A

Seminar report

On

Air Suspension

Submitted in partial fulfillment of the requirement for the award of degree of Electronics

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Acknowledgement

I would like to thank respected Mr…….. and Mr. ……..for giving me such a wonderful opportunity to expand my knowledge for my own branch and giving me guidelines to present a seminar report. It helped me a lot to realize of what we study for.

Secondly, I would like to thank my parents who patiently helped me as i went through my work and helped to modify and eliminate some of the irrelevant or un-necessary stuffs.

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Last but clearly not the least, I would thank The Almighty for giving me strength to complete my report on time.

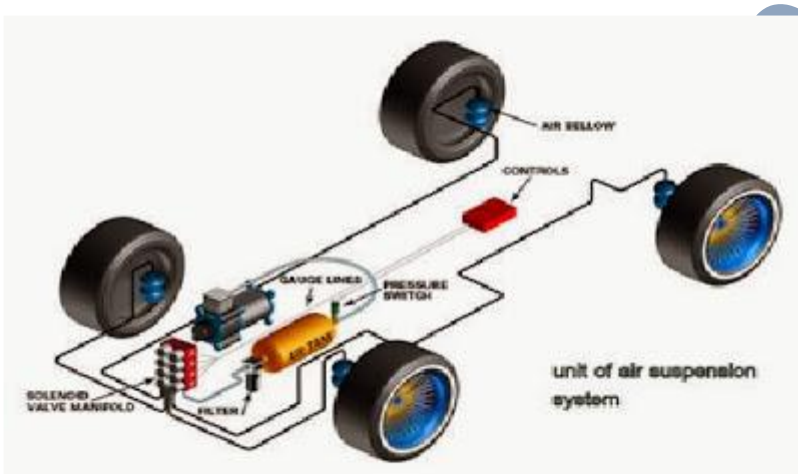
Preface

I have made this report file on the topic **Air Suspension**; I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to …………..who assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

ABSTRACT

Air ride suspension carries the load on each axle with a pressurized air bag much like a high pressure balloon. Air ride suspension systems have been in common use for over forty years and have proven to provide the smoothest and most shock-free ride of any known vehicle suspension system. Modern air bags are constructed using the same methods as a tire by using high strength cords which are then encapsulated in rubber. These units are very durable in service and have a proven life of many years.



In addition to providing extremely smooth ride quality, air ride suspension also provides other important features. First, the system automatically adjusts air pressure in the air bag so that the trailer always rides at the same height, whether lightly loaded or heavily loaded. This allows the suspension system to always provide the maximum usable wheel travel independent of trailer load. In addition, the higher air bag pressure associated with higher trailer loads, automatically provides a stiffer suspension which is exactly what is required for a smooth ride. The lower air bag pressure for lightly loaded conditions, automatically provides for a softer suspension, thus providing the same ride quality for all trailer loading conditions. Since each axle is independently supported by its own air bag, the air ride suspension is a truly, fully independent suspension system.

The automatic control of the air bag pressure is accomplished by a solid state electronic control system specifically designed and packaged for vehicle use. This system continuously monitors the "ride height" of the trailer suspension and increases air pressure if the ride height is too low, by turning on an on-board air compressor. The air compressor stops automatically when the proper ride height is reached. If the ride height is too high, an automatic vent valve vents excess air pressure and stops venting when the proper ride height is reached. All required electrical power is provided by a 12 volt battery contained in the trailer equipment compartment.

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CHAPTER -1

SUSPENSION SYSTEM

1.1 INTRODUCTION

The job of a car 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.

If roads were perfectly flat, with no irregularities, suspensions wouldn't be necessary but they are not therefore these imperfections interact with the wheels of a car and apply some forces on them. A bump in the road causes the wheel to move up and down perpendicular to the road surface. The magnitude depends on whether the wheel is striking a giant bump or a tiny speck. Either way, the car wheel experiences a vertical accelerationas it passes over an imperfection.

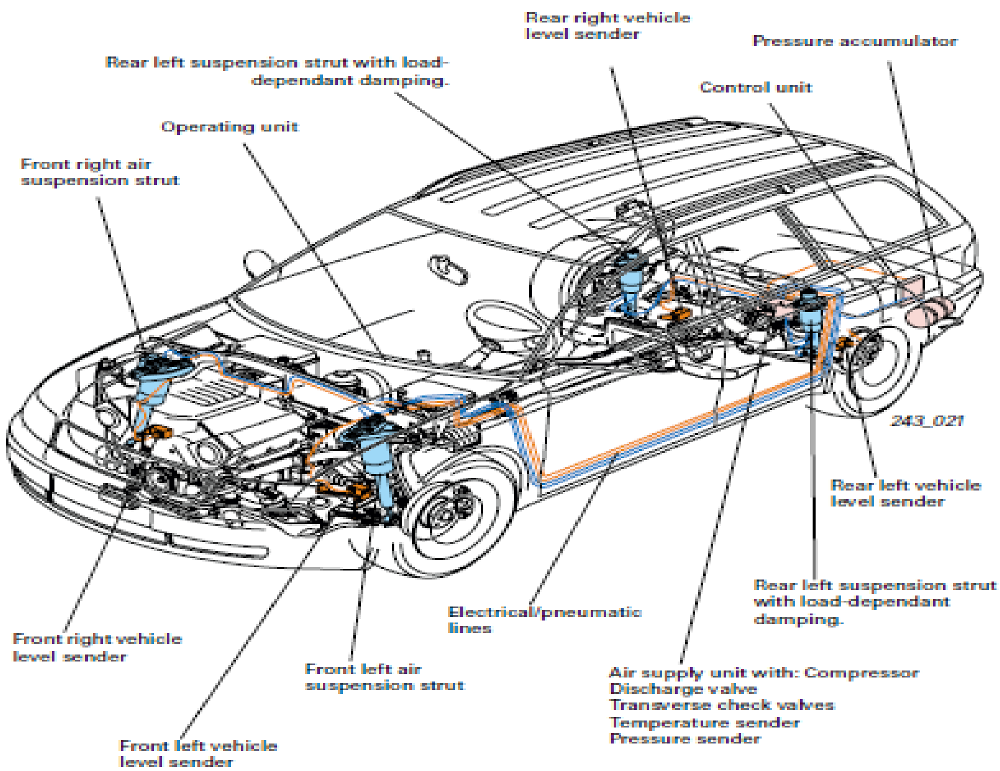


Figure 1.1: Locating Suspension Units

Suspension consists of the system of springs, shock absorbers and linkages that connects a vehicle to its wheels. The suspension systems not only help in the proper functioning of the car's handling and braking, but also keep vehicle occupants comfortable and make your drive smooth and pleasant. It also protects the vehicle from wear and tear.

1.2FUNCTIONS &OBJECTIVES OF SUSPENSION SYSTEM

Basic functions of the suspension system:

1. **TO PROVIDE SUITABLE RIDING AND CUSHIONING PROPERTIES:**
   The frame should have a high degree of isolation from the axle so that the effect of road andtyre irregularities and wheel out of balance forces are not transmitted to the vehicle frame.
2. **TO PROVIDE GOOD ROAD HOLDING :**
   The basic functions of driving, cornering and braking are obtained by virtue of the road and tyre contact area; therefore the suspension system should always maintain the wheels in contact with road to obtain these functions which would otherwise be lost.
3. The suspension system must support the vertical load imposed by the weight of the vehicle,the body and payload weight.
4. **IT MUST PROVIDE ADEQUATE STABILITY AND RESISTANCE TO SIDEWAYS AND ROLL OVER:**
   Swaying, shifting and surging loads may be encountered cornering causes a tendency for the vehicle to roll.
5. **IT MUST TRANSFER DRIVING AND BRAKING FORCES BETWEEN FRAME AND AXLES:**
   The suspension system must provide any medium to transfer the longitudinal forces generated during acceleration or deceleration.
6. It plays a crucial role in vehicle handling, vehicle dynamics and to the stability of the vehicle while it is running, pitching or rolling.

Some other usage of suspension system is discussed as following:

- **TUNABILITY:It has a wide tuning range for spring rate and load capacity.**
- **HANDLING:**In a sophisticated handling application, the air spring should be coupled with adjustable shocks.
- **PERFORMANCE CUSTOMIZATION:**The car can be driven comfortably to the track, firm up the air pressure and shock valves to go racing, and then readjust the pressure and valves to return home in comfort.
- **STANCE:**Suspension system can easily raise the car back up for normal cruising, getting into gas stations, or even rolling onto the trailer.
- **LOAD CARRYING:** Air suspensions: helps carrying heavy loads while improving driver comfort.

There are two types of suspension systems:

1. Dependent Suspension
2. Independent Suspension

A **Dependent Suspension** comprises of a beam that hold wheels parallel to each other and perpendicular to the axle. It includes Trailing arms, Satchel link, Pan hard rod, Watt's linkage, and WOBLink and Mumford linkage.

An **Independent Suspension** helps in the rising and falling movement of the wheels. It includes Swing axle, Sliding pillar, multi-link suspension, semi-trailing arm suspension, swinging arm and leaf springs.

There is also a semi-dependent suspension where the motion of one wheel affects the position of the other but they are not rigidly attached to each other.

CHAPTER -2

PROBLEM DEFINITION

2.1GENERAL PROBLEMS WITHOUT SUSPENSION SYSTEM:

- **Unsprung Weight:**

  Having a large beam connecting the two front wheels results in a lot of mass .This extra mass hinders the road holding capability of the suspension on rough road.

- **Wheel Movement:**

  Since both wheels are tied together the force acting on each wheel are directed to the other wheel. Under the load this causes the wheels to shake and decrease the stability of the vehicle in corners.

- **Bad Bump Steer:**

  Since it is difficult to locate the steering correctly with the help of a beam axle, therefore most of the solid axle suspensions suffer from an uncontrollable amount of bump steer and due to which the performance of the car decreases.

- **Size:**

  Since solid axles are huge therefore the fitting them into the chassis requires a lot of space.

- **Ride Quality:**

  Due to the high mass of the axle and the wheels being connected there is not much ride isolation between the springs and unsprung mass. This results in rough ride and decreases the road holding capacity.

2.2 PROBLEMS IN SPRING SUSPENSION:

The conventional metal springs faced some problems which were overcome by air suspension system. Some drawbacks are stated below:

1) The automatic control devices installed in the vehicle makes it optimum for using the variable space for deflection of wheel.
2) The height of the automobile remains steady and so the changes in the alignment of headlamp due to varying loads are restricted.
3) It helps to reduce the load while the vehicle in motion.

2.3 PROBLEMS IN AIR SUSPENSION SYSTEM:

1. AIR BAG OR AIR STRUT FAILURE:

It is usually caused by wet rot or moisture entering the air system and therefore damages it. Air ride suspension parts may fail because rubber becomes dry and punctures to the air bags can be caused by debris on the road. Improper installation can also cause the air bags to get rubbed against the vehicle's frame or other surrounding parts and therefore damaging it.

2. AIR LINE FAILURE:

It is the failure of the tubes connecting the air bags or struts to the air system. This failure usually occurs when the air lines are rubbed against the sharp edges of the chassis member or moving suspension components and causes a hole.

3. COMPRESSOR FAILURE:

This failure is due to the leakage in air springs or air struts. The compressor burns out maintain the air pressure in a leaking air system. Compressor burnout may also be caused by the moisture present in the air system coming in contact with its electronic parts.

4. DRYER FAILURE:

Function of dryer is to remove moisture from the air system. But when it stops performing its function and becomes saturated the moisture develops resulting in burnout failure and damaging of air springs.

CHAPTER -3

LITERATURE REVIEW

3.1 HISTORY OF SUSPENSION SYSTEM

The first suspension system was designed for the light chariots of Ramses 2 around the year of 1296 B.C. But this suspension system was very bad due to its unstable condition. Although, the Greeks have discovered many new principles in order to solve this problem, they were unable to find the best solution for good suspension system. At that time, one suspension system has been found that was really comfortable for driving Power and suspension. However, there were problems for that design in which it reduces the speeds and the rapid wear of the component and need to be changed frequently. By that time, the history witnessed a rapid evolution of suspension system design with several problems have been discovered and identified.

A new suspension system design was found by William brush at 1906, after his brother had a car accident at unpaved road with the speed of 30 mph. The impression is that the car's right wheel started shimmy violently and the entire car vibrated furiously. Brush has designed a suspension system for the brush two-seat runabout car model. The feature of the model was different with front coil springs and devices at each wheel that dampened spring bounce (shock absorber) mounted on a flexible hickory axle. After 25 years, the independent coil spring front suspension then has been introduced. Most of the car was introduced with the coil spring front suspension sprung independently and started using hydraulic shock absorbers and balloon (low pressure Tire). However after several years, manufactures have switched back and forth from model to model between leaf and coil spring. Most of them equipped the leaf spring for a heavy car while the coil spring for a light car. Some European car makers had tried coil springs, with gottliebDaimler in Germany being the leading exponent. However, most manufacturers stood fast with leaf springs. They were less costly, and by simply adding leaves or changing the shape from full elliptic to three-quarter or half elliptic, the spring could be made to support varying weights.

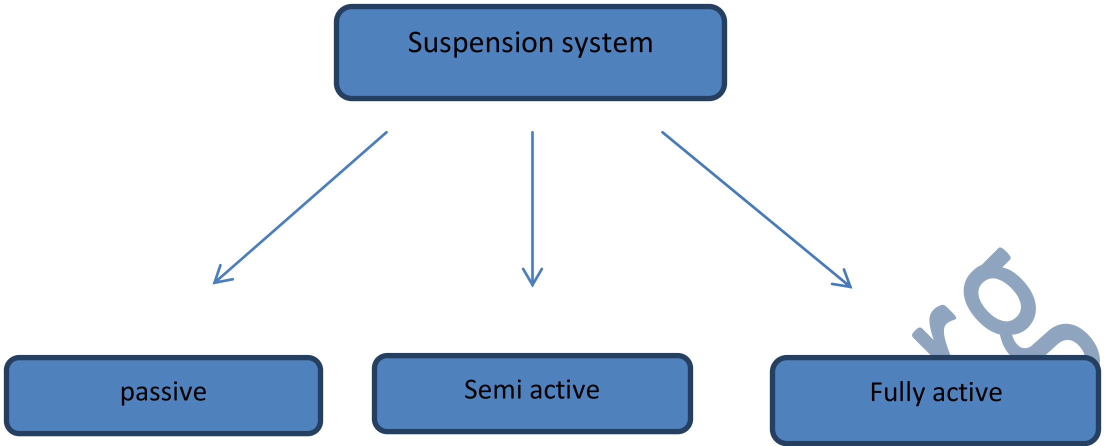


Fig.3.1 Types of suspension system

3.2 <u>PASSIVE/CONVENTIONAL SUSPENSION SYSTEM</u>

Conventional suspension system is also known as a passive suspension system consistingof spring and damper mounted at each wheels of the vehicle in parallel. The function ofspring in vehicle suspension is to support the vehicle body and at the same time it is used to absorb and store the energy. The damper or shock absorber is a component of the vehicle suspension used to dissipate the vibration energy stored in the spring and controlthe input from the road that is transmitted to the vehicle. Other purposes of suspensionsystem are to isolate sprung mass fromtheunsprung mass vibration, to providedirectional stability during cornering and to manoeuvre and provide damping for the highfrequency vibration induced fire excitations.

Different types of passive suspension systems

- Leaf spring
- Torsion beams
- Rubber bushing
- Air spring
- Coil spring

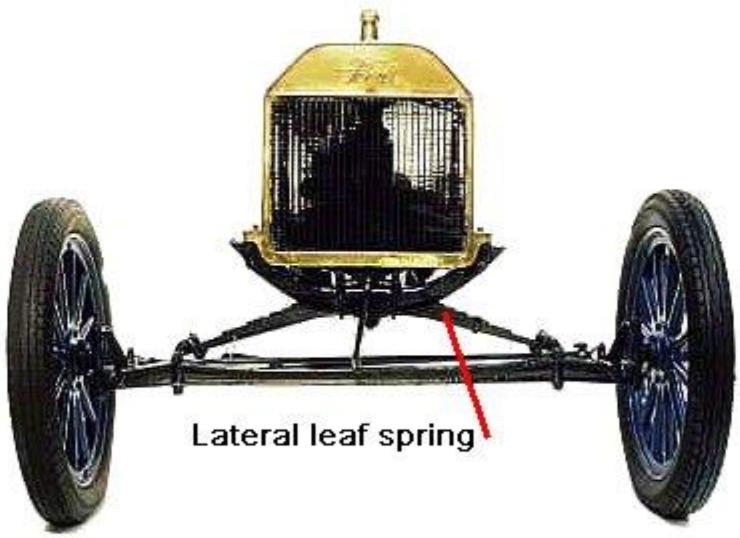


Fig.3.2Model T Ford leaf spring

3.2.1<u>DAMPERS OR SHOCK ABSORBERS</u>

The shock absorbers damp out the resonant motions of a vehicle up and down on its springs. They also must damp out much of the wheel bounce when the unsprungweight of a wheel, hub, axle and sometimes brakes and differential bounces up and down on the springiness of a tire.

3.2.2 <u>AIR SPRING</u>

Air springs combine spring and shock absorbing action in one unit and was often used without metal springs. The first one was developed by Cowey Motor Works of Great Britain in 1909. It was a cylinder that could be filled with air from a bicycle pump through a valve in the upper part of the housing. The lower half of the cylinder contained a diaphragm made of rubber and cords which, because it was surrounded by air, acted like a pneumatic tire. Its main problem was that it often lost air.

The newest air spring, developed by Goodyear, is found on some late-model Lincolns. Like the ones that have preceded them, these ride-on-air units are more costly than conventional springs and hydraulic shock absorbers.

3.2.3AIR SUSPENSION

Air suspension, which Lincoln ballyhooed for some models in 1984, was introduced in 1909 by the Cowey Motor Works of Great Britain. It did not work well because it leaked.

Fig.3.3Stout-Scarab (WilliamBushnell scout**)**

The first practical air suspension was developed by Firestone in 1933 for an experimental car called the Stout-Scarab. This was a rear-engine vehicle that used four rubberized bellows in place of conventional springs. Air was supplied by small compressors attached to each bellow. The first automobile to use torsion bar suspension was the 1921 Leyland. Most of the credit for the wide acceptance of torsion bars in Europe goes to Dr. Ferdinand Porsche who made it standard on most of his cars, beginning with the 1933 Volkswagen prototypes. By 1954, 21 makes of European cars were equipped with torsion bars.

3.3 ADVANCED SUSPENSION SYSTEM

In order to increase the performance of ride handling and stability of the vehicle, a newsuspension system has been developed in which the system is controlled electronically.There are two categories of advanced suspension system namely semi-active and activesuspensions. In automotive industries, semi-active and active suspension systems areconsidered as new technologies that used to improve ride quality and handling of the vehicle.

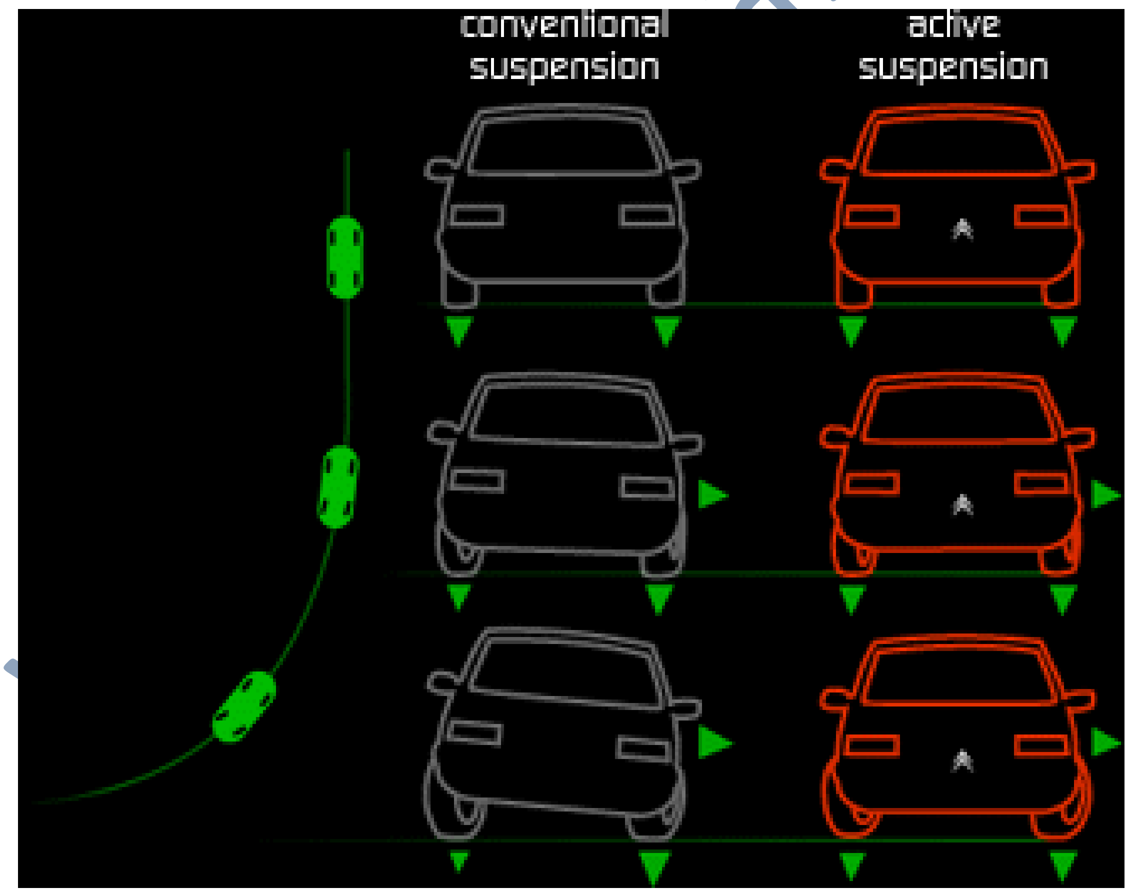


Fig.3.4 Roll-on in cars with and without active suspension

3.3.1SEMI ACTIVE SUSPENSION SYSTEM

Semi-active suspension system is quite similar with the conventional suspension system.This kind of suspension has a spring and controllable damper in which the spring elementis used to store the energy meanwhile the controllable damper is used to dissipate theenergy. Some of the semi-active suspension systems use the passive damper and thecontrollablespring, the controllable damper usually acts with limited capability toproduce a controlled force when dissipating energy.

Meanwhile in active system, the components of spring or damper are replaced with anactuator. An actuator is controlled by using the feedback from the vehicle body.Technically, active suspension system is used to control the movement of a vehicle usingon-board controller by controlling the tire movement during cornering, braking andaccelerating. The method of the controller for active suspension can be divided into fourtypes based upon the control techniques namely Solenoid Actuated, Hydraulic Actuated,Electromagnetic Recuperative and Magneto-rheological Damper.For semi-active with controllable damper, it acts like an actuator but with limitedcapability, to produce a controlled force when dissipating energy and when supplyingenergy it switches to a national zero damping state. The advantage of semi-active systemis the cost of operational is less than the other type of advanced suspension system.

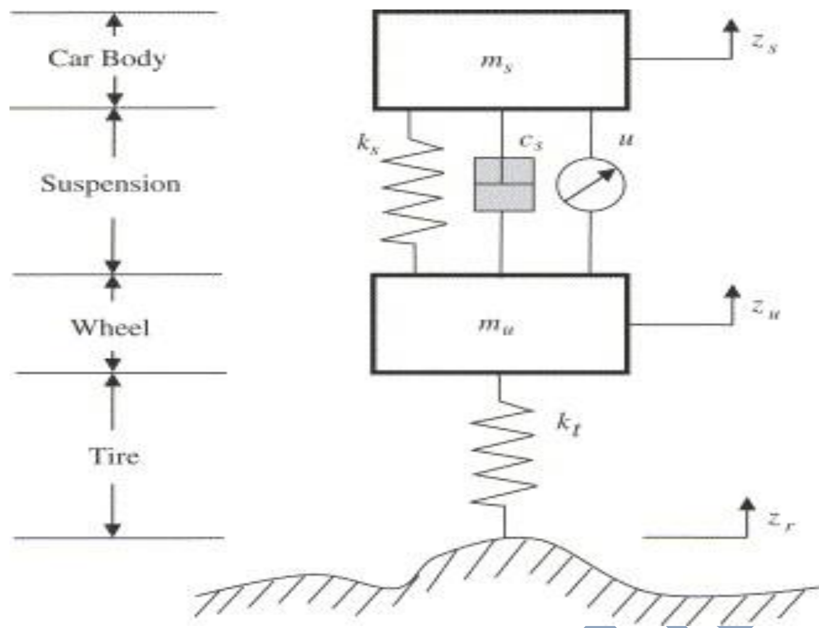
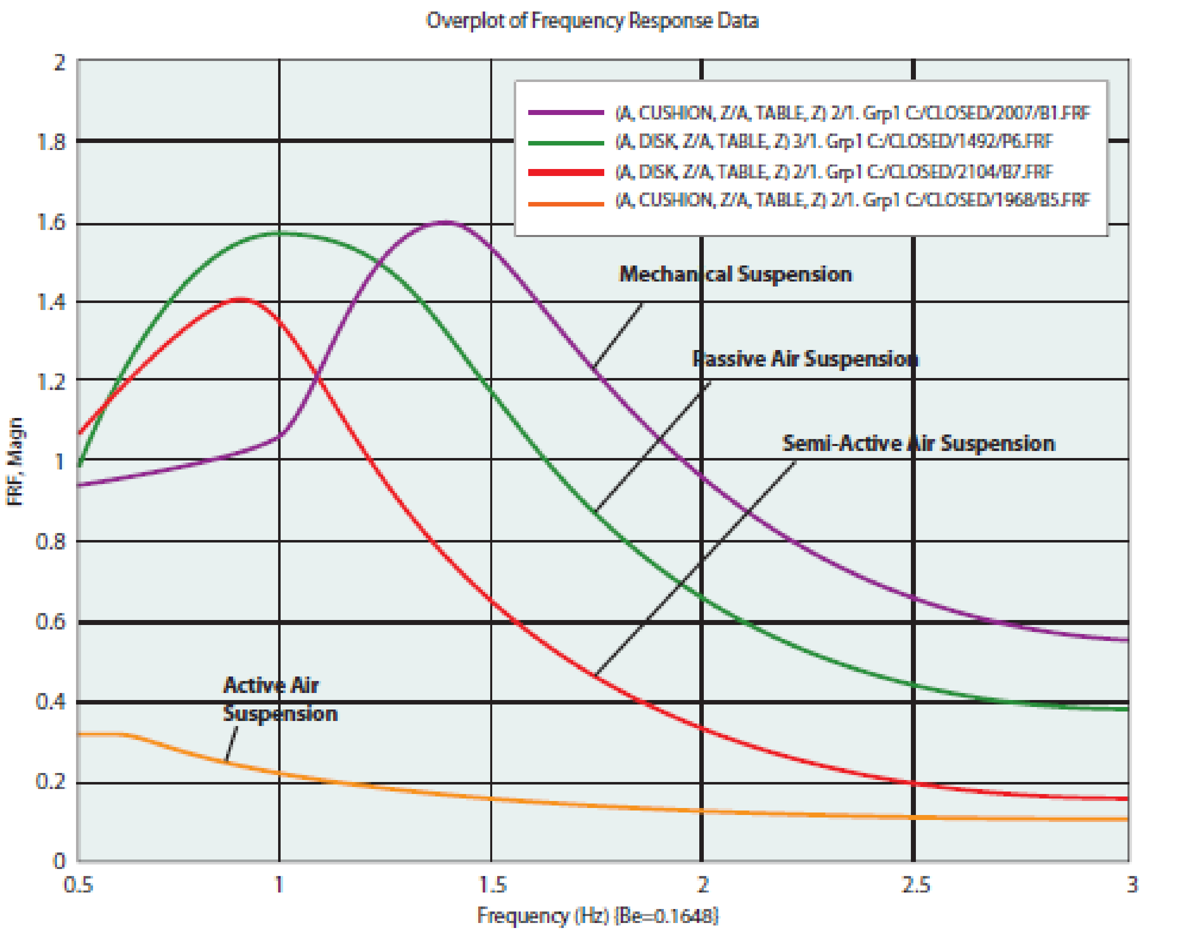


Fig.3.5 Semi active suspension system

3.3.2FULLY ACTIVE SUSPENSION SYSTEM

Active suspension system has the ability to response to the vertical changes in the road input. The damper or spring is interceding by the force actuator. This force actuator has its own task which is to add or dissipate energy from the system. The force actuator is control by various types of controller determine by the designer. The correct control strategy will give better compromise between comfort and vehicle stability. Therefore active suspension system offer better riding comfort and vehicle handling to the passengers. Figure shows simple diagram to explain how the active suspension can achieve better performance. Figure describes basic component of active suspension. In this type of suspension the controller can modify the system dynamics by activating the actuators.



Graph.1Comparisons b/w various suspension

CHAPTER-4

ACTIVE SUSPENSION SYSTEM

4.1 HISTORY

One of the earliest air suspensions was built in the 1800's. It was made up of goat skin bags with flapper valves. The valve would let air into the bag when the vehicle bounced in one direction and trap air in the bag when the axle tried to move in the opposite direction. This action provided a supply of air to the bag when the vehicle bounced up and cushioned the impact of the bump when the vehicle came back down. That application was for rail train passenger cars. Even then, air was recognized as vastly improving ride quality for vehicles, passengers and cargo.

Until the early 70's air suspensions were generally only applied to special vehicles requiring extra care for cargo. The cost and maintenance requirements restricted the use of air suspensions for many years. During the 70's and 80's, technology and the understanding of air suspensions improved greatly. From then until now, usage of air suspensions has increased on class 8 trucks and trailers to about 85% and 65% respectively. The use of air on passenger automobiles and on - off highway sports vehicles has also increased dramatically during this time period. Although the cost of an air suspension is still higher than steel or rubber suspensions, the value of the air suspension is recognized to provide an excellent return on investment. This value comes in the form of longer trailer life, decreased damage to equipment and cargo, and improved ride conditions.

4.2. OVERVIEW

The active air suspension system is an air-operated, microprocessor controlled suspension system.This system replaces the conventional coil spring suspension and provides automatic front and rear load levelling. The four air springs, made of rubber and plastic, support the vehicle load at the front and rear wheels.This technology allows car manufacturers to achieve a greater degree of ride quality and car handling by keeping the tires perpendicular to the road in corners, allowing better traction and control. An on-board computer detects body movement from sensors throughout the vehicle and, using data calculated by opportunecontrol techniques, controls theaction of the active and semi-active suspensions. The system virtually eliminates body roll and pitch variation in many driving situations including cornering, accelerating, and braking.Investigation of active suspension systems forcar models is recently increasing much becausecompared to passive and semi-active suspensionsystems, they offer better riding comfort to passengersof high-speed ground transportation. Numericaland experimental results showed that such activesuspension systems give relatively more satisfactoryperformance.Theactive control force is produced by a pneumatic actuator, inserting a device after the sensors to measure thetime responses of the acceleration, velocity anddisplacement of the car body.

An air suspension supports the vehicle on the axles with an arrangement of air bags instead of some type of steel spring, leaf or coil, or some type of torsion spring arrangement. The air bags are sometimes referred to as air springs or bellows. Suspensions that have steel or torsion springs that are supplemented by the use of air bags are not considered air suspensions. There are combination systems that have both air and steel springs. Usually the air suspension components are used on the rear of the vehicle, but for more comfort and better handling these are now incorporated in front.Depending on the situation, this type of air suspension will probably have to be dealt with for leveling purposes. Normally, the air suspension is just one part of the air system on the vehicle. Most (but not all) vehicle with an air suspension also has air brakes along with other equipment that may be operated with air.

4.3. <u>CLASSIFICATION OF ACTIVE AIR SUSPENSION</u>

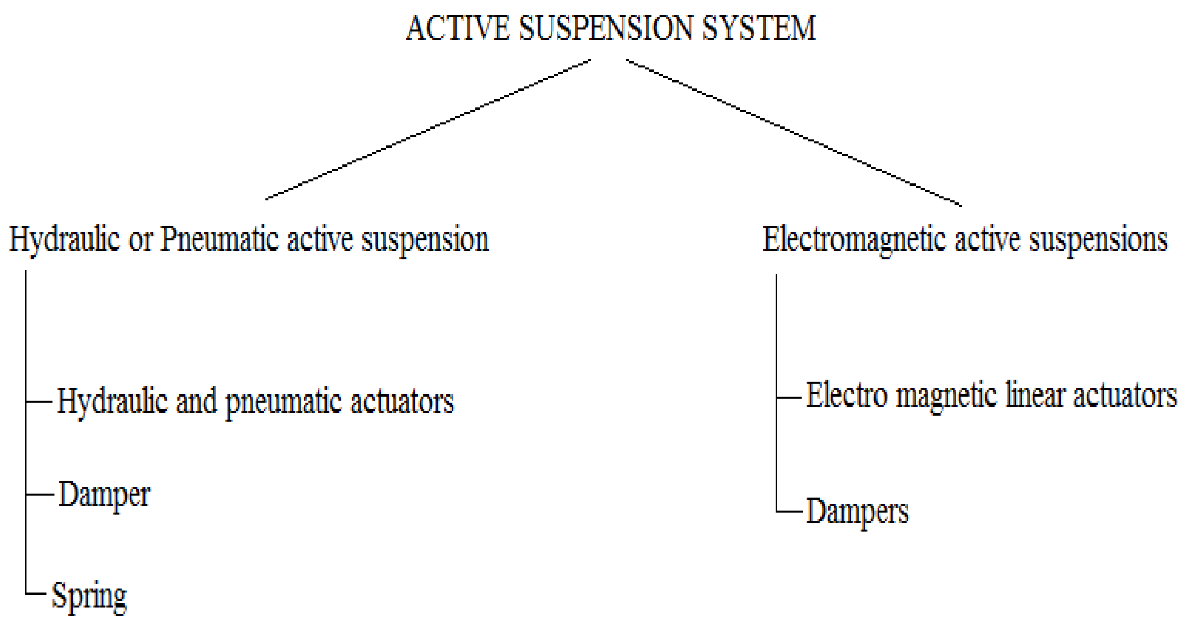


Fig.4.1 Classification of Active Suspensions

4.3.1 HYDRAULIC OR PNEUMATIC ACTIVE SUSPENSION

A hydraulic or pneumatic active suspension consists of a hydraulic or pneumatic actuator, a damper, and a mechanical spring. In general, the hydraulic or pneumatic active suspensions are suitable for low-bandwidth applications.

Hence, the typical quarter-car model of the hydraulic or pneumatic active suspensions has been illustrated in Fig. 4.2

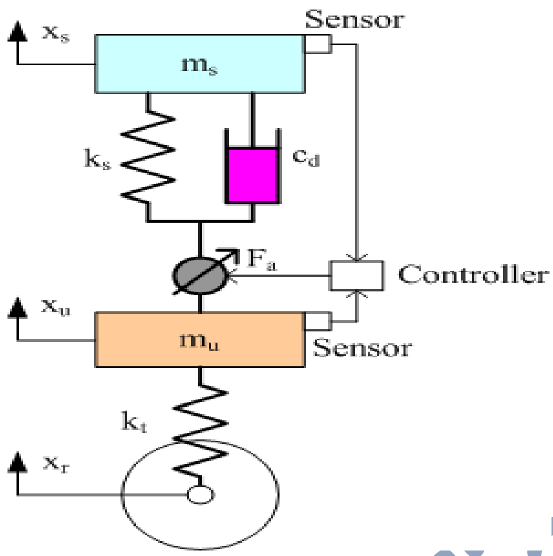


Fig.4.2Quarter-car model of a low-bandwidth active suspension

In a hydraulic or pneumatic active suspension, the hydraulic or pneumatic cylinder works under motoring as a hydraulic or pneumatic actuator. Fig. 4.3 shows the block diagram of the electronic controller of the hydraulic or pneumatic active suspension. The vehicle engine or the electric motor drives a hydraulic or pneumatic pump to supply the hydraulic or pneumatic energy to the hydraulic or pneumatic actuator involved in the hydraulic active suspension, which creates oscillation-damping forces between the vehicular sprung mass and the vehicular unsprung mass. The hydraulic or pneumatic valve is driven by the low-power electromagnetic actuator, which is controlled by the control unit with the electric converter, in order to regulate the force of the hydraulic or pneumatic actuator.

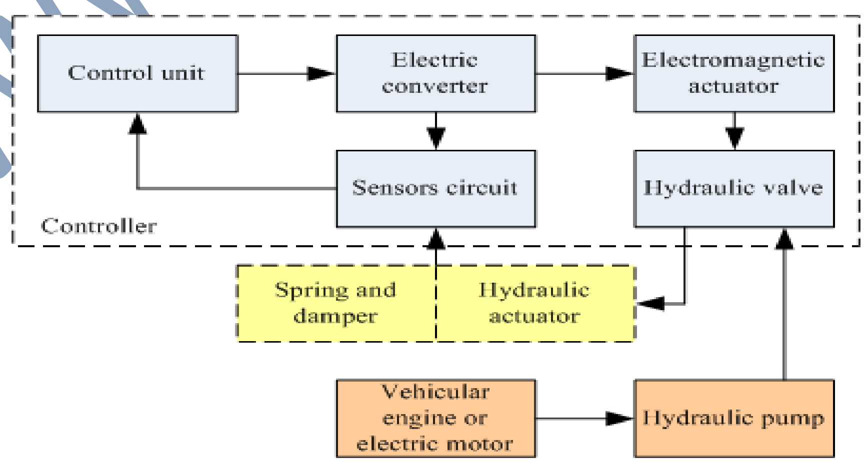


Fig.4.3 Block diagram of control for hydraulic active suspension

4.3.2ELECTROMAGNETIC ACTIVE SUSPENSIONS

In general, an electromagnetic active suspension iscomposed of an electromagnetic actuator and a mechanical damper. Both components work mechanically in parallel.The natural control flexibility of the electromagneticactuator results in the important improvement in thesuspensionbehaviour, because the active suspension canproduce the active control force to absorb road shocksrapidly, suppress the roll and pitch motions, and gives both safety and comfort.

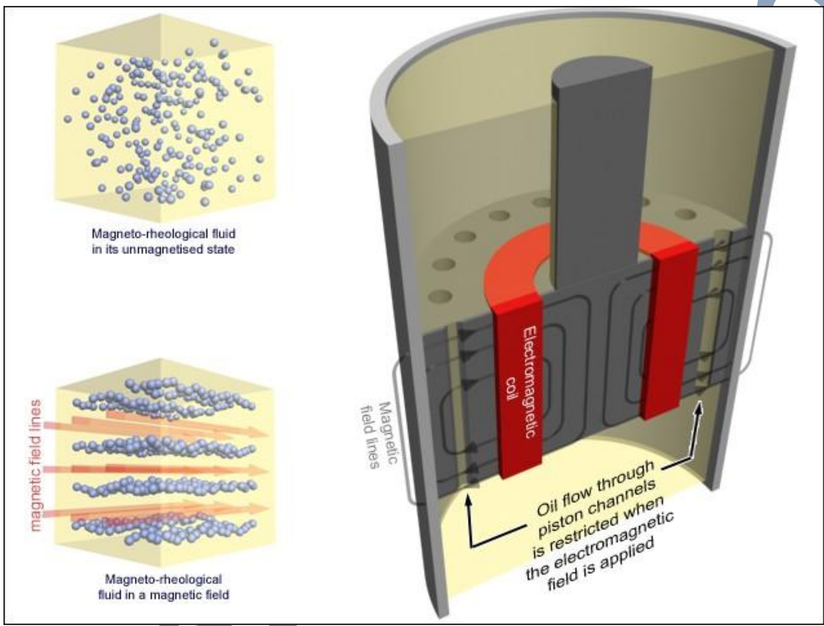


Fig.4.4 Electromagnetic Active Suspension

Furthermore, the otherpotential merit of the electromagnetic active suspensions isthat the electromagnetic actuator can work undergenerating. This characteristic allows energy recoveryfrom the suspension, when the actuator produces thedamping force. Thus, the vehicular energy consumption decreases. The mechanism required to make thisconversion results in considerable complications, whichinclude backlash and increased mass of the moving partdue to connecting transducers or gears that convert rotarymotion to linear motion. It should be noted that thesecomplications introduce an infinite inertia and therefore, aseries suspension is preferable as shown in Fig. (4.4).

It is more suited to a parallel suspension where the inertia of the electromagnetic linear actuator is minimized.The block diagram of the electronic controller of theelectromagnetic active suspensions is depicted in Fig.4.5.

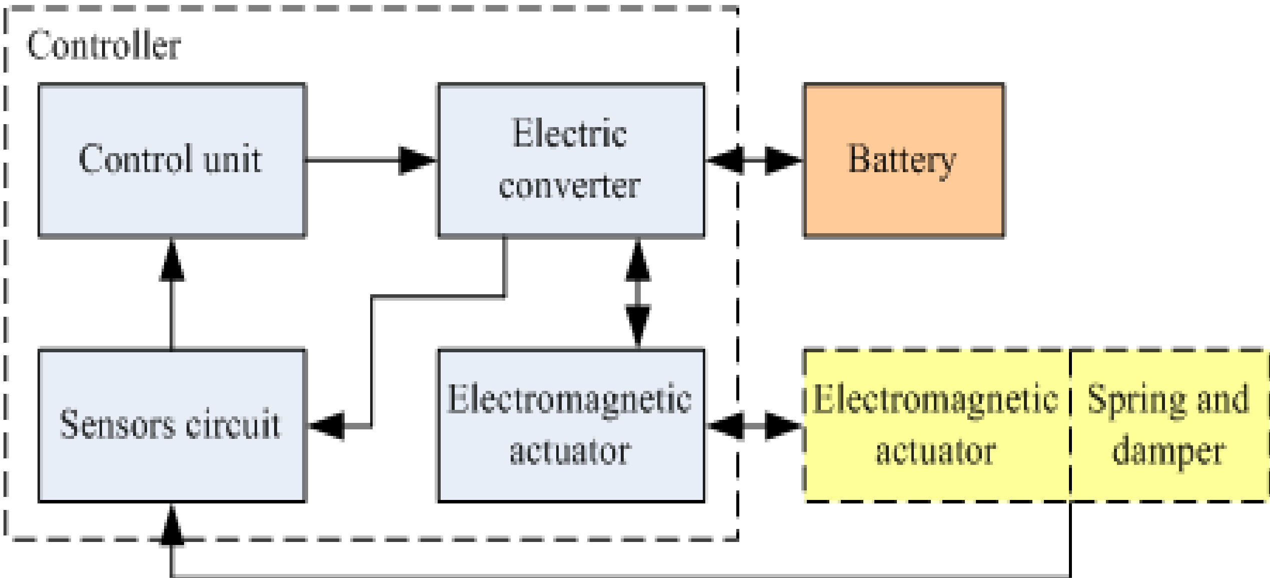


Fig.4.5 Block diagram of control for an electromagnetic active Suspension

The electromagnetic actuator is driven by the electricconverter and controlled by the control unit based on theacquired signals and the control algorithms. The actuatorpower is supplied by the battery, which can be fed by theelectric generator driven by the vehicular engine. Thus, thebattery now replaces the complex and expensive hydrauliccomponents. At the same time, the energy stored in theelectromagnetic active suspension can be fed back to thebattery via the electric converter if the electromagneticactuator works under generating.Theelectromagnetic active suspension presented in includes a permanent-magnet linear actuator, a damperand a mechanical spring, which work mechanically inparallel.

NOTE: We are making our project on active air suspensions .So further study will be based on active air suspensions.

What makes air suitable for this type of suspension system ?

Here are some reasons to say that air is suitable for this system. These are as follows:

- **Higher compressive strength.**
- **Higher load carrying capacity.**
- **Leak proof.**
- **Non-toxic etc.**

4.4BASIC COMPONENTS OF ACTIVE AIR SUSPENSIONS

An air suspension has three basic components. The **air supply**, the**height control valves**, the **air bags**and the **sensors**. In the following section, we will discuss several different arrangements of these components.

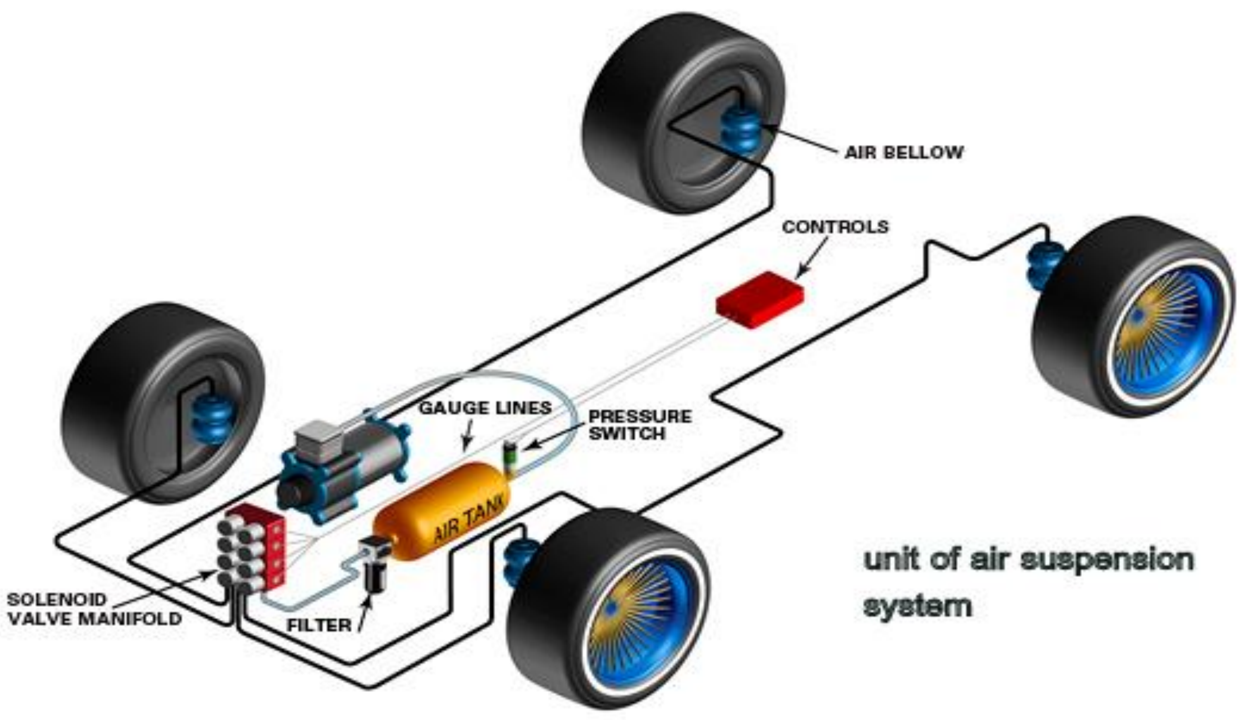


Figure.4.6 Components of air suspension

4.4.1 AIR SUPPLY

The air supply is engine air compressor, the air tanks, air valves and air lines. The engine air compressorsupplies air for every piece of air equipment on the vehicle. The maximum pressure supplied by the compressor varies. For many years, the air supply was maintained around 120 to 125 psi but on some newer, larger vehicles this has been increased to 135 psi. There will be dash gauges that will supply system pressure information but all vehicleshave what we refer to as a “pop off valve”. One can hear the valve “pop off” when the system reaches themaximum air pressure.

The air supply is maintained through an arrangement of air tanks. Air tank arrangement is one thing that varies greatly between different air systems. There can be as many as 10 to 12 different tanks. The terminology for these tanks varies greatly also. There are primary tanks, secondary tanks, wet tanks, auxiliary tanks, front brake tanks, rear brake tanks. The only purpose of air tanks is to store air for the different systems on the vehicle.

4.4.2 HEIGHT CONTROL VALVES

The height control valves (HCV) are kind of the brains of the system. They dictate how much air is in the air bags. This dictates the height the vehicle sits at, therefore they are known as Height Control Valve. Most HCVs are mechanical valves but electronic HCVs are available. The HCV is mounted to the frame of the vehicle.

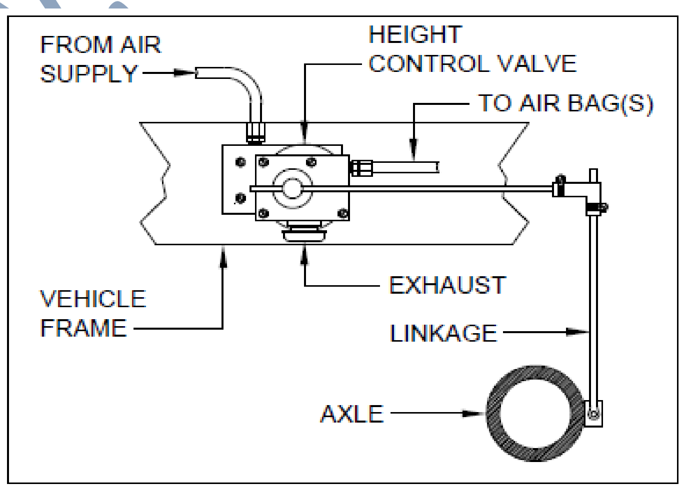


Figure.4.7 Height Control Valve

4.4.3 AIR BAGS

Air bags are simply a rubber bladder that holds air. Air bags are also referred to as air springs or bellows. The air bags are located between the frame of the vehicle and the vehicle axles. Air bags are rated for weight and pressure capacities. Air bag placement and arrangements vary amongst chassis manufacturers. At the very least, there will be one air bag for each side of each axle in the vehicle. There can be two air bags for each side of the axles but there is no system with more than one bag per side. Some manufacturers use two air bags for each side of the drive axle and some use two air bags for each side of the drive and front axles. Space between air bags for side to side placement also varies. Some place the air bags outboard as far as they can and some have the bags closer together. When two bags per side are used, one will be in front of the axle and the other behind the axle. Again, spacing can vary. Most air bags will have some device such as a cone that keeps the air bag from being crushed or damaged when fully deflated. Inflating air bags is limited to the available air pressure to the suspension system. This is why the relief setting of the engine air compressor should not be changed.

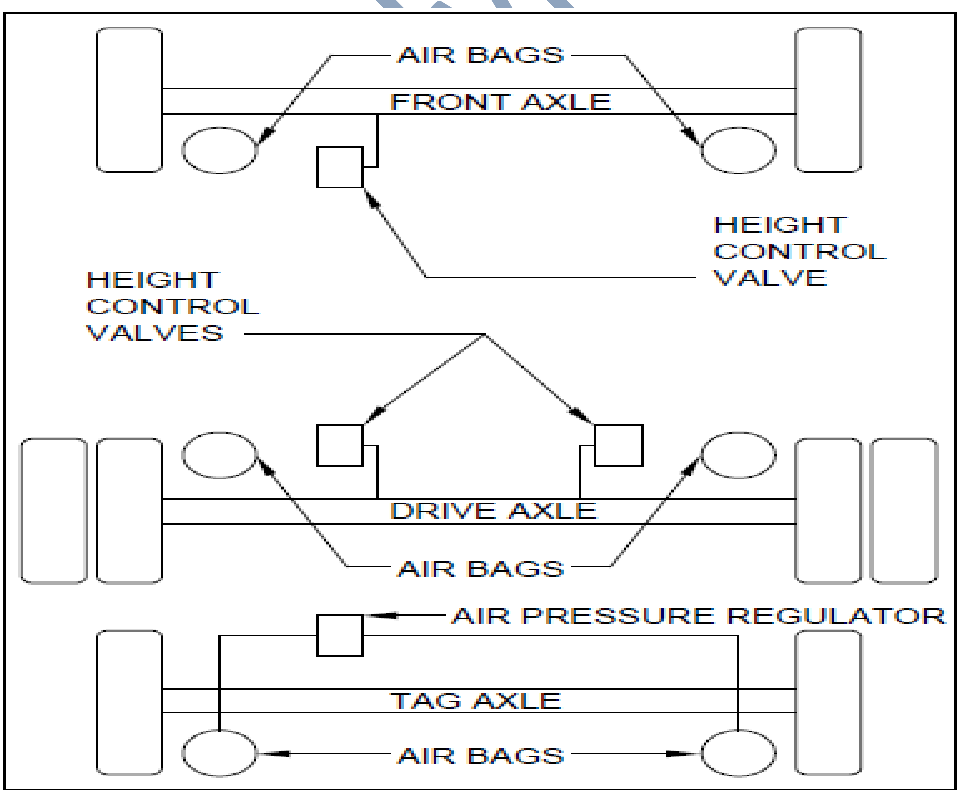


Figure.4.8 Basic diagram showing different components of active Air system

4.4.4 SENSORS

In active suspension systems, sensors are used to measure the accelerations of sprung mass and unsprung mass and the analog signals from the sensors are sent to a controller. The controller is designed to take necessary actions to improve the performance abilities already set. The controller amplifies the signals which are fed to the actuator to generate the required forces to form closed loop system (active suspension system) Fig.4.9

Some types of sensors used in active suspension system are as follows:

- Position sensor (LVDT position sensors)
- Height sensor
- Air bags pressure sensor
- Bumps sensor

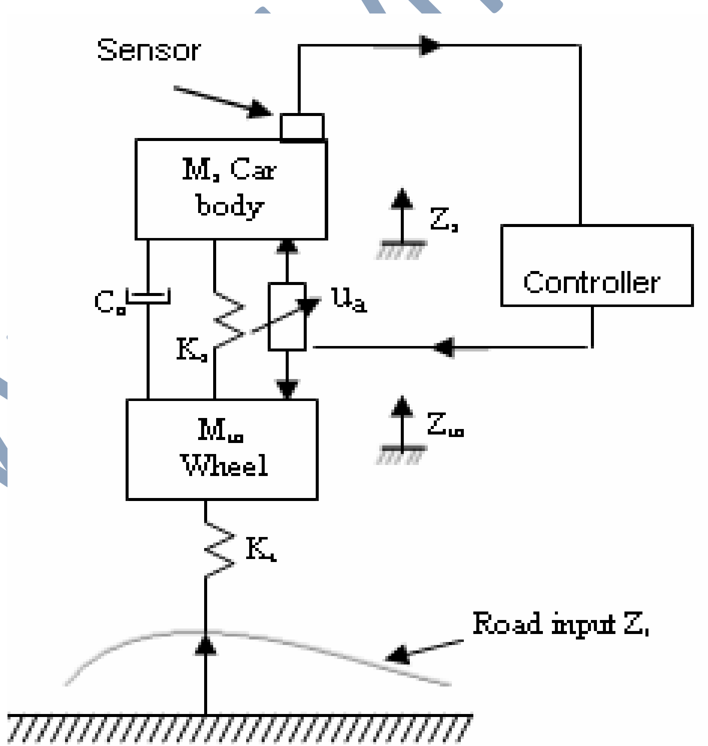


Fig.4.9 Active suspension system

4.5LAYOUT AND WORKING OF ACTIVE SUSPENSION SYSTEM

Active air suspension system consists of an air tank, 4-way air valve assembly (pressure solenoids), air compressors, the necessary pressure sensors, all wiring and air fittings, and an in-car electronic control module. In order to understand the working of active air suspension system, we need to understand functions of each component. Using the diagram below, we can find an incar input of whether to raise or lower the car through the entire system. From the cabin of the vehicle, using the control module, an air pressure is selected for each corner. Once a pressure has been chosen, the signal travels to the computer, which sends the request to the pressure solenoids. The solenoids then either send air to the air springs to inflate them or bleed pressure from the air springs to deflate them. The air compressors are used to fill the air tank, which feeds air to the pressure solenoids. In order for the in-car control module to know the pressure in each air spring, pressure sensors are used in conjunction with the pressure solenoids. In other words, the in-car control module represents the gauge faces while the sensors are the gauges themselves. While the arrangement of componentsthere is a need of attention to cutting the airlines straight and making sure to run the lines away from anything potentially harmful.

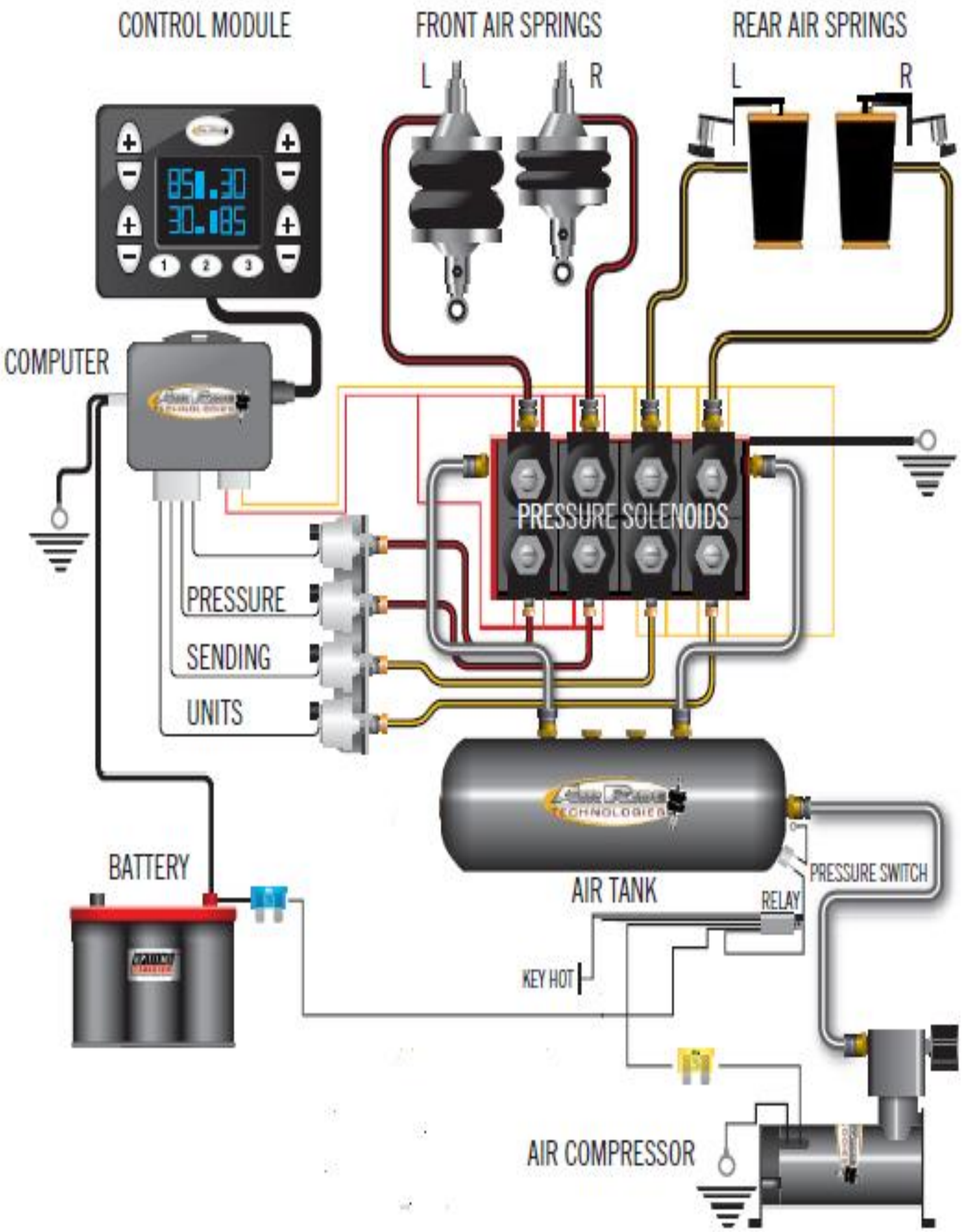


Fig.4.10 Arrangement of active air suspension system

4.5.1 **WORKING:**

The working of this system can be explained in following steps:

1) The vehicle air system, engine air compressor, tanks, lines, etc., supplies air to the height controlvalves (HCV) mounted to the frame of the vehicle.
2) The height control valves are connected to the air bagswith an air line. The linkage which connects the HCVs to the axles rotates the HCV as it moves upand down.
3) When weight is added to the vehicle or transferred through the suspension of the vehicle, the air in the air bag(s) is compressed, the frame moves closer to the axle. This forces the HCV linkage up. As the linkage moves up, the valving of the HCV connects the air supply to the air bag(s). The added pressure and volume inflates the air bag(s), causing the frame to move away from the axle. As the frame moves back to the proper ride height, the HCV linkage moves to the neutral position. This moves the valving away from the air supply and locks the air in the air bag to maintain the proper ride height.
4) As weight is removed from the vehicle or the suspension shifts weight away, the existing pressure in the air bag(s) can push the frame away from the axle. The HCV linkage is pulled down. This connects the air bag(s) to the HCV exhaust port. As air is exhausted from the air bag(s), the frame lowers back down towards the axle. As the linkage moves up to the neutral position, the exhaust port is closed and the air is again locked in the air bag(s), maintaining proper ride height. These three drawings show a schematic example of the height control valve in the neutral position, inflate position and deflate or exhaust position.

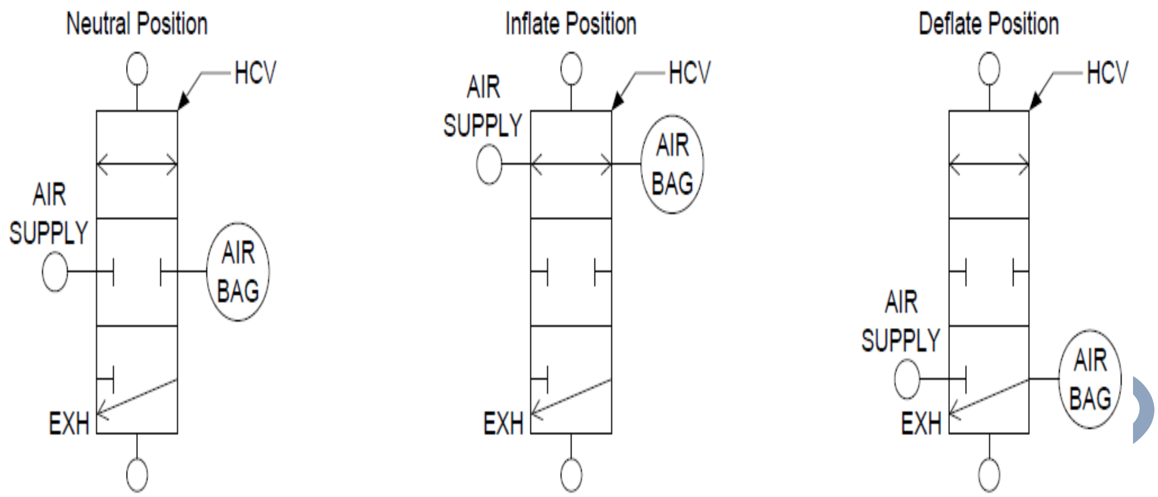


Figure.4.11 Basic working of Active Suspensions

4.5.2 <u>SPECIFICATION OF COMPONENTS :</u>

1. <u>AIR-SPRING</u>

Air spring, load-carrying component of an air suspension system used on machines &automobiles.A system used on buses consists of an air compressor, an air-supply tank, leveling valves, check valves, bellows, and connecting piping. Basically, an air-spring bellows is a column of air confined within a rubber and fabric container that looks like an automobile tire or two or three tires stacked on top of one another. The check valves admit additional air to the bellows from the air-supply tank to maintain vehicle height when the load is increased, and the leveling valves vent excess air from the bellows when the vehicle rises because of unloading. The vehicle thus remains at a fixed height regardless of load. Although an air spring is flexible under normal loads, it becomes progressively stiffer when compressed under an increased load.

Three basic types of air springsare available: the double-convoluted, the tapered-sleeve,and the rolling-sleeve. Thedouble-convoluted design looks like a large double cheese-burger and generally has moreload capacity, a shorter stroke,and a more progressive springrate that’s best suited for use onmost front suspensions wherethe spring sits considerablyinboard of the suspension’sload point. Tapered-and rolling-sleeve air springsare smaller in diameter with alonger stroke and a more linearspring rate; they're best suitedfor most rear end applicationsbecause there are more travelrequirements and fewer load-capacity requirements.

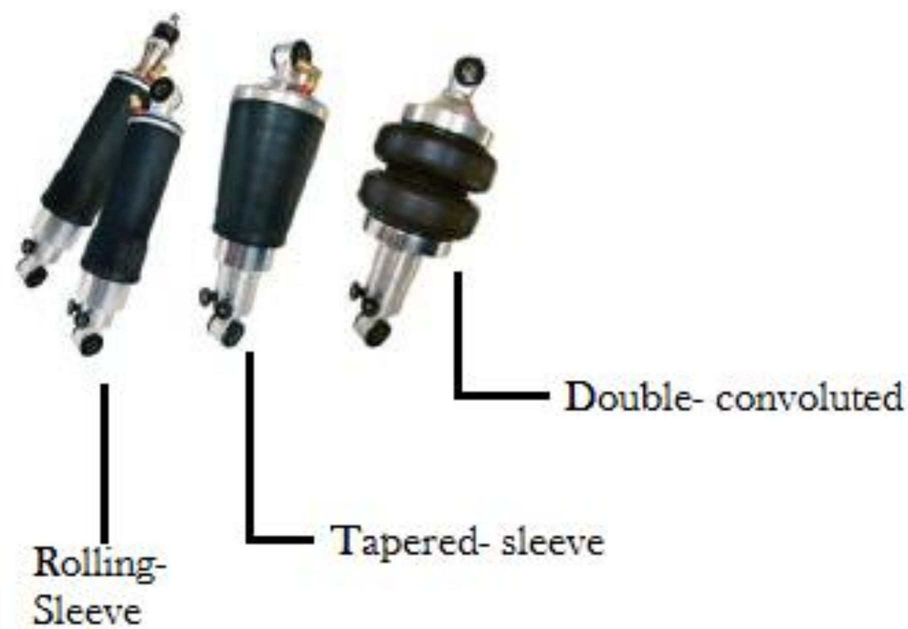


Fig.4.12 Air Springs

2. FRONT SUSPENSION

As air suspensions evolved, ahigher-end installation wasdeveloped based on coilovershock/spring combos but withan airbag replacing thecoilover's coil spring, thesesetups tend to be more expensive but offer the advantage ofeasier installation, better looks and more wheel-and-tire clearance.

For front suspension system, double-convoluted air bags are used as it is having greater load carrying capacity. The front springs are connected with the pressure solenoids controlled by the pressure sensors in order to avoid the bump by supplying the suitable amount of air in the air bags.

3. REAR SUSPENSION

In Rear suspension system, tapered sleeve or rolling sleeve air springs are generally used which are connected with the pressure solenoids. Removing several leavesfrom each spring pack andinstall air springs between theaxle housing and the vehicleframe. Residual leaves are still needed to locate the rear axle but airbags now perform theprimary load-bearing function.

4. COMPRESSORS

A compressor and reservoir tank allow quick in-vehicle altitude adjustments. Airsprings can be inflated using compressed air just like an oldair shock, but that obviates oneof the main benefits of this typeof suspension: in-use adjustability to compensate for changing road conditions, vehicleloads, or intended use.

Fig.4.13 Compressor with reservoir tank

Realizing full benefits fromthe adjustability offered by air springs really requires an on-board air source. With air suspension, ride-quality tuning isaccomplishedincrementally,with very small air-pressurechanges. Air springs have relatively low volume, so it is difficult to inflate or deflate themwith external air in smallenough increments to fine-tuneride quality.

An on-board air system consists of at least one air compressor, a storage tank and control system. A cost-effective and relativelysimple solution that providesreasonable ride and handlingbenefits would be a 2-gallontank kept full by a single compressor. On the other hand, ifthe car has to go up anddown in two seconds; on aheavy car it could take as muchas a pair of 150-psi compressorsand two or more 5-gallontanks, huge industrial air valves,and 3⁄4-inch feeder lines.

5. AIR LINES

Plastic air lines originally developed for big trucks are standard which provides aneasy, affordable solution to connecting the compressors to theair springs. Typical operatingpressures range from about 75to 150 psi, well within the capabilities of such tubing.

Stainless hard line can be used, justas in a brake or fuel system, connecting it using typical a flare nuts and pipe adapters. Atsuspension travel points, flexible hose would be needed in another wise hard-lined system,just as it is in a brake system.Also like in a brake system,braided stainless steel Teflon-core hose is preferred overbraided synthetic rubber-core fuel/oil-line hose.

4.5.3 CONTROL SYSTEM

Manual setups typically use pneumatic valves mounted to a panel with a pressure gauge. A more sophisticated approach with less under dash clutter is to use electric solenoids controlled by a switch or computer. The last 3-4 years have seen the introduction of various aftermarket active electronic height-control systems that attempt to maintain a set ride height as the vehicle drives down the road. An electronic height-control system adds a computer plus sensors to control the electric solenoids. Both pressure-based and ride-height-based electronic control systems are available.

Following are the types of systems used:

1. PRESSURE-BASED SYSTEMS

With pressure-based electronic-control systems, the computer must rely on air pressure alone to assume proper air-spring position which should then theoreticallytranslate into the position ofthe suspension, which shouldthen (again, theoretically) translate into the ride height of the vehicle. It may work fine on avehicle that seldom sees loadchanges and is reasonably wellbalanced, for many vehicles, there's a major drawback when any change occurs to theload an air spring sees, theassumption that any given airpressure will equate to a specific ride height may no longer be valid. Many transients can cause a load change actualweight change via the additionor subtraction of passengers,luggage, or fuel; the vehicle sitting on an inclineor pothole or even general suspension-geometry or suspension-bind factors that end uprequiring more air pressure toraise the vehicle than they do tomaintain a specific ride height.

Active pressure-based systems may not react properlygoing through a long, sweeping. Under such conditions, an active pressure-based system attempts todeflate the outside (loaded) airspring and inflate the inside (unloaded) spring, magnifyingbody roll and handling problems just like the old two-waysystem.

2. RIDE-HEIGHT-BASED SYSTEMS

Ride-height–based systems utilize separate sensors that directly measure the actualposition of the vehicle's suspension, thereby eliminating several assumptions made on apurely pressure-based systembecause now precise information on the relationship between the suspension and the chassis is availableto help the computer determine the vehicle's ride height.But there's still one problemknown as cross-loading. Thishappens when the ride height isachieved with radically different air pressures on each corner. Normally, any side-to-sideair-pressure variations shouldbe held to 20 percent or less; yetit is possible to fool a pure ride-height–based system by overinflating two diagonal cornerswhile leaving the opposing corners significantly underinflated.The computer keeps the carlevel, but the handling characteristics are not appropriate.

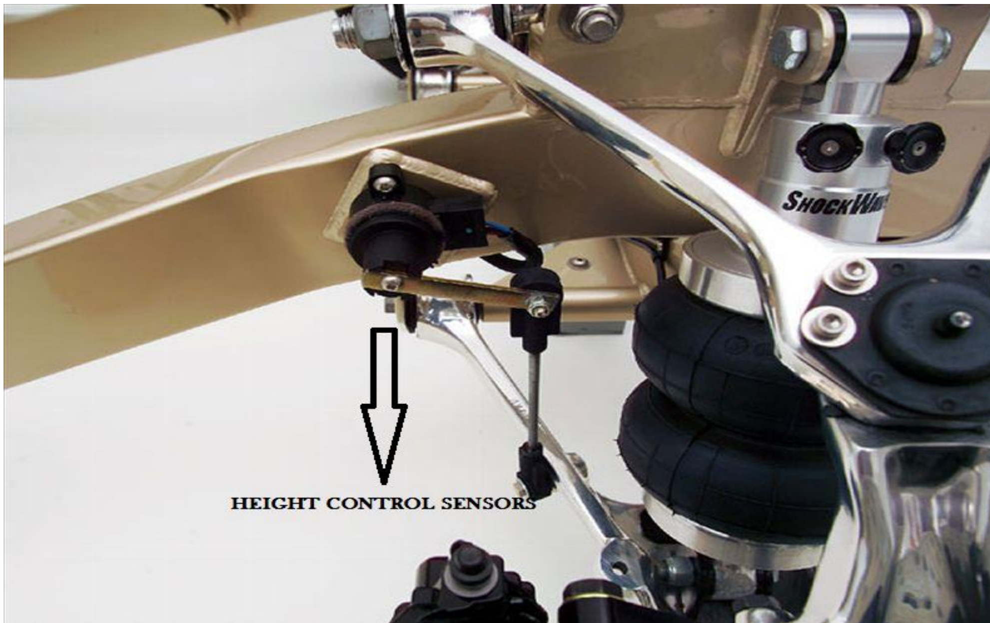


Fig.4.14 Height Control Sensor

3. COMBO SYSTEMS

The solution is to combine pressure-based and ride-height–based leveling in thesame system. Each serves as acheck on the other. This is whatAir Ride Technologies has donein its new LevelPro system. Tosave money initially, the setupcan first be configured as apressure-based system only,and the ride-height sensors canbe added later, if needed. Level-Pro systems also include theability to program three different suspension heights into thecomputer—low (for profiling),normal (for touring and racing), and high (for clearing obstacles like speed bumps).Simply punch a button, and thecar raises or lowers to a presetlevel yet can still compensate ateach preset for changes in fuelload, passengers, or cargo.

4.6COMPARISONS

From the aforesaid description and discussion, the disadvantages and advantages of various automotive suspensions can be summarized as follows.

1. Passive Suspensions

Because a passive suspension consists of a damper and a spring, the passive suspension has the following advantages:

a) Simple and firm structure,
b) Small volume,
c) Low weight,
d) Low cost, and
e) High reliability.

The disadvantages of passive suspensions are as follows:

a) The damping characteristics affects both ride comfort and handling performance, and hence passive suspensions are difficult to accomplish ride comfort and good handling performance simultaneously; &
b) When the vibration frequency of the suspension is below 0.7Hz, passengers are easily carsick, and it probably leads to mechanical resonance in the vehicle body.

2. Semi-active Suspensions

In comparison with passive suspensions, semi-active suspensions improve damping characteristics under closed-loop control. Hence, roll and pitch motions of the car body are suppressed considerably. In addition, semi-active suspensions have the advantages of easy control, small volume, low weight, and adequate cost. The disadvantages are that roll and pitch motions cannot be eliminated fully.

3. Hydraulic or Pneumatic Active Suspensions

The advantages of hydraulic or pneumatic active suspensions can be summarized as:

a) High force density,
b) Active force control,
c) Effective elimination of roll motions,
d) Commercial availability of the various parts, and
e) Commercial maturity.

The disadvantages can be described as

a) low-bandwidth due to high system time constant,
b) Environmental pollution due to hose leaks and ruptures, where hydraulic fluids are toxic,
c) No energy regeneration due to irreversible actuator,
d) Complex structure, and
e) High cost.

4.Electromagnetic Active Suspensions

Because electromagnetic active suspensions can producethe active forces under various situations of load, velocity,drive and road, an active suspension system keeps good ride quality and handling performance in all workingconditions.

In comparison with hydraulic activesuspensions, in addition, electromagnetic activesuspensions have the following advantages:

a) Improved dynamic behaviour;
b) Improved stability;
c) Accurate force control;
d) Energy regeneration due to reversibleoperation of the electromagnetic actuator;
e) Highbandwidth operation;
f) Oil-free system;
g) Flexible control; and
h) Simple structure

The disadvantagesinclude increased volume and weight in comparison withhydraulic active suspensions.

Table I: Comparisons between various automotive suspensions

Parameters	Passive suspensions	Semi-active suspensions	Hydraulic or pneumatic active suspensions	Electromagnetic active suspensions
Structure	Simplest	Complex	Most complex	Simple
Weight or volume	Lowest	Low	High	Highest
Cost	Lowest	Low	Highest	High
Ride comfort	Bad	Medium	Good	Best
Handling performance	Bad	Medium	Good	Best
Reliability	Highest	High	Medium	High
Dynamic performance	Passive	Passive	Medium	Good
Energy regeneration	No	No	No	Yes
Commercial maturity	Yes	Yes	Yes	No

4.7**INSTALLATION**

Air-suspension systems address all the issues ofair-spring installed height,shock installed height, ball-joint travel, driveline angles, ground clearance, tire clearance, and other parameters thatmust be considered whenbuilding a safe, functional system.

Fundamentally, it's no different fromengineering traditional suspension, except air springs replacemetallic springs. It may actuallybe easier because air springshave a greater operating envelope in terms of ride height andload capability than traditionalmetallicsprings.It is important tomatch the air spring to thevehicle's weight capacity andsuspensiontravel.

Identical springs and shocksmay not always yield identical results in two different applications, even if the weight andinstalledheight are similar. As mentioned earlier, on a frontsuspension, the spring-mountlocation on the control armexerts a leverage effect, multiplying the theoretical springrate as seen at the wheel. Justlike an engine rocker arm, increasing the distance of themount from the arm's pivotpoint (moving it closer to theball joint) yields a higher ratio,which multiplies the springrate. Increasing the angle of theshock also requires more springto maintain an equivalent rideheight.

Once the air spring has beenselected, it must be mounted inthe vehicle. Every air spring hasan optimum design ride heightwhere it delivers maximumperformance. This spring-height dimension should be synchronizedwith the intended ride height todetermine how to mount theair spring in the car. Themounting point must alsoallow for sufficient suspensiontravel, tire clearance, groundclearance, and appropriate driveline angles. Maintain adequate clearance between the airspring and other components—abrasion is death tothese otherwise very durableunits.
A variety of premade universal brackets are used thatmounts like a coilover shock and areeasier to install with proper geometry than separatelymounting a conventional separate air spring and shockabsorber.

The vehicle should bemocked up at its intendedhighway ride height. At thispoint, you should maintain atleast 41⁄2 inches of ground clearance and have adequate suspension travel—at least 3inches in compression and 2inches in rebound. Be sure theair spring's end plates arealigned and parallel at rideheight.

Double-convolutedair springs don't require abump stop to avoid damage; however, specific application may need a bump stop tomaintain safe ground clearancewhen deflated. For tapered-orrolling-sleeve air springs, abump stop and an extensionstrap (either a limiting strap ora shock absorber) must be usedto prevent the air spring fromexceeding its design compressed or extended dimensions or the spring will fail.Finally, set wheel alignment atthe car's normal running ride height, understanding that itwill change slightly when thesuspensionis in the raised or loweredposition.

CHAPTER -5

FABRICATION OF ACTIVE AIR SUSPENSION SYSTEM

5.1FRAME CONSTRUCTION:

Firstly we considered PVC pipes but because of its mechanical properties like tensile strength (51.37 MN/m^2) and compressive strength (66.19 MN/m^2) was not suitable to bear high load. So, we decided to make a frame using iron as its material which can bear a load of approx. 50-60 kg.

Material Used: Grey Cast Iron (Fe) (ORDINARY)

The composition of cast iron (CI) varies significantly depending upon the grade of pig iron usedin its manufacture. CI containscarbon in the range of ~2 to 4 wt. %.Themode and concentration of carbon in theCI is controlled to produce various gradesof CI, which differ significantly in theirmechanical properties and weldability.

Grey CI is named for its grey fractured surface, which occurs because the graphitic flakes deflect a passing crack and initiate countless new cracks as the material breaks. The graphite flakes, which are rosettes in three dimensions, have a low density and hence compensate for the freezing contraction, thus giving good castings that are free from porosity. The flakes of graphite have good damping characteristics and good machinability because the graphite acts as a chip breaker and lubricates the cutting tools.

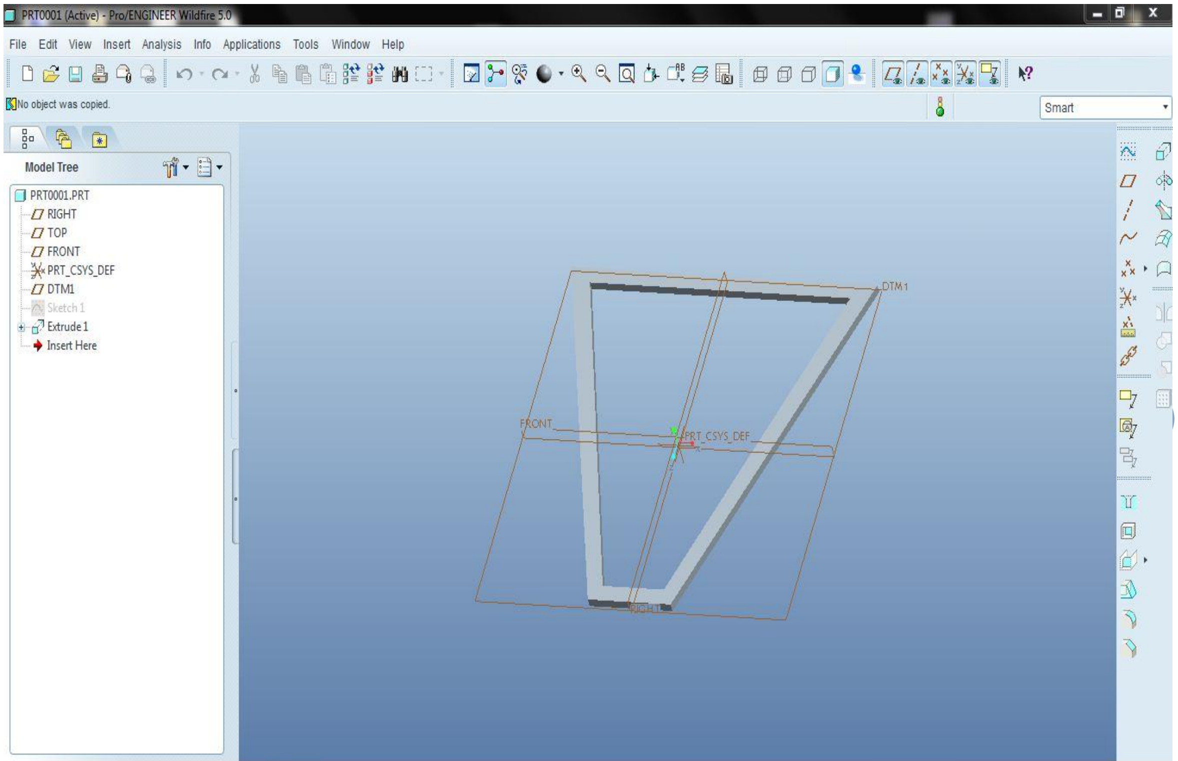


Fig.5.1.1 Design of Frame in PRO-E

Fig 5.1.2 Frame

5.2BUSHES AND IRON RODS

To make the suspension system independent, we have used the bush and rod assembly with A-arm for the front suspension. (Fig. 5.2.3)

Bush Inner Diameter : 2 cm

Bush Outer Diameter : 2.2 cm

Iron Rod Diameter : 1.5 cm

Fig.5.2.1 (Bush & rod assembly used for front wheels)Fig.5.2.2(Bush &rod assembly used for rear wheel)

Fig. 5.2.3 (A-arm used for front suspension)

5.3 AIR BELLOWS:

Air bags are simply a rubber bladder that holds air. Air bags are also referred to as air springs or bellows. The air bags are located between the frame of the vehicle and the vehicle axles. Air bags are rated for weight and pressure capacities. At the very least, there will be one air bag for each side of each axle in the vehicle.

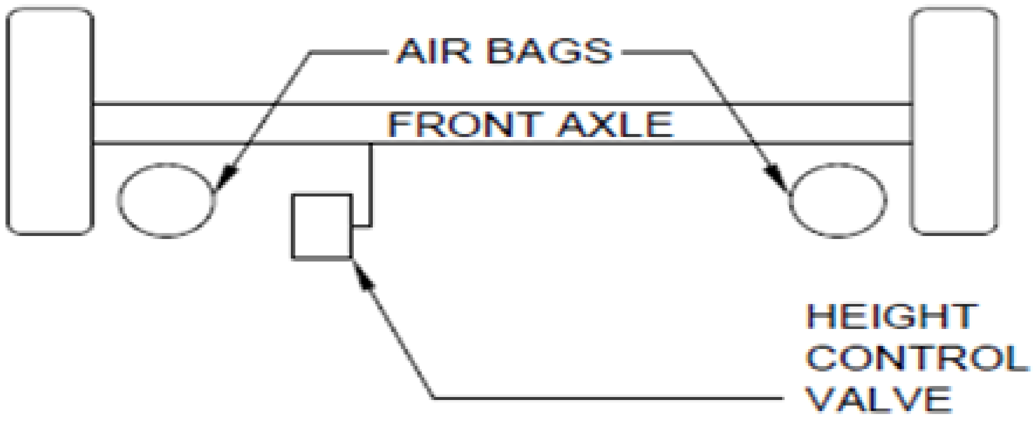


Fig. 5.3.1Arrangement of Air Bellows

We have used scooter tyre tube for making Air Bellows which is made up of rubber. End plates were used for covering these Air Bellows which are made up of steel. In order to make the bellows air tight and in a regular shape, we have used plywood of circular section at both the ends followed by end plates.

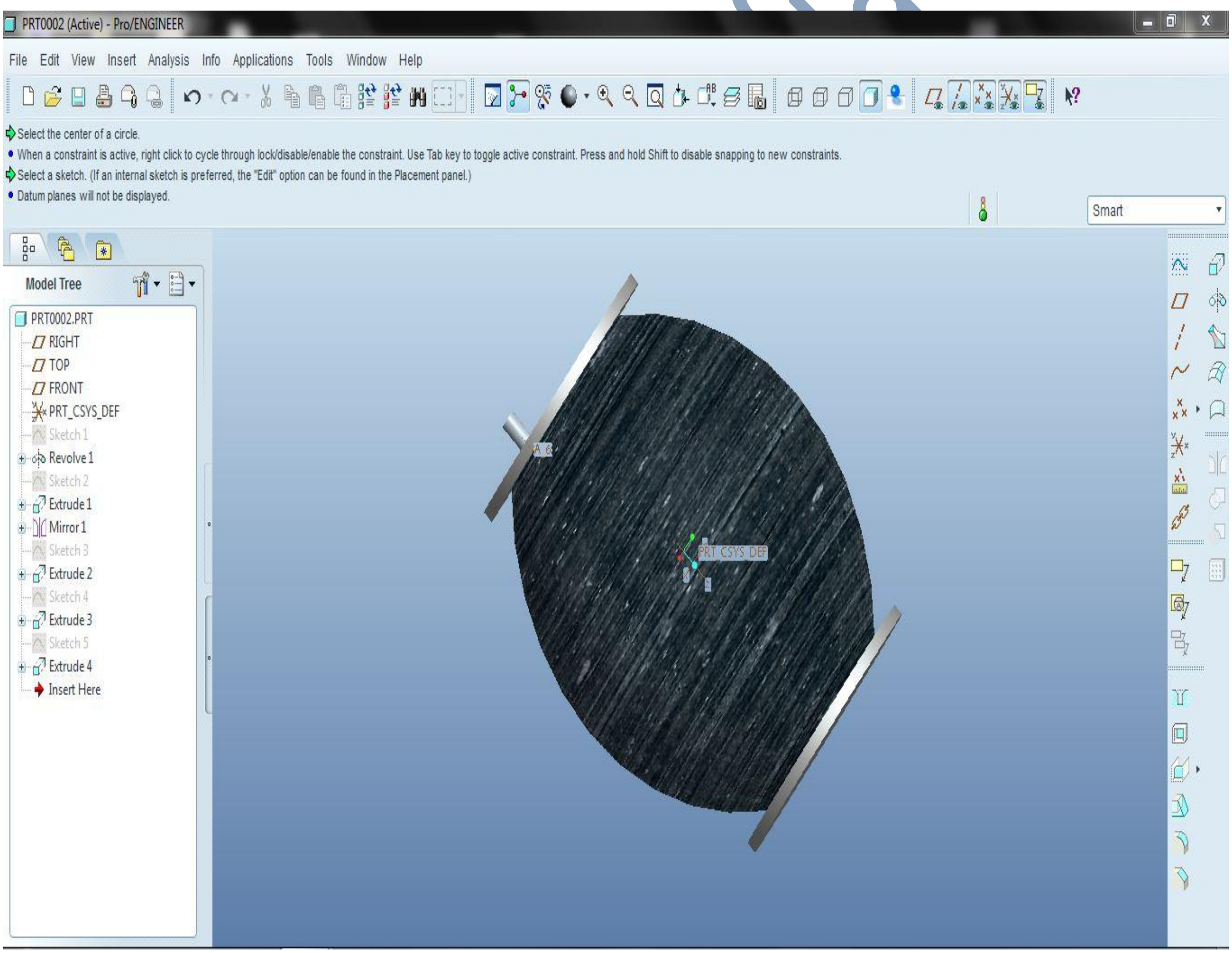
Fig. 5.3.2: Scooter Tyre Tube

- Dimensions of Air Bellows Used:
  1. **Bellow Length**: approx. 41.5 cm
  2. **Overlap**: 3 cm

     Circumference = 38.5 cm

     $\Pi D = 38.5$

     $D = 12.26$ cm
  3. **Pressure** inside the bellows is approx. 2 bars.



(Fig. 5.3.3: Design of Air Bellow in PRO-E)

Material used in fabrication of the air bellows

- 2mm thick metal sheets
- 2 scooter tubes
- Thin rubber sheets
- 3mm wooden ply
- Bicycle valves
- Adhesives

Fig.5.3.4 Steps of making of Air Bellow

- <u>Positioning of air bellows on the frame:</u>

(Fig. 5.3.5)

5.4 AIR BELLOW PRESSURE RELIEF SYSTEM

- **WHISTLE:**

  To release the pressure of air bellow at desired point, we reduced the weight of the whistle by changing the outer diameter.(Fig. 5.3.1)

S.No.	Specifications	Before machining	After machining
1.	Grab Weight	57.32 gm	
2.	Inner Dia	1.1cm	1.1cm
3.	Outer Dia	2.2cm	1.5cm
4.	Height	2.6cm	2.6cm
5.	Head Weight	7.18gm	7.18gm
6.	Vent Weight	16.99gm	16.99gm
7.	Vent Dia	.3cm	0.3cm
8.	Total Weight	74.32gm	

Fig. 5.4.1 (Pressure cooker Whistle)

(T-Joint)

5.5SOLENOID VALVES:

How a solenoid works?

When current flows through an electrical conductor, a magnetic field builds up around it. This magnetic field grows in size if the current is increased. Magnetic fields exert an attractive force on work pieces made from iron, nickel or cobalt. This force increases as the magnetic field grows.

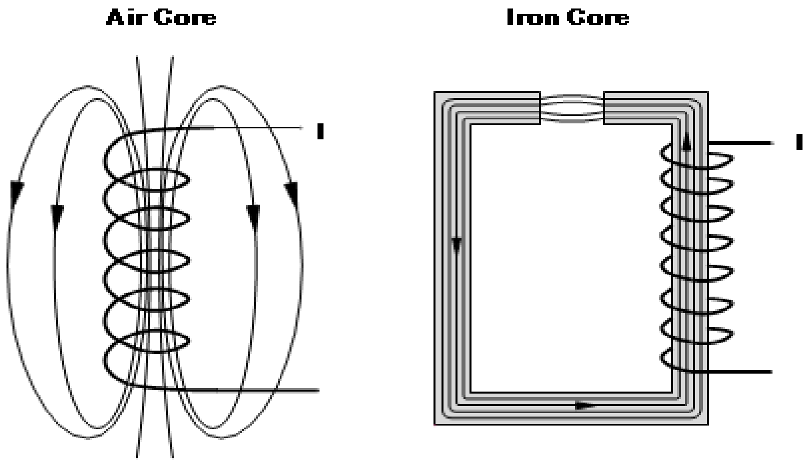


Fig.5.5.1 Electric coils with and without an iron core and their magnetic field lines

Structure of Solenoids:

A solenoid has the following structure:

- The conductor is wound in the shape of a coil (air-core). As current flows through the coil a magnetic field is generated. The magnetic field is intensified by the multiple windings (or layers) of wires.
- An iron core is placed in the coil. When current flows, the iron is magnetized. This provides a much stronger magnetic field than an air-core type coil.

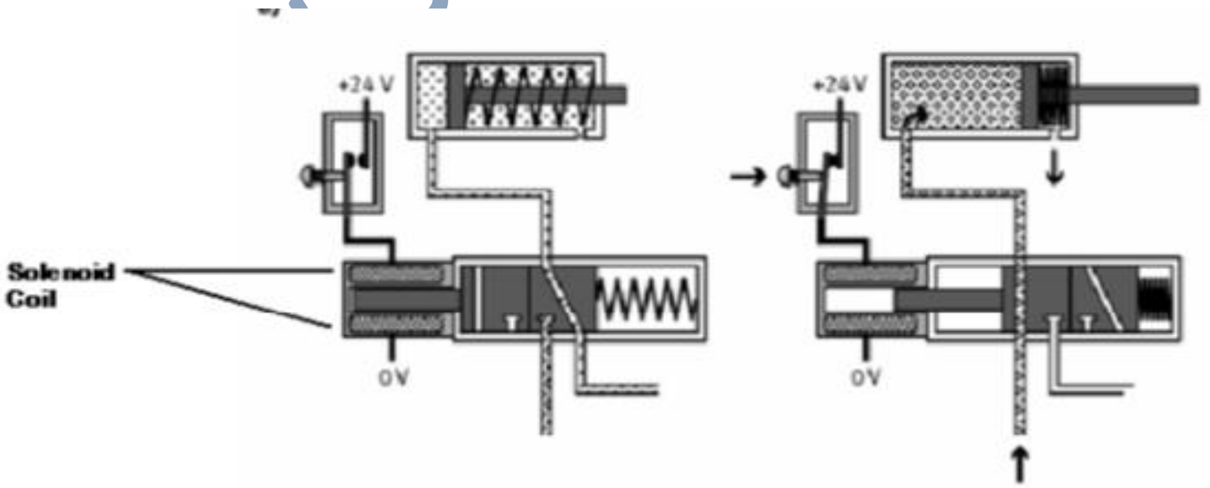


Fig.5.5.2 Operation of a solenoid valve

We are considering 3/2 single acting solenoid valve& 5/2 single solenoid valve.These3/2& 5/2 single acting solenoid valves with push-in fitting are bolted onto a function plate which are equipped with a P port and silencer.

Fig.5.5.3: Solenoid Valve

The four electrical connections are equipped with safety connectors. The unit is mounted on the profile plate using a snap-lock system with a lever. The double solenoid valve is reversed when voltage is applied to a solenoid coil and remains in this switching position after the signal is removed until an opposed signal is applied. The presence of switching signals is shown by the LEDs in the terminal housings. The valve is equipped with a manual override. The solenoid coil is characterized by very low power consumption and low heat generation.

5.6<u>SENSORS:</u>

Sensors are used to acquire information and to send the information to a "decision maker". In many cases the "decision maker" is a Programmable Logic Controller (PLC). Sensors used most frequently in automation technology are those with digital outputs as they are more immune to interference than those with analog outputs. Controllers can use the signals from these sensors directly (as opposed to using analog sensors. The output signal from analog sensors must be converted by means of analog-digital converters).

5.6.1 PROXIMITY SENSORS:

Proximity sensors are non-contacting and therefore have no external mechanical actuating force. As a result they have a long service life and are very reliable. A distinction is made between the following types of proximity sensor:

- **Sensors with mechanical switch contact**
  - Reed switches
- **Sensors with electronic switch output**
  - Inductive proximity sensors
  - Capacitive proximity sensors
  - Optical proximity sensors

5.6.1.1 OPTICAL PROXIMITY SENSORS:

We are considering Optical proximity sensors in our system for the purpose of maintaining a particular height of the vehicle.

A complete optical proximity sensor includes a light source, and a sensor that detects the light. The light source is supplied because it is usually critical that the light be "tailored" for the light sensor system. The light source generates light of a frequency that the light sensor is best able to detect, and that is not likely to be generated by other nearby sources. Infra-red light is used in most optical sensors. To make the light sensing system more foolproof, most optical proximity sensor light sources pulse the infra-red light on and off at a fixed frequency. The light sensor circuit is designed so that light that is not pulsing at this frequency is rejected. The light sensor in the optical proximity sensor is typically a semiconductor device such as a photodiode, which generates a small current when light energy strikes it, or more commonly a phototransistor that allows current to flow if light strikes it.

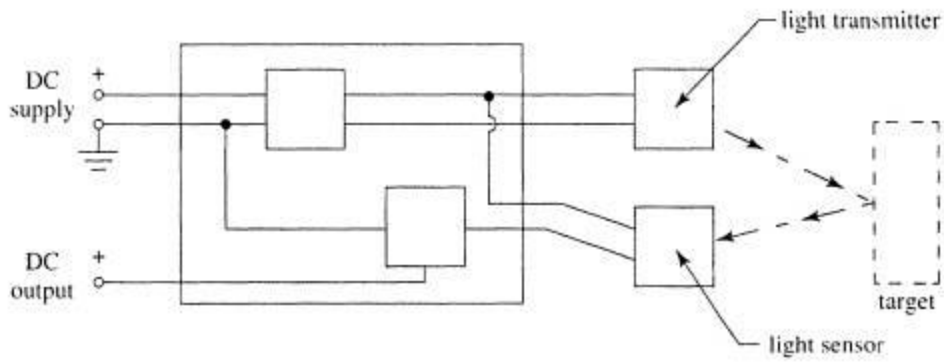


Fig.5.6.1 Working of optical proximity sensors

Fig.5.6.2 Optical proximity sensors

5.7 AIR FILTER UNIT

- Company: Festo
- P1 max.: 16 bar
- Max. 60 degree Celsius/140 degree Celsius
- 24V DC &4.5W

Fig. 5.7 FRL unit

We have used G-series Festo air filter unit with the following mentioned description

- High efficiency filters
- 3 sizes: mini, midi, maxi
- With/without threaded connections
- Condensate drain: manually, fully automatic

5.8TYRES:

Bicycle tyres may hold air with a separate, relatively impermeable inner tube; between just the tyre and rim, in a tubeless system; or in a few cases, be non-pneumatic.Tubeless tyres are primarily used on mountain bikes due to their ability to use low air pressure for better traction without getting flats.Bicycle tire casing is made of cloth, usually nylon, though cotton and silk have also been used. The casing provides the resistance against stretching necessary to contain the internal air pressure while remaining flexible enough to conform to the ground surface. The thread count of the cloth affects the weight and performance of the tyre, and high thread counts are generally preferred.

We have considered bicycle tyre whose diameter is 14 inches and its width is 1.5-2 inches. The inflation pressure of tubeless bicycle tires is below 30 psi (2 bars; 207 kPa).

Fig.5.8Bicycle tires

5.9COMPRESSORS:

A compressor and reservoir tank allow quick in-vehicle altitude adjustments. Airsprings can be inflated using compressed air just like an oldair shock, but that obviates oneof the main benefits of this typeof suspension: in-use adjustability to compensate for changing road conditions, vehicleloads, or intended use.

Fig.5.9 Compressor

Realizing full benefits from the adjustability offered by air springs really requires an on-board air source. With air suspension, ride-quality tuning is accomplished incrementally, with very small air-pressure changes. Air springs have relatively low volume, so it is difficult to inflate or deflate them with external air in small enough increments to fine-tune ride quality.

Specifications of the compressor used:

1) Model no.: SA10081R
2) Company: ELGI
3) Displacement: 107 LPM
4) Maximum Working pressure: 8 bar
5) RPM: 2800
6) HP: 1hp

5.10 PROGRAMMABLE LOGIC CONTROLLERS (PLCS):

These days complex control tasks are mainly handled using programmable logic controllers (PLCs). With this type of controller, the program is not realized through the linking of individual relays but rather using appropriate software. PLCs mainly process binary signals.

Their advantages over contact controllers or hard-wired programmed controllers are:

- Uses a few logic blocks instead of many relays
- Less wiring
- More flexible when it comes to changing the programs quickly and effectively
- Faults are easier to find
- Much more cost-effective

We have used ABB PLC of model number LM043-CE20TDC

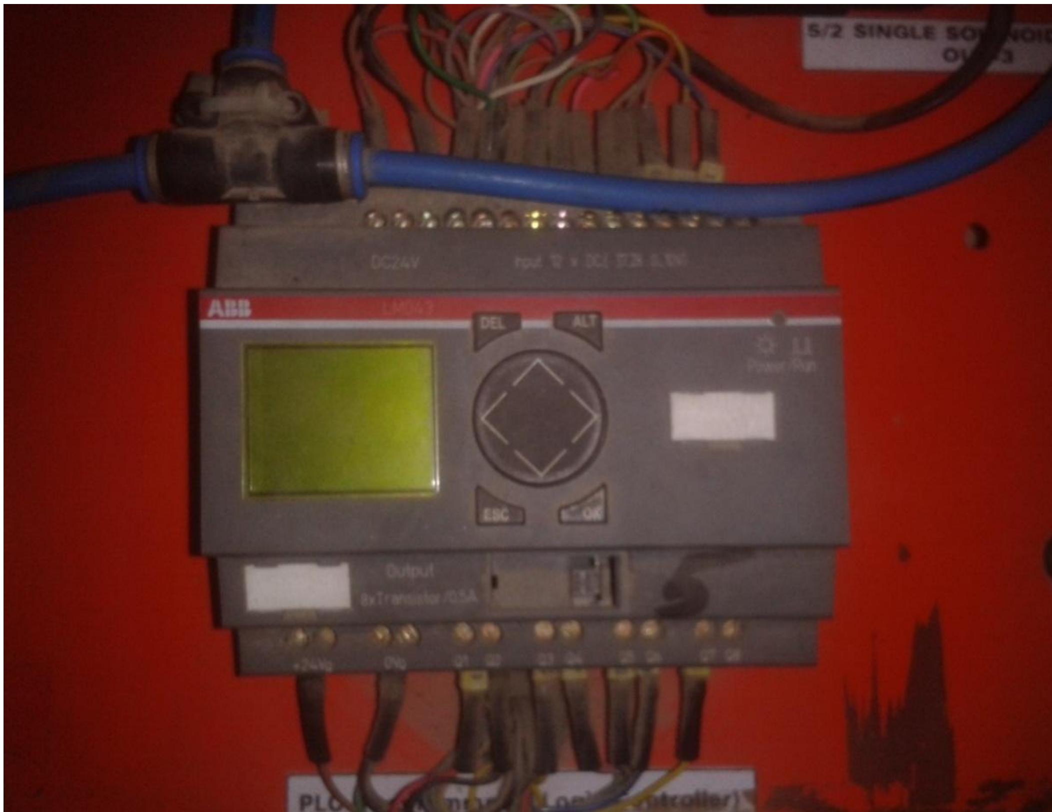


Fig.5.10PLC

5.11 WELDING USED :

5.11.1ARC WELDING:

Arc welding is the fusion of two pieces of metal by an electric arc between the pieces being joined – the work pieces – and an electrode that is guided along the joint between the pieces. The electrode is either a rod that simply carries current between the tip and the work, or a rod or wire that melts and supplies filler metal to the joint.

The basic arc welding circuit is an alternating current (AC) or direct current (DC) power source connected by a “work” cable to the work piece and by a “hot” cable to an electrode. When the electrode is positioned close to the work piece, an arc is created across the gap between the metal and the hot cable electrode. An ionized column of gas develops to complete the circuit.The arc produces a temperature of about 3600°C at the tip and melts part of the metal being welded and part of the electrode. This produces a pool of molten metal that cools and solidifies behind the electrode as it is moved along the joint.

The range of welding current used can be from 5 to 500 amps. The voltage ranges from 20 to 30 volts, AC or DC. Both are determined by the material thickness.

We have used 250-500 amps of current for welding.

Fig 5.11.1 Arc welding

5.11.1<u>GAS WELDING</u>:

Oxy-fuel welding, commonly referred to as oxy welding or gas welding is a process of joining metals by application of heat created by gas flame. The fuel gas commonly acetylene, when mixed with proper proportion of oxygen in a mixing chamber of welding torch, produces a very hot flame of about 5700-5800°F. With this flame it is possible to bring any of the so-called commercial metals, namely: cast iron, steel, copper, and aluminium, to a molten state and cause a fusion of two pieces of like metals in such a manner that the point of fusion will very closely approach the strength of the metal fused. If more metal of like nature is added, the union is made even stronger than the original. This method is called oxy-acetylene welding.

Fig 5.11.2 Gas welding

COST ESTIMATION

S.NO.	ITEMS	QTY	COST(in Rs)
1.	Frame	1	450
2.	Tyre tubes	5	100
3.	Steel plates	6	182
4.	Rubber sheets	6	60
5.	Drilling	3	30
6.	Tyres with rim	3	880
7.	Gas welding	1	100
8.	Cycle valves	5	40
9.	Bush(Front)	2	100
10.	Mild steel rod	1	40
11.	Bonding material	15	285
12.	Puncture	1	20
13.	Miscellaneous	4	195
14.	T-Joint	2	60
15.	Pressure relief valve (Whistle)	2	100
16.	Hose Pipe		60
17.			
18.	Paint	1	120

REFERENCES

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2. www.wikipedia.org
3. www.studymafia.org
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