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OVERVIEW OF ACTIVE SUSPENSION SYSTEM IN AUTOMOBILES

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Abstract - *Active Suspension had made a big improvement in the research area that concern about vehicle dynamics for the past few decades. Active Suspension were compared with different other vehicular suspension to improve the system. Active suspensions are also separated into different types according to their damping types. Over all this, electromagnetic suspensions have better properties when compared to other active suspension. Active suspension makes a huge improvement in handling, comfort, confidence to the driver and passengers. Now Active suspension is being implementing in areas such as passenger cars, commercial vehicles, commercial buses, military vehicles such as tanks and other types which include all-terrain vehicles. Active suspension prevents or eliminates a body roll of the vehicle. With the help of body roll control, the cornering speed can be significantly increased. By implementing this system, the ride height of the vehicle can be increased or decreased. It provides significant improvement in ride comfort. Researches are going on to develop active suspension with air suspension combinations in the future.*

Key Words: **Active Suspension, Skyhook theory, Hydraulic or Pneumatic actuator, Electromagnetic Suspension, Dynamic ride control, MEMS Sensor.**

1. INTRODUCTION

Suspension of a vehicle is mainly used for separating vehicle body and passengers from oscillations that is generated due to road abnormality. The primary requirement of the vehicle suspension is to allow a wheeled vehicle in motion to keep all wheels in adequate contact with the road surface. The other requirement or secondary requirement is to minimise the effect of the shock and vibration on the vehicle and its components. It also minimises passenger discomfort and to preserve the vehicle ability to obey directional commands and maintain directional stability. Active suspension is a type of suspension in which it uses an onboard system to control the movement of wheels of the vehicle relative to the chassis. The Active suspension is introduced in 1990 and that was a failure, but later on it starts getting improved and by now it is the main improved version of the vehicle suspension. The Active suspension system virtually eliminates body role and pitch variations from many driving situations including acceleration, cornering and braking. Active suspension system had been in investigation for about 20 years and becoming more improved. Now every manufacturing company is concentrating on implementing active suspension at a low cost. Many aftermarket products there in the market for implementing this active suspension in a cheaper rate such as Tein suspension etc.

Active suspensions commonly are automatic and also there are driver adjustable electronic damper for making different damping ratio for different road condition. The movement towards fully electric vehicle is the present trend in the automobile industry. The efficiency of the electric drive train is best when it is fully implemented and incorporated to the wheel. So, this shows that the need of the active suspension is improving and it need to be integrated in automobiles. It is already asserted that some of this active suspension system cannot be fully solve automobile oscillations problems because these suspension systems are very costly. Automobile manufactures often competing against each developer for comfort drive characteristics and provide best stability during braking and cornering. With passive suspension it only provides a stated feature or it does not give the max level of handling and ride comfortability. In order that researchers had proposed and found many active suspension systems both in theoretical and experimental terms. Active suspension system simultaneously eliminates most road interferences from pitch and roll.

2. ACTIVE SUSPENSION

Active suspensions are also called as ultimate Suspension. It uses an onboard system to control the vertical and horizontal movement of the vehicle body relative to the chassis and vehicle's wheel. Active suspension uses the hydraulic or pneumatic actuators to raise and lower the frame of each individual wheel depending on road conditions. Fully active suspension systems are based on actuator operations. The principle used in active suspension is skyhook theory. In skyhook theory it is said that the ideal suspension would let the vehicle to maintain a stable posture like an imaginary hook in the sky and it is unaffected by road conditions. Skyhook theory is not practically possible but it can be used for designing the suspension system. Active suspensions are divided into two; They are:

1. Fully Active suspension.

2. Adaptive or semi–Active Suspension.

These suspensions are been again classified into different types according to their actuation of damping. Adaptive suspension only varies shock absorbers firmness to

according to the changing road condition but active suspension uses actuators which are hydraulically or pneumatically controlled or electromagnetically controlled actuators which raise and lowers the chassis independently at each wheel.

3. SEMI-ACTIVE SUSPENSION

Semi active suspensions adjust and modify the damping in real time based on road conditions and vehicle dynamics. A semi active suspension uses different types of dissipaters. Semi active suspension has a time response less than active suspension to a few milliseconds. Semi active suspension also utilizes variable damper component in the automobile suspension. Semi active suspension is similar to passive suspension system with only one difference which is, the semi active suspension has a variable damping coefficient but still fixed spring constant and it also lags in active force sources. Semi active suspension can be switched electronically or remotely to harden or soften the system and change the damping factor continuously or intermittently. When the suspension is stiffened, it increases the vehicle's ability to corner, braking, acceleration, reducing low frequency response towards the inertial forces which are roll and pitch. It also avoids wheel resonances and body excitation. Here a twin tube viscous damper is used and the damping coefficient can be varied by changing the diameter of the orifice in the piston cylinder setup.

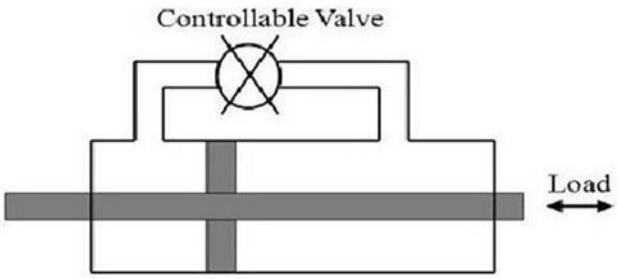

Fig-1: Viscous Damper

In this figure, the viscous damper is equipped with a piston cylinder setup with an orifice control valve for controlling the oil flow. The load side is where the vehicle wheels are placed. The diameter of the orifice allows the control of oil flow inside the piston cylinder setup. This system can be controlled manually or by actuators. The control valve is the main component in this system. This semi active system only allows to eliminate the vertical movements of the wheels formed by the road surface. When the piston moves inside the cylinder, the fluid starts flowing through the orifice. When the orifice opening is larger then, it provides less dissipative resistance and when at smaller orifice it provides increased dissipative resistance.

4. FULLY ACTIVE SUSPENSION

Fully active suspensions are working on the basis of actuators. These types of systems are better able to withstand the axial forces generated by unpredictable variations at the entrance to the road, due to shocks and springs combined by driving forces. This system can moderate through different controller types based on design. When an active suspension with proper controlling methods, it can result in best vehicle ride comforts and road handling stableness and thus making overall enhanced suspension design. Fully active suspension is classified into: -

1. Hydraulic or pneumatic.

2. Electromagnetic.

4.1. Hydraulic or pneumatic Active suspension

Active suspension systems with hydraulic or pneumatic actuators are managed through electric drives. In hydraulic or pneumatic active suspension, the actuators are managed or worked by electric drives and the power needed for the working of the actuators is provided from the battery source or the conventional IC engine. Because of the simplicity, high force density, reliability, technology and parts availability, the hydraulic system are more widely used in body control system. BMW and AUDI recently developed new hydraulic suspension. BMW has developed an anti-roll control system by mounting a hydraulic rotary actuator at the rear of the vehicle's anti-roll hub. AUDI developed a fully hydraulic active suspension called dynamic ride control where it eliminates the pitch and roll of the vehicle. Different types of hydraulic active suspension that have been developed and those manufacturers are: -

1. Lotus

2. Nissan

3. Automotive production

Table-1: Hydraulic active suspension manufacturers

Type	Configration	Features
A (Lotus)	Load Senser, Valve, Controller, Stroke Senser, Body Accelerometer	Directy Linked Cylinder and Valve; High Response Servo Valve
B (Nissan)	Valve, Controller, Body Accelerometer	Feedback Type Pressure Control Valve; Conpact Accumulator for Reducing Pressure Fluctuations
C (A.P.)	Valve, Controller, Stroke Senser, Body Accelerometer	Improved Hydro Pneumatic Suspension

Type A- Lotus

• It is characterized by its direct linkage of a double acting cylinder and a high response control valve. It is a spring-loaded piston cylinder setup.

• The control valve provides fast response in order to absorb vibrational inputs. The control capability of the system is quite high.

• It consists of a stroke sensor which senses the strokes on the vertical movement of the vehicle's wheel. An accelerometer sensor which is used to measure the acceleration of the body and gyroscope of the body. • Load sensor is placed on top of the damper to measure the load taken by the vehicle.

• The controller controls the flow of the valve and flow of oil as per the damping coefficient needed for the vehicle under different road condition.

Type B- Nissan

• This system consumes large amount of energy especially on rough road surfaces.

• It has a spring-loaded piston reacting to changes in the feedback pressure to control the valve opening. It is having a groove on the piston for the flow of the oil.

• This is an advanced suspension when compared to lotus.

Type C- Automotive production

• It is a hydro pneumatic suspension.

• It is only having a piston cylinder setup and it is not loaded with spring.

• It is equipped with a flow regulating valve which achieves active control by filling the accumulator and supplying hydraulic fluid to the cylinder.

4.2. Electromagnetic Active suspension

An electromagnetic active suspension is a type of suspension system which consists of a sprung and unsprung mass. Electromagnetic suspensions are mainly suitable for parallel active suspension. The electromagnetic actuators used in electromagnetic suspension works with regards to electric supplied range by implemented control systems. Electromagnetic suspension is also a combination of electromagnet and hydraulic drive. Electromagnetic suspension has better active controlled forces for speedily absorbing road shocks, and eliminating most of the pitch and roll motions and improving comfort as well as better safety. When electromagnetic actuator is compared to hydraulic actuators, there are many improvements. The main is that efficiency of the actuator increases rapidly. The dynamic behavior of the electromagnetic suspension has improved when compared to hydraulic suspension. The main property of the active suspension increases when using electromagnetic suspensions which are anti roll and stability. The problem of implementing an electromagnetic suspension is that, it is more expensive than other system. But when understanding the better improvements, we can ignore this extra expense. The other problem is that the volume of the suspension increases and load on the vehicle increases. An electromagnetic suspension cut section is been shown: -

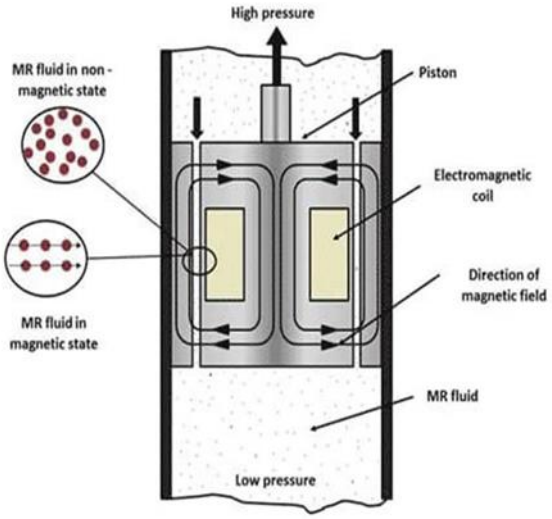

Fig -2: Electromagnetic suspension cut section.

In this figure, it is a piston cylinder setup and the cylinder is filled with Magnetorheological fluid (MR fluid). The piston has an electromagnetic coil that is used to change the density of the MR fluid in the cylinder. An ECU is connected to the system and the ECU is taking signals from the stroke sensor, accelerometer etc. This signal from the sensors is given to the ECU and the ECU then gives signal to the electromagnetic coil. The electromagnetic coil gets different voltages from the ECU to get the damping coefficient according to the road condition. When the electromagnetic coil gets magnetized, it produces a magnetic field inside the cylinder and makes the MR fluid magnetize. When the MR fluid is magnetized the apparent viscosity of the fluid increases and becomes a viscoelastic solid. So, when MR fluid is magnetized, it increases the viscosity of the fluid and thereby increase the damping force and when the magnetic force decreases, the damping of the fluid decreases. In this way the electromagnetic active suspension damping works and the damping coefficient is changed by the magnetization and demagnetization of the MR fluid. The piston inside the cylinder is given grooves in it and these grooves are used for the flow of the MR fluid. When the MR fluid is magnetized, the viscosity increases and the flow of the fluid becomes slower and it decreases the damping. When the MR fluids magnetization decreases, the viscosity decreases and the flow of the fluid increase and decreases the damping force. The working of the electromagnetic suspension is simpler compared to other suspension and it gives better Active suspension properties.

5. DYNAMIC RIDE CONTROL (AUDI)

Dynamic Ride Control is a n Active suspension which is introduced by Audi. Dynamic Ride Control is fully mechanical suspension, so it is fully lag free. It reduces body roll and pitch around the transverse and longitudinal axes. The DRC suspensions are placed in order that the pair of shock absorbers are diagonally opposed and are linked with hydraulic lines and a central valve. When cornering quickly, the valve regulates the flow of oil in the outer front wheel shock absorbers which are deflected immediately. They increase the support provided and reduce lateral tilt, thus improving the dynamics of the vehicle.

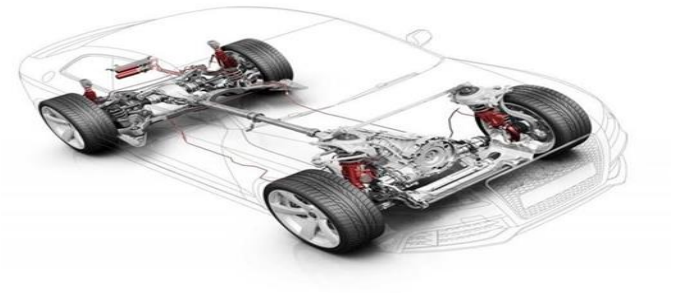

Fig-3: Audi dynamic ride control.

In DCR the front and rear axles handle the longitudinal and transverse forces independently. Audi's DRC is available as a Performance-oriented alternative. The DRC incorporates roll and pitch stability, including steel springs and three-way adjustable shock absorbers that operate without electronics and without flaps. The shock absorbers on one side of the vehicle are connected to the opposite shock absorbers diagonally by two separate oil lines, each with a central valve. These valves provide the necessary compensating volume via internal piston with the gas-filled compartment behind them.

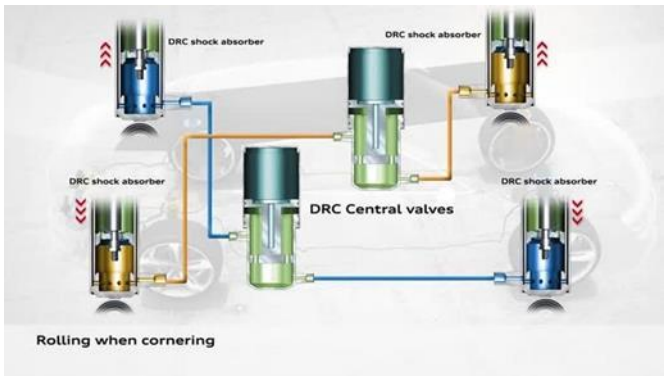

Fig-4: Working of DRC.

A stream of oil travels diagonally through the center valve between the shock absorbers creating additional damping force. One-sided damping changes the damping properties and almost completely eliminates pitch and roll movements. Therefore, the stability of the track when negotiating the corner is good.

6. MAIN SENSOR USED FOR ACTIVE SUSPENSION

The main sensor which is used for the working of Active Suspension is Low-G Accelerometer. The mainly used Accelerometer sensor is from Bosch. The sensor series is SMB43x. (E.g.: SMB431, SMB433, SMB437). It is manufactured by using surface micromachining technology. This sensor consists of Micro-Electro-Mechanical-system (MEMS) sensor, which is a miniaturized Mechanical and Electro-mechanical elements and ASIC for signal processing, mounted in a plastic case for mounting on a printed circuit board. The SMB43x accelerometers are designed for vibration control. They are particularly suitable for usage in second level housing as a peripheral sensor. Accelerometer sensor senses acceleration of the chassis or wheel, and senses the vibration.

Fig-5: SMB43x IC

The accelerometer sensor features suspended free moving comb like seismic mass elements and fixed counter electrodes. And this results the external forces acting on the vehicle, the deflection of the seismic masses along the sensitive axis generates changes in system capacitance These sensors are a part of large sensor portfolio and it consists of acceleration sensors, angular rate sensors and combined inertial sensors for occupant safety systems. Fully digitized signal and filter paths provide excellent signal performance with tight tolerances. When digital peripheral sensor interface (PA15 interface) is combined, then the signal degradation between sensor and control is effectively impeded. This SMB43x is really cost-efficient system because of the small size of the sensor and the need of only few passive elements leads to reduced PCB cost. The applicable temperature of the sensors ranges from -40°C to +125°Cand it can be operated with a power supply that can produce an output of 5v to 11v.

6.1. MEMS SENSOR

MEMS sensor is used for finding out Accelerometer, Gyroscope, Pressure, Magnetism etc. MEMS sensors combine electrical and mechanical components in or on a single chip. In other words, it is an electromechanical sensor. Therefore, the MEMS sensor represents a continuum connecting an electronic sensor at one end of the spectrum with a mechanical sensor at the other end. However, an important criterion for MEMS sensors is that

they often have mechanical functional elements - i.e. An element can stretch, deflect, rotate or vibrate.

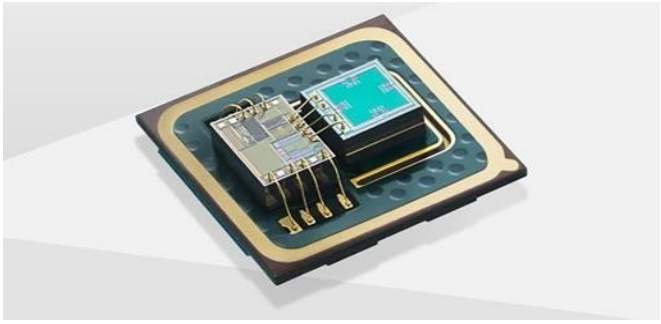

Fig-6: MEMS Sensor module

This sensor consists of: -

• MEMS element – Senses acceleration, pressure, yaw rate or chemical parameters such as gases or humidity, depending on the type of sensor.

• Decoupling unit – Ensures a stress-free storage of the MEMS element. Without a decoupling, the MEMS element would be set under pressure or tension stresses during temperature fluctuations, which could falsify measuring signals.

• ASIC – An electronic circuit, that amplifies the measuring signals of the MEMS chip, evaluates them and issues a corresponding output signal.

• Bonding wires – Create the electrical connection between the MEMS element and the evaluation circuit (ASIC).

• Printed circuit board (PCB) – Conducts the output signals of the ASIC via internal conductive tracks outwards or the supply voltage from outside to inside.

7. EDFC ACTIVE SUSPENSION(TEIN)

EDFC means electronic damping force controller. This suspension system von Tein makes it easy for the driver to adjust the damping force, by controlling the stepper motors mounted on each shock absorber. Built-in G-sensor allows automatic adjustment of damping force with G while driving. For more active management of damping force depending on the driver Conditions are two available auto-adjustment modes.

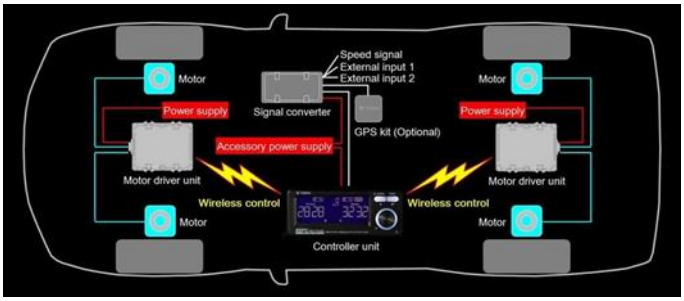

Fig-7: EDFC suspension Layout

The motor control units at the front and rear of the vehicle as well as the control units are Connect wirelessly to reduce the hassle of cable work. The control unit has all sensor functions, with built-in optical sensor to detect brightness inside Environment and connectivity with optional GPS speed detection kit. The power cable is the only cable needed between the controller and the car, allowing and easier to build a wider version. To install a well thought out vehicle model or size and a well thought out design make it a controller easy to install in the desired position without bulky wires.

Fig-8: EDFC Suspension Components

8. ADVANTAGES AND DISADVANTAGES

The active chassis is independent of the overall condition of the chassis and stabilizes vehicle independently. It doesn't depend on the general state of the suspension to stabilize the car independently. It eliminates body roll during high-speed cornering. It eliminates pitch of the vehicle. When active suspension is implemented in vehicle, the Anti-roll bar can be omitted while using a fully active suspension. It has adjustable characteristics of the system even during driving. It increases the contact of tire with road, so the overall grip of the vehicle is increased and hence creates a safer ride. The disadvantage that comes after installing an active suspension is that, its complexity in servicing. Significant power consumption is taken by the dampers. Active suspension requires a high peak power. So, a high current is always needed from the battery, if the battery of the vehicle is down, then the active suspension won't work perfectly. Active suspensions concern over reliability due to complexity. It is a complex design and working can't be simply studied.

9. CONCLUSION

The active suspension is more effective in controlling and improving performance than the passive suspension. It can maintain the necessary stability and comfort due to the adaptability of the suspension according to driving condition. Active suspension prevents or eliminates the body roll of the vehicle. Thanks to this body roll control, you can significantly increase your cornering speed. As the vehicle does not lean or hunch back, there is a relative improvement in the acceleration of the vehicle. By implementing this system, we can increase or decrease the ride height of the vehicle. The improvement of ride comfort is unimaginable. Succeeding investigation in

electromagnetic active suspension should concentrate on research and developing more towards electromagnetic linear actuators. Active suspension with air suspension combinations is been going on researching and it will make a drastic change in the active suspension technology.

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