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Design and Analysis of Automated Truck Cabin Suspension System

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Abstract

The suspension system is used to isolate the chassis from the shock loads due to irregularities of the road surface. This must be handled without impairing the stability, steering or general handling of the vehicle. Suspension system for the cab is placed between the chassis using bolts. The loads coming from the floor and the chassis are taken by the suspension. Constraint equations and couples are used to connect various regions of the suspension system. The loads are applied on the leaf spring of the suspension system. Static analysis is made to study the deflection of the leaf spring. Modal analysis is made to check the natural frequencies. Harmonic analysis is also done to plot various graphs between frequency and amplitude. Results and discussions are made from the results obtained from the Ansys and conclusions are given and scope for future work is also given.

Keywords: Leaf Spring, Suspension System, Analsis.

Introduction

Trough this paper, we will describe the different truck cab Configuration and explain why a large portion of the related literature is primarily focused on the Cab over Engine (COE) truck Configuration. This work is primarily targeted at conventional heavy trucks which are the most common trucks on the market at this time. Portions of the work could easily be applied to COE trucks but will not be discussed at length at this time. It is, however, important to have an understanding of the evolution of semi truck cabs to better grasp the needs of the driver, such as:

A. The complete suspension system is to isolate the vehicle body from road shocks and vibrations which would otherwise be transferred to the passengers and load. It must also keep the tires in contact with the road, regardless of road surface. A basic suspension system consists of springs, axles, shock absorbers, arms, rods, and ball joints. The spring is the flexible component of the suspension. Basic types are leaf springs, coil springs, and torsion bars. Modern passenger vehicles usually use light coil springs. Light commercial vehicles have heavier springs than passenger vehicles, and can have coil springs at the front and leaf springs at the rear. Heavy commercial vehicles usually use leaf springs, or air suspension. Solid, or beam, axles connect the wheels on each side of the vehicle. This means the movement of a wheel on one side of the vehicle is transferred to the wheel on the other side. With independent suspension, the wheels can move independently of each other, which reduce body movement. This prevents the other wheel being affected by movement of the wheel on the opposite side, and this reduces body movement.

B.While making long days on the road, truck drivers spend much time in their truck cabins. Vibrations induced by the road and cargo are transmitted to the cabin and consequently to the driver. These vibrations are can be uncomfortable and even unhealthy.

To make the truck drivers ride as comfortable as possible truck cabins are equipped with cabin suspension systems. The main purpose of these systems is to minimize the vibrations transmitted to the driver. Nowadays, most trucks are equipped with passive suspension systems. However, automated suspension systems are gaining popularity, as can be seen in the passenger car industry. These automated suspension systems can alter their characteristics, using only a small amount of external energy. When these characteristics are controlled in a smart way the driver comfort can potentially be improved. In this thesis research is done on the potential of different passive and semi-active cabin suspension systems to improve driver comfort in commercial vehicles.

Therefore To make a fair comparison, the various suspension concepts applied to the cabin suspension of this quarter-vehicle model are all numerically optimized to the same criterion. In this criterion the driver comfort is optimized, by minimizing the so-called ride index. Meanwhile, the suspension travel is kept within the absolute limits of the available working-space. The suspension concepts selected from the literatures show a limited potential improvement of driver comfort. Therefore, in this thesis a new control strategy is designed for a automated cabin suspension system using an analysis on leaf spring. The automated suspension system using this controller is compared to the passive and semi-active suspension concepts selected from the literature. Finally it is shown that a road adaptive control strategy would improve all the investigated automated cab suspension systems. A road adaptive LQ/LPV controlled system even leads to a driver comfort improvement of 45%.

Literature Review

An extensive literature study is first performed on the topic of passive and semi-active automotive suspension systems. Since the amount of publications on cabin suspension systems is very limited, suspension concepts applied in primary vehicle suspensions are also regarded.

From this literature study, several passive and semi active suspension concepts are selected. The performances in terms of driver comfort of the selected suspension concepts, applied to a truck cabin suspension, are compared. Therefore a 4 degree-of-freedom quarter-vehicle model is used to describe the dynamics in vertical direction of a truck with axle suspension, cabin suspension and engine suspension.

According to Gillespie and Karamihas (2000) it is not possible to model the vertical truck dynamics using only one quarter vehicle model. It is indicated that the inclusion of suspension friction is essential various designs for front and rear axle congurations with leaf springs can be found in Gillespie (1985). In nonlinear truck suspension components are investigated and optimized in the framework of the so-called CASCOV project. In the CASCOV project only axle suspensions are regarded.

In the past the numerical optimization of a passive cabin suspension has5been performed by Bessel ink, as part of the numerical optimization of the total suspension system of a truck/semi-trailer, including axle and engine suspensions.

However, modeling and optimization techniques used in research on primary vehicle suspensions can also be valuable when regarding secondary suspension systems.Therefore, three different nonlinear quarter vehicle models are suggested when focusing on the dynamic tyre forces: one for the steer axle; one for the drive axle with leaf spring; and one for the drive axle with air spring.

Cabin Suspension

To be able to evaluate any passive or (semi-)active suspension system, models which accurately describe the dynamic behavior of the vehicle and suspension are often desirable. For a fair comparison of various suspension concepts, they should be applied to the same vehicle model. Furthermore it is important that the variables of the suspension component models are chosen such that the suspension systems perform optimal with respect to the same objectives and constraints. When investigating a truck cabin suspension system to improve driver comfort, bounded by working space constraints, the most important function of the vehicle model is to describe the cabin motion caused by to road irregularities and other disturbances.

Besides the vehicle model, it is important to have representative suspension component models at disposal. A passive suspension system consists of passive elements like (linear or nonlinear) springs and dampers bump stops and possibly inerter. It may be worthwhile to evaluate the performance of some of these suspension concepts in a cabin suspension system. Semi-active suspension components can be regarded as essentially passive, meaning they can only store or dissipate energy from the system but the automated suspension components can be regarded as essentially active that is, they can store energy and dissipate energy from the system simultaneously.

However, a relatively small amount of external energy can be used to change its characteristics. By doing so, the performance of the suspension system can be improved. These automated suspension components are typically variable rate springs and dampers.

Briefing a Component of Suspension System

The performance of the suspension system can be improved by reducing the impact of vibrations on the cabin system which are caused by various factors as discussed earlier. So now let us consider in improving the performance of a cabin suspension system by a performing an analysis on a leaf spring which is a major component of a suspension system.There are four basic designs of leaf spring that are used in stock car racing. They are:

The Mono-Leaf Spring
Multi-Leaf Springs
Parabolic Leaf Springs
Composite Leaf Springs

There will be positives and negatives for every design for suppose the advantages of using a leaf spring are Supports some or all of the chassis weight, Controls chassis roll more efficiently by utilizing a higher rear moment center and a wide spring base, Controls rear end wrap-up when not mounted with birdcage-type mounts, Controls axle dampening, Controls lateral forces much the same way a Pan hard bar does, but with very , Little lateral movement, Controls braking forces when not mounted with birdcage-style mounts, Better at maintaining wheelbase lengths (reduced rear steers) under acceleration and braking, etc in the same way the dis advantages of leaf springs can be noted as they are expensive (Steel coils are commodity items; a single composite leaf spring costs more than two of them.), design complexity (Composite mono-leafs allow for considerable variety in shape, thickness, and materials.

They are inherently more expensive to design, particularly in performance applications.), cost of modification (as a result of specialized design and packaging, changing spring rates often requires a custom unit.

Design of Leaf Spring

Considering several types of vehicles that have leaf springs and different loads on them, various kinds of composite leaf spring have been developed. In the case of multi- leaf composite leaf spring, the interleaf spring friction plays a spoil spot in damage tolerance. It has to be studied carefully. In the present work, only a leaf spring with constant thickness, constant width design is analyzed.

The following cross-sections of leaf spring for manufacturing easiness are considered.

1. Constant thickness, constant width design
2. Constant thickness, varying width design
3. Varying width, varying width design.

Parameters	Value
Total Length of the spring (Eye to Eye)	1540 mm
Free Camber (At no load condition)	136 mm
No. of full length leave (Master Leaf)	01
Thickness of leaf	13 mm
Width of leaf spring	70 mm
Maximum Load given on spring	25 Kg
Young's Modulus of the spring	22426.09 Kgf/mm2
Weight of the leaf spring	23Kg

For steel leaf spring cross section is according to considered design and not altered. Due to manufacturing ease, a composite leaf spring with uniform rectangular cross section is considered and analyzed.

Analysis on Leaf Spring

The leaf spring modeled in AutoCAD Inventor was imported to ANSYS in IGES format. Since leaf spring was modeled as a solid, solid element named SOLID187 was used to mesh the model. SOLID187 element is a higher order3-D, 10-node element. SOLID187 has a quadratic displacement behavior and is well suited to modeling irregular meshes (such as those produced from various CAD/CAM systems). The element is defined by10 nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions.

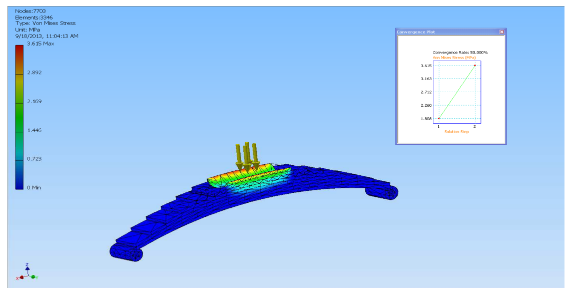

Fig.1 VonMises for Leaf Spring

The element has plasticity, hyper elasticity, creep, stress stiffening, large deflection, and large strain capabilities. The geometry, node locations, and the coordinate system for this element are shown in the figure 5.In addition to the nodes; the element input data includes the orthotropic or anisotropic material properties. Orthotropic and anisotropic material directions corresponding to the element coordinate directions.

Results and Conclusion

It was observed that the deflection in the composite leaf spring was almost equal so we can say that composite spring had the same stiffness as that of steel spring.

It was observed that the composite leaf spring weighed only 39.4% of the steel leaf spring for the analyzed stresses. Hence the weight reduction obtained by using composite leaf spring as compared to steel was 60.48 %.

By analyzing the design, it was found that all the stresses in the leaf spring were well within the allowable limits and with good factor of safety. It was found that the longitudinal orientations of fibers in the laminate offered good strength to the leaf spring. Ride quality is generally quantified as the natural frequency of a suspension system.

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Table .1: Result Values

Parameters	Analytical	FEA
Load(N)	2943	2943
Maximum STRESS (MPa)	220.37	224.5
Maximum Deflection (mm)	5.9573	7.545 2
Maximum Stiffness (N/mm)	494.015	390

Suspension system natural frequencies less than 1 Hz will cause motion sickness in a vehicle's passengers, and suspension system natural frequencies greater than 2.5 Hz will provide a "harsh" ride. In the present work, the 2mode shape of the composite leaf spring has a natural frequency of 1.7444Hz and 1.7496 Hz which provides for good ride quality.

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