# Modern Automotive Suspension Systems: Principles, Calculations and Comparative Analysis

Niket Ashok Shinde
*Assistant Professor, Sinhgad Institute of Technology*

***Abstract* — this paper presents the occupants of motor vehicle would suffer severely as well as its structure would be subjected to excessive fatigue loading if the chassis is provided with direct transmission of the loads carried by rolling wheels of the vehicle.**

**To safeguard the working parts of the motor vehicle against fracture or break down due to continued and severe stresses on the engine and the transmission systems as well as body work the vehicle components or axels should be properly suspended. Moreover if the front and the rear wheel axels are allowed to run in bearings rigidly attached to the frame, extremely uncomfortable rides would be resulted. To avoid the transmission of road effects to the passengers while travelling in vehicles on uneven ground, it is, therefore, necessary that the wheels and the axels should be insulated from the frame. For this purpose, suspension systems are used. A good suspension should have springiness and damping. A spring is liable to overshoot its original position and start bouncing up and down if energy is not absorbed. Springs are mounted on a rubber packing to reduce noise and add more softness. In order to provide a comfortable ride to the passengers and avoid additional stresses in motor car frame, the car should neither bounce or roll or sway the passengers when cornering nor pitch when accelerating.**

***Index Terms*—Vehicle stability, suspension system dynamics, load calculations.**

## I. INTRODUCTION

The automobile has undergone significant development over the past two centuries, driven by innovations in engineering, performance, and passenger comfort. The introduction of four-wheeled, self-propelled vehicles in the 19th century marked the beginning of modern automotive design. By the late 19th century, internal combustion engine vehicles were developed by pioneers such as Daimler-Benz (1885) in Germany, Renault and Peugeot (1893) in France, and Henry Ford (1895) in the United States, laying the foundation for mass production and global adoption of automobiles.

Among the critical components influencing vehicle performance, the suspension system plays a central role in ensuring ride comfort, stability, and structural integrity. It isolates the vehicle body and occupants from road irregularities, absorbs shocks, and maintains optimal tire-road contact. Different suspension configurations—convention(dependent), independent, and multi-link systems—offer varying levels of comfort, handling, and durability, depending on their design principles and intended applications. This study presents a comprehensive analysis of modern automotive suspension systems, focusing on their objectives, functional principles, and comparative performance. The findings aim to guide engineers in optimizing suspension design to enhance ride quality, handling, and overall vehicle dynamics.

## II. LITERATURE REVIEW

Independent suspension allows each wheel to move vertically without affecting the opposite wheel, providing improved ride comfort and handling. Early implementations appeared in passenger cars in the early 20th century, with front independent suspension being particularly common. Independent systems offer better roll control, reduced vehicle vibrations, and enhanced stability compared to dependent suspensions. However, their design involves multiple linkages and bearings, increasing manufacturing complexity and cost.

Multi-link suspensions, introduced by Mercedes-Benz in the 1980s, employ multiple arms or links per wheel to control wheel kinematics and distribute forces more effectively. The design allows precise control over camber, toe, and wheel alignment during suspension travel, improving handling, braking stability, and ride comfort. Despite their superior performance, multi-link systems are complex and expensive to manufacture and maintain.

## III. DESIGN CALCULATION

A four-link suspension uses links to locate the axle from moving, side to side and front to back, while allowing it to travel up and down . The well designed and tested four-link will provide a superior translation of power to the ground and higher ride quality than a leaf-spring suspension.

Four links are required to provide longitudinal and lateral control of the wheels and reacting brake torque. The use of linkages provides flexibility for the designer to achieve the wheel motions desired. In case of four link suspensions with a solid axle, the lateral force acting on the wheel, in the top view must react as tension and compression forces in the control arms. The first problem with building a four-link is that how long they should be and where they should be attached to the frame and axle. Material was an important factor and concern for strength and safety.

Table 1: Specification of wheel axle dimensions

| Sr.No | Description | Symbol | Value |
|---|---|---|---|
| 1 | Outside diameter | OD | 63.5 mm |
| 2 | Thickness | Th | 12.7 mm |
| 3 | Inside diameter | ID | 38.1 mm |
| 4 | Weight | W | 31025 kg |
| 5 | Length | L | 1150 mm |
| 6 | Moment of inertia | M.I. | 804887.5 $mm^4$ |
| 7 | Section modulus | Z | 21868.54 $mm^3$ |
| 8 | Stress | Σ | 400.128 N/ $mm^2$ |

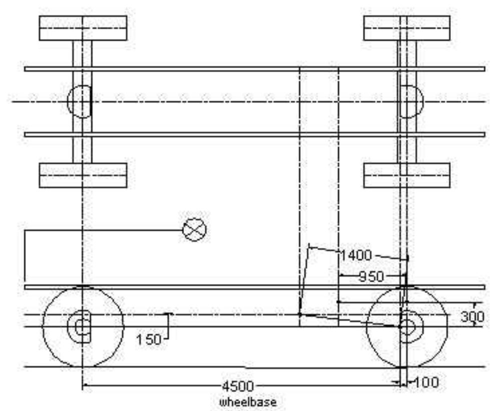


Fig.1: Load Distribution on Suspension System

## VI. CONCLUSION

The comparative analysis demonstrates that the selection of a suspension system should consider factors such as vehicle type, intended application, cost, and desired dynamic performance. Advances in suspension technology continue to enhance vehicle safety, comfort, and efficiency, underscoring the importance of optimizing suspension design in modern automotive engineering. High mobility is the prime requirement in cross country terrain for any off road vehicle. The technical parameter considered for improving the mobility of vehicle was wheel travel. Four link suspensions for rear axle of the truck were designed. The leaf spring were removed and instead the nested coil spring were designed. Since the leaf spring was to be removed the axle was provided with longitudinal and lateral support with the help of four links. Calculation for estimation of length and cross section was also undertaken as part of this project.

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