Design and Analysis of Front Suspension Unit for Light Duty Vehicle

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Abstract- **Suspension unit is the term given to the system that consists of springs, Shock Absorbers and Linkages that connects a vehicle body to its wheel. Suspension unit has many purposes which are vehicle handling, passenger's comfortable, avoiding noise and bumps to the vehicle, etc. Independent suspension is a term for any automobile suspension system that allows each wheel on the same axle to move vertically and independently of each other reacting to a bump in the road. Independent suspension typically offers better ride quality and handling characteristics, due to the ability of each wheel to address the road undisturbed by activities of the other wheel on the vehicle. Independent suspension requires additional engineering effort in development versus a beam or live axle arrangement. Introducing Independent Suspension in Commercial Passenger Vehicles will increase the comfortable in long journey. Existing suspension units in the commercial passenger vehicles have only the leaf springs which are connected between the vehicle chassis and wheels. So the movement on one side will affects the wheel on the other side and whole body will affected by the shock.**

Index Terms **Suspension, Vehicle**

1. INTRODUCTION

1.1 SUSPENSION UNIT

Suspension is the term given to the system of leaf springs, shock absorbers and linkages that connects a vehicle to its wheels. Suspension systems serve a dual purpose, contributing to the car's road holding/handling and braking for good active safety and driving pleasure, and keeping vehicle occupants comfortable and reasonably well isolated from road noise, bumps, and vibrations, etc. These goals are generally at odds, so the tuning of suspensions involves finding the right compromise.

It is important for the suspension to keep the road wheel in contact with the road surface as much as possible, because all the forces acting on the vehicle do so through the contact patches of the tires. The suspension also protects the vehicle itself and any cargo or luggage from damage and wear. The design of front and rear suspension of a car may be different.

Independent suspension is a broad term for any automobile suspension system that allows each wheel on the same axle to move vertically (i.e. reacting to a bump in the road) independently of each other. This is contrasted with a beam axle and live axle system in which the wheels are linked - movement on one side, affects the wheel on the other side. Note that "independent" refers to the motion or path of movement of the wheels/suspension.

1.2 PROBLEM IDENTIFICATION

When people think of automobile performance, they normally think of horsepower, torque and zero-to-60 acceleration. But all of the power generated by a piston engine is useless if the driver can't control the car. That's why automobile engineers turned their attention to the suspension system almost as soon as they had mastered the four-stroke internal combustion engine. The job of a commercial vehicle suspension is to maximize the friction between the tires and the road surface, to provide steering stability with good handling and to ensure the comfort of the passengers.

In this design project, the major problems in the current suspension unit of the commercial vehicle was founded and the new design feature was created to rectify the major problem occurred from the suspension unit. If a road were perfectly flat, with no irregularities, suspensions wouldn't be necessary. But roads are far from flat. Even freshly paved highways have subtle imperfections that can interact with the wheels of a car. It's these imperfections that apply forces to the wheels. According to Newton's laws of motion, all forces have both magnitude and

direction. A bump in the road causes the wheel to move up and down perpendicular to the road surface.

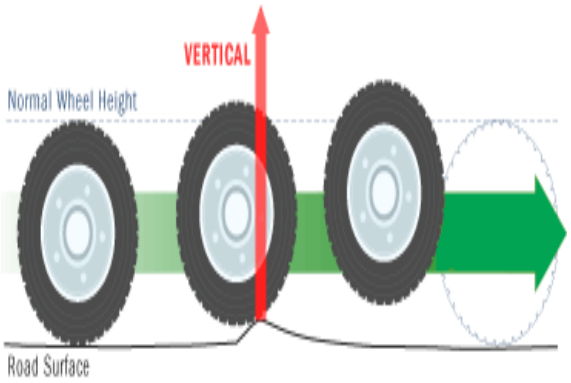

FIG.1: VERTICAL ACCELERATION EXPERIENCED BY WHEELS

Without an intervening structure, all of wheel's vertical energy is transferred to the frame, which moves in the same direction. In such a situation, the wheels can lose contact with the road completely. Then, under the downward force of gravity, the wheels can slam back into the road surface. What you need is a system that will absorb the energy of the vertically accelerated wheel, allowing the frame and body to ride undisturbed while the wheels follow bumps in the road. Most automobile engineers consider the dynamics of a moving commercial passenger vehicle from two perspectives:

Ride - ability of the vehicle to smooth out a bumpy road

Handling - ability of the vehicle to safely accelerate, brake and corner

1.3 OBJECTIVE OF THE PROJECT

To design an independent suspension unit for front wheel in commercial passenger vehicle. By providing independent suspension system to each wheel, it will give better suspension to the vehicle. It will reduce the cost of the luxury commercial passenger vehicles by reducing the design cost. We can manufacture the luxury Hi-Class vehicles instead of importing the vehicles from abroad. This design is aimed to provide independent suspension unit for Indian commercial passenger vehicle manufactures like TATA and ASHOK LEYLAND to make the Indian passenger vehicle to the international standards and to give more comfortable journey for the passenger in short and long journey.

2. LITERATURE REVIEW

2.1 GENERAL

Suspension is the term given to the system of springs, shock absorbers and linkages that connects wheels to a vehicle. Suspension systems serve a dual purpose contributing to the vehicle's handling and braking for good active safety and driving pleasure, and keeping vehicle occupants comfortable and reasonably well isolated from road noise, bumps, and vibrations. These goals are generally at odds, so the tuning of suspensions involves finding the right compromise. The suspension also protects the vehicle itself and any cargo or luggage from damage and wear.

Leaf springs have been around since the early Egyptians. Ancient military engineers used leaf springs in the form of bows to power their siege engines, with little success at first. The use of leaf springs in catapults was later refined and made to work years later. Springs were not only made of metal, a sturdy tree branch could be used as a spring, such as with a bow.

2.2 AUTOMOBILES

Automobiles were initially developed as self-propelled versions of horse drawn vehicles. However, horse drawn vehicles had been designed for relatively slow speeds and their suspension was not well suited to the higher speeds permitted by the internal combustion engine. The year 1886 is regarded as the birth of the modern automobile with the Benz Patent Motorwagen, the German inventor Karl Benz. In 1901 Mors of Germany first fitted an automobile with shock absorbers. With the advantage of having a dampened suspension system in his 'Mors Machine'. In 1901, British inventor Frederick William Lanchester patented the disc brakes. In 1920, Leyland used torsion bars in a suspension system. In 1922, independent front suspension was pioneered on the Lancia Lambda and became more common in mass market cars from 1932.The Hotchkiss drive invented by Albert Hotchkiss was the most popular rear suspension system used in American cars from the 1930s to the 1970s. In 1893, the first running, gasoline-powered American_car was built and road-tested by the Duryea brothers of Springfield, Massachusetts. The first public run of the Duryea Motor Wagon took place on 21 September 1893, on Taylor Street in Metro Center Springfield. The

Studebaker Automobile Company, subsidiary of a long-established wagon and coach manufacturer, started to build cars in 1897 and commenced sales of electric vehicles in 1902 and gasoline vehicles in 1904.

2.3 PARTS OF SUSPENSION UNIT

2.3.1 CHASSIS

The suspension of a vehicle is actually part of the chassis, which comprises all of the important systems located beneath the body of the vehicle. This suspension unit then connected to the axle which is connected with wheels of the vehicle.

These systems include:

FRAME: structural, load-carrying component that supports the vehicle's engine and body, which are in turn supported by the suspension.

SUSPENSION SYSTEM: setup that supports weight, absorbs and dampens shock and helps maintain tire contact.

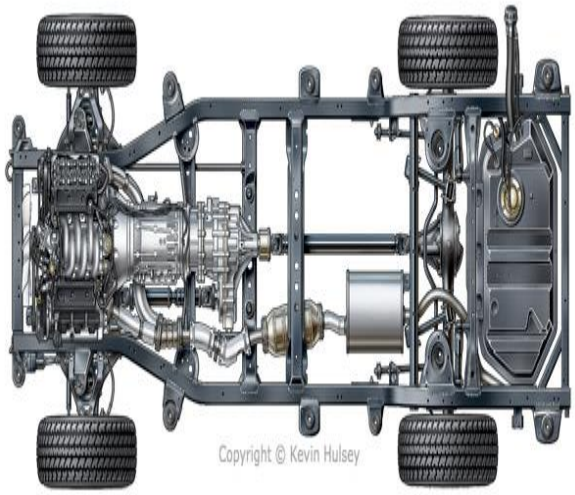

FIG 2: CHASSIS OF A LIGHT DUTY VEHICLE

AXLE: the solid bar which supports the vehicle chassis with the help of leaf spring and connected to the wheels of the vehicle. There are drive axle and beam axle.

STEERING SYSTEM: Mechanism that enables the driver to guide and direct the vehicle.

TIRES AND WHEELS: components that make vehicle motion possible by way of grip and/or friction with the road. So the suspension is just one of the major systems in any vehicle.

2.3.2 LEAF SPRINGS

Would a leaf spring help out this sorry state? Probably not, not for trailer built with leaf spring capabilities, leaf springs can improve suspensions weighted down with heavy loads.

FIG.3: LEAF SPRINGS

Compared to most automotive technology currently available, leaf springs don't look too fancy. They're simply long and narrow plates attached to the frame of a trailer that rest above or below the trailer's axle. Slightly curved, they look a little like a metal bow from an archery set, except without the string. Leaf springs come in several different varieties. There are mono-leaf springs, or single-leaf springs, that consist of simply one plate of spring steel. These are usually thick in the middle and taper out toward the end, and they don't typically offer too much strength and suspension for towed vehicles.

Drivers looking to tow heavier loads typically use multi-leaf springs, which consist of several leaf springs of varying length stacked on top of each other. The shorter the leaf spring, the closer to the bottom it will be, giving it the same semi- elliptical shape a single leaf spring gets from being thicker in the middle. Leaf springs also have different ends, depending on where they're connected to the frame.

2.3.3 DAMPERS: SHOCK ABSORBERS

Unless a dampening structure is present, a spring will extend and release the energy it absorbs from a bump at an uncontrolled rate. The spring will continue to bounce at its natural frequency until all of the energy originally put into it is used up.

Enter the shock absorber, a device that controls unwanted spring motion through a process known as

dampening. Shock absorbers slow down and reduce the magnitude of vibratory motions by turning the kinetic energy of suspension movement into heat energy that can be dissipated through hydraulic fluid. A shock absorber is a mechanical device designed to smooth out or damp shock impulse, and convert kinetic energy to another form of energy (usually thermal energy, which can be easily dissipated). It's a type of dashpot.

2.4 TYPES OF FRONT SUSPENSION

The wheels of a vehicle work together in two independent systems, the two wheels connected by the front axle and the two wheels connected by the rear axle. That means that a vehicle can and usually does have a different type of suspension on the front and back

FIG 5: FRONT TYPE SUSPENSION SYSTEM

Much is determined by whether a rigid axle binds the wheels or if the wheels are permitted to move independently. The former arrangement is known as a dependent system, while the latter arrangement is known as an independent system. The suspension system of an automobile must perform two primary functions: to support the weight of the vehicle and absorb road shocks. Several types of front-suspension systems can be found in modern automobiles.

2.4.1 DEPENDENT FRONT SUSPENSIONS

Dependent front suspensions have a rigid front axle that connects the front wheels. Basically, this looks like a solid bar under the front of the vehicle, kept in place by leaf springs and shock absorbers. Common on trucks, dependent front suspensions haven't been used in mainstream cars for years.

The dependent suspension system is known as solid axle, when both wheels (left and right) are mounted the same solid axle. In this case, any movement of any wheel will be transmitted to the opposite wheel causing them to camber together. Solid drive axles usually are used on the rear axle of many passenger cars, trucks and on the front axle in many four-wheel drive vehicles. The dependent front suspension uses a solid axle. This design consists of one steel or aluminum beam extending the width of the vehicle. This beam is held in place by leaf springs. There is transfer of road shock from one wheel to the other due to the way the wheels are connected to the axle.

2.4.2 INDEPENDENT FRONT SUSPENSIONS

In this setup, the front wheels are allowed to move independently. The MacPherson strut, developed by Earle S. MacPherson of General Motors in 1947, is the most widely used front suspension system, especially in cars of European origin.

3.METHODOLOGY

3.1 GENERAL

This chapter presents a general framework of design process for developing conceptual design and analysis of Independent front suspension unit for commercial passenger vehicle. There are several activities which are to be followed to design the suspension unit. The major activities for defining the suspension unit are carried out sequentially as presented in the following figure.

3.2 DESIGN PROCESS

The new design process for independent front suspension unit of the commercial passenger vehicle was conducted based on the steps given in the Fig.3.1. First of all, the existing model which are currently used in automobile was studied to find out the problems that was faced by current design and limitations faced by the passengers. Based on the study and problem identification, a possible solution was created to overcome the limitation. As per the solution, a new design was created which will support the existing design of entire frame of the vehicle and also it should overcome the limitations that were occurred both to the vehicle and passengers. The new design which created was then analysed using the Analyzing software to identify the

failure results and also to check whether the design support with particular load and operating condition.

3.2.1 DATA COLLECTION

Data Collection is mainly used to describe a process of preparing and collecting data which is the part of developing the process and improving the project. Here the main purpose of data collection is to obtain information to keep on record, to make decisions about important issues. Prior to any data collection, pre-collection activity is one of the most crucial steps in the process. It is often discovered too late that the value of their interview information is discounted as a consequence of poor sampling of both questions and informants and poor elicitation techniques. After pre-collection activity is fully completed, data collection in the field, whether by interviewing or other methods, can be carried out in a structured, systematic and scientific way. A formal data collection process is necessary as it ensures that data gathered is both defined and accurate and that subsequent decisions based on arguments embodied in the findings are valid. The process provides both a baseline from which to measure from and in certain cases a target on what to improve.

3.2.2 TOOLS FOR DESIGN AND ANALYSIS

Pro/Engineer Wildfire 2.0 takes main part in design and creating 3D prototype models. It helps in creating part models and to make assembly from those part models. Extended toolsets help in detailing and creating bills of material. Solid Works 3D CAD Software was used to resolve complex assembly issues early in the design process. Solid Works Simulation and COSMOS Works Software bolster the depth of Simulation with additional capabilities, including a powerful set of tools for simulating with different materials and with different loading. Static and Dynamic loading is fully supported. No matter the material or use environment, Solid Works Simulation will provide valuable insight to improve product reliability in the most cost effective manner.

4.DESIGN, ANALYSIS AND INTERPRETATION

4.1 DESIGN FOR PASSENGER VEHICLES

In this chapter the independent front suspension design will be explained. First the suspension rides, the suspension handling and the suspension geometry design objectives are summarized. According to these objectives the final design of the independent front suspension for commercial passenger vehicle will present.

4.2 DESIGN OBJECTIVES

Before an independent front suspension can design, first the design objectives must clearly state. The design objectives define the most important suspension characteristics. Regarding to those objectives the best design decisions can make. Looking back to the objectives, during the development period prevents losing the main design points out of sight.

4.2.1 GENERAL OBJECTIVES

OVERALL: The Independent Front Suspension is designed as an independent front twin tube shock absorber with coil spring suspension module with ride, handling and weight superior to all competitive suspensions. Detailed performance objectives are given below.

DURABILITY: System durability requirements are set as being equal to or better than the existing ones. Of particular importance is the need to offer a zero maintenance system.

WEIGHT: Design Independent Front Suspension with low weight comparing to the weight of the original rigid beam suspension.

SIMPLICITY: A simple design offering ease of assembly and with a reduced number of parts is desirable, together with features that reduce assembly time and costs.

4.2.2 SUSPENSION RIDE OBJECTIVES

RIDE COMFORT: The ride comfort of the IFS must be better or at least equal to the original rigid axle configuration. In general, the isolation from road inputs measured at the cab must to be better than the original rigid axle suspension.

UNSPRUNG MASS: Apart from the general desirability of a low weight design a lower unsprung mass contributes to improving ride comfort. The important components that must be low weight

designed are the unsprung elements of the suspension.

DAMPING: System damping needs to be optimized to cope with a very low hysteresis suspension while not compromising ride quality.
WHEEL TRAVEL: A design requirement comparable to the original rigid axle suspension of the wheel travel is necessary, bearing in mind that its attainment dependent on wheel tracks and frame width.

4.2.3 SUSPENSION HANDLING OBJECTIVES
ROLL STABILITY: The roll stiffness has to be equal to or greater than the original rigid axle suspension that has demonstrated the ability to cope with the high sleeping cabins.

ROLL STEER: Understeer to neutral behaviour in roll is mandatory. The exact coefficient must be tuned to the value best suited to the vehicle selected.

BUMP STEER, BRAKE STEER, WHEEL KICK AND LATERAL STIFFNESS: For all these characteristics it is decided to use the best well-known characteristics of the original rigid axle suspension and adopt this as a target to equal or surpass.

4.3 SUSPENSION GEOMETRY
CAMBER: Static camber must be the same as the original rigid axle suspension. Camber change is now (in the Independent Front Suspension design) for the first time Possible for vehicles, the change rate has to be investigated and depends on the suspension arms lengths.

KINGPIN: The kingpin angle and offset must be comparable with the in the vehicle industry standard values. This to find easy acceptance of the Independent Front Suspension in the truck industry, after acceptance those values can still be optimized.

CASTER: Static caster must also be comparable to the original rigid axle suspension. Although there is caster change possible it is recommendable to minimize it, because caster change will affect the forward driving stability, which is an important issue during driving a vehicle straight forward.

STEERING GEOMETRY: In the passenger vehicle market is it common to use full Ackermann steering to realize minimum tire wear. Obviously passenger vehicles don't reach high lateral accelerations, but maneuverer a lot at low speed.

4.4 ANALYSIS OF INDEPENDENT FRONT SUSPENSION
Analysis of Independent Front Wheel Suspension unit for commercial passenger vehicle takes main part in this project. Here assembly for imported to the simulation package and also sub-assemblies are used for easy of simulation. Solid Works Simulation Express and COSMOS Works Simulation Software bolster the depth of Simulation with additional capabilities, including a powerful set of tools for simulating with different materials and with different loading. Static and Dynamic loading is fully supported. No matter the material or use environment, Solid Works Simulation will provide valuable insight to improve product reliability in the most cost effective manner.

4.4.1 SPRING ASSEMBLY ANALYSIS MODE 1

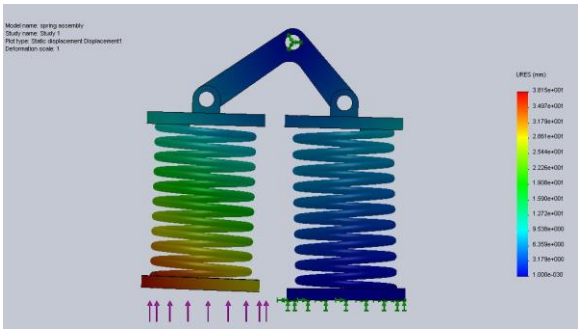

FIG20: SPRING ASSEMBLY ANALYSIS MODE 1

4.4.2 SPRING ASSEMBLY ANALYSIS MODE 2

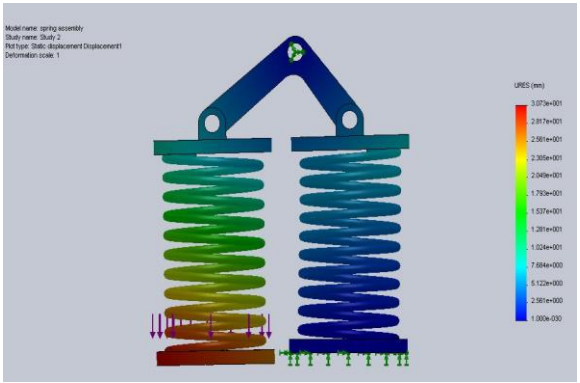

FIG22: SPRING ASSEMBLY ANALYSIS MODE 2

4.4.3 SPRING ASSEMBLY ANALYSIS MODE 3

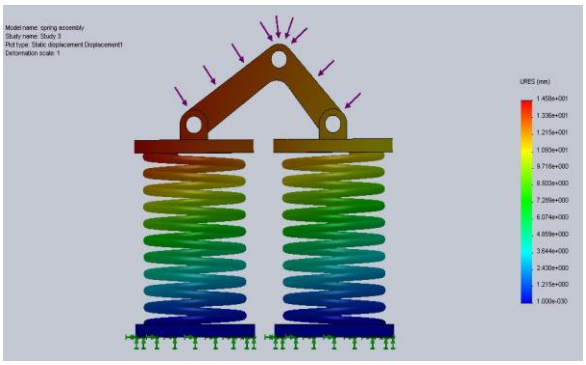

FIG24: SPRING ASSEMBLY ANALYSIS MODE 3

4.4.4 SPRING ASSEMBLY ANALYSIS MODE 4

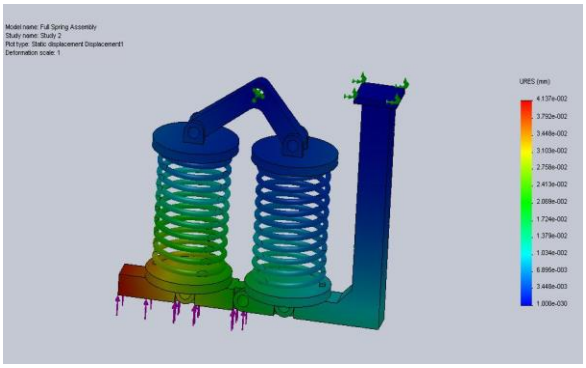

FIG26: SPRING ASSEMBLY ANALYSIS MODE 4

4.4.5 SPRING ASSEMBLY ANALYSIS MODE 5

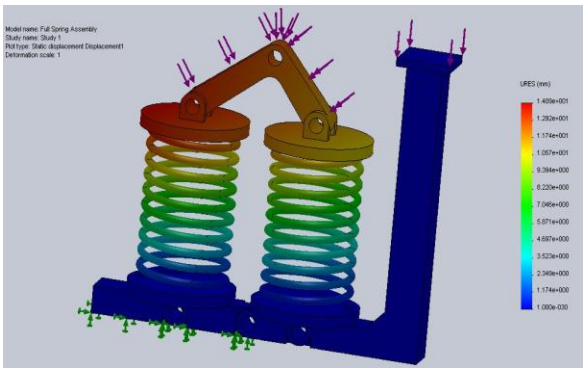

FIG 28: SPRING ASSEMBLY ANALYSIS MODE

5. RESULT

An Independent Front Wheel Suspension is evaluated using a pair of Twin Tube Shock Absorber with Heavy Coil Spring. According to the design and analysis conducted, new concept of Independent Front Suspension unit for commercial passenger vehicle will works smoothly while carrying normal load and absorbs heavy shocks without passing them to the vehicle body parts and to the passenger compartment. Also it operates in maximum load condition, but it came to know that life of the moving part will be reduced when load condition exceeds the limit. As comparing with the imported model of suspension unit, this design will reduce the cost of luxurious vehicles and fit to the mid-range commercial passenger vehicles. The expected ride comfort improvement originating from an independent front wheel suspension was obtained using this design and analysis. Adding an extra spring damper mass body which act as air suspended driver seat will give more ride comfort simulation. An interesting future study might involve testing the independent front wheel suspension unit at different load condition and also extending the design concept to the rear wheel suspension unit. Also it can be developed and fitted to heavy commercial vehicles where there are only dependent suspension unit are possible.

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