them essential in countless mechanisms, from everyday items to complex machinery. The unique ability of springs to deform and return to their original shape makes them invaluable in providing support, absorbing shocks, and controlling motion within mechanical systems.

1.5.1. Types of Springs

Springs come in a diverse array of shapes and sizes, each designed to meet specific engineering requirements. The two primary categories of springs are:

1.5.1.1. Compression Springs:

Fig.1.1. Compression spring

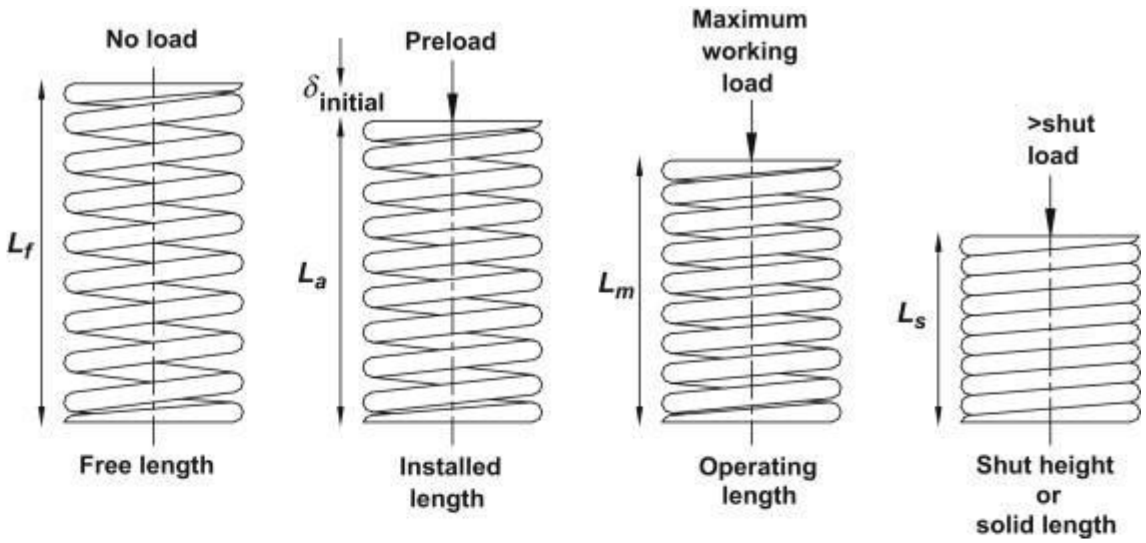

Fig.1.2. Nomenclature of Compression Spring

The nomenclature of a compression spring refers to the standardized terms and symbols used to describe its various dimensions, characteristics, and features. Here is a typical set of nomenclature used for compression springs:

Wire Diameter (d): The diameter of the wire used to form the coil.

Outer Diameter (D): The maximum outer diameter of the compression spring.

Inner Diameter (d'): The minimum inner diameter of the compression spring.

Mean Diameter (Dm): The average diameter of the compression spring, calculated as (D + d')
/ 2.

Free Length (L0): The overall length of the compression spring when it is not under any load.

Solid Length (Ls): The length of the compression spring when it is fully compressed, also known as the solid height.

Total Coils (Nt): The total number of coils in the compression spring.

Active Coils (Na): The number of coils that are free to deflect under load.

Pitch (P): The axial distance between adjacent coils, measured parallel to the axis.

Pitch Diameter (Dp): The diameter of the imaginary cylinder that touches the tops of the compression spring coils.

Rate or Spring Constant (k): The amount of force required to compress the spring by a unit distance. Usually measured in force per unit length (e.g., N/mm).

Maximum Load (Fmax): The maximum force the compression spring can withstand without permanent deformation.

Initial Tension (Fi): The force exerted by the compression spring when it is in its free, uncompressed state.

Ends:

Closed and Ground Ends: Both ends are closed and ground to provide a flat surface.

Closed Ends: Both ends are closed but not ground.

Open Ends: Both ends are open.

Tapered Ends: The ends are tapered to a point.

Surface Finish: Describes the surface condition of the compression spring, whether it is shotpeened, plated, or has a specific coating.

Material: Specifies the material from which the compression spring is made, such as music wire, stainless steel, or an alloy.

Direction of Wind: Indicates the direction in which the wire is wound to form the coil (righthand or left-hand).

Compressed or squashed when a force is applied.

Introduction:

Compression springs represent a fundamental category of mechanical components, widely used for their ability to absorb and store energy when compressed. This essential quality makes compression springs integral in various applications, ranging from simple household items to complex industrial machinery.

Design Principles:

Coil Shape: Compression springs typically feature a helical coil shape, where each coil is wound around a central axis. This design enables the spring to compress and absorb force evenly.

Wire Diameter and Pitch:

The wire diameter and pitch (distance between consecutive coils) are crucial design parameters.

They determine the strength, resilience, and load-bearing capacity of the compression spring.

Ends and Connections:

The ends of compression springs may take various forms, such as closed and ground, open, or tapered. These end configurations influence the spring's behavior and application suitability.

Material Selection

The choice of material for compression springs is critical, as it directly impacts performance, durability, and corrosion resistance. Common materials include high-carbon steels, stainless steels, and alloys suitable for specific environmental conditions.

Applications

Compression springs find applications in diverse industries, contributing to the functionality of numerous devices and systems:
Automotive: Suspension systems, brakes, and engine components.

Manufacturing: Conveyor systems, stamping and pressing machines.

Electronics: Switches, connectors, and various mechanisms in electronic devices.

Medical Devices: Compression springs are used in surgical instruments and various medical equipment.

Spring Constant and Compression Analysis

Spring Constant (k): The spring constant is a measure of the spring's stiffness and is defined as the force required to compress the spring by a unit distance. It plays a crucial role in predicting the behavior of the compression spring under different loads.

Compression Testing: Analyzing compression springs involves testing their response to applied forces. Compression testing machines measure parameters like load, displacement, and stress to determine the spring constant and assess performance characteristics.

1.5.2.1. Factors Affecting Performance:

Load Capacity: The ability of a compression spring to bear loads without permanent deformation.
Solid Height: The minimum height of the spring under full compression, crucial for design considerations.
Fatigue Resistance: The spring's ability to endure repeated cycles of compression and decompression without failure.

1.5.3.1. Manufacturing Processes:

Common manufacturing processes for compression springs include cold winding, hot winding, and precision grinding. Each process has specific advantages and is chosen based on the required precision and production volume.

Compression springs, with their versatile designs and widespread applications, are indispensable components in the realm of mechanical engineering. Understanding their principles, design considerations, and performance characteristics is vital for engineers and designers aiming to harness the full potential of these resilient components in their applications. The subsequent sections of this report will explore in-depth the testing and analysis of compression springs, focusing on the innovative techniques and technologies employed in the field.

Commonly found in devices where the load acts along the axis of the coil.

1.5.1.2. Extension Springs:

Fig.1.3.Extenssion Spring

Nomenclature of Extension Spring

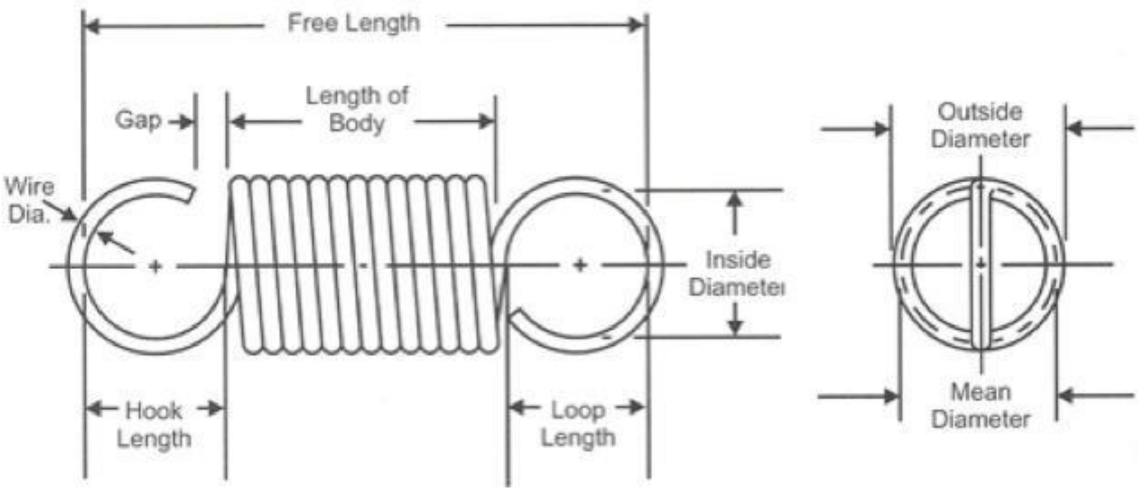

Fig.1.4. Nomenclature of Extension Spring

The nomenclature of an extension spring involves standardized terms and symbols used to describe its various dimensions, characteristics, and features. Below is a typical set of nomenclature used for extension springs:

Wire Diameter (d): The diameter of the wire used to form the coil.

Outer Diameter (D): The maximum outer diameter of the extension spring.

Inner Diameter (d'): The minimum inner diameter of the extension spring.

Mean Diameter (Dm): The average diameter of the extension spring, calculated as (D + d') / 2.

Free Length (L0): The overall length of the extension spring when it is not under any load.

Initial Tension (Fi): The force exerted by the extension spring when it is in its free, uncompressed state.

Total Coils (Nt): The total number of coils in the extension spring.

Active Coils (Na): The number of coils that are free to extend under load.

Pitch (P): The axial distance between adjacent coils, measured parallel to the axis.

Load (F): The force applied to the extension spring that causes it to extend.

Spring Rate or Constant (k): The amount of force required to extend the spring by a unit distance. Usually measured in force per unit length (e.g., N/mm).

Maximum Load (Fmax): The maximum force the extension spring can withstand without permanent deformation.

Ends:

Full Loop at Both Ends: Both ends form a full loop.

Full Loop at One End: One end forms a full loop.

Double Full Loop at Both Ends: Both ends form a double full loop.

Double Full Loop at One End: One end forms a double full loop.

Extended Hooks: Both ends are extended with hooks.

Surface Finish: Describes the surface condition of the extension spring, whether it is shotpeened, plated, or has a specific coating.

Material: Specifies the material from which the extension spring is made, such as music wire, stainless steel, or an alloy.

Direction of Wind: Indicates the direction in which the wire is wound to form the coil (righthand or left-hand).

These terms provide a comprehensive description of an extension spring, aiding in design, manufacturing, and communication among engineers and manufacturers. When specifying or ordering extension springs, using this nomenclature ensures clear and accurate communication of the desired specifications.

Stretched or extended when a force is applied.

Used in applications where the load pulls the coil apart.

Applications of Springs:

Springs find applications in a wide range of industries, contributing to the functionality and efficiency of numerous devices. Some common applications include:

Automotive Industry: Springs are essential components in vehicle suspension systems, ensuring a smooth ride and absorbing shocks.

Manufacturing: Springs play a crucial role in machinery, providing precision and control in various manufacturing processes.

Consumer Electronics: Springs are used in products like watches, keyboards, and door hinges, contributing to their functionality and durability.

Aerospace: Springs are employed in aircraft components, where lightweight yet resilient materials are crucial.

The Importance of the Spring Constant:

Central to the understanding of springs is the concept of the spring constant (k). The spring constant defines the stiffness of a spring and determines how much it will deform under a given load. It is a critical parameter in engineering design, as it influences factors such as the frequency of vibration, stress distribution, and overall system dynamics.

Challenges in Spring Analysis:

While springs are integral to many systems, accurately quantifying their behavior and performance can be challenging. Traditional methods of spring analysis often rely on manual measurements, which may be subjective and prone to error. To address these challenges and enhance the precision of spring analysis, testing methods such as the Spring Constant Testing Machine have been developed.
Springs, with their versatile applications and fundamental role in mechanical systems, underscore the importance of understanding their characteristics. The subsequent sections of this report will delve into the intricacies of spring analysis, with a particular focus on the development and functionalities of the Spring Constant Testing Machine—a tool designed to provide accurate and reliable measurements of the spring constant, thereby contributing to advancements in engineering, manufacturing, and product design

1.6. Objectives:

Design a robust and versatile testing machine capable of measuring the spring constant accurately.
Implement digital sensors and controls for increased precision and ease of use.

Develop a user-friendly interface for data input, control, and result visualization.

Ensure the machine is adaptable to test different types and sizes of springs.

2. LITERATURE REVIEW

[1]. Muhammad Abu Rahat, Muhammad Ferdous Raiyan, MD. Safayet Hossain, J.U. Ahamed, Nahed Hassan Jony-
The main objective of this project is to determine the stiffness which is commonly known as spring constant of a compression spring under various load. The kit which has been built into a machine to stretch or compress test springs, while measuring load and displacement is called spring testing kit. It tests springs and finds their properties – good for mechanical workshops use. It includes a set of different springs to compare spring rates and effect of different spring sizes. It has wide range and variety of experiments. Easy-to-use, compact instrument that fits on a small bench or desktop and as a spring force constant determination as a learning tool for graphing and modeling. Compression of a spring in a spring constant testing machine is an example of a loading that can be treated as a combination of a direct shear load and a torsional load. This project is just a prototype which can be improved for implementation in industrial work.
They concluded In this experiment, we determine the spring constant of a compression spring using Hook's Law. We took three springs of different sizes. But every steps some error occurred. For first spring error is 3%, for second spring error 4.7% and for third spring error 1.3%. The sources of error in this part of the experiment are due to the precision of the location measurement using the meter stick and the accuracy of the slotted masses. The meter stick was mounted vertically and behind the spring. By plotting the value of force and displacement on the graph a straight line is found.

[2]. Prof.Amit chaudhary, Mr. Vaibhav sirame, Mr.Gajanan bharude, Mr. Amol dubal, Mr. Rajkumar wade
Mechanical Engineering without production and manufacturing is meaningless and inseparable. Production and manufacturing process deals with conversion of raw materials inputs to finished products as per required dimensions specifications and efficiently using recent technology. In our project spring load testing machine is used to find out the stiffness, modulus of rigidity, bulk modules. In spring working industry a wide range inspection machines are used. As the industry is a large and growing industry different type of machines are used for different operations. Our project the spring rolling machine is very simple in operation by using microcontroller with digital display. This machine is used to testing the various types of spring load

test in different diameters and length of the spring. This machine can be used in various fields. This machine is simple in construction and working principle.

And concluded that Design and implementation of spring stiffness testing machine is successfully completed. The main purpose of this project for student to analysis different types of spring stiffness and application of different types of sprigs uses. Manufacturing cost is also less. Less time required to find stiffness. Easy for student to analyze different types of springs.

It has high accuracy in spring testing and precision work.

[3]. Olugboji Oluwafemi Ayodeji , Matthew Sunday Abolarin , Jiya JonathanYisa ,Alaya Garba Muftau , Ajani Clement Kehinde.

A spring stiffness testing machine was produced which differentiates a good spring from bad one using hydraulic principle and locally sourced materials were used to produce at relative low cost and high efficiency. It also categories each spring by stiffness into one of several distinct categories based on its performance under test. This is to ensure that in the final assembly process, springs with similar performance characteristics are mated to ensure a better ride, more précised handling and improved overall vehicle or equipment performance. The construction of the machine involves basically the fabrication process which includes such operation as cutting, benching, welding, grinding, drilling, machining, casting and screw fastening. Taken into consideration under test, were types of compression springs with varying spring loading and their different displacement recorded at different pressures to compare their stiffness. Keywords - spring, stiffness, coil, extension, compression. And concluded that From the results obtained, it can be deduced that Sample 1 spring stiffness in TABLE 2 is within tolerance limit of ±0.3 when subjected to various loading. At 2, 4, 6, 8 and 10 bars, the spring stiffness is within the limit. This suggests that the spring will give the optimal performance if used together with other springs of the same stiffness and properties. TABLE 3 shows that the Sample 2 spring stiffness is within tolerance limit when subjected to 2, 6 and 10 bars, but deviated from the limit at 4 bars and 8 bars. If this spring is used, the performance at certain loading will not be accurate and might cause damage to engine valve, piston and the connecting rod. This sample failed the test. Sample 3 spring stiffness as shown in TABLE 3 is within tolerance limit when subjected to only 4.

[4]. Rahul Kumar, Neeraj Panday, Arun Kumar, Vivek Kumar studied The helical spring is the most common element that has been used in automobile industries. In this work the spring constant and deflection of the spring at different loads have been calculated. A closed coil helical spring is used for calculating tension and open coil helical spring is used for compression. The component used for the fabrication of the spring testing machine are frame, hydraulic, spring weighing machine, open coiled and closed coiled helical spring etc. In this machine the combined testing of both tension and compression can be done. The data obtained from the machine the compared with the manually calculated data and all the result obtained are in good agreement and concluded The spring constant and deflection of the spring at different loads have been calculated. A closed coil helical spring is used for calculating tension and open coil helical spring is used for compression. In this machine the combined testing of both tension and compression can be done. The data obtained from the machine the compared with the manually calculated data and all the result obtained are in good agreement.

[5]. Long-term fatigue tests on shot peened helical compression springs were conducted by means of a special spring fatigue testing machine at 40 Hz. Test springs were made of three different spring materials oil hardened and tempered SiCr- and SiCrV-alloyed valve spring steel and stainless-steel. With a special test strategy in a test run, up to 500 springs with a wire diameter of d = 3.0 mm or 900 springs with d = 1.6 mm were tested simultaneously at different stress levels. Based on fatigue investigations of springs with d = 3.0 mm up to a number of cycles N = 109 an analysis was done after the test was continued to N = 1.5x109 and their results were compared. The influence of different shot peening conditions were investigated in springs with d = 1.6 mm. Fractured test springs were examined under optical microscope, scanning electron microscope (SEM) and by means of metallographic micro sections in order to analyze the fracture behavior and the failure mechanisms.

[6]. Elastomeric components have wide usage in many industries. The typical service loading for most of these components is variable amplitude and multi axial. In this study a general methodology for life prediction of elastomeric components under these typical loading conditions was developed and illustrated for a passenger vehicle cradle mount. Crack initiation life prediction was performed using different damage criteria. The methodology was validated with component testing under different loading conditions including constant and variable amplitude in-phase and out-of-phase axial–torsion experiments. The optimum method for crack initiation life prediction for complex multiaxial variable amplitude loading was found to be a critical plane approach based on maximum normal strain plane and damage quantification by cracking energy density on that plane. Rain flow cycle counting method and Miner's linear damage rule were used for predicting fatigue life under variable amplitude loadings.

[7]. Very high cycle fatigue (VHCF) properties of newly developed clean spring steel were experimentally examined under rotating bending and axial loading. As a result, this steel represents the duplex S–N property only for surfaceinduced failure under rotating bending, whereas it represents the single S–N property for surface-induced failure and interior inhomogeneous micro structure induced failure under axial loading. The surface morphology of the interior inhomogeneous microstructure with distinct plastic deformation is much rougher than that of the ambient matrix, which means the stress concentration resulted from the strain inconsistency between the micro structural inhomogeneity as soft phase and the ambient matrix as hard phase plays a key role in causing interior crack initiation.

[8]. A 3D geometric modelling of a twin helical spring and its finite element analysis to study the spring mechanical behavior under tensile axial loading. The spiraled shape graphic design is achieved through the use of Computer Aided Design (CAD) tools, of which a finite element model is generated. Thus, a 3D 18-dof pentaedric elements are employed to discrete the complex 'wired-shape" of the spring, allowing the analysis of the mechanical response of the twin spiraled helical spring under an axial load. The study provides a clear match between the evolution of the theoretical and the numerical tensile and compression normal stresses, being of sinusoidal behavior. On the other hand, the minimum stress level is located in the center of the filament cross section.

[9]. The paper gives an overview of the present state of research on fatigue strength and failure mechanisms at very high number of cycles (Nf > 107). Testing facilities are listed. A classification of materials with typical S–N curves and influencing factors like notches, residual stresses and environment are given. Different failure mechanisms which occur especially in the VHCF-region like subsurface failure are explained. There micro structural in homogeneities and statistical conditions play an important role. A double S–N curve is suggested to describe fatigue behavior considering different failure mechanisms. Investigated materials are different metals with body-centered cubic lattice like low- or high strength steels and quenched and tempered steels but also materials with a face-centered cubic lattice like aluminum alloys and copper.

[10]. Ever since high-strength steels were found to fail below the traditional fatigue limit when loaded with more than 108 cycles, the investigation of metals' and alloys' very high cycle fatigue properties has received increased attention. A lot of research was invested in developing methods and machinery to reduce testing times. This overview outlines the principles and testing procedures of very high cycle fatigue tests and reports findings in the areas of crack formation, non-propagating small cracks, long crack propagation and thresholds. Furthermore, superimposed and variable amplitude loading as well as frequency effects are reported. [11]. A stranded wire helical spring (SWHS) is a unique cylindrically helical spring, which is reeled by a strand that is formed of 2∼16 wires. In this paper, a parametric modelling method and the corresponding 3D model of a closed-end SWHS are presented based on the forming principle of the spring. By utilizing a PC + PLC based model as the motion control system, a prototype machine tool is designed and constructed, which improves the manufacturing of the SWHS. Via the commercial CAD package Pro/Engineering, numerical simulation is carried out to test the validity of the parametric modeling method and the performance of the machine tool. The scheme of the tension control system is analyzed and the control mechanism is set up, which have achieved the constant tension of each wire. A human machine interface is also proposed to achieve the motion control and the tension control. Experimental results show that the tension control system is well-qualified with high control precision.

[12]. An adjustable-stiffness actuator composed of two antagonistic non-linear springs is proposed in this paper. The elastic device consists of two pairs of leaf springs working in bending conditions under large displacements. Owing to this geometric non-linearity, the global stiffness of the actuator can be adjusted by modifying the shape of the leaf springs. A mathematical model has been developed in order to predict the mechanical behavior of our proposal. The non-linear differential equation derived from the model is solved, obtaining large stiffness variations.

[13]. The characterization of vibrationfatigue strength is one of the key parts of mechanical design. It is closely related to structural dynamics, which is generally studied in the frequency domain, particularly when working with vibratory loads. Fatigue-life estimation in the frequency domain can therefore prove advantageous with respect to a time-domain estimation, especially when taking into consideration the significant performance gains it offers, regarding numerical computations. Several frequency-domain methods for a vibration-fatigue-life estimation have been developed based on numerically simulated signals. This research focuses on a comparison of different frequency-domain methods with respect to real experiments that are typical in structural dynamics and the automotive industry. The methods researched are: Wirsching–Light, the a0.75 method, the experimental comparison researches the resistance to close-modes, to increased background noise, to the influence of spectral width, and multivibration-mode influences. Additionally, typical vibration profiles in the automotive industry are also researched. For the experiment an electro-dynamic shaker with a vibration controller was used. The reference-life estimation is the rain flow- counting method with the Palmgren– Miner summation rule.

[14]. High strength steel grade 51CrV4 in thermo-mechanical treated condition is used as bending parabolic spring of heavy vehicles. Several investigations show that fatigue threshold for very high cycle fatigue depends on inclusion's size and material hardness. In order to determine allowed size of inclusions in spring's steel the Murakami's and Chapetti's model have been used. The stress loading limit regarding to inclusion size and applied stress has been determine for loading ratio R=-1 in form of S-N curves. Experimental results and prediction of S-N curve by model for given size of inclusion and R ratio show very good agreement. Prestressing and shot-penning cause higher compress stress magnitude and consequently change of loading ratio to more negative value and additionally extended life time of spring.

3. DESIGN PHASE

3.1. Specifications

Maximum load capacity- 100 kg

Range of spring lengths and diameters - 100 mm

Accuracy requirements- 0.1 gm

Digital display resolution – 26*4

3.2. Sensor Integration:

3.2.1. Load cell for force measurement

A load cell is a transducer designed to convert a mechanical force or load into an electrical signal that can be measured and analyzed. Load cells are commonly used in various applications for accurate force measurement. The design and principles behind load cells can vary, but they generally operate based on strain gauge technology. Here's an overview of load cells for force measurement:

3.2.2. Principle of Operation:

Load cells typically rely on the deformation of a material, often in the form of a metal or alloy, when subjected to a force. This deformation results in a change in electrical resistance, which can be measured and correlated with the applied force.

3.2.3. Types of Load Cells:

Strain Gauge Load Cells:

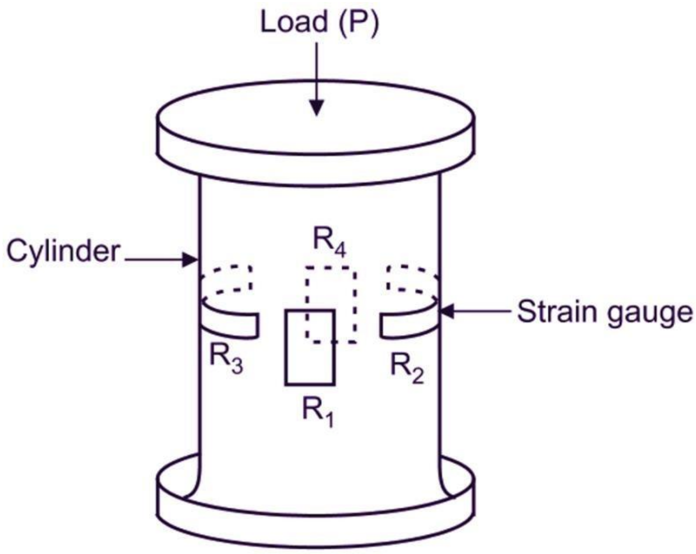

Fig.3.1.Strain Gauge Most common type.

Utilizes strain gauges bonded to a deformable element.

As the load is applied, the strain gauges experience deformation, causing a change in resistance. A strain gauge is a sensor used to measure the deformation or strain in an object. It works on the principle that the electrical resistance of a conductor changes when it is subjected to mechanical strain. Strain gauges are commonly used in various applications, including structural monitoring, material testing, and force measurement. Here's an overview of strain gauges:

Principle of Operation:

The basic principle of a strain gauge is that the electrical resistance of a wire changes when it is deformed. When a strain is applied to the object to which the strain gauge is attached, the gauge deforms, causing a change in its electrical resistance. This change in resistance is proportional to the mechanical strain experienced by the object.

Types of Strain Gauges:

Metal Foil Strain Gauges:

Consist of a thin foil (commonly made of constantan or Karma alloy) bonded to a backing material.
The foil undergoes elongation or compression with strain, altering its electrical resistance.

Semiconductor Strain Gauges:

Made of semiconductor materials like silicon.

Utilize the piezoresistive effect, where the resistance of the semiconductor changes with strain.

Bonded Wire Strain Gauges:

A wire is bonded to the surface of the material under strain.

Changes in the wire's electrical resistance are measured to determine strain.

Installation:

Strain gauges are carefully bonded or attached to the surface of the object being measured. The installation process is critical, and factors such as temperature, surface preparation, and adhesive selection must be considered to ensure accurate measurements.

Wheatstone Bridge Configuration:

Strain gauges are often arranged in a Wheatstone bridge configuration to measure small changes in resistance. The Wheatstone bridge consists of four resistive arms, with the strain gauge forming one of these arms. When a strain is applied, the bridge becomes unbalanced, and the resulting voltage change is proportional to the strain.

Applications:

Structural Health Monitoring:

Used to monitor the structural integrity of buildings, bridges, and other infrastructure.

Aerospace:

Employed in aircraft and spacecraft for monitoring structural components and materials.

Material Testing:

Used to measure the deformation and stress in materials under various loads.

Force Measurement:

Incorporated into load cells and force sensors for accurate force measurements.

Automotive:

Integrated into vehicles for measuring strain in critical components, contributing to safety and performance monitoring.
Biomechanics:

Applied in biomechanical studies to measure strain in bones and tissues.

Considerations:

Temperature Compensation:

Temperature changes can affect the accuracy of strain measurements, so compensation mechanisms are often employed.

Calibration:

Regular calibration is necessary to ensure accurate and reliable results.

Environmental Conditions:

Consideration of the environmental conditions, including humidity and corrosive substances.

Selection of Strain Gauge Type:

Choosing the appropriate type of strain gauge based on the material, strain levels, and application requirements.

Advancements:

Recent advancements in strain gauge technology include the development of flexible and stretchable strain gauges for applications in wearable devices, robotics, and biomedical sensors. Strain gauges play a crucial role in modern engineering and research, providing valuable insights into the mechanical behavior of materials and structures under various conditions. Their versatility and precision make them indispensable tools in fields ranging from civil engineering to aerospace and beyond.

Piezoelectric Load Cells

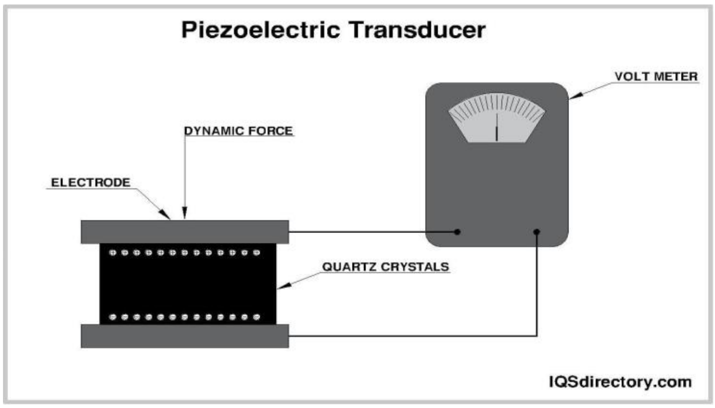

Fig.3.2. Piezoelectric Transducer

Generate an electrical charge in response to mechanical stress.

Suitable for dynamic force measurements and high-frequency applications.

Rapid response time.

Hydraulic Load Cells:

Use hydraulic fluid to measure force.

Changes in pressure within the hydraulic system correlate with the applied force.

Suitable for heavy-duty and high-capacity applications.

Pneumatic Load Cells:

Utilize changes in air pressure to measure force.

Often used in applications where electrical signals are undesirable, such as in explosive environments.

Capacitive Load Cells:

Measure changes in capacitance between plates.

Suitable for applications requiring high precision.

Load cells are used in a wide range of industries and applications, including:
Industrial Manufacturing: Monitoring and controlling force in manufacturing processes.

Aerospace: Aircraft weight and balance systems, structural testing.

Automotive: Testing components, vehicle dynamics, crash testing.

Medical Devices: Force sensing in medical equipment, prosthetics.

Material Testing: Strength testing of materials and structures.

Weighing Scales: Precision scales for commercial and industrial use.

Considerations:

Capacity: Choose a load cell with a capacity suitable for the maximum force expected in the application.
Accuracy: Consider the required precision and accuracy for the specific application.

Environmental Conditions: Ensure the load cell is compatible with the environmental conditions, including temperature, humidity, and potential exposure to corrosive substances.
Calibration: Regular calibration is essential to maintain accuracy over time.

Mounting: Proper mounting is crucial for accurate force measurement. Consider the direction and point of force application.
Load cells are versatile instruments that have revolutionized force measurement across industries. The selection of the appropriate type of load cell depends on the specific requirements and conditions of the application.

Displacement sensors for measuring spring deformation

Digital encoders for accurate displacement tracking

Displacement sensors are crucial in accurately measuring the deformation of springs. These sensors detect and quantify the changes in position or distance between two points, allowing for precise monitoring of the spring's displacement. Various displacement sensor types can be employed for this purpose, depending on the specific requirements of the application. Here are some commonly used displacement sensors for measuring spring deformation.

Linear Variable Differential Transformer (LVDT):

Principle:

LVDT operates on the electromagnetic induction principle. It consists of a primary coil and two secondary coils placed on either side of a movable core. The displacement of the core alters the inductance, producing an output voltage proportional to the displacement.
Advantages: High precision, reliability, and linearity. Suitable for both static and dynamic measurements.

Potentiometric Displacement Sensors.

Principle: These sensors use a resistive element and a sliding contact to measure displacement.

The position of the sliding contact on the resistive element determines the output voltage.

Advantages: Simplicity, cost-effectiveness, and suitability for various displacement ranges.

Optical Encoders.

Principle: Optical encoders use light to measure displacement. A light source and a photodetector are separated by a rotating or linearly moving patterned disk. The movement of the disk alters the light pattern, generating electrical signals.
Advantages: High resolution, non-contact measurement, and suitability for dynamic applications.

Strain Gauges with Extensometers.

Principle:

Strain gauges, bonded to the surface of the spring, measure the strain induced by deformation.

Extensometers with multiple strain gauges provide accurate displacement measurements.

Advantages: High sensitivity to deformation, suitable for material testing applications.

Capacitive Displacement Sensors.

Principle: Capacitive sensors measure the change in capacitance between two parallel plates as the distance between them varies. The capacitance is directly proportional to the displacement.

Advantages: High resolution, fast response, and non-contact measurement.

Eddy Current Displacement Sensors.

Principle: These sensors induce eddy currents in a conductive target. The interaction between the induced currents and the sensor's magnetic field is used to measure displacement. Advantages: Non-contact measurement, suitable for high-speed and high-temperature applications.

Piezoelectric Displacement Sensors

Principle: Piezoelectric sensors generate an electrical charge in response to mechanical deformation. The magnitude of the charge is proportional to the displacement.
Advantages: High sensitivity, suitable for dynamic measurements, and rapid response times.

Considerations:

Measurement Range: Choose a displacement sensor with a measurement range suitable for the expected deformation of the spring.
Resolution: Consider the required level of precision in displacement measurement.

Environmental Conditions: Ensure that the sensor is compatible with the environmental conditions of the application, including temperature and humidity.
Integration: Consider the ease of integration with other measurement systems or data acquisition devices.
The selection of a displacement sensor depends on the specific characteristics of the spring, the measurement requirements, and the environmental conditions of the application. Each type of sensor has its advantages and limitations, and the choice should be based on the unique needs of the measurement task

3.5. Mechanical Design:

Sturdy frame and fixtures to securely hold various spring types

Adjustable parameters to accommodate different spring sizes

Safety features to prevent overloading and damage

5. Development

Selection of Materials:

High-quality materials for durability

Corrosion-resistant components

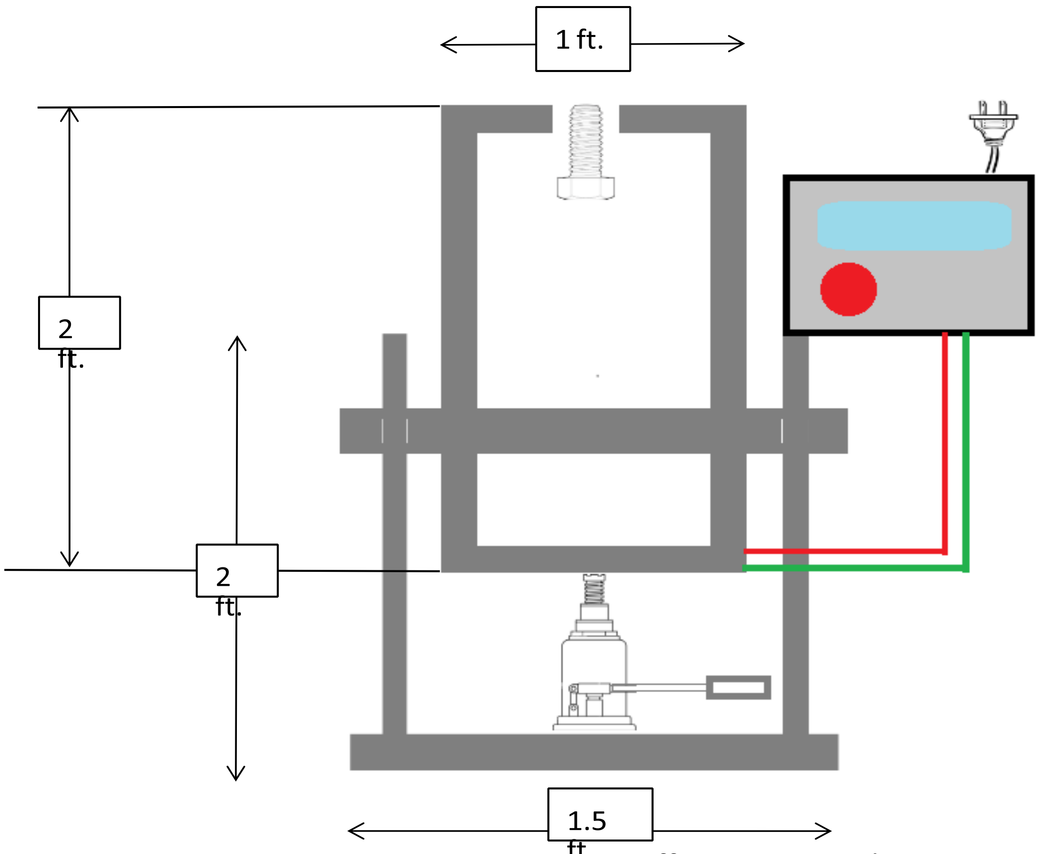

Fig.5.1.Spring Stiffness Testing machine

Assembly and Calibration:

Precise assembly of components

Calibration of sensors and digital displays

5.1.Components Used

5.1.1. Mild Steel Square Pipe

Mild steel square pipes are hollow structural sections made from mild steel, a low-carbon steel that is strong and durable. These pipes are commonly used in construction, engineering, and manufacturing due to their versatility and affordability.

Properties of Mild Steel Square Pipes:

1. Strength: Mild steel has good tensile and yield strength, making it suitable for structural applications.
2. Ductility: It can be easily formed and welded without losing its strength.
3. Malleability: Mild steel can be shaped into various forms, including square pipes, with ease.
4. Weldability: It can be welded using common welding techniques, such as MIG welding and arc welding.
5. Corrosion Resistance: While mild steel is susceptible to corrosion, it can be mitigated through protective coatings or painting.

Common Uses of Mild Steel Square Pipes:

1. Construction: Used in building frames, support columns, and roof trusses.
2. Furniture: Utilized in making frames for tables, chairs, and shelves.
3. Automotive: Used in the manufacturing of vehicle frames and chassis components.
4. Piping: Used for conveying fluids and gases in plumbing and irrigation systems.

Manufacturing: Used in the fabrication of machinery, equipment, and storage racks. Sizes and Dimensions: Mild steel square pipes are available in various sizes and thicknesses to suit different applications. Common sizes range from 1/2 inch to 6 inches in diameter, with wall thicknesses ranging from 1.6 mm to 12 mm. These dimensions can vary depending on the manufacturer and specific requirements.

Advantages:

1. Cost-Effective: Mild steel is relatively inexpensive compared to other materials.
2. Easy to Work With: It can be easily cut, drilled, and welded, making it ideal for fabrication.
3. Versatile: Suitable for a wide range of applications in different industries.
4. Recyclable: Mild steel is recyclable, making it environmentally friendly.

Disadvantages:

1. Susceptible to Corrosion: Without proper protection, mild steel can rust and corrode.
2. Low Resistance to Heat: It may deform or weaken at high temperatures.

Maintenance:

To maintain mild steel square pipes, it is essential to protect them from moisture and corrosion by applying a suitable coating or paint. Regular inspection and maintenance can help prolong the lifespan of the pipes.
In summary, mild steel square pipes are versatile and widely used in various industries due to their strength, affordability, and ease of fabrication.

Fig.5.2. Mild Steel Square Pipe

5.2. Sheet Metal Plate

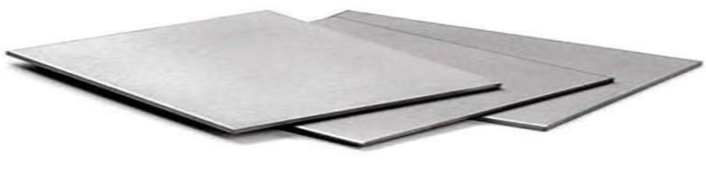

Fig.5.1 Mild steel plate

A 3 mm mild steel plate refers to a flat metal sheet that is 2 millimeters thick and made of mild steel. Mild steel, also known as low carbon steel, is a type of carbon steel with a low amount of carbon content (typically less than 0.3%). It is one of the most commonly used materials in manufacturing and construction due to its strength, durability, and affordability.

Properties of Mild Steel:

Strength:

Mild steel has good tensile strength and is suitable for structural applications.

Ductility:

It can be easily formed, bent, and welded without losing its strength.

Malleability:

Mild steel can be shaped and molded into various forms.

Weldability:

Mild steel is easily weldable using common welding techniques.

Corrosion Resistance:

While mild steel is susceptible to corrosion, it can be protected with coatings or painting.

Common Uses of 2 mm Mild Steel Plate:

Construction:

Used in building structures, roofing, and reinforcement.

Automotive:

Used in the manufacturing of car bodies, chassis, and components.

Shipbuilding:

Used in the construction of ships and marine structures.

Industrial:

Used for machinery, equipment, and storage tanks.

DIY and Home Improvement: Used for various DIY projects, such as brackets, frames, and shelves.

Advantages:

Affordability: Mild steel is relatively inexpensive compared to other materials.

Strength: It provides good structural support and durability.

Ease of Use: Mild steel is easy to work with using common tools and techniques.

Recyclability: Mild steel is recyclable, making it environmentally friendly.

Disadvantages:

Corrosion Susceptibility: Without proper protection, mild steel can rust and corrode.

Low Resistance to Heat: Mild steel may deform or weaken at high temperatures.

Maintenance: To maintain a 2 mm mild steel plate and prevent corrosion, it is recommended to apply a protective coating, such as paint or galvanization. Regular inspections and cleaning can also help prolong the lifespan of mild steel plates.

In summary, a 2 mm mild steel plate is a versatile and cost-effective material used in various industries and applications due to its strength, durability, and ease of use.

5.3.3 ton Hydraulic Jack

Fig.5.2. Hydraulic Jack

A 3-ton hydraulic jack is a mechanical device used to lift heavy loads, typically vehicles such as cars, trucks, or SUVs. It operates using hydraulic pressure to lift the load, making it easier to change tires, perform maintenance, or make repairs underneath the vehicle.

Here's a brief overview of how a 3-ton hydraulic jack works:

Hydraulic System: The jack consists of a hydraulic pump, cylinder, and piston. When the pump handle is operated, it forces hydraulic fluid (usually oil) from the reservoir into the cylinder, which causes the piston to rise and lift the load.

Lifting Capacity: The "3-ton" rating indicates the maximum weight the jack can lift safely. It is important not to exceed this weight limit to prevent damage to the jack and ensure safety. **Safety Features:** Hydraulic jacks typically have safety features such as overload protection valves to prevent overloading and lowering valves to control the descent of the load.

Usage: To use a hydraulic jack, place it under the vehicle's jacking point and pump the handle to raise the vehicle. Once the desired height is reached, insert a jack stand for added safety before working under the vehicle.

Maintenance: Regular maintenance, such as checking for leaks, ensuring the hydraulic fluid is at the correct level, and keeping the jack clean, is essential for safe and effective operation. Overall, a 3-ton hydraulic jack is a versatile tool for lifting heavy loads and is commonly used in automotive workshops, garages, and for roadside emergencies.

5.3.4. Microcontroller

Fig.5.3Nano-Microcontroller

The Arduino Nano is a small, versatile, and easy-to-use microcontroller board based on the ATmega328P microcontroller. It is part of the Arduino family of boards and is designed for projects that require a compact and low-cost solution. Here are some key features and specifications of the Arduino Nano.

Key Features:

Microcontroller: ATmega328P

Operating Voltage: 5V

Input Voltage (recommended): 7-12V

Input Voltage (limits): 6-20V

Digital I/O Pins: 14 (of which 6 provide PWM output)

Analog Input Pins: 8

DC Current per I/O Pin: 40 mA

Flash Memory: 32 KB (of which 2 KB used by bootloader)

SRAM: 2 KB

EEPROM: 1 KB

Clock Speed: 16 MHz

USB Interface: Mini USB

Dimensions: 45mm x 18mm

Programming: The Arduino Nano can be programmed using the Arduino Software (IDE), which is based on the C++ programming language. It has a boot loader pre-installed, making it easy to upload code via a USB connection. **Applications:** The Arduino Nano is suitable for a wide range of applications, including:

Robotics

Home automation

IoT (Internet of Things) projects

Sensor interfacing

Embedded systems

Advantages:

Compact Size: The small form factor of the Arduino Nano makes it suitable for projects where space is limited.

Ease of Use: The Arduino platform is beginner-friendly, with a large community and plenty of resources available.

Low Cost: The Arduino Nano is an affordable option for hobbyists and makers.

Versatility: The Arduino Nano can be used in a wide range of projects and applications.

Disadvantages:

Limited I/O Pins: The Arduino Nano has fewer I/O pins compared to other Arduino boards, which may limit its use in complex projects.

Less Processing Power: The ATmega328P microcontroller on the Arduino Nano has less processing power and memory compared to newer Arduino boards, which may limit its use in more demanding applications.

In summary, the Arduino Nano is a versatile and cost-effective microcontroller board that is well-suited for a wide range of projects, especially those that require a compact size and low cost.

5.3.5. LCD Display

Fig.5.4. LCD Display

A 2x16 line LCD display is a type of liquid crystal display (LCD) module that can display 2 lines of text, with each line capable of displaying up to 16 characters. These displays are commonly used in embedded systems, such as microcontroller-based projects, to provide visual feedback and information to the user. Here are some key features and specifications of a 2x16 line LCD display:

Key Features:

1. **Display Type:** Liquid Crystal Display (LCD)
2. **Number of Lines:** 2
3. **Number of Characters per Line:** 16
4. **Backlight:** Most 2x16 LCD displays come with a built-in LED backlight for improved visibility in low-light conditions.
5. **Interface:** Typically, these displays use a parallel interface to communicate with a microcontroller or other host device.

Specifications:

1. **Operating Voltage:** Typically 5V DC
2. **Operating Temperature:** Most displays operate within a temperature range of -20°C to +70°C
3. **Character Size:** The character size is usually 5x8 pixels, although some displays may offer larger characters.

Applications:

1. **Embedded Systems:** Used in microcontroller-based projects for displaying text-based information, such as sensor readings, menu options, and status messages.
2. **Consumer Electronics:** Can be found in various consumer electronics devices, such as digital clocks, appliances, and instrumentation panels.
3. **Industrial Control:** Used in industrial control systems and equipment for displaying process parameters, alarms, and messages.
4. **DIY Electronics:** Popular in hobbyist projects and DIY electronics for adding a visual display to projects.

Advantages:

1. **Low Power Consumption:** LCD displays consume less power compared to other display technologies, making them suitable for battery-

powered devices.

2. **Easy to Interface:** LCD displays can be easily interfaced with microcontrollers and other devices using a parallel interface.
3. **Cost-Effective:** 2x16 LCD displays are relatively inexpensive and offer a cost-effective solution for adding a display to a project.
4. **Readability:** The characters displayed on an LCD are typically easy to read, even in bright light conditions, especially with the backlight turned on.

Disadvantages:

1. **Limited Display Area:** 2x16 LCD displays have a limited display area, which may restrict the amount of information that can be displayed simultaneously.
2. **Complexity:** Interfacing an LCD display with a microcontroller may require some knowledge of electronics and programming, especially for beginners.
3. **Refresh Rate:** LCD displays have a slower refresh rate compared to other display technologies, which may affect the display of fast-changing information.

In summary, a 2x16 line LCD display is a versatile and cost-effective display solution for a wide range of applications, offering easy interfacing, low power consumption, and readability in various lighting conditions.

5.3.6. 100 KG Strain Gauge (load cell)

Fig.5.5. Load Cell

A 100 kg load cell is a type of sensor used to measure force or weight. It is designed to accurately measure loads up to 100 kilograms (220 pounds). Load cells are commonly used in various applications such as industrial scales, weighing systems, and force measurement devices.

Here's a brief overview of how a 100 kg load cell works:

Strain Gauge Principle: Load cells typically operate on the principle of strain gauges. Strain gauges are bonded to a metal structure (often called the "spring element") that deforms slightly when a force is applied to it. This deformation causes a change in the electrical resistance of the strain gauges, which is proportional to the applied force.

Wheatstone Bridge Configuration: The strain gauges are arranged in a Wheatstone bridge configuration to measure the change in resistance accurately. When a force is applied to the load cell, the Wheatstone bridge circuit produces a voltage output proportional to the force. **Signal Conditioning:** The voltage output from the Wheatstone bridge is typically very small and needs to be amplified and conditioned for further processing. Signal conditioning circuits are used to amplify the signal and convert it into a usable form (e.g., digital signal for display or control).

Calibration: Load cells need to be calibrated to ensure accurate and reliable measurements.

Calibration involves applying known forces to the load cell and adjusting the output signal to match the expected values.

Applications: 100 kg load cells are commonly used in applications where moderate to heavy weights need to be measured, such as bench scales, platform scales, and industrial weighing systems.

Overall, a 100 kg load cell is a versatile and reliable sensor for measuring force or weight in various industrial and commercial applications.

5.3.7. Digital Vernier

Range 0.02 mm to 16 cm

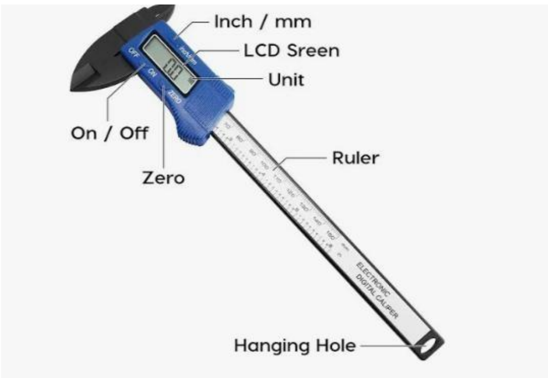

Fig.5.6. Digital Vernier Scale

A digital vernier caliper is a precision measuring tool used to accurately measure linear dimensions such as length, width, and thickness. It is a digital version of the traditional vernier caliper, offering higher accuracy and ease of use. Here's a brief overview of its features and how it works:

1. **Digital Display:** The main feature of a digital vernier caliper is its digital display, which provides a direct reading of the measured dimension in either metric (millimeters) or imperial (inches) units. This eliminates the need for manual interpretation of scale markings, improving accuracy and reducing errors.
2. **Measuring Range:** Digital vernier calipers typically have a measuring range of 0 to 150 mm (0 to 6 inches) or 0 to 200 mm (0 to 8 inches), although other sizes are also available. This range covers a wide variety of measurement needs in various industries and applications.
3. **Accuracy:** Digital vernier calipers offer high accuracy, often with a resolution of 0.01 mm (0.0005 inches) or better. This makes them suitable for measuring small tolerances and dimensions with precision.
4. **Construction:** Digital vernier calipers are usually made of stainless steel or other highquality materials to ensure durability and resistance to wear and corrosion. They are designed to be robust and reliable for long-term use.
5. **Usage:** To use a digital vernier caliper, the jaws are opened or closed to fit the object being measured. The digital display shows the measurement directly, making it easy to read and record. Some models also have additional features such as zero setting, data hold, and conversion between metric and imperial units.
6. **Battery:** Digital vernier calipers are powered by batteries, typically coin cell batteries, which provide long-lasting power for continuous use.

Overall, a digital vernier caliper is a versatile and essential tool for precise measurement in industries such as manufacturing, engineering, and quality control, where accurate dimensional inspection is required.

6.CONCLUSION

The design and development of a 100 kg spring testing machine is a complex and challenging process that requires careful consideration of various factors such as the load capacity, accuracy, reliability, and safety of the machine.

In conclusion, the successful design and development of a 100 kg spring testing machine require a thorough understanding of the principles of force measurement, materials science, and mechanical engineering. By utilizing advanced technologies and adhering to strict design standards, a high-quality spring testing machine can be created that meets the needs of the industry for accurate and reliable testing of springs.

Future Enhancements

Integration with computer software for advanced data analysis
Wireless connectivity for remote monitoring
Expansion of the machine's capabilities for testing additional spring properties

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