

“Front Suspension and Handlebar Design For E-Three Wheelers Analysis and Development”

1 Prof.J.B.Mule

2 Rohit Dhanaji Kharade

3 Avinash Anil Choramale

4 Arti Ramchandra Londhe

Assistant Prof Mechanical Engineering Department, S.B. Patil College Of Engineering Indapur (MH), India

Email: {, jbmule2507221¹ rohitkhara240²·avinashchoramale96³,artilondhe2003, ⁴ @gmail.com}

ABSTRACT

The increasing demand for electric three-wheelers in urban transportation necessitates improvements in ride comfort, stability, and steering ergonomics. This study presents the design and analysis of a front suspension system and handlebar mechanism for an electric three-wheeler vehicle. The work focuses on load distribution, spring-damper design, suspension geometry, and ergonomic optimization of the handlebar. Analytical calculations and structural considerations are used to ensure safety and performance. The proposed design enhances vibration isolation, steering control, and overall vehicle stability while maintaining cost-effectiveness and manufacturability.

Keywords: Electric three-wheeler, Front suspension, Handlebar design, Telescopic fork, Vehicle dynamics, Ergonomics

1.INTRODUCTION

Electric three-wheelers are widely used for short-distance transportation due to their energy efficiency, compact size, and low operational cost. However, conventional designs often suffer from poor suspension performance and inadequate steering ergonomics, resulting in rider discomfort and reduced vehicle stability.

The front suspension system plays a crucial role in absorbing road shocks and maintaining tire-road contact, while the handlebar system directly influences steering control and rider comfort. Therefore, an optimized design of these systems is essential for improved vehicle performance.

2.LITERATURE REVIEW

In 2013 Manish Dakhore et al.

discuss about locomotive suspension coil springs, their fundamental stress, distribution, materials characteristic, manufacturing and common failures. Investigation on the premature failure of suspension coil spring of a locomotive, which failed within few months after being put into service, has been carried out analytically and using FEA software. Inherent material defect in association with deficient processing led to the failure of the spring.”[1]

In 2020 P. Spanoudakis et al.

Designed a front single-sided swingarm suspension for an electric three-wheeler. Finite Element Analysis (FEA) was used to determine stress, deflection, and fatigue life. The optimized design reduced weight by 18% without compromising strength, improving ride stability and handling.”[2]

In 2020 J. Park et al.

Studied handlebar ergonomics using digital human modelling in CATIA. The research optimized handlebar height, width, and reach angles to reduce shoulder and wrist strain, improving rider comfort and control -a key consideration in electric vehicle design.”[3]

In 2021 R. Mehta and P. Joshi

Investigated vibration reduction techniques for motorcycle handlebars. Modal analysis identified vibration modes between 20–80 Hz affecting rider comfort. The study recommended tuned mass dampers and rubber mounts to minimize vibration transmission to the riders hands.”[4]

In 2021 L. Zhang et al.

Proposed hybrid composite materials for suspension arms using carbon fibre and aluminium inserts. Testing revealed 30% higher stiffness-to-weight ratio than traditional steel parts, suggesting potential for lightweight EV suspension design with improved durability.”[5]

In 2022 S. K. Patel and R. Sharma

Analysed telescopic suspension systems for lightweight two-wheeler EVs. The study examined spring stiffness and damping ratio variations using MATLAB Simulink. Results showed that optimized damping improved comfort and reduced vibration amplitude under dynamic loading.”[6]

In 2022 T. Deshmukh and A. Bhosale

Designed a front suspension for an electric tricycle using CAD and ANSYS. They analysed braking and cornering loads, optimizing link geometry for stability. The system enhanced ride quality and reduced frame vibrations during uneven road conditions.”[7]

In 2022 S. Patil and M. More

Developed a front telescopic suspension with ergonomic handlebar for an electric scooter prototype. The study combined FEA, vibration testing, and ergonomic evaluation. Result indicated smoother ride performance, reduced vibration transfer, and better rider posture alignment.”[8]

In 2023 A. Kumar and V. Singh

Performed fatigue and static analysis on aluminium alloy (AA6061-T6) suspension forks. They compared steel and aluminium materials and concluded that aluminium provides better weight efficiency but requires reinforcement at high-stress joints to ensure long fatigue life.”[9]

In 2023 N. Gupta and S. Yadav

Conducted a dynamic performance study on front suspension systems under varying speeds. Experimental results showed that optimized damping and spring stiffness significantly reduce pitch motion and improve handling, especially critical in compact electric vehicles.”[10]

1. Problem Statement

- Existing electric three-wheelers exhibit the following issues:
- High vibration transmission to the chassis
- Inefficient shock absorption
- Poor steering alignment and rider discomfort
- Structural wear due to uneven load distribution

2. Objectives

- To Design front suspension for smooth ride on uneven roads.
- To Optimize suspension geometry for better three-wheeler stability.
- To Create ergonomic handlebar for comfort and improved steering.
- To Increasing the load-carrying capacity of a suspension system.

3. Methodology

- The research work is divided into the following stages:
- Literature review and problem identification
- Selection of suspension type (telescopic fork)
- Load calculation and distribution
- Spring and damper design
- Handlebar ergonomic design
- Material selection
- Structural validation through analytical methods

5.Design Calculations

5.1 Natural Frequency

The recommended range for vehicle comfort is 1–1.5 Hz.

5.2 Damping Force

damping coefficient

velocity

6.Suspension System Design

6.1Type Selection

- A telescopic fork suspension system is selected due to:
- Compact design
- High shock absorption capability
- Ease of manufacturing.

6.2 Components

- Outer fork tube
- Inner slider
- Helical compression spring
- Damper rod
- Oil seal and bush

6.3Working Principle

- When the wheel encounters a road irregularity:
- The spring compresses and absorbs energy
- The damper controls oscillations

- Hydraulic oil flow dissipates energy

7. Handlebar Design

7.1 Design Parameters Width:

600–750 mm

Sweep angle: 10°–20°

Rise: 50–100mm

7.2 Ergonomic Considerations

- Neutral wrist alignment
- Reduced muscular strain
- Improved steering control
- Proper rider posture

8. Material Selection

Component

1. Handlebar



The handlebar is an important structural and control component of the vehicle, and its material selection plays a crucial role in ensuring strength, durability, and reliability during operation. In most cases, the handlebar is manufactured from mild steel (low-carbon steel) tubing. This material is widely preferred due to its excellent combination of mechanical properties, ease of fabrication, and cost-effectiveness. Mild steel offers sufficient tensile strength and toughness to withstand the forces applied by the rider during steering, as well as external loads caused by road irregularities, vibrations, and dynamic conditions.

One of the key advantages of using mild steel is its high ductility, which allows the handlebar to be easily bent into the desired ergonomic shape without cracking or failure. This is essential for achieving the required geometry, including bends and curves that improve rider comfort and control. Additionally, mild steel has good weldability, making it easy to attach various mounting brackets, supports, and fixtures such as brake lever mounts, mirror holders, and control switches. These welded joints maintain structural integrity and ensure proper functioning of all mounted components.

1. Steering Bearing



The image shows a threaded mechanical assembly used in a steering or headset system, commonly found in bicycles and light electric vehicles such as E-three wheelers. It consists of a threaded lock nut or adjustable race and a bearing housing containing ball bearings. The threaded component is mounted on the steering shaft or steerer tube and is used to apply axial preload to the bearing assembly. This preload ensures that there is no looseness or play in the steering mechanism, improving stability and control. The bearing unit allows smooth rotational motion by converting sliding friction into rolling friction through the use of steel balls. When the handlebar is turned, the balls roll between the inner and outer races, reducing resistance and enabling efficient steering. These components are typically made from high-strength materials such as medium carbon steel for the threaded parts and chrome steel for the bearings, ensuring durability, wear resistance, and reliable performance under varying loads and road conditions.

3. Axle (Front Wheel Shaft)



The image illustrates the working of a front suspension system with an axle (front wheel shaft) and a telescopic fork assembly used in two or three-wheelers. The axle is mounted at the lower end of the fork and holds the wheel hub, allowing smooth rotation while supporting the vehicle load. When the vehicle encounters bumps or uneven road surfaces, the impact force is transmitted from the wheel to the axle and then to the fork structure. The telescopic fork consists of an inner tube (stanchion) and an outer tube (slider), along with an internal spring and damping mechanism. Under load, the inner tube slides into the outer tube, compressing the spring and absorbing shock energy. The damper controls the rate of compression and rebound, preventing excessive oscillations and ensuring stability. After the impact, the spring expands gradually, maintaining continuous contact between the tire and the road. This system improves ride comfort, enhances handling, and ensures safe steering by allowing the fork to absorb shocks while simultaneously enabling directional control.

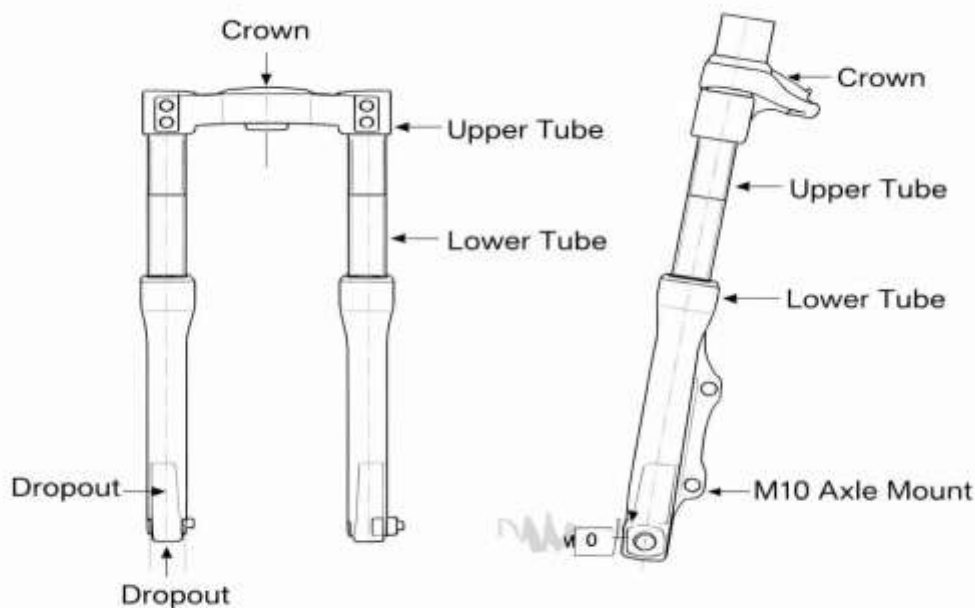
4. Bushings



A bushing functions as an interface element between two moving parts, typically between a shaft/bolt and a housing. Its primary role is to reduce friction, absorb shocks, and isolate vibration.

When the system operates (e.g., during steering or suspension movement), the inner sleeve of the bushing remains fixed to the bolt or shaft, while the outer surface is fitted into the housing. The material in between—often rubber or elastomer—allows controlled deformation. This deformation accommodates relative motion without direct metal-to-metal contact.

5. Front Fork



The image illustrates the working of a telescopic front fork suspension system, which is a critical component in two-wheelers responsible for shock absorption, load transmission, and steering control. This system consists primarily of two parallel fork assemblies, each made up of an upper tube (stanchion) and a lower tube (slider). These components are connected to the vehicle frame through the triple tree (yoke) and steering head, while the lower ends hold the front wheel axle. Internally, each fork contains a helical spring and a hydraulic damping mechanism, forming a combined spring-damper system that governs its dynamic behavior.

6. Fork Cap



The image shows an oil seal (radial shaft seal), a critical component used in mechanical systems to retain lubricating oil and prevent the entry of contaminants such as dust, water, and debris. The working of an oil seal is based on the principle of controlled interference and hydrodynamic sealing between a flexible sealing element and a rotating shaft. It is typically constructed from an elastomeric material (such as nitrile rubber, fluoroelastomer, or silicone) bonded to a rigid metal casing that provides structural strength and ensures proper fitting within the housing. The image shows an oil seal (radial shaft seal), a critical component used in mechanical systems to retain lubricating oil and prevent the entry of contaminants such as dust, water, and debris. The working of an oil seal is based on the principle of controlled interference and hydrodynamic sealing between a flexible sealing element and a rotating shaft. It is typically constructed from an elastomeric material (such as nitrile rubber, fluoroelastomer, or silicone) bonded to a rigid metal casing that provides structural strength and ensures proper fitting within the housing.

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