Automotive System Design-Syllabus.

Unit-I: Design of Clutches & Gearbox:

Design requirements of friction clutches, selection criterion, torque transmission capacity, lining materials, Design of single plate clutch, multi- plate clutch and centrifugal clutch. Selection of gear ratios and final drive ratio, numerical on 3- speed and4- speed gearbox.

Unit-II: Design of Propeller Shafts and Axles:

Design of propeller shafts for bending, torsion and rigidity, Design of universal joints and slip joints, final drive, Design of live and dead axles.

Unit-III: Brake Systems:

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Unit-V: Statistical Consideration in Design and Optimization:

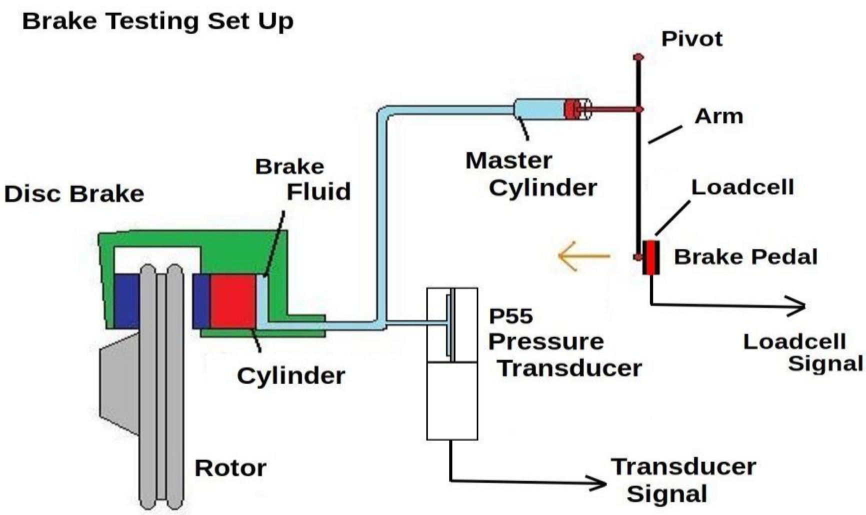
Ergonomics and aesthetic design, statistics in design, design for natural tolerances, statistical analysis, and mechanical reliability, introduction to design optimization of mechanical elements, adequate and optimum design, methods of optimization, Johnson's method of optimum design-simple problems in optimum design like axially loaded members.

Unit-III: Brake System

Syllabus: Design of hydraulic braking system, internal expanding shoe brake and disc brake, design of master and wheel cylinder and piping design.

Designing a hydraulic braking system involves creating a system that efficiently converts the driver's input into the necessary braking force to slow down or stop a vehicle. Here are the key steps and considerations for designing a hydraulic braking system.

1. System Components:



Master Cylinder

1. Choose an appropriate master cylinder size based on the vehicle's weight, desired braking force, and number of wheels.
2. Ensure the master cylinder bore diameter matches the pedal effort required by the driver.

Brake Lines and Hoses:

1. Select brake lines and hoses with suitable material properties and diameter to handle the hydraulic pressure and ensure efficient fluid flow.
2. Position and route the brake lines to minimize exposure to external elements and potential damage.

Wheel Cylinders/Calipers:

1. Choose brake calipers or wheel cylinders that match the vehicle's weight, wheel size, and braking force requirements.
2. Select a design (disc or drum) that suits the vehicle's application and performance goals.

Brake Fluid:

1. Choose a brake fluid with the appropriate viscosity, boiling point, and compatibility with the system's components.
2. Regularly check and replace brake fluid to maintain system efficiency and prevent degradation.

2. Hydraulic System Design:

1.Master Cylinder Design:

Ensure the master cylinder is properly sized to provide sufficient hydraulic pressure to the wheel cylinders or calipers.
Calculate the pedal ratio to match the driver's pedal force to the hydraulic force generated.

Brake Line Sizing:

1. Calculate the required brake line diameter to minimize pressure drop and ensure consistent braking force across all wheels.

Caliper/Wheel Cylinder Sizing:

1. Select callipers or wheel cylinders that match the braking force required for each wheel.
2. Consider factors like piston size, number of pistons, and materials to balance braking force and heat dissipation.

Brake Bias:

1. Design the braking system to achieve proper front-to-rear brake bias for stable and effective braking under various conditions.
2. Consider factors like vehicle weight distribution, tire characteristics, and suspension geometry.

4. Anti-lock Braking System (ABS):

1. If desired, integrate an ABS to prevent wheel lockup during braking and maintain steering control.
2. Ensure proper integration of ABS sensors, control module, and hydraulic components.

5. Thermal management:

1. Design the braking system to handle heat generated during braking to prevent brake fade and maintain consistent performance.
2. Choose appropriate materials for the rotors, pads, and other components to withstand heat without deformation.

6. Testing and Validation:

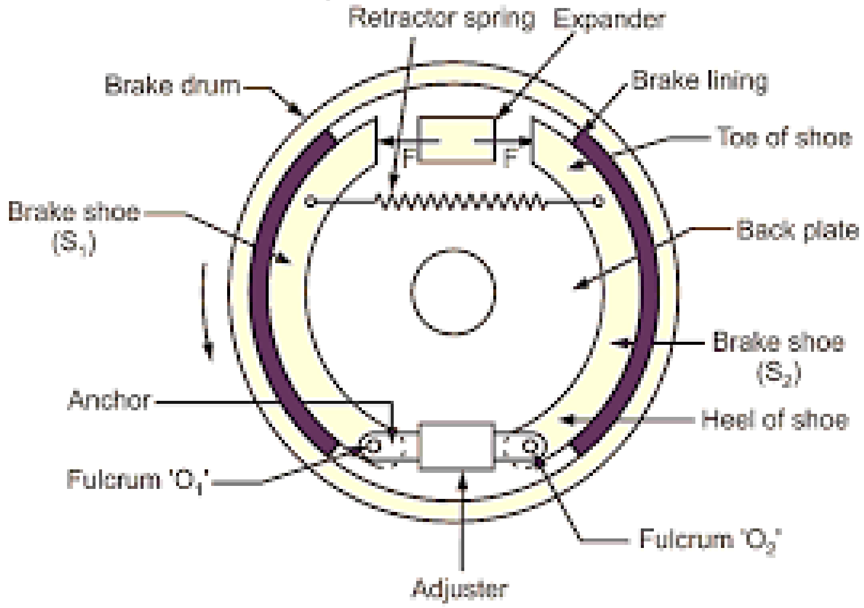
1. Conduct rigorous testing and validation, including brake performance tests, pressure tests, and durability tests.

2. Ensure compliance with relevant safety and performance standards.

7. Maintenance and Service:

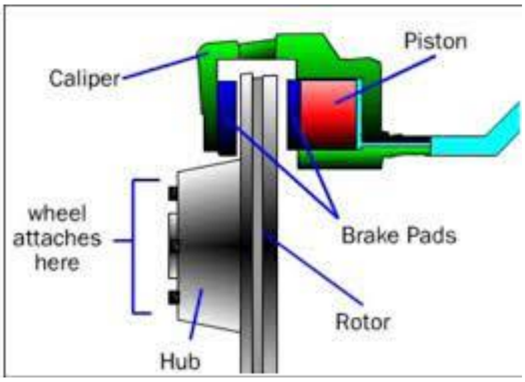
Design the system for ease of maintenance and service, including bleeding the brake lines and replacing components.

2. Internal expanding shoe brake:



1. In internal expanding brake consists of two shoes S1 and S2. The outer surface of the shoes are lined with some friction material (usually with Ferodo) to increase the coefficient of friction and to prevent wearing away of the metal.
2. Each shoe is pivoted at one end about a fixed fulcrum O1and O2 and made to contact a cam at the other end. When the cam rotates, the shoes are pushed outwards against the rim of the drum.
3. The friction between the shoes and the drum produces the braking torque and hence reduces the speed of the drum. The shoes are normally held in off position by a spring .
4. The drum encloses the entire mechanism to keep out dust and moisture. This type of brake is commonly used in motor cars and light trucks.

3. Disc Break:



1. The brake rotor (disc) which rotates with the wheel, is clamped by brake pads (friction material) fitted to the calliper from both sides with pressure from the piston(s) (pressure mechanism) and decelerates the disc rotation, thereby slowing down and stopping the vehicle.
2. The driver steps on the brake pedal, the power is amplified by the brake booster (servo system) and changed into a hydraulic pressure (oil-pressure) by the master cylinder. The pressure reaches the brakes on the wheels via tubing filled with brake oil (brake fluid)
3. The delivered pressure pushes the pistons on the brakes of the four wheels. The pistons in turn press the brake pads, which are friction material, against the brake rotors which rotate with the wheels.
4. The pads clamp on the rotors from both sides and decelerate the wheels, thereby slowing down and stopping the vehicle.

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Ergonomics:

Ergonomics is the study of designing products, systems, and environments that fit human capabilities and limitations. The primary focus of ergonomics is to enhance user comfort, safety, and efficiency, ultimately leading to a positive user experience. Here are key points related to ergonomics:

1. User-Centered Design:

Ergonomics places the user at the centre of the design process. Understanding users' physical abilities, limitations, and preferences is crucial to creating products that are user-friendly and effective.

2. Comfort and Well-being:

Ergonomic design aims to create products that promote user comfort and well-being. This involves considering factors like seating posture, reach ability of controls, and the reduction of repetitive strain.

3. Usability and Accessibility:

Products should be intuitive and easy to use. Ergonomics helps designers create interfaces, controls, and interactions that are clear, logical, and accessible for a wide range of users, including those with disabilities.

4. Safety:

Ergonomic design reduces the risk of user-related errors and accidents. This can involve incorporating features like rounded edges, safety guards, and warning labels.

5. Cognitive Load:

Well-designed products minimize cognitive load by organizing information and controls in a logical manner. This improves user understanding and minimizes the mental effort required to operate the product.

Aesthetic Design:

Aesthetic design involves the visual and sensory aspects of a product. It focuses on creating a pleasing and emotionally resonant appearance that enhances the overall user experience. Key points related to aesthetic design include:

1. Visual Appeal: Aesthetic design aims to create products that are visually appealing and evoke positive emotions. It involves considering factors like symmetry, proportion, and visual balance.

2. Brand Identity: Aesthetic design contributes to a product's alignment with a brand's identity and values. Design choices such as color palettes, typography, and logo placement reflect the brand's personality.

3. Emotional Connection:

Products that are aesthetically pleasing often form an emotional connection with users. Design elements can trigger feelings of familiarity, comfort, and excitement.

4. Material Selection and Texture:

The choice of materials and finishes impacts the tactile experience of the product. Aesthetic design considers how these elements contribute to the overall sensory appeal.

5. Contextual Fit:

Aesthetic design considers the environment in which the product will be used. Products should harmonize with their surroundings and context to create a seamless user experience.

Johnson's Method of Optimum Design is a classical approach to solving simple problems in structural optimization, particularly for axially loaded members (columns or bars). This method provides a straightforward way to determine the optimal dimensions of a structural member subjected to axial loading while considering material and geometric constraints. Here's an overview of how Johnson's Method works and an example problem.

Johnson's method of optimum design-simple problems in optimum design like axially loaded members

Johnson's Method:

- **Problem Formulation:**Define the problem by specifying the available materials, constraints, and objectives (e.g., minimizing the weight of the member).
- **Initial Estimation**: Start with an initial estimate of the member's dimensions (cross-sectional area or diameter).
- **Calculate Load and Resistance**:Calculate the critical load (buckling load) of the member using appropriate buckling formulas.Determine the allowable load based on material properties and safety factors.
- **Comparison:**Compare the calculated allowable load with the actual applied load.If the applied load is smaller than the allowable load, the design is already satisfactory.If the applied load exceeds the allowable load, optimization is needed.
- **Optimization Process**:Adjust the member's dimensions (area or diameter) to increase the critical load.Recalculate the allowable load using the updated dimensions.Repeat the comparison step until the calculated allowable load matches or exceeds the applied load.

Example Problem: Axially Loaded Column Optimization:

Let's consider a simple example of optimizing the dimensions of a steel column subjected to an axial load:

- **Given:**

Applied axial load (P) = 100 kN

Material: Steel (Elastic Modulus E = 200 GPa)

Allowable Stress (σ_{allow}) = 150 MPa

Initial Estimate of Area ($A_{initial}$) = 2000 mm^2

- **Step 1: Calculate Buckling Load (Critical Load)**

Using a buckling formula (such as Euler's formula for long columns):

Critical Load (P_{cr}) = (π^2 * E * I) / (K^2 * L^2), where I is the moment of inertia, L is the length, and K is the effective length factor.

Assume K = 1 (both ends pinned), L = 3000 mm, and the cross-section is a circular shape with diameter D.

Solve for D using the initial estimate of area ($A_{initial}$).

Step 2: Calculate Allowable Load

Allowable Load = σ_{allow} * $A_{initial}$

Step 3: Compare

If Allowable Load ≥ Applied Load (100 kN), the initial design is adequate.

If Allowable Load < Applied Load, optimization is needed.

Step 4: Optimization

Adjust D to increase the critical load.

Recalculate Allowable Load based on the new D.

Repeat steps 3 and 4 until Allowable Load ≥ Applied Load.

By iteratively adjusting the diameter of the column, you can find the optimal dimension that ensures the column can withstand the applied axial load while using the least material possible.

Methods of optimization:

There are several methods of optimization that can be applied to solve engineering and design problems. These methods vary in complexity, computational requirements, and suitability for different types of optimization problems. Here are some common methods of optimization:

**1. Mathematical Programming:

- Linear Programming (LP): Optimizing linear objective functions subject to linear constraints.
- Integer Programming (IP): Similar to LP but with integer decision variables, often used for discrete optimization problems.

- Nonlinear Programming (NLP): Optimizing nonlinear objective functions with nonlinear constraints.
- Mixed-Integer Nonlinear Programming (MINLP): Combines integer and nonlinear programming.

2. Gradient-Based Methods:

- Gradient Descent: Iterative method that uses gradient information to minimize or maximize an objective function.
- Conjugate Gradient: Iterative method that minimizes quadratic functions without computing the Hessian matrix.
- Quasi-Newton Methods: Updates the approximation of the Hessian matrix to improve convergence speed.
- Newton's Method: Uses the second derivative (Hessian) of the objective function to update the solution.

1. **Heuristic Algorithms**

2. **Gradient-Free Methods:**

3. **Dynamic Programming**
4. **Response Surface Methods:**
5. **Metaheuristic Methods:**

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Unit-IV: Design of Suspension and Steering System

Syllabus Points: General design considerations of suspension system, design of helical and leaf springs for automobile suspension system, design considerations of Belleville springs, elastomeric springs, design considerations of steering system and vehicle frame design.

Question: What is general consideration of suspension system?

A suspension system in an automotive context refers to the components that connect a vehicle's wheels to its frame or body. It plays a crucial role in ensuring a smooth ride, stable handling, and proper tire contact with the road. The design of a suspension system involves various considerations to achieve the desired balance between comfort, performance, safety, and durability. Here are some general design considerations for a suspension system:

Vehicle Type and Usage:

The type of vehicle (sedan, SUV, truck, sports car, etc.) and its intended usage (off-road, city driving, track racing, etc.) greatly influence the suspension design. Each application may require different suspension characteristics, such as ground clearance, handling precision, and load-carrying capacity.

Load Capacity:

The suspension system should be designed to accommodate the expected maximum load the vehicle might carry. This includes passengers, cargo, and any towing loads. Overloading can lead to premature wear and reduced performance.

Ride Comfort:

A good suspension system should absorb and dampen road irregularities, providing a comfortable ride for passengers. This involves selecting appropriate springs, shock absorbers, and other components to minimize vibrations and jolts.

Handling and Stability:

The suspension system should provide predictable and stable handling characteristics. Factors like vehicle weight distribution, suspension geometry, and alignment settings influence how the vehicle responds to steering inputs and corners.

Tire Contact and Grip:

Maintaining consistent tire contact with the road is crucial for traction and handling. Suspension design affects how the tires respond to road changes, preventing loss of grip and maximizing traction during acceleration, braking, and cornering.

Suspension Geometry:

The geometric arrangement of suspension components, such as control arms, tie rods, and axles, impacts factors like camber, caster, and toe. Proper geometry minimizes tire wear, maximizes tire grip, and optimizes steering response.

Damping Control:

Shock absorbers (dampers) control the rate at which the suspension components move. Adjustable dampers can allow for fine-tuning the suspension to balance comfort and performance based on driving conditions.

Spring Rates:

The stiffness of the springs determines how much the suspension compresses under load. Springs need to be chosen based on the vehicle's weight and intended purpose. Stiffer springs offer better handling but can compromise comfort.

Anti-Roll Bars (Sway Bars):

These components reduce body roll during cornering by connecting the left and right suspension components. The size and stiffness of anti-roll bars affect the vehicle's cornering behaviour.

Durability and Maintenance:

Suspension components are subjected to significant forces and wear over time. Designing for durability includes selecting robust materials, minimizing stress points, and considering ease of maintenance.

Cost and Manufacturing:

The suspension system's design should also take into account production costs, assembly complexity, and the availability of materials and components.

Integration with Other Systems:

The suspension system interacts with various other vehicle systems, such as steering, braking, and stability control. Design considerations should ensure proper integration and compatibility for optimal overall performance.

Regulations and Safety Standards:

Suspension systems must comply with safety regulations and standards specific to the region where the vehicle will be sold. Safety considerations include crashworthiness, stability, and impact absorption.

Design of helical and leaf springs for automobile suspension system.

Helical springs (coil springs) and leaf springs are two common types of springs used in automobile suspension systems. Each type has its own design considerations and advantages. Here's an overview of the design considerations for both helical and leaf springs:

Question: Design of helical spring?

Design of Helical Springs:

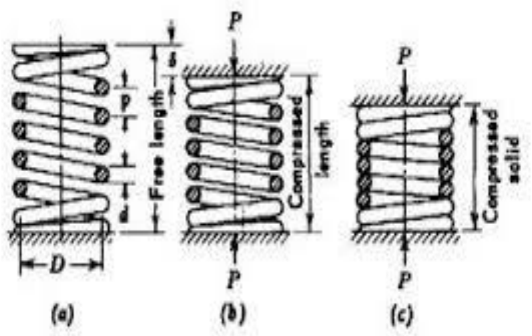


Fig. Helical compression spring.

1. **Load and Deflection Requirements**:

Determine the required spring rate (stiffness) based on the vehicle's weight, load distribution, and desired ride characteristics. Calculate the deflection (compression) of the spring under different loads to ensure it meets the required travel range.

2. **Wire Diameter and Coil Pitch:**

Select an appropriate wire diameter and coil pitch that achieve the desired spring rate and deflection while considering factors like available space and manufacturing feasibility.

3. **Number of Active Coils**:

The number of active coils affects the spring's performance. More active coils generally provide a softer spring rate, while fewer active coils result in a stiffer spring. Balance this with the available space and the need to avoid coil bind (when the coils fully close under compression).

4. **End Types**:

Determine the types of ends for the spring (closed, open, ground, squared, etc.). The end type affects how the spring interfaces with other suspension components and influences the spring's overall behavior.

5. **Materials and Heat Treatment:**

Choose an appropriate material for the spring that balances strength, fatigue resistance, and weight. Heat treatment processes can further improve the spring's durability and performance.

6. **Dynamic Characteristics:**

Analyze the dynamic behavior of the spring, including natural frequency and damping effects. These characteristics influence the ride comfort and handling of the vehicle.

7. **Manufacturing Considerations**:

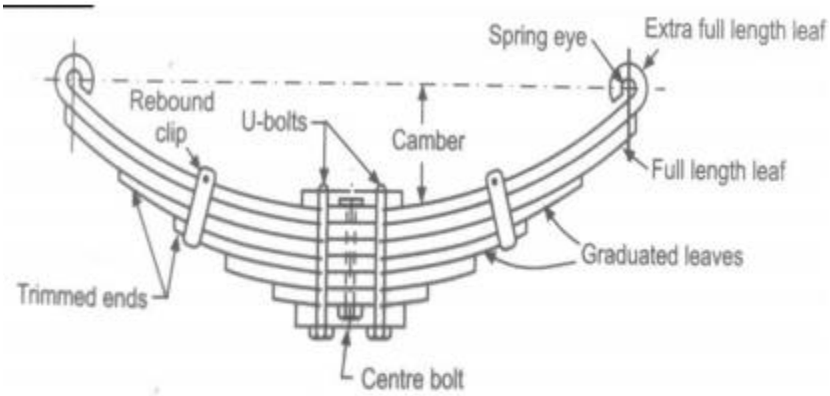
Consider the ease of manufacturing, cost, and feasibility of producing the spring design. Manufacturing processes include coiling, stress relieving, shot peening, and surface finishing.

8. **Installation and Packaging:**

Ensure that the spring design fits within the available space in the vehicle's suspension system and aligns with the overall packaging requirements.

Question: Design of Leaf Spring?

Design of Leaf Springs:



1. **Load Distribution and Configuration:**

Determine the appropriate number of leaves in the spring stack to distribute the load effectively. Multi-leaf springs are common and can provide a balance between load-carrying capacity and flexibility.

2. **Length and Width of Leaves:**

The length and width of each leaf affect the overall spring rate, load capacity, and flexibility. Longer and wider leaves generally provide greater load-carrying capacity.

3. **Thickness of Leaves:**

Choose the appropriate thickness for each leaf based on load requirements, fatigue resistance, and ride characteristics. Thicker leaves offer higher load capacity but may result in a stiffer suspension.

4. **Arch and Camber:**

Determine the arch (curvature) and camber (curvature along the length) of the leaf spring. These factors influence the spring's flexibility and alignment under load.

5. **Materials and Heat Treatment:**

Select suitable materials and consider heat treatment processes to enhance the spring's strength and fatigue resistance.

6. **Mounting and Bushings:**

Design the mounting points and bushings to allow controlled movement of the spring while maintaining proper alignment.

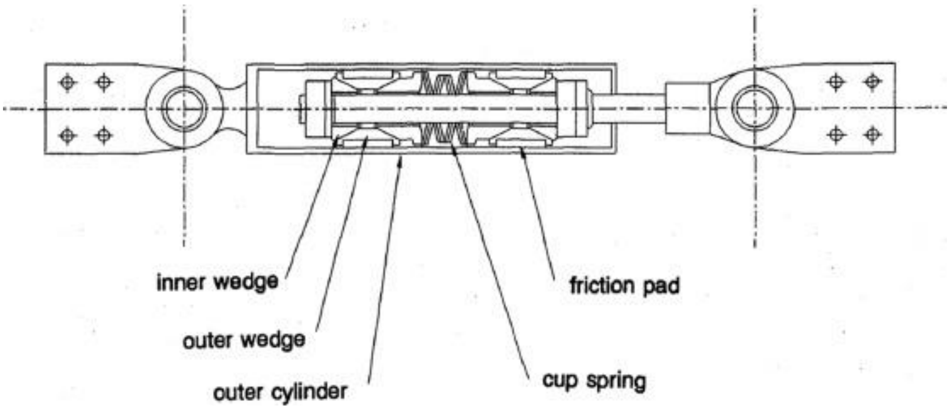
7. **Interl eaf Friction**:

Manage interleaf friction through appropriate lubrication or anti-friction pads to prevent binding and noise.

8. **Packaging and Integration**:

Ensure that the leaf spring design fits within the available space in the vehicle's suspension system while accommodating other components.

Question: What are the Design considerations of Belleville springs?



Design considerations of Belleville springs

Belleville springs, also known as conical disc springs or Belleville washers, are a type of spring that consists of a conical shape with a slight curvature. These springs are commonly used to provide high load capacity and limited axial space in various mechanical applications. Here are some design considerations for Belleville springs:

1. **Load and Deflection Requirements**: Determine the required load capacity and deflection range for the Belleville spring. These factors will guide the selection of the appropriate spring size, number of springs in a stack, and overall configuration.
2. **Material Selection:** Choose a material for the Belleville spring that offers the necessary strength, durability, and resistance to fatigue and corrosion. Common materials include stainless steel, carbon steel, and alloys with specific properties.

3. **Spring Stack Arrangement:** Belleville springs are often used in stacks, with multiple springs stacked on top of each other. Determine the optimal arrangement and number of springs in the stack to achieve the desired load-deflection characteristics.
4. **Geometry and Dimensions:** Define the geometry of the Belleville spring, including the outer and inner diameters, thickness, and cone angle. These dimensions will affect the spring's stiffness, load capacity, and deflection characteristics.

5. **Stacking Sequence:** The order in which Belleville springs are stacked can impact their behaviour. Stacking sequences can lead to different load-deflection curves and overall performance. Experiment with different sequences to achieve the desired outcomes.

6. **Preload and Stacking Ratio:** Preloading involves compressing Belleville springs beyond their flat state before use. This preload provides initial tension and prevents loose stacking. Determine the appropriate preload and stacking ratio to ensure optimal performance.
7. **Axial Space and Compression Limit:** Consider the available axial space in your application and ensure that the Belleville springs do not exceed their compression limits, which could lead to deformation or failure.
8. **Fatigue and Stress Analysis:** Perform fatigue and stress analysis to ensure that the Belleville springs can withstand repeated loading and unloading cycles without failure. This involves considering factors like alternating stress levels and the spring material's fatigue properties.
9. **Surface Treatment:** Depending on the application environment, consider applying surface treatments like coatings or plantings to enhance corrosion resistance and improve the spring's lifespan.

10. **Temperature and Environment:** Understand the operating temperature range and environmental conditions in which the Belleville springs will be used. Different materials and coatings may be necessary for high-temperature or corrosive environments.
11. **Spring Rate and Load-Deflection Curve:** Calculate and analyze the spring rate (stiffness) and load-deflection curve of the Belleville spring to ensure it aligns with the application's requirements.
12. **Contact Surfaces:** Pay attention to the contact surfaces between Belleville springs and other components in the assembly. Adequate seating and contact are essential for consistent performance.
13. **Application-Specific Considerations:** The design of Belleville springs can be highly application-specific. Consider any unique requirements or constraints posed by the specific mechanical system in which the springs will be used.

Question : What are the Elastomeric Springs design consideration?

1. **Elastomeric Springs:**

Elastomeric springs are made of rubber or elastomeric materials and are used to provide vibration isolation, shock absorption, and damping in various applications. When designing elastomeric springs:

2. **Load and Deflection Requirements**:

Determine the required load capacity and deflection range to select the appropriate elastomeric material and geometry for the spring.

3. **Material Selection:**

Choose an elastomeric material that meets the desired vibration isolation and damping characteristics. Consider factors like stiffness, fatigue resistance, and environmental compatibility.

4. **Geometry and Shape:**

Design the shape and dimensions of the elastomeric spring to optimize its performance. This could include cylindrical, conical, or custom shapes.

5. **Durometer and Hardness:**

Select the appropriate durometer (hardness) of the elastomer to achieve the desired load-bearing capacity and deflection characteristics.

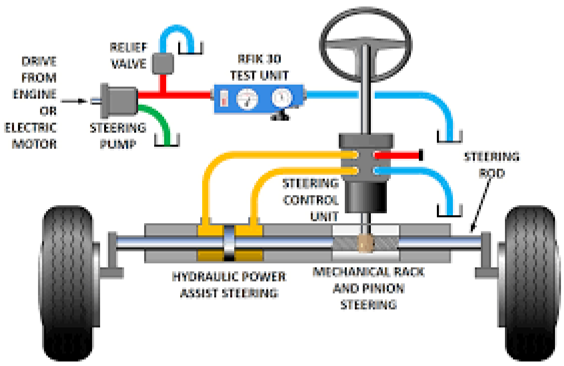
6. **Layered Design:**

Elastomeric springs are often made with multiple layers of elastomeric with varying properties. Consider the layer arrangement to achieve the desired stiffness and damping properties.

7. **Dynamic Properties:**

Analyze the dynamic behaviour of the elastomeric spring, including its natural frequency, resonance points, and damping effects.

Question: What are the design considerations of steering system and vehicle frame design?



Mounting and Isolation:

Design the elastomeric spring's mounting points and interfaces to effectively isolate vibration and shock from the components it connects.

1. **Temperature and Environment:**

Evaluate the operating temperature range and environmental conditions to ensure the elastomeric material maintains its properties over time.

2. **Fatigue and Durability:**

Consider fatigue resistance and durability, especially if the elastomeric spring will be subjected to repeated loading cycles.

3. **Steering System Design**:

The steering system plays a critical role in controlling the direction of the vehicle. Key design considerations include:

4. **Steering Mechanism:**

Choose between rack-and-pinion, recirculating ball, and other steering mechanisms based on factors like vehicle size, intended use, and performance requirements.

5. **Steering Ratio:**

Determine the steering ratio to achieve the desired responsiveness and handling characteristics. A higher ratio provides more precise steering but requires more rotations to turn the wheels.

6. **Power Steering:**

Decide whether to implement power steering (hydraulic, electric, or electronic) to reduce driver effort and enhance maneuverability.

7. **Steering Column and Shaft:**

Design the steering column and shaft to ensure proper connection between the steering wheel and the steering mechanism while accommodating safety features like airbags.

8. **Linkages and Joints**:

Design the linkages, tie rods, and joints to provide smooth and accurate steering motion while considering factors like durability and wear resistance.

9. **Steering Wheel Design:**

Consider ergonomics, material selection, and features like airbags and controls when designing the steering wheel.

10. **Vehicle Frame Design:**

The vehicle frame provides structural integrity and supports various components. Important considerations include:

Question: What are the design considerations of vehicle frame design?

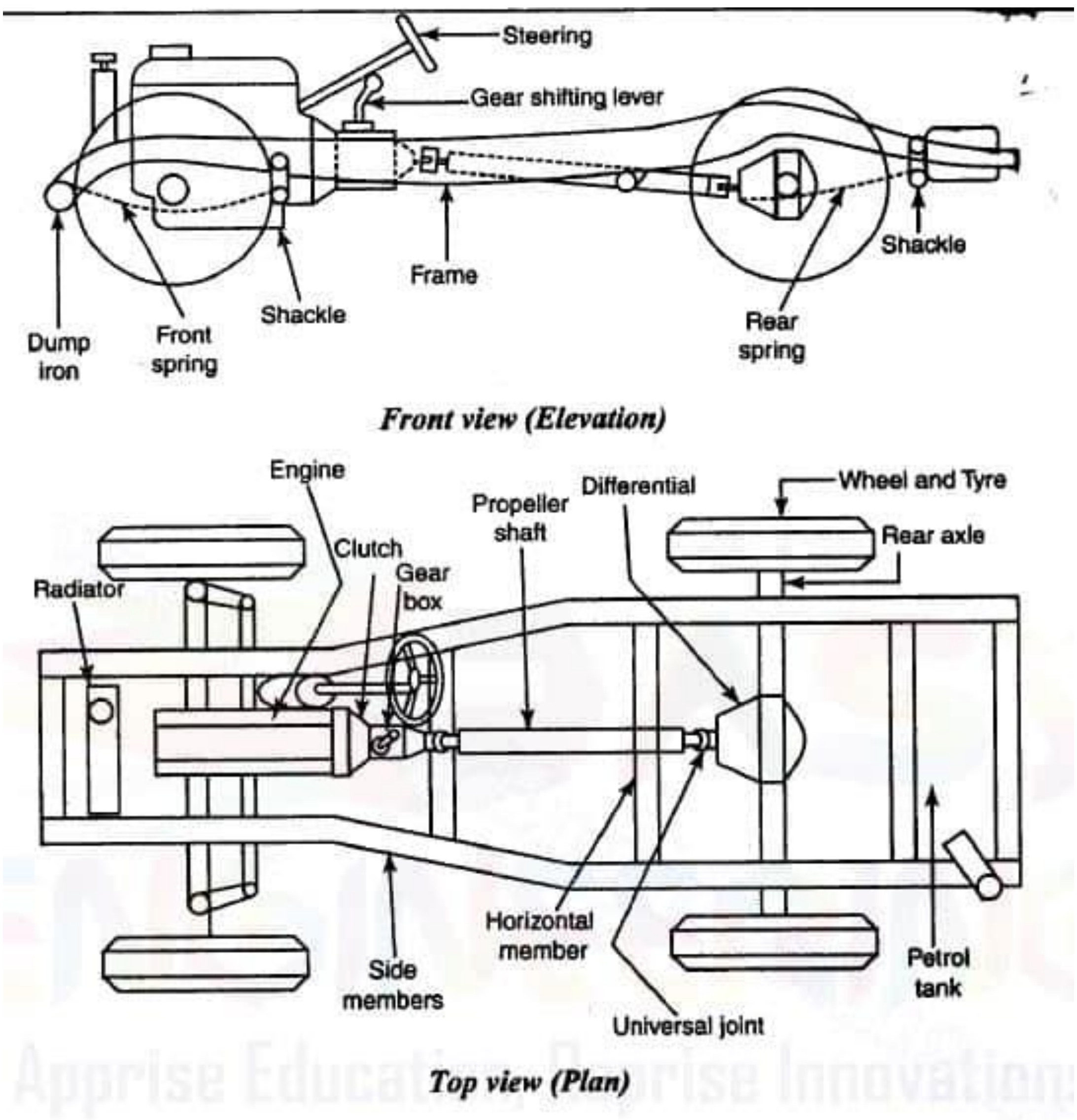


Figure 1.13 Layout of chassis

<u>Frame Type:</u>

Choose between body-on-frame and unibody (monocoque) designs based on factors like vehicle type, intended use, and structural requirements.

1. **<u>Material Selection:</u>**

Select appropriate materials (steel, Aluminum, composites) based on strength, weight, cost, and manufacturing feasibility.

2. **Rigidity and Strength:**

Design the frame to provide the necessary rigidity and strength for structural integrity and crash safety.

3. **Crashworthiness:**

Consider deformation zones, crumple zones, and energy-absorbing structures to enhance occupant safety during collisions.

4. **Suspension Attachment Points:**

Integrate suspension attachment points into the frame design to ensure proper alignment, handling, and load distribution.

5. **Packaging:**

Plan for the optimal placement of components, including the engine, transmission, suspension, and passenger compartment, within the frame.

Stress and Load Analysis:

Perform stress and load analysis to ensure that the frame can withstand various forces and loads under different driving conditions.

6. **Manufacturability:**

Design the frame for ease of manufacturing, assembly, and repair while minimizing production costs.

7. **Regulations and Standards:**

Ensure the frame design complies with safety and emissions regulations, crash standards, and structural requirements.

8. **Integration with Other Systems:**

Consider the integration of subsystems like suspension, power train, and body panels within the frame design.

These design considerations for elastomeric springs, steering systems, and vehicle frames are just a starting point. Each consideration needs to be carefully evaluated based on the specific vehicle's intended use, performance targets, and regulatory requirements. Iterative design, simulation, and testing are essential to refine and validate the designs before production.