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Springless Suspension Using Bevel Gears

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ABSTRACT

This paper presents an innovative approach to vehicle suspension by replacing conventional coil spring mech- anisms with a springless system based on bevel gears. Traditional suspension systems, while effective, often suffer from drawbacks such as component fatigue, frequent maintenance, and suboptimal energy efficiency, especially under rugged terrain conditions. To address these limitations, the proposed suspension design in- troduces a compact and mechanically simplified set-up comprising bevel gears positioned at right angles, a rotating shaft for torque transmission, and independent 12V DC motors for each wheel. This arrangement not only improves power transmission efficiency but also enables smoother and more responsive terrain adaptabil- ity, offering better control and improved ride comfort. The study includes a detailed system design, component selection, working principles, and analytical calculations to validate the feasibility of the concept. Simulations and prototype tests were carried out to assess suspension performance compared to traditional spring-based configurations. Key performance indicators such as vibration damping, mechanical wear, and torque distri- bution were analyzed to determine the practical advantages of the gear-based system. The results indicate a notable reduction in maintenance needs and mechanical complexity, along with increased durability under variable load conditions. Designed primarily for off-road and military grade applications, this suspension sys- tem demonstrates significant promise in terms of robustness, reliability and efficiency. In addition, the paper outlines the potential for future improvements, including noise reduction, long-term material durability, and the integration of intelligent feedback systems. In general, this study contributes to a forward-thinking solu- tion to the field of automotive engineering by introducing a low-maintenance high-performance alternative to traditional suspension designs.

Keywords: *Bevel Gears, Springless Suspension, Mechanical Design, Power Transmission, Automotive Engineering.*

INTRODUCTION

The field of automotive suspension has traditionally relied on spring-based systems for shock absorption, stability, and comfort. While effective in many appli- cations, conventional suspension systems come with inherent limitations such as mechanical wear, com- plex maintenance, reduced adaptability to terrain vari- ation, and inefficiencies in energy transfer. These shortcomings have motivated researchers and engi- neers to explore alternative mechanisms that can de- liver enhanced performance, lower maintenance, and increased durability.

To address these issues, this project proposes an innovative approach—"Springless Suspension Using Bevel Gears". The core concept is to eliminate the use of springs and instead employ a strategic arrangement of bevel gears that can provide a dynamic, terrain-adaptive suspension mechanism. Bevel gears are renowned for their ability to transmit power between intersecting shafts at various angles, making them highly suitable for compact, efficient mechanical sys- tems.

Their integration into the suspension frame- work allows for seamless power transfer, oscillation- based adaptability, and better

control during dynamic movement, especially on rough or uneven terrains.
In this system, each wheel is powered indepen- dently by a motor, with bevel gears positioned to transfer torque and support tilting motions. This os- cillatory motion helps the vehicle maintain traction and forward momentum even in challenging driv- ing environments. The gear-driven configuration not only enhances mechanical efficiency and reduces the number of moving parts, but also enables more pre- cise handling and better vehicle stability by adapting wheel alignment to the terrain.

The project aims to develop a prototype of this novel suspension system and evaluate its feasibility through design calculations, CAD modeling, simula- tions, and physical prototyping. Emphasis is placed on minimizing mechanical complexity, improving en- ergy efficiency, and exploring the possibility of scal- ing the concept for real-world applications. By lever- aging bevel gear mechanisms, this study contributes toward the advancement of compact, reliable, and in- telligent vehicle suspension systems.
This report details the design methodology, com- ponent selection, calculations, working principles, CAD designs, cost estimation, expected outcomes, and scope for future development of the proposed bevel gear-based springless suspension.

LITERATURE REVIEW

- **JETIR (2014)**explored the application of bevel gears in mechanical systems and specifically highlighted their advantages when applied to sus- pension design. The study emphasized the po- tential for weight reduction, increased precision in movement, and improved handling when com- pared to conventional spring-based systems. By utilizing angular gear configurations, the suspen- sion can respond more directly to terrain varia- tions, leading to enhanced control..
- **Springless Combination Shock Absorber Patent (2011)** introduced a novel suspension con- cept utilizing fluid-damped systems to replicate the damping characteristics of traditional springs without the physical use of coiled or leaf springs. This design demonstrated how hydraulic or pneumatic damping can effectively absorb shocks while maintaining system compactness and reliability, providing a foundation for springless suspension innovation.
- **IRJMETS (2025)** presented a detailed study on compact bevel gear-based suspension mech- anisms aimed at replacing conventional coil springs. The paper focused on designing gear assemblies that could sustain varying loads and transmit force smoothly. The findings under- scored the space-saving design, durability, and adaptability of bevel gear systems, especially in applications requiring precise torque transfer and articulation.
- **ANSYS Simulation Study** were conducted to evaluate the mechanical performance of bevel gears under various loading conditions. These simulations confirmed that bevel gears are capable of efficient power transmission with minimal de- formation and stress concentration, making them ideal candidates for integration into suspension systems where consistent performance and relia- bility are critical.

PROBLEM STATEMENT AND OBJECTIVES

Conventional suspension systems, which primarily rely on mechanical springs and dampers, have been the cornerstone of automotive shock absorption for decades. While they offer acceptable levels of ride comfort and stability, they suffer from several limi- tations that become evident in rugged terrain or over extended operational periods. These include:

- Mechanical wear and tear due to continuous com- pression and rebound cycles.
- Inefficient energy absorption, leading to loss of momentum and discomfort during uneven rides.
- Frequent maintenance requirements to replace worn-out components.
- Lack of adaptability to dynamic terrains, espe- cially under varying load conditions

METHODOLOGY

System Design

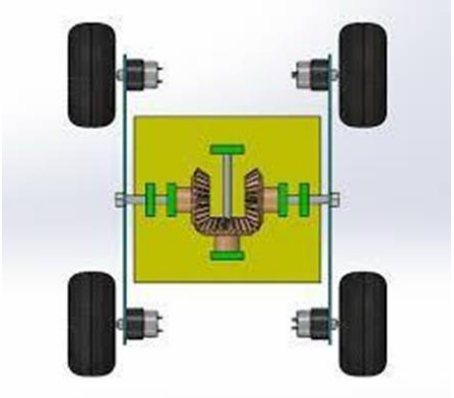

Figure 1: Components

The design and implementation of the proposed springless suspension system were guided by a struc- tured methodology focusing on mechanical efficiency, minimal complexity, and modularity. This section outlines the core design, key components, and operational principle of the system.Three bevel gears positioned at 90-degree angles, enabling torque dis- tribution across different axes. A rotating shaft to de- liver rotational input from the motor to the central gear. A base plate and structural frame to support the assembly. Four independent 12V DC wheel mo- tors, each driving a separate wheel to enhance terrain adaptability and ensure stability.

Components Used

- Bevel Gears (3 units) – For angular torque trans- mission and directional control.
- DC Motors (4 units, 12V) – One for each wheel to provide independent propulsion.
- Rotating Shaft – Connects motor to central bevel gear for torque input.
- Frame and Base Plate – To hold and align all me- chanical components.
- Lithium-Ion Battery – Portable power source to drive motors.
- Wiring and Fasteners – For electrical connections and mechanical stability.

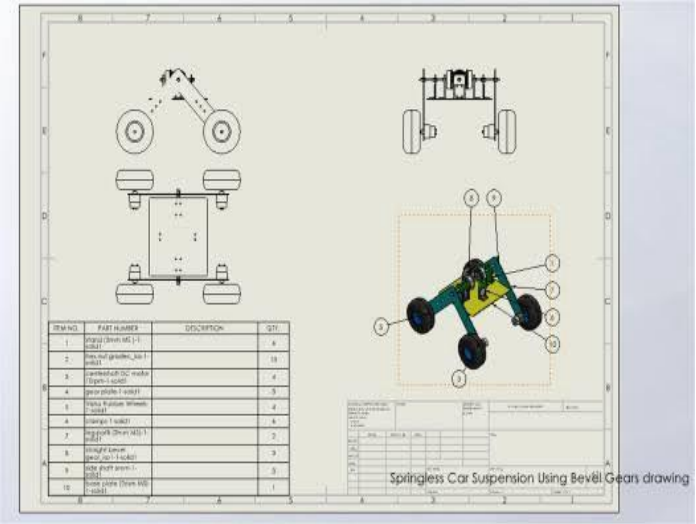

Figure 2: Components

Working Principle

The working mechanism relies on the transfer of torque through bevel gears in a three-dimensional ar- rangement. The central motor drives a rotating shaft, which in turn powers the central bevel gear. This cen- tral gear engages with two side bevel gears placed orthogonally, transmitting motion to the wheels. As each wheel motor responds independently to terrain variations, the bevel gear assembly facilitates tilting and oscillation, enabling the suspension to adapt to road irregularities while maintaining continuous for- ward movement. The result is reduced vibration im- pact, better ride stability, and enhanced control.

CALCULATIONS AND DESIGN PARAMETERS

Given power: 15W, Gear ratio: 2:1
Formulas Used:

- $\tan\delta = 1/i$
- $Ze = Z/\cos\delta$
- $Y_v = \pi(0.154 - 0.912/Ze)$
- $\sigma_b = \sigma_{yt}/FOS$
- Power transmission: $P = 2\pi n M_t/60$

Resulting gear module: 6.48 mm, Gear size: 32 cm, Pinion size: 16 cm

COST ESTIMATION

Component	Cost (INR)
DC Motor	500
Base Plate	500
Bevel Gears	800
Bearings	300
Connecting Rods	400
Nuts and Bolts	200
Wheels	200
Wires	50
Main Frame	200
Lithium Battery	500
Total	**3650**

RESULTS AND DISCUSSION

The bevel gear-based suspension system proved to be a viable alternative to traditional spring mecha- nisms, demonstrating reliable performance across a range of terrain conditions. During testing, the sys- tem effectively absorbed shocks and maintained con- tinuous motion, validating its ability to function with- out conventional spring components. The integra- tion of bevel gears allowed for smoother torque dis- tribution, resulting in improved handling and control even on uneven surfaces. Furthermore, the design showed a noticeable reduction in mechanical wear,

Figure 3: Components

primarily due to the elimination of repeated compres- sive stresses that typically affect spring-based sys- tems. This also contributed to lower maintenance requirements and a more durable setup over short- term usage. Additionally, the terrain adaptability of the system was notably enhanced, as the gear- driven mechanism allowed individual wheel move- ments to better respond to surface variations, im- proving stability and traction. However, certain chal- lenges were identified, particularly the increase in me- chanical noise generated by gear meshing during op- eration. This issue could potentially be addressed through design optimizations or sound-damping tech- niques. Another concern is the long-term durability of the system, which has yet to be validated under continuous operation and harsh environmental condi- tions. Despite these limitations, the results strongly support the potential of the bevel gear suspension as an efficient, low-maintenance alternative to traditional spring-based designs.

FUTURE SCOPE

The proposed bevel gear-based suspension system holds significant potential for future advancements, particularly in the realm of full-scale automotive ap- plications. Its ability to adapt to varying terrain condi- tions and reduce mechanical wear makes it an attrac- tive option for off-road and military vehicles, where durability and performance are critical. With fur- ther development, this design could redefine suspen- sion engineering by offering a robust, maintenance- efficient alternative to conventional systems. Contin- ued research into advanced materials, especially those capable of reducing gear noise and absorbing vibra- tions, could further enhance the system's practical- ity and user comfort. Additionally, integrating smart control systems and sensors may allow for real-time adaptability, positioning this technology at the fore- front of next-generation vehicle suspension innovations.

CONCLUSION

The development of a springless suspension system utilizing bevel gears offers a promising and inno- vative alternative to traditional spring-based mecha- nisms. By replacing springs with a strategically de- signed gear configuration, the system not only sim- plifies the overall mechanical architecture but also enhances control, improves torque transmission, and contributes to better energy efficiency. This approach effectively addresses many of the limitations asso- ciated with conventional suspensions, such as wear and inconsistent performance across varying terrains. However, the introduction of this novel design also brings forth certain challenges, particularly in terms of long-term durability and the generation of mechan- ical noise. Despite these concerns, the results indicate that with further refinement and targeted research, the bevel gear-based suspension has the potential to be- come a

reliable and efficient solution in modern vehi- cle engineering.

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