Design and Fabrication of Active Suspension Model for Motorbikes

A Project Report

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BONAFIDE CERTIFICATE

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ABSTRACT

The motorcycle industry has witnessed numerous changes and developments mainly in the area of engine and transmission. While in the four wheeler industry, passenger comfort has been given top priority, biking was never ever considered a luxury segment. Hence a change has to be effected. Traditionally automotive suspension designs have been a compromise between the three conflicting criteria of passenger comfort, load carrying and road handling. It has always failed to deliver all the three, collectively in one piece.

The search for an alternative suspension system has led to a new technology called Active Suspension System, adopted in high end four wheelers. So it was decided to incorporate the same in motorcycles with the needful adjustments.

This project is mainly concerned with designing and fabricating a fully operational prototype of the active suspension system that would be implemented on a live motorcycle. Various components and the medium needed to make this system functional have been developed through the course of the project. Pneumatics was incorporated as the operating medium with an electronic control unit that serves as the brain of the system. Also the high speed limit switches and solenoid valves helped in achieving the desired results.

By this project it has been possible to attain the required criteria (passenger comfort, load carrying and road handling) with an active suspension system.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES / GRAPHS / PHOTOS

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

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.

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. The magnitude, of course, depends on whether the wheel is striking a giant bump or a tiny speck. Either way, the car wheel experiences a vertical acceleration as it passes over an imperfection.

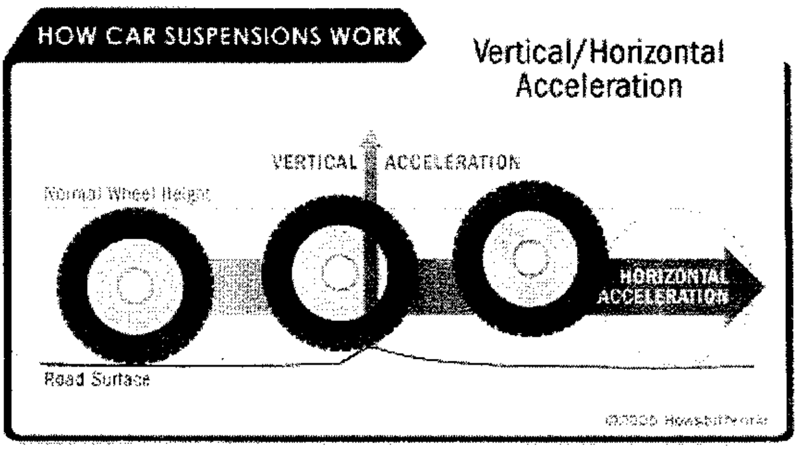


FIG 1.1 NEED FOR SUSPENSION

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.

appreciate why a suspension is necessary in the first place. Most automobile engineers consider the dynamics of a moving car from two perspectives:

- Ride - a car's ability to smooth out a bumpy road
- Handling - a car's ability to safely accelerate, brake and corner.

These two characteristics can be further described in three important principles - road isolation, road holding and cornering. The table below describes these principles and how engineers attempt to solve the challenges unique to each.

TABLE 1.1 FACTORS TO BE CONSIDERED

Principle	Definition	Goal	Solution
Road Isolation	The vehicle's ability to absorb or isolate road shock from the passenger compartment	Allow the vehicle body to ride undisturbed while traveling over rough roads.	Absorb energy from road bumps and dissipate it without causing undue oscillation in the vehicle.
Road Holding	The degree to which a bike maintains contact with the road surface in various types of directional changes and in a straight line (Example: The weight of a bike will shift	Keep the tires in contact with the ground, because it is the friction between the tires and the road that affects a vehicle's	Minimize the transfer of vehicle weight from side to side and front to back, as this transfer of

	from the rear tire to the front tire during braking. Because the nose of the bike dips toward the road, this type of motion is known as "dive." The opposite effect -- "squat" -- occurs during acceleration, which shifts the weight of the bike from the front tire to the back.)	ability to steer, brake and accelerate.	weight reduces the tire's grip on the road.
Cornering	The ability of a vehicle to travel a curved path	Minimize fish tailing, which occurs as centrifugal force pushes outward on a bike's center of gravity while cornering.	Transfer the weight of the bike during cornering from the high side of the vehicle to the low side.

CHAPTER 2

SUSPENSION SYSTEMS

2.1 DEFINITION

Suspension is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels. Suspension systems serve a dual purpose - contributing to the car'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.

The suspension system, while not absolutely essential to the operation of a motor vehicle, makes a big difference in the amount of pleasure experienced while driving. Essentially, it acts as a "bridge" between the occupants of the vehicle and the road they ride on. The term *suspension* refers to the ability of this bridge to "suspend" a vehicle's frame, body and power train above the wheels.

As the tire revolves, the suspension system is in a dynamic state of balance, continuously compensating and adjusting for changing driving conditions. Today's suspension system is automotive engineering at its best.

2.2 PRINCIPLES OF SUSPENSION SYSTEM

There are three principles of the suspension system underlying the satisfactory damping of the motor vehicles. They are,

a) Reduction of the weight of the wheels and other components receiving the road shocks to minimum or reduction of unsprung weight.
b) Reduction of rolling or pitching of the body to a minimum with suitable design and attachment of the springs.
c) To absorb satisfactorily the large as well as the smaller road impacts with the help of single springing device.

2.3 FUNCTIONS

Suspension systems have several functions that make a modern motorcycle much safer to ride than the bikes of the past, especially considering the speed that modern motorcycles are capable of. First of all, the suspension makes riding any bike more comfortable for its rider. Beyond this function, however, the suspensions job is to keep the tires in contact with the road over bumps of all descriptions, sharp and quick ripples or big bruisers. The suspension must perform at straight up high speeds, but most importantly at high lean angles in mid turn to keep the tires in contact with the road and provide traction. The more effective the suspension is, the faster a corner can be taken and the safer it will be to do so. Ideally, the limit of cornering speed will be determined by tire adhesion and lean clearance and not suspension performance.

The components of the suspension system perform six basic functions:

1. Maintain correct vehicle ride height:

   To provide the requisite height to the body structure as well as to bear the torque and braking reactions.

2. Reduce the effect of shock forces:

   To minimize the effect of stresses due to road shocks on the mechanism of the motor vehicle and provide a cushioning effect.

3. Maintain correct wheel alignment:

   To keep the body perfectly in level while traveling over rough uneven ground, i.e. the up and down movement of the wheels should be relative to the body.

4. Support vehicle weight

5. Keep the tires in contact with the road:

   To keep the body of the motor vehicle on even keel while traveling over rough ground or when turning in order to minimize the factors like roll and pitch.

6. Control the vehicle's direction of travel

2.4 COMPONENTS OF SUSPENSION SYSTEM

2.4.1 Primary Components

Springs and dampers are the main components of a suspension system.

2.4.1.2 Spring

The springs support the weight of the vehicle, maintain ride height, and absorb road shock. Springs are the flexible links that allow the frame and the body to ride relatively undisturbed while the tires and suspension follow the bumps in the road.

Springs are the compressible link between the frame and the body. When an additional load is placed on the springs or the vehicle meets a bump in the road, the springs will absorb the load by compressing. The springs are a very important component of the suspension system that provides ride comfort. Shocks and struts help control how fast the springs and suspension are allowed to move, which is important in keeping tires in firm contact with the road.

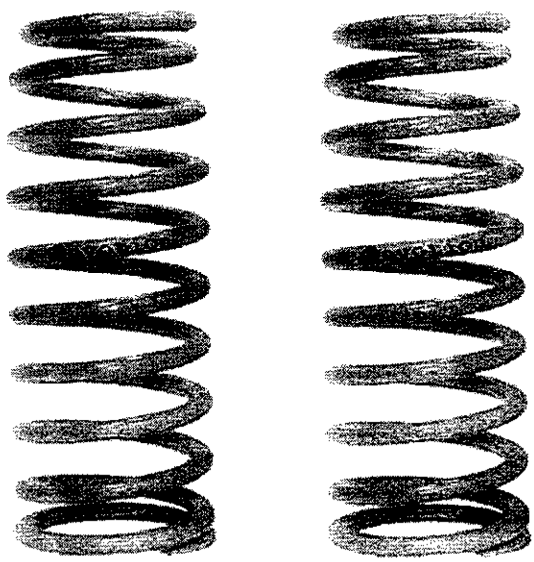


FIG 2.1 SPRINGS

2.4.1.3 Dampers

The other main part of a car's suspension is the damper or more commonly the shock absorber. Contrary to its name, a shock absorber plays a minimal role in absorbing impacts taken by the suspension. That's the spring's job. A shock absorber dampens road impacts by converting the up and down oscillations of the spring into thermal energy.

than-average bumps in the road so that the shock isn't transmitted to the car chassis. Secondly, they keep the suspension at as full a travel as possible for the given road conditions. Shock absorbers keep your wheels planted on the road.

During the study of springs, the term bounce refers to the vertical (up and down) movement of the suspension system. The upward suspension travel that compresses the spring and shock absorber is called the jounce, or compression. The downward travel of the tire and wheel that extends the spring and shock absorber is called rebound, or extension.

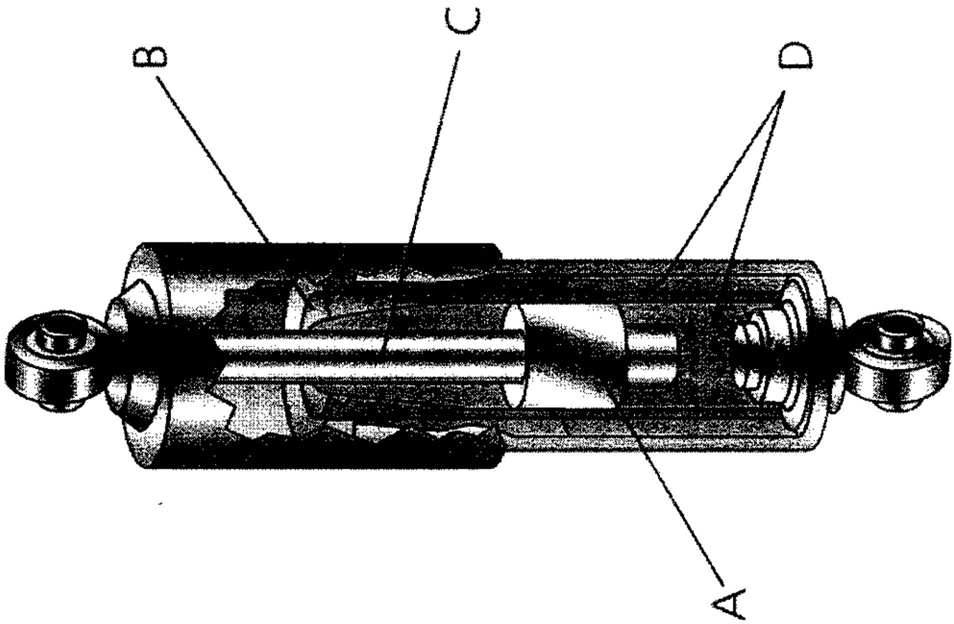


FIG 2.2 SHOCK ABSORBERS

2.4.2 Other Components

BASE VALVE - The compression piston and valving that fits onto the compression bolt assembly.

BLADDER - A closed-end, thick rubber, cylindrical shaped piece that contains the nitrogen gas in a rear shock. The bladder works like an extra cushion on HSC.

BUMPER - A taper shaped dense foam piece that fits on the shock shaft.

BUSHING - A bronze ring used as a load bearing surface in forks or shocks.

CLEVIS - A fork shaped piece of aluminum used as the bottom mount

DAMPER ASSEMBLY - The parts of a shock comprised of the clevis, shaft, forks.

NITROGEN - An inert gas used to pressurize the bladder or reservoir of shocks.

PISTON - A cylindrical shaped piece of steel with several ports arranged around the periphery so as to direct oil towards the face of shocks.

CLICKERS - The screws or knobs used to fine-tune the low speed damping on forks or shocks.

COMPRESSION BOLT ASSEMBLY - A large diameter bolt that houses the low speed compression adjusting screw and the compression valve assembly.

PISTON ROD - A small diameter steel rod that fits into the upper legs of cartridge forks. It fastens to the fork cap on one end and holds the rebound piston and shims on the other end.

PISTON RING - A ring that fits around the piston and prevents oil from by-passing the piston and shims.

RESERVOIR - A cylindrical shaped device that contains oil and nitrogen gas.

SEAL - A rubber or plastic cylindrical shaped piece that prevents oil from being lost from the damper.

SHAFT - The chrome rod on the rear shock that has a clevis on one end and the piston and shims fastened to the other end.

SHIMS - A thin, steel, round, flat washer used to exert resistance on the oil flow through a piston. A series of shims (valve stack or valving) with varying outer diameters and thicknesses are arranged in sequence to provide a damping affect.

TRANSITION SHIMS - These are shims with very small outer diameters that are used to separate the normal shims of the low and high speed valve stacks.

SHOCK BODY - The aluminum cylinder which contains the damper assembly.

SPRING - A steel wire that is wound into a coil shape and tempered in order to provide resistance to compression forces and store energy for release to the extended position.

TRIPLE-CLAMP ASSEMBLY - Includes the steering stem-bottom clamp, and top clamp. The triple clamp assembly connects the forks to the frame.

VALVES - A term that refers to a series of shims either for the compression or the rebound damping.

2.5 TERMINOLOGIES CONCERNED

YAW - A motion that veers left or right from the motorcycle's heading angle.

PITCH - A motion fore or aft, when the front end dives or when the rear end squats.

ROLL - A motion where the motorcycle leans left or right from straight-up riding.

AXLE - The spin axis of a wheel.

CHASSIS - The frame, swing arm, suspension, and wheels of a motorcycle.

CENTER OF GRAVITY/MASS CENTER - The center point of the motorcycle's mass. It is normally located somewhere behind the cylinder and below the carburetor of a dirt bike.

DAMPER - A fluid chamber with a means of regulating the fluid flow to restrain the speed of the moving end of the damper during the compression or rebound strokes. A set of forks and a rear shock are considered dampers.

DAMPER SPEED - The relative speed in which the moving end of a damper compresses or rebounds. The two different speeds are high and low.

DAMPING - The process of absorbing the energy of impacts transmitted through the forks or rear shock on the compression stroke, and the process of absorbing the energy of the spring on the rebound stroke.

COMPRESSION DAMPING - The damping circuit that absorbs the energy of compression forces on the damper.

REBOUND DAMPING - The damping circuit that affects the stored energy release of the compressed spring in order to reduce the rebounding speed of the damper.

PIVOT - A fixed point at which a lever rotates. Example: swinging arm or suspension linkage.

PRE-LOAD - Pre-load is applied to the fork and shock springs in order to bring biased to change the bike's steering geometry. High pre-load/less sag in the front forks will make the steering heavy/slow and more stable at high speed.

RAKE - The angle between the steering axis and a vertical line.

STEERING ANGLE - The angle of the handle bars as you rotate them left or right about the steering axis.

STEERING AXIS - The axis where the forks rotate in the frame.

SWINGARM - The rear fork that connects the rear wheel to the frame.

S.A. ANGLE - The angle of rotational motion about the swinging arm pivot axis.

S.A. PIVOT AXIS - The point where the swinging arm mounts to the frame and rotates.

TRAIL - On the front end, the horizontal distance between the steering axis at the road surface, to the tire contact point. Generally forks with off-set axles have more trail than forks with straight through axles.

UNSPRUNG/SPRUNG WEIGHT - The unsprung weight of the motorcycle are parts like the wheels, brakes, swingarm and suspension linkage, and the lower front fork legs. The sprung weight is all the parts of the motorcycle that are supported by the suspension.

WHEELBASE - The distance between the front and rear axle centers.

TRANSMITABILITY - This term refers to the suspension oil's ability to transmit shock loads. As the oil's temperature rises, the transmitability falls. Example: With every increase in temperature of 18 degrees Fahrenheit the transmitability of the oil falls 50%.

VISCOSITY - A rating system for oils that measures the oil's flow rate through a fixed orifice at a certain temperature. Also known as the oil's weight. Example: SAE 30 Wt.

BOTTOMING - A riding situation whereby all the suspension travel is utilized.

CLICKERS - The knobs or screws that control the forks or shock.

STIFF/SLOW, SOFT/FAST - These words are used to describe the damping the direction of rotation that you will turn the clickers in order to improve the damping. Turning the clickers clockwise will make the damping stiff/slow. Turning the clickers counter-clockwise will make the damping soft/fast.

FLICKING - The action of putting the bike into a full lean position quickly.

FRONT END DIVING - This is what happens when the front forks compress quickly. It usually occurs when braking for turns.

HANDLING - The quality of response from the chassis of a motorcycle, while riding through a variety of obstacles like turns, jumps, hills, whoops and bumps.

HARSHNESS - A word used to describe the quality of the damping.

HEAD SHAKING - A term that describes the high speed oscillation of the forks when braking for a bend at the end of a fast straight-away. Every motorcycle has a certain frequency band when it oscillates. This frequency can be tuned to a higher vehicle speed with a sacrifice in the bike's ability to turn.

HOPPING - Wheel hopping is when the tire bounces up off the ground due to a reaction from a bump.

PACKING - When the rear shock is compressed by the wheel hitting one bump and cannot rebound quickly enough to absorb the impact of the second or third bump.

POGOING - When the rear shock rebounds so quickly that the rear wheel leaves the ground.

RACE SAG - This term refers to number of millimeters that the forks or shock sag with the rider on the bike in full riding gear. This is essential to proper suspension tuning but is often overlooked or adjusted incorrectly.

REAR END SQUATTING - Squatting occurs when you accelerate the motorcycle. The chain forces push down on the rear wheel. The resultant forces are transferred up the swinging arm into the main frame causing a lifting force which extends the front end causing a weight shift backwards.

COUNTER STEERING - When the rider applies steering pressure in the opposite direction of the turn.

SHOCK FADE - A condition that occurs when the shock oil becomes so hot that it loses it's transmitability. The damping affect is reduced and the shock compresses easily and rebounds quickly.

SPIKING - A word used to describe how the forks work when the damping is too stiff/slow. This is also associated with "Arm Pump". The feeling in your arms when your forks aren't absorbing the energy of impacts to the wheel but instead transfers them to your arms.

STICTION - A combination of the words static and friction. This word is used to describe the tension exerted on the moving damper parts by the stationary parts like the bushings, seals, and wipers. Low stiction is desirable because it has less of an affect on the damping.

2.6 IMPORTANCE OF RAKE ANGLE

FIG 2.3 RAKE ANGLE DEPICTION

Sports bikes typically have less rake which means less trail. Fewer trails mean less stability, which means a quicker-steering bike. This makes the sport bikes a lot less stable to ride in a straight line, but a lot more flickable in the corners. Conversely, cruisers, choppers and customs, have much more rake. More rakes mean more trails, which mean more stability, which makes the bike harder to turn. However, bikes with more rake work better in a straight line, which is why long-distance cruisers have more rakes. It's worth noting that when we talk about more and less rake, the difference can be within 5°.

2.7 FORCES INVOLVED IN SUSPENSION ACTION

There are totally three forces involved, they are spring forces, damping forces and frictional forces.

2.7.1 Spring Force

The key thing to note about spring forces are that they are dependent on position only. Springs only care where they are in the travel, not how fast the suspension is compressing or rebounding.

2.7.2 Damping Force

Damping is viscous friction. It is caused when liquids are forced through some type of restriction. The key thing to remember about damping is that it is dependent on fluid movement. This means a shock creates no damping force unless there's movement-movement of the damper unit in compression or rebound as opposed to bike movement. Damping cares about vertical wheel velocity, not bike speed.

2.7.3 Frictional Force

The third type of force is frictional force. Frictional forces depend on the perpendicular load on the surfaces in question and the materials involved, including lubrication, if available. The higher the load, greater the friction. More slippery materials, better surface finishes, more sophisticated lubricants and better design can minimize friction.

2.8 WORKING OF SUSPENSION SYTEM

A shock absorber is basically an **oil pump** placed between the frame of the bike and the wheels. The upper mount of the shock connects to the frame (i.e., the sprung weight), while the lower mount connects to the axle, near the wheel (i.e., the unsprung weight). In a **twin-tube design**, one of the most common types of shock absorbers, the upper mount is connected to a piston rod, which in turn is reserve tube. The reserve tube stores excess hydraulic fluid.

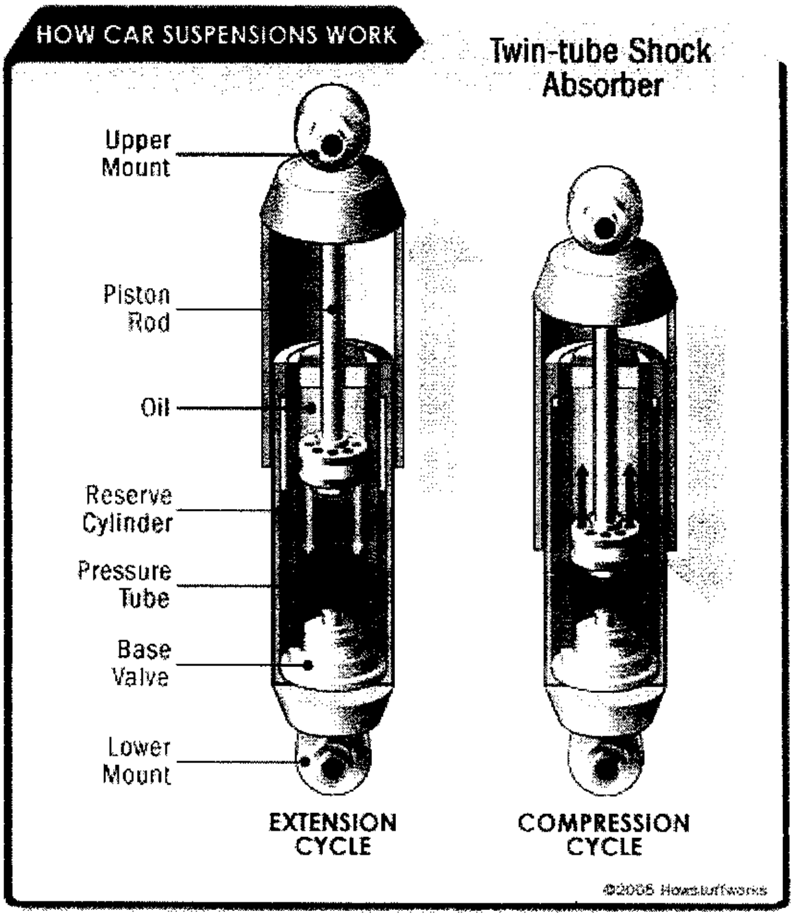


FIG 2.4 SUSPENSION WORKING

When the bike wheel encounters a bump in the road and causes the spring to coil and uncoil, the energy of the spring is transferred to the shock absorber through the upper mount, down through the piston rod and into the piston. Orifices perforate the piston and allow fluid to leak through as the piston moves up and down in the pressure tube. Because the orifices are relatively tiny, only a small amount of fluid, under great pressure, passes through. This slows down the piston, which in turn slows down the spring.

Shock absorbers work in two cycles -- the compression cycle and the extension cycle. The compression cycle occurs as the piston moves downward, compressing the hydraulic fluid in the chamber below the piston. The extension cycle occurs as the piston moves toward the top of the pressure tube, compressing the fluid in the chamber above the piston. A typical bike will have more resistance extension controls the heavier, sprung weight.

All modern shock absorbers are velocity-sensitive -- the faster the suspension moves, the more resistance the shock absorber provides.

When the vehicle encounters a bump the spring is deflected, and it stores energy. Without shocks the spring will extend and release this energy at an uncontrolled rate. The spring's inertia causes it to bounce and overextend itself. Then it re-compresses, but will again travel too far. The spring continues to bounce at its natural frequency until all of the energy originally put into the spring is used. The spring allows movement of the wheel to be transformed into kinetic energy of the unsprung mass, whereupon it is dissipated by the damper.

Shock absorbers that are in good condition will allow the suspension to oscillate through one or two diminishing cycles, limiting or damping excessive movement, and maintaining vertical loads placed upon the tires. The damper does this by forcing gas or oil through a constriction valve (a small hole). Adjustable shock absorbers allow you to change the size of this constriction, and thus control the rate of damping. This helps keep the tires in contact with the road.

If the shock absorbers are worn and the vehicle meets a bump in the road, the vehicle will bounce at the frequency of the suspension until the energy of the bump is used up. This may allow the tires to lose contact with the road. By controlling spring and suspension movement, while the vehicle is in motion, dynamic wheel alignment will be maintained.

2.9 HISTORY OF SUSPENSION SYSTEMS

In the beginning of motorcycling in the early twentieth century, motorcycles were basically just heavy duty bicycle frames with internal combustion engines. “Suspension” as it was then was little more than the air in the tires and springs under the seat. Other systems were rudimentary such as brakes, ignition systems, oiling systems, etc. These were the formative years of motorcycle design and over the years many design improvements were made long before the technology and metallurgy of the time were able to supply the ideas in metal, rubber, plastic, or whatever material might be called for As motorcycle front end. Rear suspensions came later in motorcycle development.

Suspensions, however, have been pretty much incorporated as they were engineered throughout the history of the twentieth century motorcycle. Through the twenties, thirties, and forties rear and front suspensions of various designs were developed. It was in the fifties and early sixties that the twin shock, swingarm designed rear suspension and the telescopic fork became pretty much standard. However, the single shock rear suspension known now days as a soft tail has been around for many years. Likewise the system of monoshock suspension that is considered quite advanced by today's standards had been around for a long time. The progressive linkage of modern sport and road racing machinery is a relatively recent adaptation of the single shock, however.

2.9.1 Front Suspension

The girder fork is one early attempt at controlling the front of a motorcycle, but it had disadvantages in its design and did not work well compared to competing designs. Its main drawback is as it works through its arc of movement, the motorcycles chassis length constantly changes. This is not conducive to stability at speed.

The progressive linkage of modern sport and road racing machinery is a relatively recent adaptation of the single shock.

There are modern designs for hub center steering as seen in some of the production sport touring motorcycles. The idea in these systems is that the wheel steers at the center of its hub and is held by a suspension arm which hinges at the frame in the vertical direction only. A standard shock is used to control travel, much as in a automobile's torque arm suspension or it can be likened to a single sided rear swing arm in reverse mounted to the front of the motorcycle. It offers advantages such as fewer dives under braking and less stiction of the front end than a conventional fork. Also, as the bike brakes and accelerates, the rake and trail figures that would be changing in a conventional fork do not apply with this arrangement. Steering geometry is constant. This is advantageous in maintaining control and reduces weight transfer under heavy braking. These systems may see further development in the future, but for now the telescopic front fork still rules

One other modern development is the "telelever" system. This is sort of a combination of the telescopic fork with an arm, reminiscent of a hub center steered suspension arm, which controls the travel of the forks through a shock mounted to it and which mounts to the frame of the motorcycle. This effectively reduces fork flex under braking to near zero and much reduces dive under braking. The system works very well and allows for a very stable ride.

2.9.2 Rear Suspension

A hard tail suspension, that is no suspension at all, was the norm for the first half century of motorcycling. There were some early types similar to what today are called the "soft tails" which involve a swinging triangular swingarm at the rear of the bike connected to shocks and springs up under the seat. Actually, this suspension type was ahead of it's time and has some advantages over the traditional twin shock swingarm system. It is quite stiff being a triangulated and well braced arm by design. When the industry came out with the Monoshock system in the early '70s, it was reminiscent of this design. It placed a modern adjustable gas shock up under the gas tank, but the swingarm was quite similar to a soft tail design. Twin shock systems came along in the 50s with the Norton featherbed being legendary among motorcycles of this era and the twin shock frame persists to this day. Among sportbikes though, the progressive linkage single shock systems have taken over. The progressive link systems rapidly developed into state of the art for performance suspension on the street and roadrace tracks as well as motocross. Other than the obvious advantage of progressive action of the shock, it also allows for a lower center of gravity of the bike. Modern box section aluminum swingarms are flex free and lighter than a Monoshock system. As that weight is unsprung, this is a significant advantage. The less mass and inertia the shock has to dampen, the better it can do it's job.

CHAPTER 3

TYPES OF SUSPENSION SYSTEMS

3.1 FRONT END SUSPENSION

3.1.1 Telescopic Forks

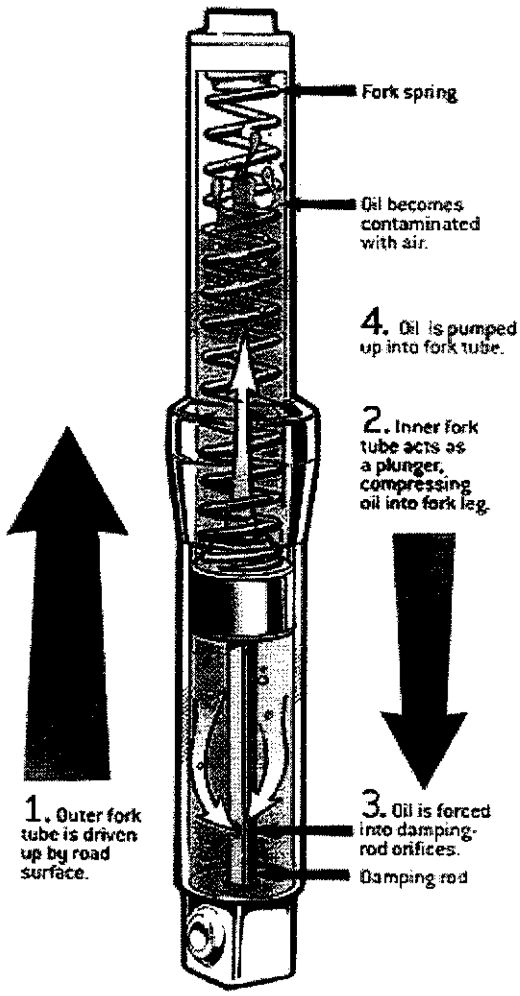


FIG 3.1 DAMPING ROD FORK

3.1.1.1 Damping Rod Fork

Most cruisers are in the Stone Age regarding fork technology. They use what's called a damping-rod fork, in which the damping action comes solely from oil being pushed around inside the fork and through sets of comparatively small holes.

There are two fork tubes the outer and the inner, the outer tube envelops the inner tube partially. In the normal position the hydraulic oil is contained in the outer tube. The outer fork tube is driven up by road surface when the front wheel rides over a bump. The inner fork tube acts as a plunger compressing oil in the then pumped into the inner fork tube through the damping rod. This action provides the cushioning effect. However this oil gets contaminated with air in the inner fork tube.

The big problem with a damping-rod fork is that it can be soft and under damped during low-speed movement but suddenly turn harsh over the small stuff. This is because oil forced through a fixed-size hole offers resistance related to its velocity. When the oil is barely moving, there's little resistance. But try to force it quickly through a small hole and the resistance shoots way up.

3.1.1.2 Cartridge Fork

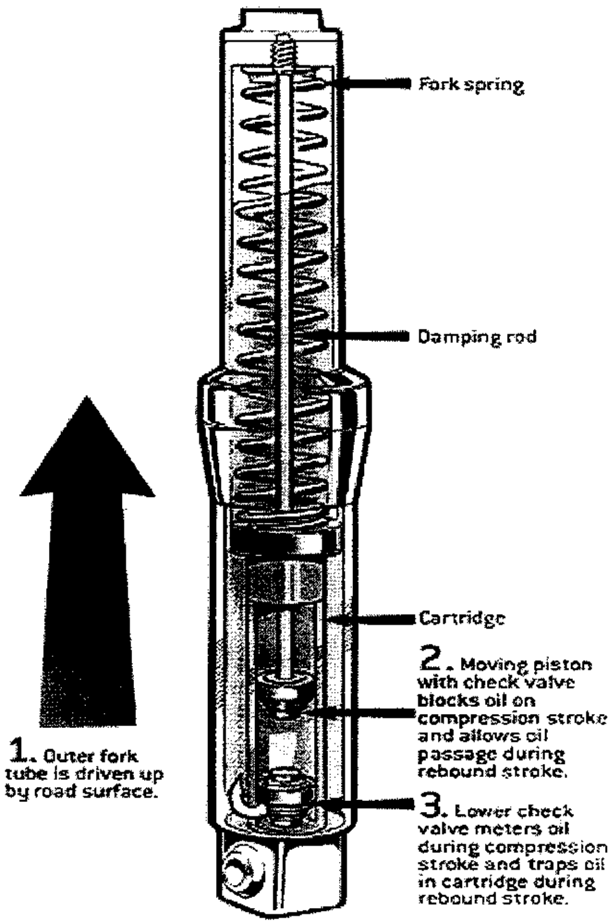


FIG 3.2 CARTRIDGE FORK

The technology that has superseded the damping-rod fork in sport bikes and a few cruisers is called a cartridge fork. One or both fork legs carry a small cylinder inside the lower section that is, basically, an open-chamber shock absorber. A piston slides through this cartridge, which is submerged in the fork suspension moves, the piston is forced through the oil, which in turn forces the shim away from the piston face. The thickness and diameter of the shim determines how much force is required to move it out of the way, and therefore how much damping you get. These shims can be fine-tuned to offer resistance even at low suspension speeds—needed to keep the chassis on an even keel—but also "blow off" sufficiently to allow the wheels to move rapidly in response to sharp bumps.

One end of the damping rod is connected to the piston and the other end is screwed into the top of the inner tube. During compression stroke the piston with check valve moving down blocks oil and allows oil passage during rebound stroke. On the other hand lower check valve meters oil during compression stroke and traps oil in cartridge during rebound stroke. Unlike the damping rod fork this system isolates the damping function from air contamination.

3.1.2 Telelever Suspension System

3.1.2.1 Front Telelever

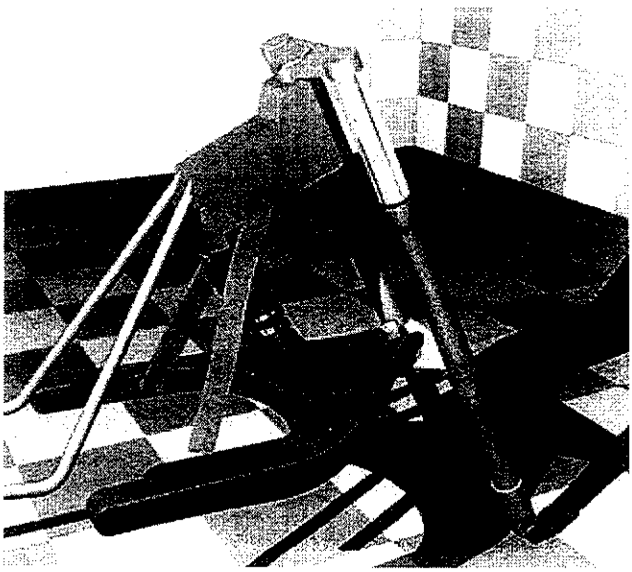


FIG 3.3 FRONT TELELEVER

The problem with traditional telescopic fork suspension is that all the forces acting on the front of the bike are transmitted to the handlebars, and thus the rider. Some people think this is A Good Thing - it keeps the rider "informed" as to what is going on. Others argue that it is a necessary evil and that telescopic forks are an unfortunate accident of history. With telelever, there is now a single forks. Telelever still has front forks, but their primary function now is to make a stiff frame for the front wheel to sit in, and to allow the rider to steer the bike (which is always useful). The strut/shock unit is connected to a wishbone which itself is connected to the frame of the bike at the back via a yoke, and to the cross member of the forks at the front using a ball joint. When you hit a bump with telelever, the suspension forces are transmitted through the ball joint, across the wishbone and up through the strut / shock unit into the frame of the bike. One of the biggest advantages of this system is that you don't need to engineer an anti-dive system into the forks. The design of the Telelever effectively reduces fork flex under braking to near zero which in turn reduces dive under braking. Another benefit is that the forces acting on the steering head bearings are dramatically reduced. In fact with telelever, as a rider you have to get used to the concept of braking without the bike diving at the front. It's really quite unique.

3.1.2.2 Front Duolever

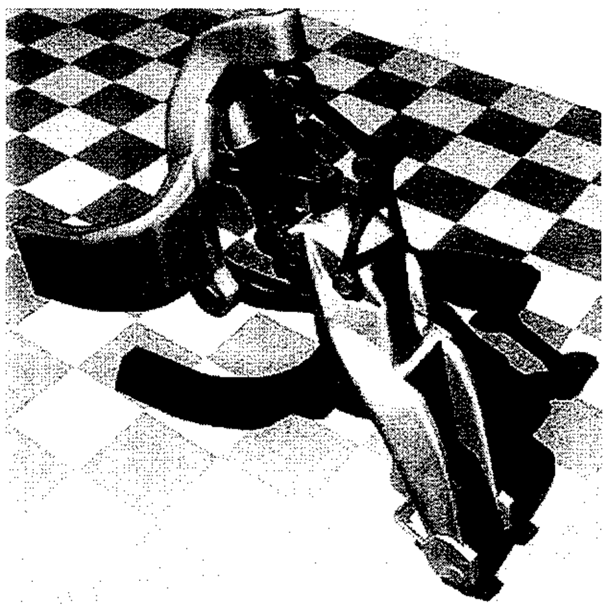


FIG 3.4 FRONT DUOLEVER

Duolever is an evolution of double wishbone / parallelogram suspension, which is why its sometimes referred to as Hossack Suspension. Like the rear paralever, its geometrically a double wishbone system. As with telelever, in duolever the pivoting links and springs are not steered. But with duolever, the physical link from the handlebars to the suspension is radically different, suspension is completely independent of the steering, with the two only being connected by the hinged link up top. (That link is simply used for *turning* the fork assembly and provides no structural support or strength.

3.2 REAR END SUSPENSION

3.2.1 Swing arm suspension

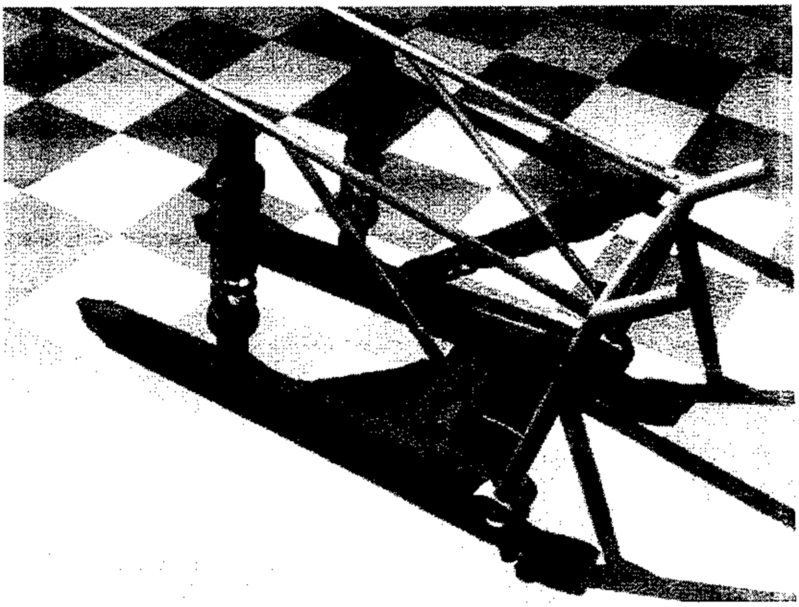


FIG 3.5 TWIN SHOCK- REGULAR SWING ARM

3.2.1.1 Twin shock- Regular Swing arm

This is the classic motorcycle suspension system. An H-shaped swingarm is pivoted at the front to the motorbike frame. On either side there are basic coil over units which provide the suspension. The shocks are inside the coil over units. This is about as basic as you can get on a motorbike and has been around for as long as the motorbike itself. This style of suspension began to fall out of favor in the 80's due to weight considerations and the availability of newer, stronger materials. It was also not a particularly robust design by modern considerations. It all got a bit bendy and flexible under extreme riding conditions and the only way to make it stronger was to add more metal, which added more unsprung weight, which reduced the efficiency of the suspension.

3.2.1.2 Monoshock, older style, regular swingarm

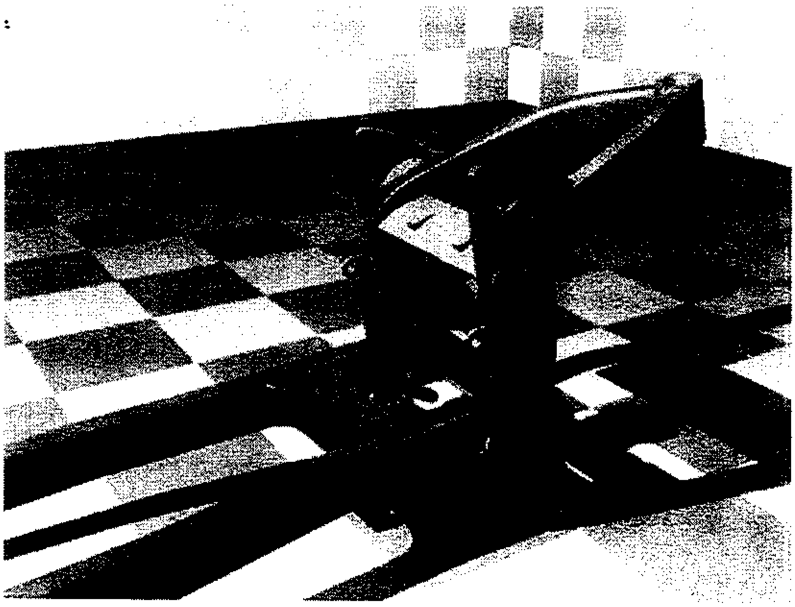


FIG 3.6 MONOSHOCK, REGULAR SWINGARM

On the current monoshock designs, there is now a complex linkage at the bottom end which joins the coilover to the swingarm itself, and its important to lube the joints in these linkages regularly. They are very exposed to the elements when riding. The linkage adds leverage to the suspension plus it allows the coilover to be mounted more vertically. Ever in need of less weight (and hence more speed), those clever engineers who devised this variation were able to remove the 'basket' part of the swingarm, and revert to the traditional "H" shaped arm, only with a bit more welding here and there and stronger materials.

3.2.1.3 Monoshock, single-sided swingarm

The ultimate evolution of the monoshock design is the single-sided swingarm. These are super-strong, super-lightweight swingarms like you might find on a VFR800. The advantage of a single-sided system is that the wheel can quickly be taken out and replaced. Not really a huge advantage for you or I fiddling with our bikes at the weekend, but for Moto-GP style racing, it does make a huge difference for the pit crew.

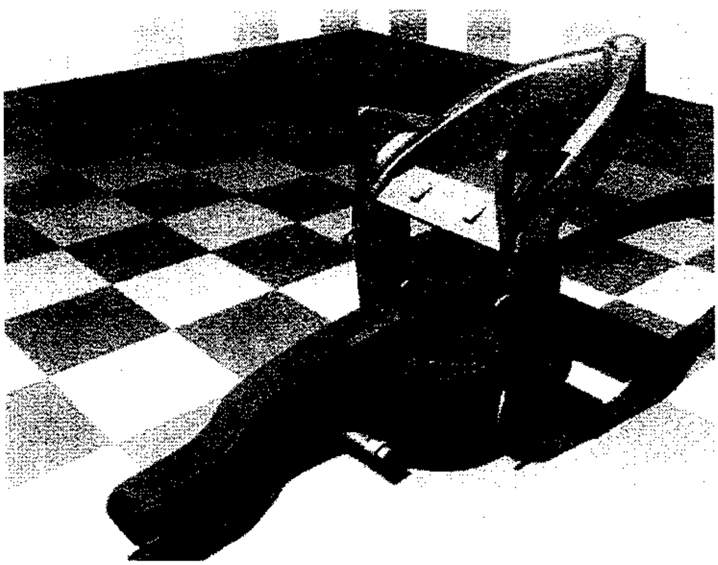


FIG 3.7 MONOSHOCK, SINGLE-SIDED SWINGARM

Single-sided swingarms need to be pretty heavily engineered because they bear the all the stresses from the rear axle offset to one side. With the traditional double-beam swingarm, the design needs to have longitudinal stiffness to stop it from bending. With the single-sided design, it needs to also have torsional stiffness to stop it from twisting under the offset load. As a result, single-sided swingarms are typically a lot larger and have a huge amount of cross-bracing inside them.

3.2.2 Telelever suspension

3.2.2.1 Rear monolever

In 1980, BMW introduced the world to the monolever suspension system on the back end of their big dirt bikes. Little did anyone know at the time that it was a sign of the radical design changes to come. Most BMW bikes, modern ones anyway, have shaft drive, so it's given on a beemer that one side of the rear suspension is going to be pretty beefy because it has to house the driveshaft and ultimately the rear drive. BMW capitalized on this and with the monolever, they created a single-sided suspension system, much like the monoshock, but the shock / strut unit was mounted to one side of the bike, rather then in the centre. The driveshaft ran down the inside of the single-sided swingarm and into the rear drive.

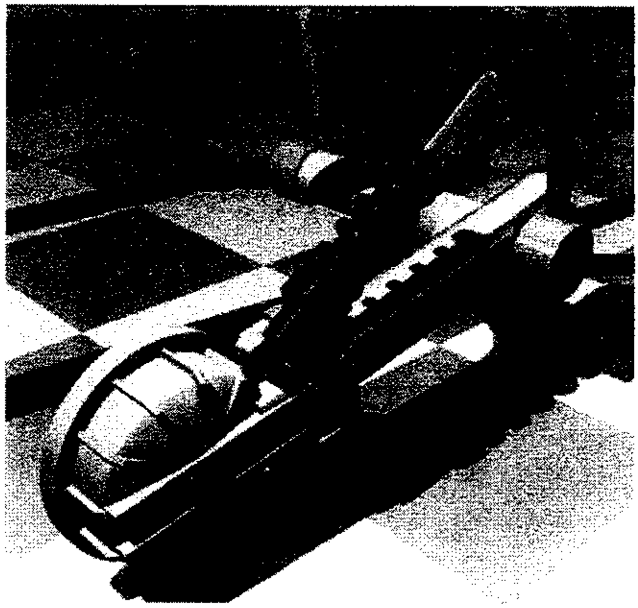


FIG 3.8 REAR MONOLEVER

This design helped eliminate the need for beefier engineering at the front of the swingarm which would have been needed to resist the torsional load of having the wheel mounted to a single-sided swingarm.

3.2.2.2 Rear paralever, first generation

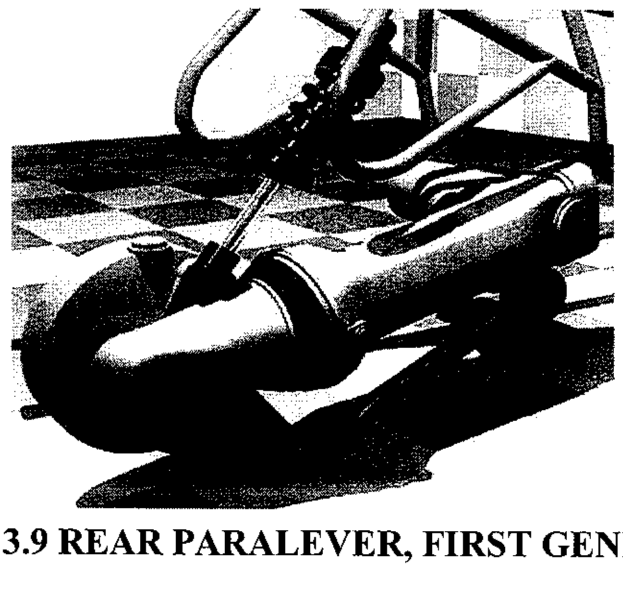


FIG 3.9 REAR PARALEVER, FIRST GENERATION

In 1987, BMW improved on their design and introduced the paralever suspension system on the back end of their new bikes. Paralever uses the same basic principle as monolever but adds a lower control arm to the mix and an extra pivot point between the main swingarm and the rear drive. The effect is that the stiffness to the suspension, but it also kept the rear drive at the same orientation relative to the rest of the bike. Because of the extra link at the rear drive, the strut / shock unit was turned over so that it was "the right way up", and it was still mounted to one side of the bike. Because the whole system now acts as a *double* swingarm, it substantially reduces the change of load response of the driveshaft. Using this type of suspension was also the impetus for BMW to change to using the engine as an integral stressed member of the frame, which allowed the swingarm and suspension components to be bolted directly to it.

3.2.2.3 Rear paralever, second generation

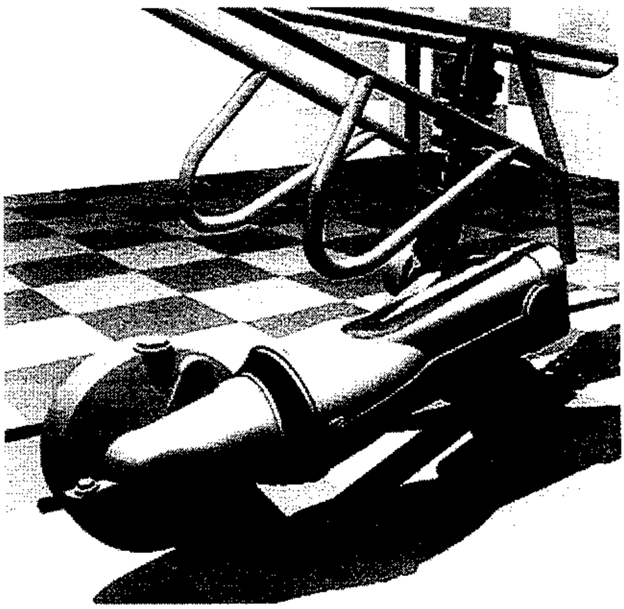


FIG 3.10 REAR PARALEVER, SECOND GENERATION

In 1993, the second generation paralever system was developed. The basic design was the same as the original paralever except that the strut/shock unit was moved away from the side of the bike and on to the centerline, bringing it more in line with the monoshock type system. It also gained a remote preload adjuster and spring plate height adjuster. This new paralever was made of aluminium instead of steel so it was lighter than the original whilst maintaining the strength needed for the single-sided shaft drive system.

3.2.2.4 Rear paralever, third generation

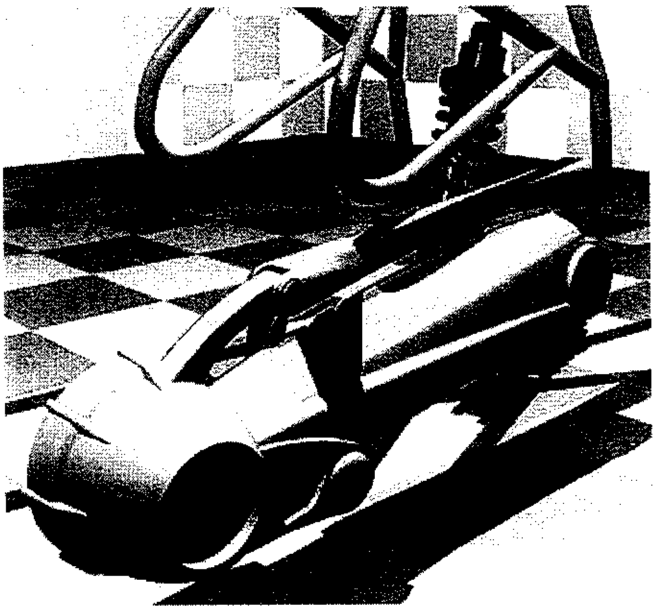


FIG 3.11 REAR PARALEVER, THIRD GENERATION

Skip forward ten years to 2004 - which tells you how good the Para lever II was that its design didn't change in nearly a decade. This design is similar but at the same time noticeably different to its predecessor, and at the time of writing is now the current BMW rear suspension of choice. The control arm was moved above the shaft drive from underneath, and the rear drive was changed to have a hole through the middle of it to save weight. The unsprung weight of the latest generation paralever is considerably lighter than its predecessors. That's not to say that it couldn't still be used as a substantial bludgeoning weapon if you got it off the bike, but in engineering terms, it has slimmed down considerably.

3.3 LIMITATIONS OF CONVENTIONAL SUSPENSION SYSTEMS

In the last 5 decades, the automobile industry has seen various developments and the field of suspension system is not exclusion. Whatever may be the developments these systems have always thrown up various drawbacks especially when subjected to extreme conditions. Some of the draw backs of the conventional system are given below.

- Lack of performance at high speeds.

- Fish tailing when banking around curves.
- Less flexibility.
- Lack of adjustability on different road conditions.
- Bending of fork stems may occur in case of accident.
- Leakage of hydraulic fluid
- Improper cooling of the internal parts.

When we refer to a traditional or a conventional suspension system, we mean a system that comes "as is." In other words, a conventional system is a passive system. Once it's been installed in the bike, its character changes very little. Once the system has reached these limits, it has no way of compensating for situations beyond its design parameters. Thus shock absorbers bottom out, struts overextend, and springs respond sluggishly, torsion bars get tweaked.

In order to overcome all these drawbacks, we need a new, more efficient suspension system. Something which could absorb more severe shocks and something which responds to the feedback from the road conditions. So we decided to implement Active Suspension Systems which are currently employed in few foreign cars on to our production motor bikes.

CHAPTER 4

ACTIVE SUSPENSION SYSTEM –AN OVERVIEW

4.1 AUTOMATION - AN OUTLOOK

This is an era of automation where it is broadly defined as replacement of manual effort by mechanical power in all degrees of automation. The operation remains an essential part of the system although with changing demands on physical input as the degree of mechanization is increased.

Degrees of automation are of two types, viz.

- Full automation.
- Semi automation.

In semi automation a combination of manual effort and mechanical power is required whereas in full automation human participation is very negligible.

4.1.1 Need for automation

Automation can be achieved through computers, hydraulics, pneumatics, robotics, etc., of these sources, pneumatics form an attractive medium for low cost automation. The main advantages of all pneumatic systems are economy and simplicity. Automation plays an important role in mass production.

For mass production of the product, the machining operations decide the sequence of machining. The machines designed for producing a particular product are called transfer machines. The components must be moved automatically from the bins to various machines sequentially and the final component can be placed separately for packaging. Materials can also be repeatedly transferred from the moving conveyors to the work place and vice versa.

Nowadays almost all the manufacturing process is being atomized in order to deliver the products at a faster rate. The manufacturing operation is being atomized for the following reasons.

- To achieve mass production
- To reduce man power
- To increase the efficiency of the plant
- To reduce the work load
- To reduce the production cost
- To reduce the production time.

Traditionally automotive suspension designs have been a compromise between the three conflicting criteria of road holding, load carrying and passenger comfort. The suspension system must support the vehicle, provide directional control during handling maneuvers and provide effective isolation of passengers/payload from road disturbances. Good ride comfort requires a soft suspension, whereas insensitivity to applied loads requires stiff suspension. Good handling requires a suspension setting somewhere between the two.

Due to these conflicting demands, suspension design has had to be something of a compromise, largely determined by the type of use for which the vehicle was designed. Active suspensions are considered to be a way of increasing the freedom one has to specify independently the characteristics of load carrying, handling and ride quality. A passive suspension system has the ability to store energy via a spring and to dissipate it via a damper. Its parameters are generally fixed, being chosen to achieve a certain level of compromise between road holding, load carrying and comfort. An active suspension system has the ability to store, dissipate and to introduce energy to the system. It may vary its parameters depending upon operating conditions and can have knowledge other than the strut deflection the passive system is limited to.

4.2 DEFINITION

An electronically controlled pneumatic suspension system that uses a pneumatic drive unit with conventional springs and shock absorbers to support the vehicle's movement under irregular surfaces.

An active suspension system has the capability to adjust itself continuously to changing road conditions. It "artificially" extends the design parameters of the system by constantly monitoring and adjusting itself, thereby changing its character on an ongoing basis. It's schizophrenic, if you will, but with a purpose. With advanced sensors and microprocessors feeding it information all the time, its identity remains fluid, contextual, and amorphous. By changing its character to respond to varying road conditions, active suspension offers superior handling, road feel, responsiveness and safety.

Active suspension works by constantly sensing changes in the road surface components then act upon the system to modify its character, adjusting shock stiffness, spring rate and the like, to improve ride performance, drivability, responsiveness, etc.

4.3 LITERATURE SURVEY:

As we have discussed earlier few state-of-the-art production passenger vehicles offer fully active suspension systems as standard or optional equipment. Here's a brief rundown.

- Cadillac. Beginning in 1996, Cadillac began offering active suspension on its Eldorado Touring Coupe, DeVille Concours and Seville STS models. Known as continuously variable road-sensing suspension (CVRSS), the system uses a series of sensors to actuate hydraulic shock absorbers at all four corners, improving road feel and dampening. The system adjusts in a fraction of a second -- the amount of time it takes a vehicle going 65 mph to travel 15 inches.

- Land Rover. Starting with the 1999 model year, the Land Rover Discovery Series II sport ute comes with active cornering enhancement (ACE). The Land Rover system is a first for sport-utility vehicles. It utilizes a hydraulic system that replaces the more traditional front and rear anti-roll bars, applying torque to the body via two piston/lever configurations. The system has the capability to counteract up to 1.0 g lateral acceleration in 250 milliseconds.
- Mercedes-Benz, the new 2000 CL500 boasts what MB modestly terms "the world's only active suspension system," a technology with which one of our editors was awesomely impressed on a recent first drive. The Mercedes system, known as Active Body Control (ABC), uses 13 different on-board sensors, which feed into four hydraulic servos positioned atop each coil spring. The ABC computer adjusts the ride every 10 milliseconds.

4.4 FLUID POWER

Fluid power technology is a means to convert, transmit, control and apply fluid energy to perform useful work. Since a fluid can be either a liquid or a gas, fluid power in genera includes hydraulics and pneumatics. Oil hydraulics employs pressurized liquid and pneumatics employs compressed air.

4.4.1 Advantages of fluid power systems

The advantages of fluid power systems are,

- The utilization of electrical materials is limited by the fact that the ferromagnetic materials saturate at a low flux density, i.e. only a certain amount of torque can be obtained by a kilogram of iron present in the motor armature. But the limitation in the hydraulic drives relates to the ultimate tensile strength of the material. By selecting a material of higher tensile strength, a system's working pressure can be increased and correspondingly higher torque can be achieved. Thus, the amount of moving mass less in case of hydraulics drive. The fluid power drives are more compact than a mechanical drive because eliminate the need for links like cams and gears.
- Multiplication of small forces to achieve greater forces for performing work.
- It easily provides infinite and step less variable speed control which is difficult to obtain from other drives.
- Accuracy in controlling small or large forces with instant reversal is possible with hydraulic systems.
- Constant force is possible in fluid power system regardless of special motion requirements, whether the work output moves a few millimeters or serves meters per minute.
- As the medium of power transmission is a fluid, it is not subjected to any breakage of parts as in a mechanical transmission.
- The parts of hydraulic system are lubricated with the hydraulic liquid itself.

4.4.2 Hydraulic Fluids and Properties

Hydraulic fluid is the life blood of the system, the one element that ties everything together. There is no universal or ideal hydraulic fluid for all applications. One major reason is the imposing list of fluid characteristics considered important by users, system designers and manufactures. So selection of a proper fluid for a given application is always a compromise. To do its job well a hydraulic fluid must be able to perform at least the following the following functions.

- Transfer fluid power efficiently.
- Lubricants the moving parts.
- Absorb, carry and transfer the heat generated within the system.
- Be compatible with hydraulic components.
- Remain stable against a wide range of possible physical and chemical changes, both during storage and while in use.

4.4.3 Pneumatics

Pneumatic systems use pressurized air to transmit and control power. Air is used as the fluid because it is safe, less expensive and is readily to the atmosphere and a return line is not necessary as with hydraulics.

Pneumatics has a variety of uses in the industry. It is an indispensable source of power for various tools like pneumatic hammers, pneumatic drills, pneumatic wrenches and runners, Pneumatic grinders etc. Moreover, pneumatic is widely used for material handling operations, high speed clamping and in robotic power drives for arms and grippers. Pneumatics is used widely in industries like food, pharma, textile, engineering, automobile etc.

In modern industries, pneumatic systems are used as a means of work place mechanization and automation where a major part of manual and tedious work may be supplemented by pneumatic controls for quick and economic production.

4.4.4 Comparison of Pneumatic System with Hydraulic System

1. Liquid exhibit greater inertia than gases. Therefore, in hydraulic systems,

the actuators and when suddenly opening and closing the valves. In accordance with Newton's law of motion, the force required to accelerated oil is many times greater than that that required to accelerate an equal volume of air.

2. Liquid also exhibit greater viscosity than gases. This results in large frictional pressure and power losses.
3. Since hydraulic systems use a fluid foreign to the atmosphere, they require reservoirs and a no-leak system design. Pneumatic system use air which is exhausted directly back into the surroundings environment. Generally, pneumatic systems are less expensive than hydraulic systems.
4. Due to compressibility of air, it is impossible to obtain a precise control of actuator velocities in pneumatic systems. In applications where the actuator travel is to be smooth and steady against a variable load, the air exhaust from the actuator is normally metered.
5. While pneumatic pressures are quite low due to compressor design, hydraulic pressures are high. Thus, hydraulic can be used in high power systems whereas pneumatics are confined to low power applications.

4.5 BASIC ELEMENTS IN A PNEUMATIC SYSTEM

The basic system requirements for introducing pneumatics in ones plant are listed below:

4.5.1 Compressor Plant

The production plant using pneumatic tools, etc.. should be equipped with the compressed air plant of appropriate capacity to meet the compressed air need of the systems.

4.5.2 Pipeline

A well-laid compressed air pipeline should be drawn from the compressor plant to the consumption point of pneumatic arrangement in various sections of the plant where the pneumatic gadgets and systems are to be introduced.

4.5.3 Control Valve

Various types of control valves are used to regulate, control, monitor the air energy, for control of direction, pressure, flow, etc.

4.5.4 Air Actuator

Various types of air cylinders or air motors are used to perform the usual work for which the pneumatic system is designed like using cylinders for linear movement of jigs, fixtures, raw material feeding, etc.

4.5.5 Auxiliary Appliances

Various types of auxiliary equipments may have to be used in pneumatic systems for effecting better performance, easy controllability and higher reliability.

4.6 PRODUCTION OF COMPRESSED AIR

Pneumatic systems operate on a supply of compressed air, which must be made available, in sufficient quantity and at a pressure to suit the capacity of the system. When pneumatic system is being adopted for the first time, however it wills indeed the necessary to deal with the question of compressed air supply.

The key part of any facility for supply of compressed air is by means using reciprocating compressor. A compressor is a machine that takes in air, gas at a certain pressure and delivered the air at a high pressure.

Compressor capacity is the actual quantity of air compressed and delivered and the volume expressed is that of the air at intake conditions namely at atmosphere pressure and normal ambient temperature.

Clean condition of the suction air is one of the factors, which decides the life of a compressor. Warm and moist suction air will result in increased precipitation of condense from the compressed air.

4.6.1 Types of Air Compressors

There are two basic types of compressors (1) Positive displacement and (2) Turbo compressor. Their main distinction lies in their method of energy transfer and pressure generation.

4.6.1.1 Positive Displacement Compressors

Work on the principle of increasing the pressure of a definite volume of air by reducing that volume in an enclosed chamber. Positive displacement compressors are most frequently employed for compressed air plant and have proved highly successful and supply air for pneumatic control application. The types of positive compressor

- Reciprocating type compressor
- Rotary type compressor

4.6.1.2 Dynamic (Turbo) Compressor

Employs rotating vanes or impellers to impart velocity and pressure to the flow of air. The pressure comes from the dynamic effects such as centrifugal force. Positive displacement compressors are sub-divided into two groups. Reciprocating type and rotary type compressors. Turbo compressors are employed where large capacity of air required at low discharge pressures. They cannot attain pressure necessary for pneumatic control application unless built in multistage designs and are seldom encountered in pneumatic service.

4.6.1.3 Reciprocating Compressors

Built for either stationary (or) portable service the reciprocating compressor is by far the most common type. Reciprocating compressors lap be had is sizes from the smallest capacities to deliver more than 500 m^3/min. In single stage compressor, the air pressure may be of 6 bar machines discharge of pressure is up to 15 bars. Discharge pressure in the range of 250 bars can be obtained with high pressure reciprocating compressors that of three & four stages. Single stage and 1200 stage models are particularly suitable for pneumatic applications , with preference going to the two stage design as soon as the discharge pressure exceeds 6 bar , because it in capable of matching the performance of single stage machine at lower costs per driving powers in the range .

4.6.2 Compressor Classifications

There are many geometrical and operational features of air compressor resulting in various types of compressor classification. Depending on the various features, classification can be done in number of ways:

1. As a single or double acting compressor, by no of stage of compressor, eg. Single, two or three or multiple stages.

2. As per disposition of cylinders related to crankshaft (cylinders in vertical, inline, horizontal, radial, vee positions. etc
3. By compressor drive or prime mover such as diesel engine driven, electrical motor driven, gas/turbine drive.
4. By condition of compressed air, viz lubricating oil, contaminated air, or oil air free..
5. By mounting and portability conditions, viz portable compressor, stationary compressor or skid mounted compressor.
6. By cooling medium applied, viz air cooled, water cooled, liquid injected compressor, etc.

Air compressors air invariably specified in terms of their capacity to deliver free air and pressure of the compressed air at the final discharge point. At this point it would be relevant to define single acting and double acting cylinder.

4.7 PNEUMATIC CYLINDERS

4.7.1 Types of Pneumatic Cylinders

4.7.1.1 Single Acting type

It has a single air inlet line. When this line is pressurized, the piston extends. The return movement of the piston is affected by a built-in spring mounted on the rod side of the piston or by application of an external force like gravity. Single acting cylinders with a return spring are limited in stroke, because the spring force that must be overcome while extending increase with the stroke.

The advantage of a single acting cylinder lies in its reduced air consumption, since air is not wasted while retracing the piston.

4.7.1.2 Double Acting type

The force exerted by the compressed air moves the piston in two direction in a double acting cylinder produces less force during retraction, because the piston rod's cross-sectional area is subtracted from the piston area under pressure.

They are used particularly when the piston is required to perform work not only on the advance movement but also on the return movement. In principle, the stoke length is unlimited, although buckling and bending must be considered before we select a particular size of piston diameter, rod length and stroke length.

4.7.1.3 Tandem Cylinder

It consists of two pistons operating in separate sections along the same axis with a common piston rod. Since the available force is doubled, this design is useful when larger forces are required, but a single cylinder with a larger diameter cannot be accommodated.

4.7.1.4 Three Position Cylinder

It is quite similar to the tandem cylinder, except that the left piston rod is not connected to the right piston and left cylinder is shorter than the right one. With the left piston extended, the retraction of the right piston is limited to an intermediate position which is determined by the ability of the right piston to retract fully.

4.7.1.5 Through Rod Cylinder

Here the piston rod extends to both ends of the piston. This will ensure equal force and speed on both sides of the cylinder.

4.7.1.6 Adjustable Stroke Cylinder

The cylinder stroke can be adjusted by screwing the left hand piston in or out. By using the shortest possible stroke needed for a given job, better rapid cycling is achieved and air consumption is reduced.

4.7.1.7 Telescoping Cylinder

When pressure is applied to the left side, the inner cylinder acts as a piston and extends. Once it reaches the end of its stroke, the innermost piston begins to extend. The available stroke is almost double when compared to a normal cylinder having the same retracted length.

4.7.2 Materials for Pneumatic cylinder

The important parts of pneumatic cylinders have been discussed. Various types of materials are needed to construct a cylinder. The main parts which may etc. materials selection of the pneumatic cylinder is most important. The most common materials that are used for cylinder parts are given below.

4.7.2.1 Cylinder barrel or tubes

Generally hard drawn seamless aluminum, brass, steel are used. For low pressure applications nylon or plastic may also be used. For high pressure or heavy duty application seamless steel tubes are mostly used.

4.7.2.2 Piston

The universal choice is castings of aluminum, bronze, etc. cast iron is also widely used.

4.7.2.3 Piston rod

As it is highly stressed part, the piston rod is made up of grounded polished, or chrome plated medium carbon steel. The rod is hardened to ensure its strength and provide its scratch free characteristics.

The most common material for cylinder end covers is aluminium, brass, bronze and cast iron.

4.7.2.4 Mounting brackets

Aluminium alloy, brass, cast iron, or high tensile castings are most common.

4.7.2.5 Tie rod

High tensile steels are a good choice.

4.7.3 Cylinder Size

Normal cylinder sizes are confined within economic cylinder- eg. From 6 mm dia to 250 mm dia for normal line pressures of 5 to 6 bar. Impact cylinders of high energy rate forming and similar applications are made in broze sizes upto 200 mm diameter. The stroke length should be greater than 2000 mm. With the large cylinder diameter and larger stroke, the high consumption makes pneumatics uneconomical due to heavy investment in compressor plant.

With large piston stroke, the mechanical stress on the piston rod, the pilot bearing is too great. To avoid the danger of buckling, a large stroke, the piston rod support length must also be increased.

4.8 PNEUMATIC CONTROLS

To control the to and fro motions of a pneumatic cylinder, the air energy has to be regulated, controlled and reversed with the pre-determined sequence in a pneumatic system. Similarly, one may have to control the pressure and the flow rate to generate the desired level of force and speed of actuators. To achieve these functions, valves are used. The valves are fluid power elements used for controlling and regulating the working medium that is the compressed air in the case of a pneumatic system. Broadly valves are used to (1) Start and stop pneumatic energy (2) Control the direction of flow of the compressed air (3) Control the flow rate of the compressed air (4) Control the pressure rating of the compressed air.

These are the various types of valves available in the family of compressed air systems but according to their main functions they may be divided into three broad groups:

1. Direction control valve
2. Direction control check valve
3. Flow control valve.

According to their constructions, valves may be classified into two groups.

1. Seal type
2. Spool type.

4.8.1 Mode of Control

In direct controlled direction controlled valve, the controlling force is directly applied on the working piston or spool. The following control methods used are

- Electro-magnetic control
- Pneumatic
- Mechanical
- Manual

4.8.1.1 Electro-Magnetic Control

Electromagnet is very commonly used for actuation of pneumatic valves. It consists of a plunger in 'C' frame structure. The armature presses on the valve spool when the electromagnet is excited. The plunger gets attracted due to magnetic force of the valve. In an AC magnet the ferromagnetic system is composed of stacked iron laminations. Laminations are not needed in case of DC solenoids.

4.8.1.2 Pneumatic Control

The pneumatic method acts on a spool or piston with a large effective area, which in turn transfers the actuating force to the spool. The pilot control element used in pneumatic actuation is mostly 3/2 or 2/2 direction control valve.

4.8.1.3 Mechanical Control

Here rollers, springs or similar mechanical elements are used. The roller tappet is pushed in by cam or similar devices and presses the spool. The spool moves and actuates the valve plunger. Roller operated valves are most common examples.

4.8.1.4 Manual Control

The angular movement of the pedal or lever is transmitted to a tappet from there to the spool. The detents in the lever-operated valves in the individual positions are achieved with the use of balls, which are pressed into angular grooves in the tappet by springs. Push button is operated.

4.8.1.5 Electro-Pneumatic Control

This is a combination of electric and pneumatic control methods. The 3/2 way valve (pneumatic) is actuated by a solenoid and in turn controls the main direction control valve.

4.9 APPLICATION OF PNEUMATICS

The technology of pneumatics deals with the study of the behavior and application of the compressed air. Though the science of air was known to man for centuries, it was not much used till the beginning of the second world war

During the war, many industries all over the developed western countries started switching over more and more to automatic equipment. Many of these were operated and retrofitted with pneumatics operated gadgets and accessories for the purpose manufacturing and other activities, to meet the sudden need of the enhanced production of war commodities under the tremendous shortage of technical man power.

This was the age present day concept of automation started provoking man to use compressed air in production plants. Today air operated tools and accessories are a common sight in each and every industry, not only in the technologically advanced countries but even in the countries where industrial activities are still at the age sheer infancy. With the introduction of pneumatics in the manufacturing process, the industry is benefited with a cheaper medium of industrial automation which if judiciously used, may bring down the cost of production to much lower level. A few years ago maximum application of the pneumatics was probably in the field of construction where the main source of power for tools like power hammers, drills, nut runner, riveting hammers etc. was compressed air only. Today the list is endless. Now the compressed air is used in every walk of the life starting with pneumatic cranes, to the use of air in the brake systems of automobiles, railway coaches, railway wagons, printing pressed and what not. In fact today we find that it is extensively used in all fields.

4.9.1 Salient features of Pneumatic Systems

It is because of the following basic feature that make the application of pneumatics in industries more advantageous and exceptionally suitable in handling. The following features are notable:

- Wide availability of air
- Compressibility of air
- Easy transportation of compressed air in pressure vessels, containers, and in long pipes.
- Fire proof characteristics of the medium
- Simple in construction of pneumatic elements and easy handling
- High degree of compatibility of pressure, force and speed

- Easy maintenance
- Explosion proof characteristics of the medium
- Comparatively cheaper in cost

Compared to the hydraulic systems, pneumatic systems have operational advantages but it cannot replace hydraulic system so far as power requirements and accuracy of the operations are concerned. In areas of hazards, probably air will be a better medium of power than electrical system, hydraulic system and steam power system. It may not be necessary at this stage to dwell further on the multitude of advantages that may be derived from applying pneumatic energy on production plants and systems except what has been already mentioned earlier.

4.9.2 Maintenance need of the Pneumatic Systems

In comparison to other types of mechanical systems, pneumatic systems are found to be less problematic and hence offer more trouble free life. However, industrial experience shows even the best of the systems fails and hence to take necessary care against such failures. It is very important that pneumatic system is subjected to regular and adequate preventive maintenance checks and sound foolproof routine inspection should be carried out in order to keep running at their optimum efficiency. From the experiences of various engineers and technicians engaged in maintenance and repairing work in different plans and factories, where a large number of pneumatic attachments, accessories and hand tools are employed in production machines and other systems, it has been seen that a well maintained pneumatic system encounters minimum problems and probably minimizes the downtime to a greater extent with more fruitful work cycles.

While designing a pneumatic system specific care should be taken to make the system simpler and easy to handle. The following guidelines may also help both the designer and service personnel if followed properly:

- It should be easy to handle, operate, reliable, light in weight and simple.
- For each system the circuit diagram and the functional diagram must be available.
- The control elements must be as small as possible.

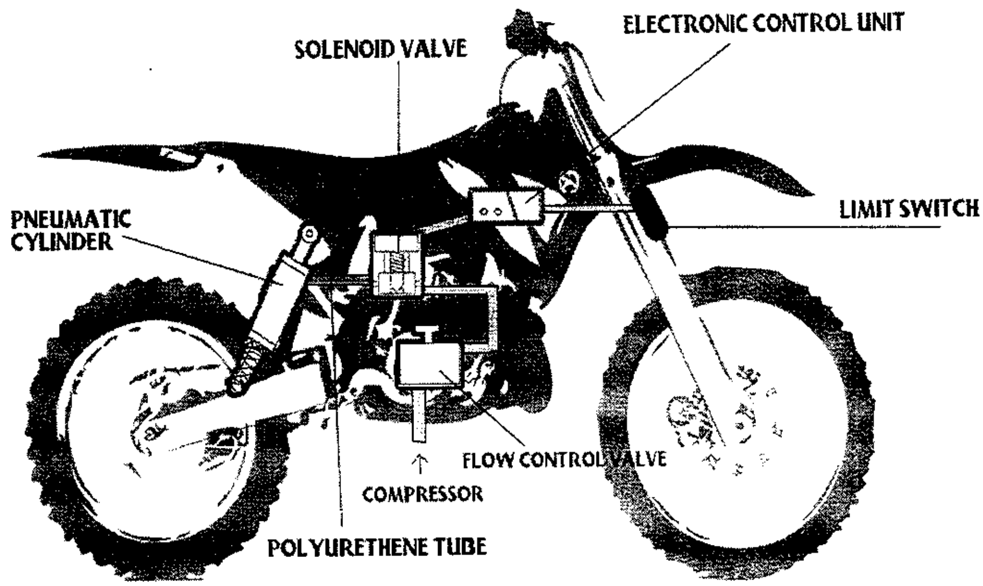
- The impulse valves should be guarded against dirt, cooling water and mechanical shocks.
- Before assembly of each unit care must be taken such that it is free of dust.
- The imprints on the units and the elements should be easily visible.
- Use valve openings provided by the manufacturers. No new openings are to be drilled on the elements.
- All the elements must be given proper identification number from the diagram.
- The service unit should be easily visible, serviceable and be placed at a higher level.
- The valve with spools should not be buckled when assembling in the unit.
- Throttles must be connected as nearer to the air passages.
- When dismantling and assembling valves and the cylinders takes care of the sealing materials.
- Silencer should be used as they decrease the noise of the air.
- Lies should be short, tension free and bend free. Plastic hoses should be also connected that they do not get too bent and they block the air passages.
- Cut the plastic hoses straight. If they are many bind them together.
- If hot chips or mechanical shocks are likely to occur on the plastic hose cover the hose by a sheet metal or used plastic pipes.

Lines and working units should be numbered according to the circuit and functional diagrams. Connections of plastic hoses to the elements must be screwed properly.

CHAPTER 5

ACTIVE SUSPENSION SYSTEM –WORKING

5.1 WORKING



COURTESY: YAMAHA CORPORATION

FIG 5.1 WORKING OF ACTIVE SUSPENSION SYSTEM

The components of active suspension system are,

- Limit Switch,
- Electronic Control Unit,
- Solenoid Valve,
- Flow Control Valve,
- Air compressor,
- Polyurethene Tube,
- Single acting Pneumatic Cylinder.

This is a front wheel guided system, i.e. the signal from the limit switch that is mounted on the front fork, governs the operation of the system.

When the front wheel encounters potholes or bumps on the road, the front fork is compressed, resulting in the activation of the limit switch, which in turn generates an electrical signal. This signal is fed to the Electronic Control Unit (ECU), where the signal is processed and a control signal (voltage) is generated. This voltage is applied to the solenoid valve, which is actuated accordingly. Compressor receives air from the atmosphere and pressurizes the air. This compressed air is sent to the (pneumatic cylinder) through the polyurethane tube, hence charging it. All these actions happen in a fraction of a second, i.e. before the rear wheel reaches the pothole. Thus the rear suspension becomes stiffer enabling it to absorb more shock. The pressurized air from the cylinder is vented out into the atmosphere through an orifice in the solenoid valve. The air is retained in the cylinder for a specific time and a mechanical knob provided in the ECU can adjust this time.

The above said sequence of operations is depicted in the flowchart shown below.

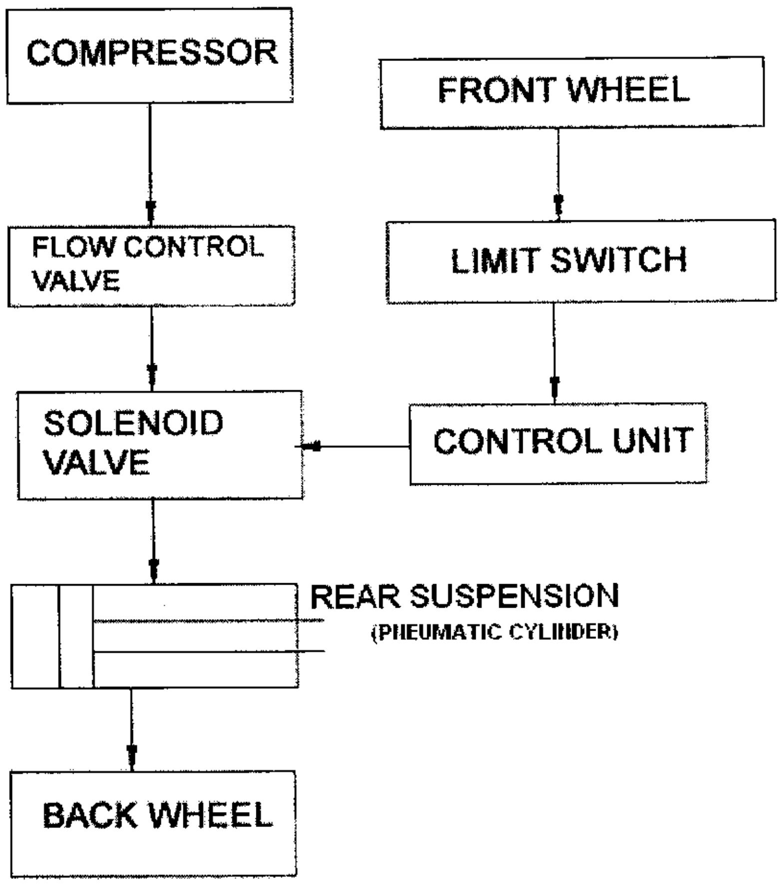


FIG 5.2 FLOW CHART

5.2 DESIGN OF PNEUMATIC CYLINDER

5.2.1 Design of Piston rod

Load due to air Pressure.

Diameter of the Piston (d)	=	35 mm
Pressure acting (p)	=	6 kgf/cm^2
Material used for rod	=	C 45

Assuming factor of safety = 2

Force acting on the rod (P) = Pressure x Area

= p x (? d² / 4)

= 6 x {(? x 3.5²) / 4 }

P = 57.73 Kgf

Design Stress(s_y) = sy / F0 S

= 36 / 2 = 18 Kgf/mm²

= P / (? d² / 4)

d = v 4 p / ? [s_y]

= v 4 x 57.73 / {? x 18}

= v 4.02 = 2.02 mm

Minimum diameter of rod required for the load = 2.02 mm

We assume diameter of the rod = 12.5 mm

5.2.2 Design of cylinder thickness

Material used = Cast iron

Assuming internal diameter of the cylinder = 35 mm

Ultimate tensile stress = 250 N/mm = 2500 gf/mm²

Working Stress = Ultimate tensile stress / factor of safety

Assuming factor of safety = 4

Working stress (f_t) = 2500 / 4 = 625 Kgf/cm²

According to 'LAMES EQUATION'

Minimum thickness of cylinder (t) = ri {v (f_t + p) / (f_t – p) -1 }

Where,

ri = inner radius of cylinder in cm.

f_t = Working stress (Kgf/cm²)

p = Working pressure in Kgf/cm²

Substituting values we get,

t = 1.75 { v (625 + 6) / (625 – 6) -1}

t = 0.0168 cm = 0.17 mm

We assume thickness of cylinder = 2.5 mm

Inner diameter of barrel = 35 mm

Outer diameter of barrel = 35 + 2t

= 35 + (2 x 2.5) = 40 mm

5.2.3 Design of Piston rod

5.2.3.1 Diameter of Piston Rod

Force of piston Rod (P) = Pressure x area =p x ? /4 (d^2)

= 6 x (? / 4) x $(3.5)^2$

= 57.73 Kgf

Also, force on piston rod (P) = (? /4) $(d_p)^2$ x f_t

P = (? /4) x $(dp)^2$ x 625

57.73 = (? /4) x $(dp)^2$ x 625

dp^2 = 57.73 x (4/?) x (1/625)

= 0.12

dp = 0.34 cm

By standardizing dp = 12.5 mm

5.2.3.2 Length of piston rod

Approach stroke = 50 mm

Length of threads = 2 x 20 = 40mm

Extra length due to front cover = 12 mm

Extra length of accommodate head = 20 mm

Total length of the piston rod = 50 + 40 + 12 + 20

= 122 mm

By standardizing, length of the piston rod = 130 mm

5.3 COMPONENTS OF ACTIVE SUSPENSION SYSTEM

5.3.1 Limit Switch

FIG 5.3 LIMIT SWITCH

5.3.1.1 Technical Data

- Quantity – 1
- Capacity - 2amperes
- Normally Open Type

5.3.1.2 Working

Limit switch is the sensing element in the active suspension system. Limit switch is connected to the front telescopic fork. It is a normally open type switch, i.e. when the switch is in normal condition the contact points are open. When the switch is operated the contacts points are closed and it develops an electrical signal proportional to the displacement of the front fork. It is connected to the electronic control unit, thus communicating the signal.

5.3.2 Electronic Control Unit

ECU is the heart of the active suspension system. It deals with processing of the signals. ECU acquires the electrical signal from the limit switch and processes the signal. This generates a control signal (voltage) which actuates the solenoid valve. The various components inside ECU are

- Comparator
- Operational amplifier
- Filters
- Voltage Regulator
- Relay Circuit

FIG 5.4 ELECTRONIC CONTROL UNIT

5.3.3 Solenoid Valve

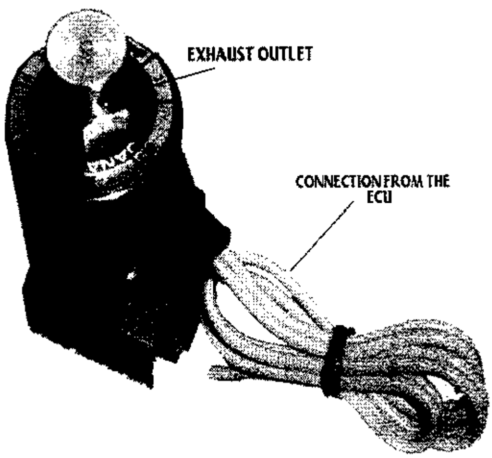


FIG 5.5 SOLENOID VALVE

5.3.3.1 Technical Data

- Size : ¼"
- Pressure : 0 to 8 kg / cm2
- Media : Air
- Type : 3/2
- Applied Voltage : 230V A.C
- Frequency : 50 Hz

5.3.3.2 Working

The directional control valve is one of the important parts of a pneumatic system. Commonly known as DCV, this valve is used to control the direction of air flow in the pneumatic system. The directional control valve does this by changing the position of its internal movable parts. Directional control valve used here is the solenoid valve. A solenoid is an electrical device that converts electrical energy into straight line motion and force. Solenoids may be push type or pull type. The push type solenoid is one in which the plunger is pushed when the solenoid is energized electrically. The pull type solenoid is one is which the plunger is pulled when the solenoid is energized.

The solenoid coil is made of copper wire. The layers of wire are separated by insulating layer. The entire solenoid coil is covered with a varnish that is not affected by solvents, moisture, cutting oil or often fluids. The Solenoid plunger is the mover mechanism of the solenoid. The plunger is made of steel laminations which are riveted together under high pressure. The solenoid plunger is moved by a magnetic force in one direction and is usually returned by spring action.

The solenoid valve selected for this project is a 3/2 solenoid valve, i.e. 2 positions and 3 vents. This is a normally closed type solenoid valve.

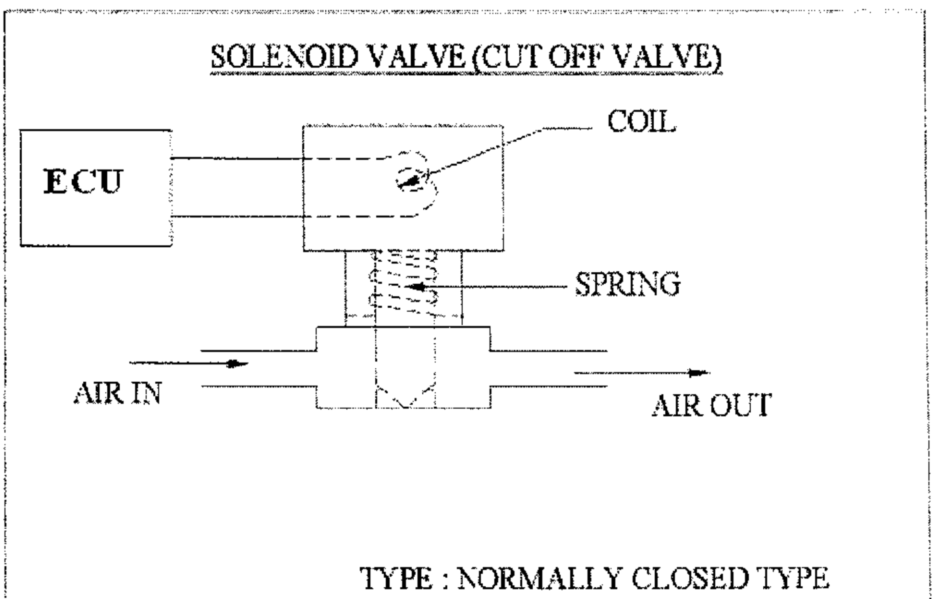


FIG 5.6 WORKING OF SOLENOID VALVE

It consists of an electromagnetic coil, spring and a plunger as shown above. Electromagnetic coil receives voltage from the ECU and becomes energized. Thus it attracts the plunger upwards against the spring action. The upward displacement is proportional to the control signal from the ECU. This allows the corresponding quantity of air to pass through to the cylinder.

5.3.4 Flow Control Valve

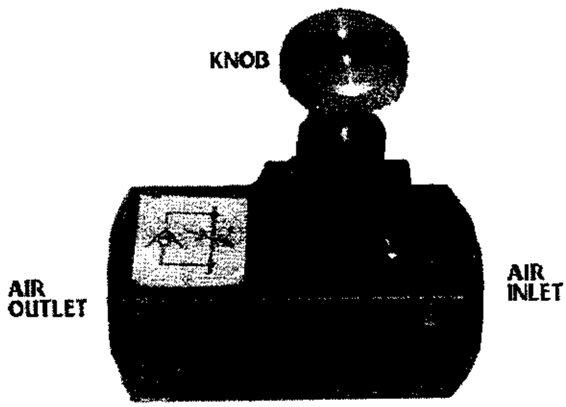


FIG 5.7 FLOW CONTROL VALVE

5.3.4.1 Technical data

- Port size : 0.635×10^{-2} m
- Pressure : 0-8 x 10 N/m²
- Media : Air
- Quantity : 1

5.3.4.2 Working

Flow control valve consists of two ports an inlet and an outlet port and a knob. The inlet port is connected to the compressor and the outlet port to the solenoid valve. The knob controls the mass flow rate of the compressed air from the compressor.

5.3.5 Pneumatic Cylinder

The piston is a cylindrical member of certain length which reciprocates inside the cylinder. The diameter of the piston is slightly less than that of the is made up of aluminium alloy for light and medium work and brass or bronze for CI-Heavy duty.

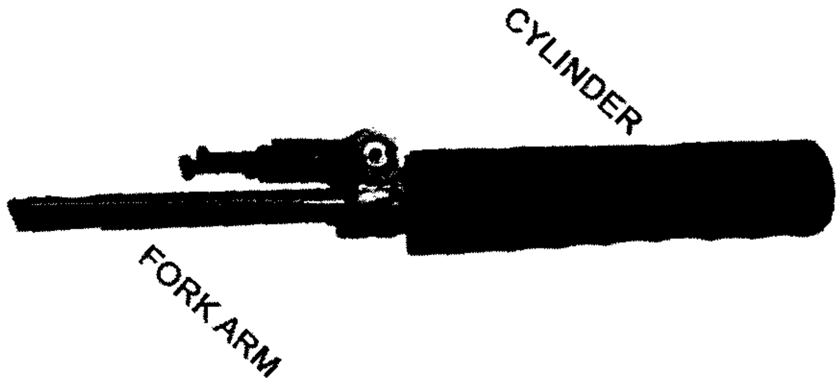


FIG 5.8 PNEUMATIC CYLINDER

5.3.5.1 Technical Data

- Stroke length : 170 mm
- Quantity : 2
- Seals : Nitride (Buna-N) Elastomer
- End cones : Cast iron
- Piston : EN – 8
- Media : Air
- Temperature : 0-80 ° C
- Pressure Range : 8 N/m²

5.3.5.2 Working

The cylinder used here is a single acting type. It has a single air inlet line. When this line is pressurized, the piston extends. The return movement of the piston is affected by a built-in spring mounted on the rod side of the piston or by application of an external force like gravity. Single acting cylinders with a return spring are limited in stroke, because the spring force that must be overcome while extending increase with the stroke.

The advantage of a single acting cylinder lies in its reduced air consumption, since air is not wasted while retracing the piston.

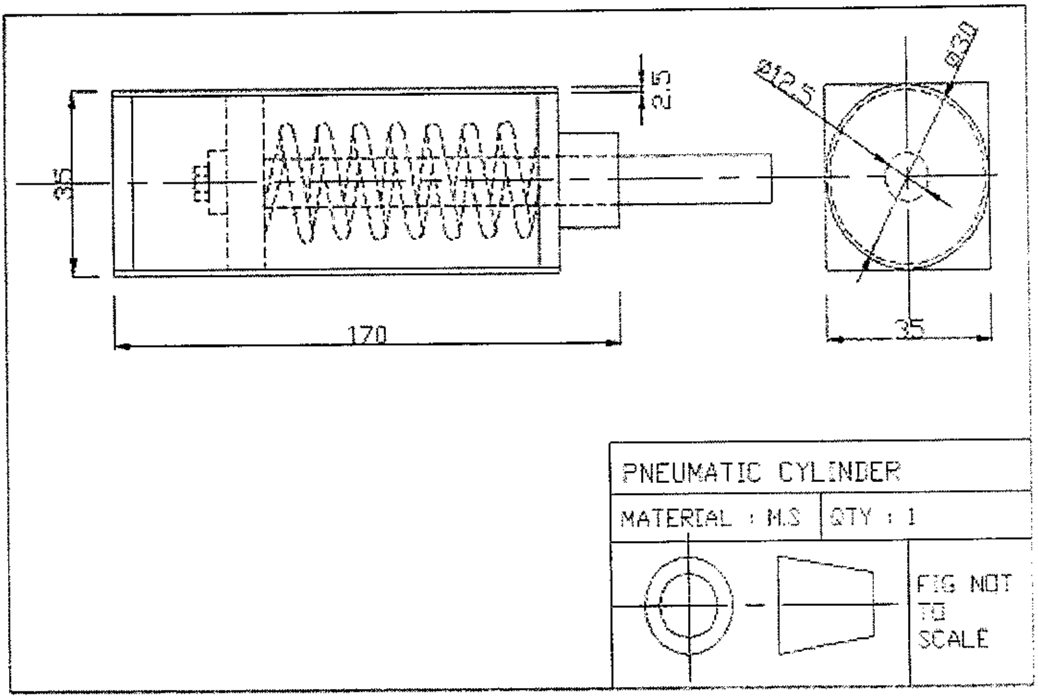


FIG 5.9 CYLINDER DIMENSIONS

5.3.6 Polyurethene Tube

FIG 5.10 POLYURETHENE TUBE

5.3.6.1 Technical Data

- Material : Polyurethene
- Max pressure : 10x105 N/m^2
- Outer diameter : 6 mm
- Inner diameter : 3.5 mm

5.3.6.2 Working

It is used to communicate compressed air from the solenoid valve to the

5.3.7 Wheel Arrangement

The simple wheel arrangement is fixed to the frame stand. The front and back wheel is fixed to the square pipe frame stand with suitable arrangement.

FIG 5.11 WHEEL ARRANGEMENT

5.3.8 Pu Connectors, Reducer and Hose collar

In our pneumatic system there are two types of connectors used; one is the hose connector and the other is the reducer. Hose connectors normally comprise an adapter (connector) hose nipple and cap nut. These types of connectors are made up of brass or Aluminium or hardened steel. Reducers are used to provide inter connection between two pipes or hoses of different sizes. They may be fitted straight, tee, "V" or other configurations. These reducers are made up of gunmetal or other materials like hardened steel etc.

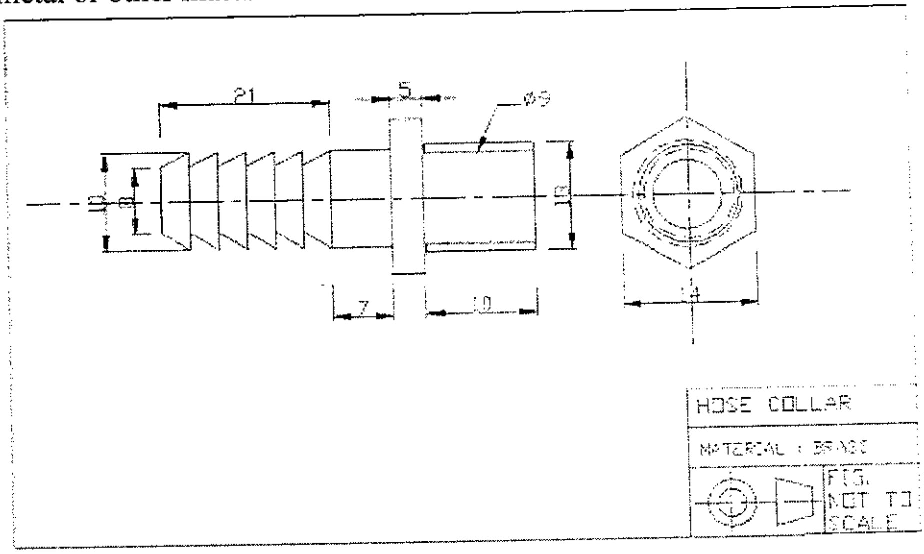


FIG 5.13 CONNECTORS

TABLE 5.1 LIST OF MATERIALS

Sl. No.	PARTS	Qty.	Material
i.	Single Acting pneumatic Cylinder	2	Mild Steel
ii.	Solenoid Valve	1	Aluminium
iii.	Electronic Control Unit	1	Electronics
iv.	Wheel	2	Rubber
v.	Limit Sensor	1	Plastic
vi.	Flow control valve	1	Aluminium
vii.	Hose collar and reducer	-	Brass
viii.	Connecting PU Tube	-	Polyurethene
ix	Stand (Frame)	1	Mild Steel

5.4 ELECTRONIC CONTROL UNIT:

The control unit is used to suspension the back wheel for the particular time period when there is any input signal from the front wheel. The control unit having one variable resister is there, you have to vary the off time of the timer unit. The OP-AMP 324 IC is used as a comparator. The comparator is giving the output voltages depends upon the two input voltage values.

In our project one input voltage (Reference Voltages) is given to the PIN number 2 (- ive pin) of 324 IC from the variable resistor (10 K Ohm). The

CIRCUIT DIAGRAM:-

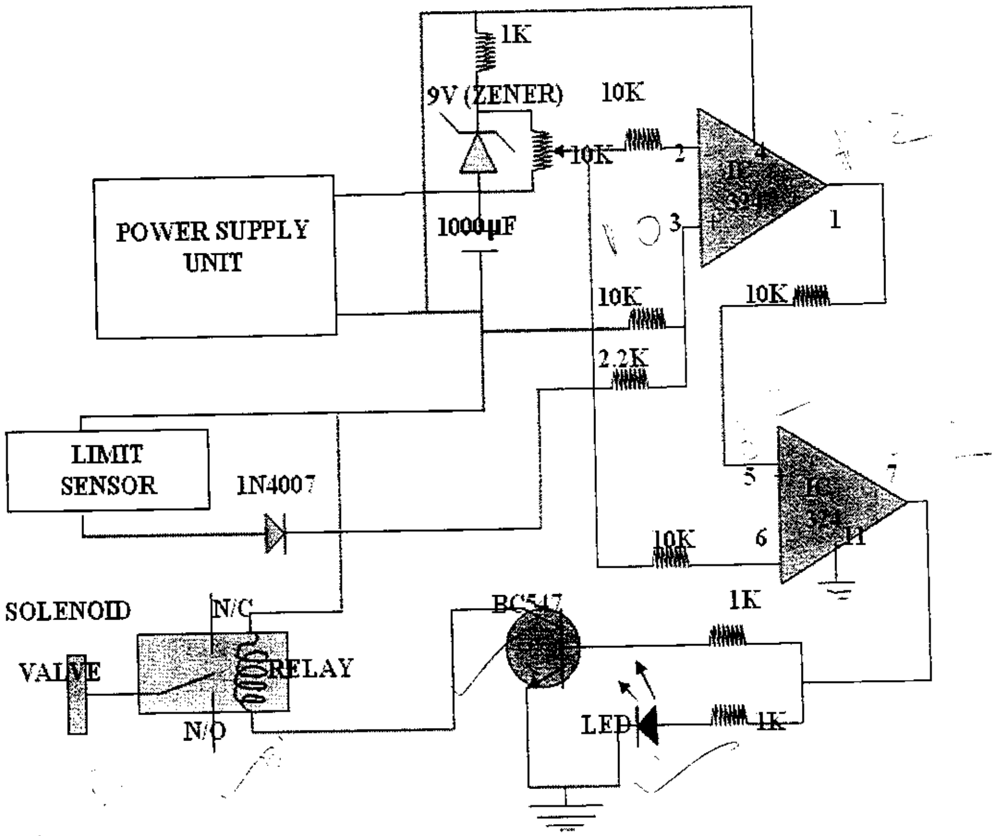


FIG 5.14 ECU CIRCUIT DIAGRAM

In normal condition the voltages applied to the non-inverting terminal (+ ive) is low when compared to the inverting terminal voltages (- ive). In that time, the OP-AMP output is –Vsat. (I.e -12 Volt). The transistor and relay are in "**OFF**" condition. In that condition, the solenoid valve is off condition.

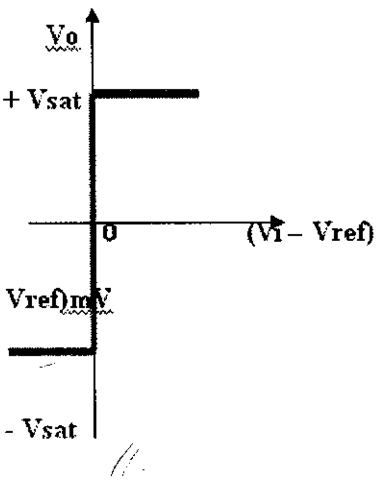
In operating condition the voltages applied to the non-inverting terminal (+ ive) is high when compared to the inverting terminal voltages (- ive). In that time, the OP-AMP output is +Vsat. (I.e +12 Volt). The transistor and relay are in "**ON**" condition. In that time, the solenoid valve is in ON condition for the particular time period, the back wheel suspension occurs.

5.4.1 Comparator

A comparator is a device which is used to sense when a varying signal reaches some threshold value and this comparator output is used to driven logic

It is basically an open-loop op-amp with output ±Vsat (= Vcc) as shown in the ideal transfer characteristics of fig (a). bellow. However, a commercial op-amp has the transfer characteristics of fig (b). There are basically two types of comparators:

- Non-inverting comparator
- Inverting comparator



Fig(a) Ideal Comparator

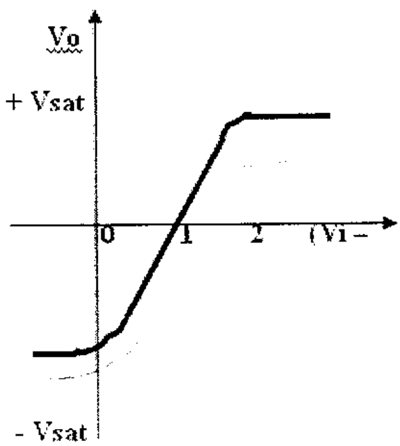
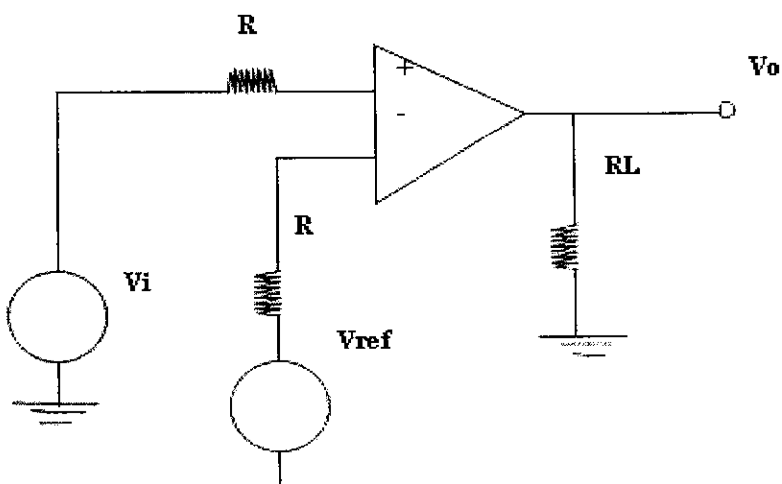


Fig (b) Practical Comparator

FIG 5.15 OP-AMP TRANSFER CHARACTERISTICS

5.4.1.1 Non-inverting Comparator

A fixed reference voltage Vref is applied to negative input and time varying signal Vi is applied to the positive terminal of the op-amp.



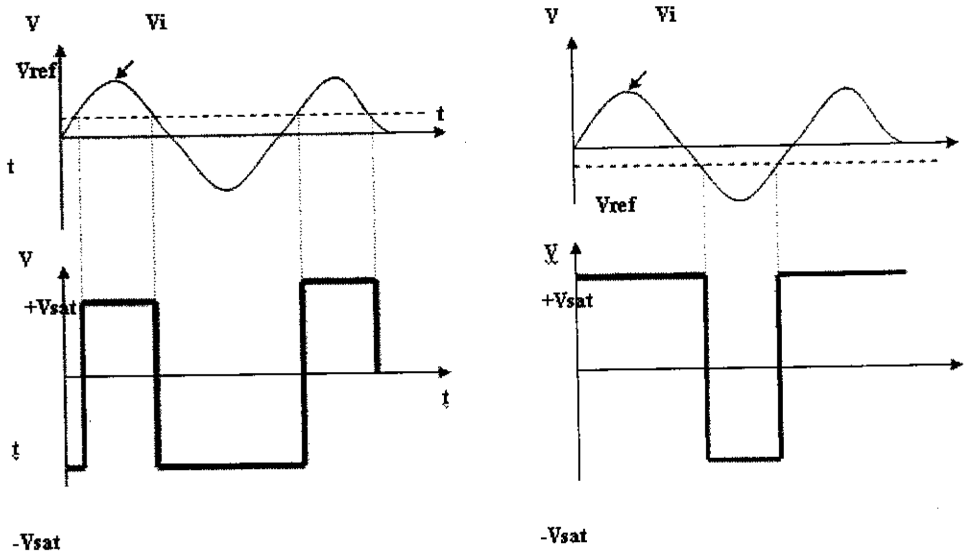
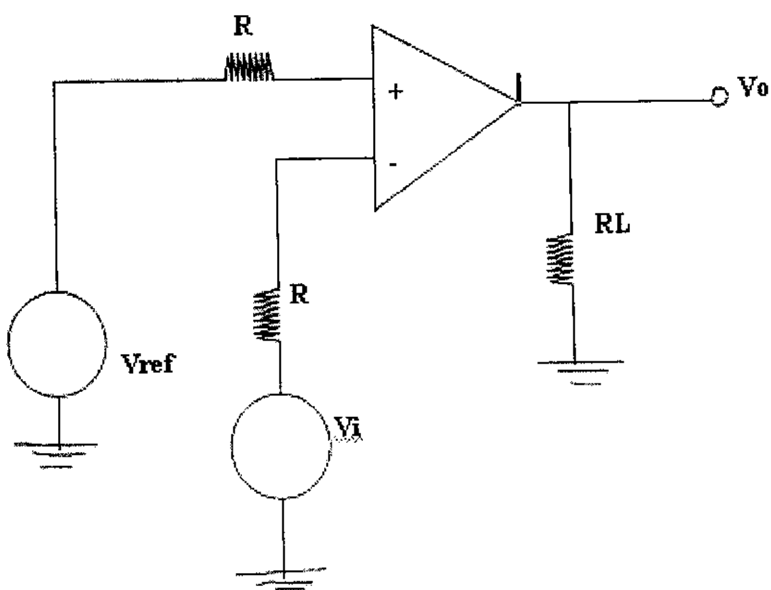


FIG 5.16 NON-INVERTING COMPARATOR

The output voltage is at –Vsat for Vi < Vref. And Vo goes to + Vsat for Vi > Vref. In a practical circuit Vref is obtained by using a 10 kO potentiometer which forms a voltage divider with the supply voltages V+ and V- with the wiper connected to the (-) input terminal.

5.4.1.2 Inverting Comparator

The reference voltage Vref is applied to the (+) input and Vi is applied to (-) input. The output voltage is + Vsat for Vi < Vref. And Vo goes to –Vsat for Vi > Vref.



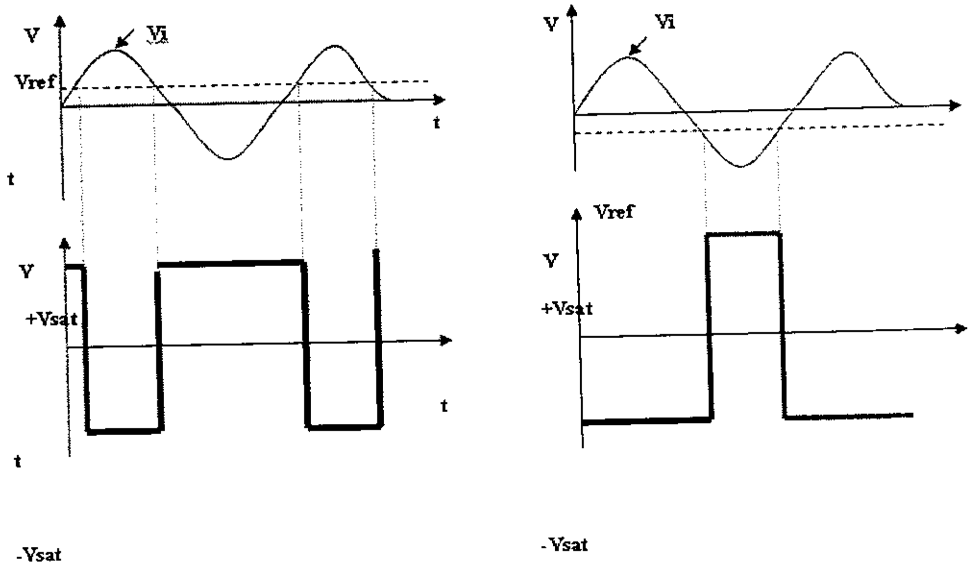
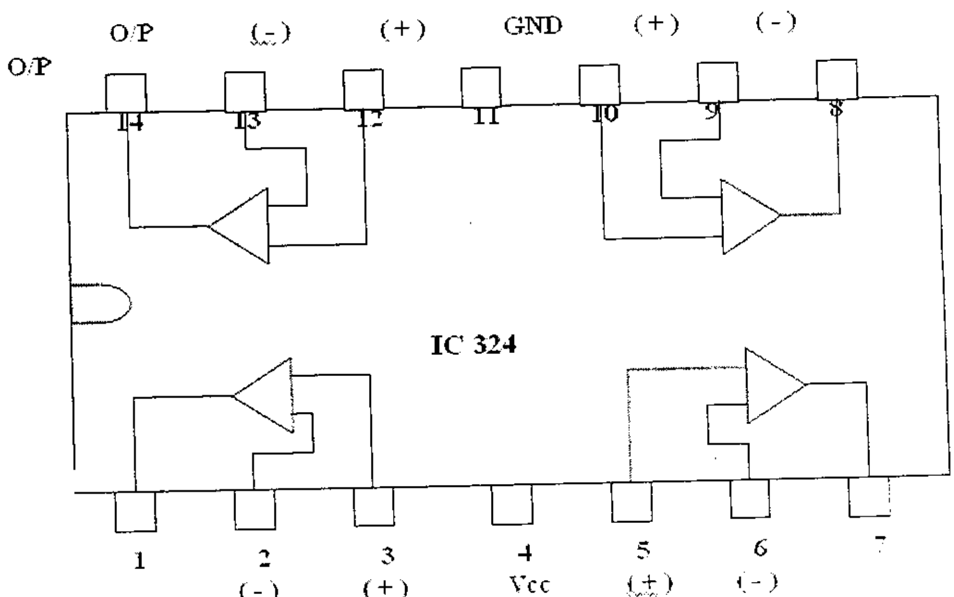


FIG 5.17 INVERTING COMPARATOR

5.4.2 Operational Amplifier(IC 324)

The IC324 is an operational amplifier. An operational amplifier is a direct coupled high gain negative feedback amplifier. The op-amp can amplify signals having frequency ranging from 0Hz to 1MHz. It is used to perform a wide verity of linear integrated circuit. There are two inputs.

The signal given to the inverting input is always inverted at the output. The signal given to the non inverting input is available at the output without any change in sign.



5.4.2.1 Characteristic of an Ideal Op-Amp

1. Input resistance = a infinity
2. Output resistance (R0) = 0
3. Voltage gain, AV = a infinity
4. Bandwidth (B.W) = infinity
5. Its characteristic does not drift with temperature.
6. It will be operated up to 1MHz.

5.4.3 Power Supply

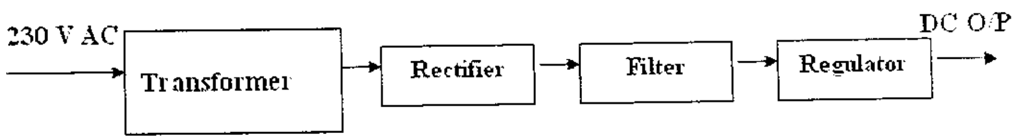
A 12V direct current is required to make function of the solenoid valve, which operates only in current.

5.4.3.1 Introduction

Since all electronic circuits work only with low D.C. voltage we need a power supply unit to provide the appropriate voltage supply. This unit consists of transformer, rectifier, filter and regulator. A.C. voltage typically 230V rms is connected to a transformer which steps that AC voltage down to the level to the desired AC voltage.

A diode rectifier then provides a full-wave rectified voltage that is initially filtered by a simple capacitor filter to produce a DC voltage. This resulting DC voltage usually has some ripple or AC voltage variations. A regulator circuit can use this DC input to provide DC voltage that not only has much less ripple voltage but also remains the same DC value even the DC voltage varies some what, or the load connected to the output DC voltages changes.

5.4.3.2 Block Diagram



5.4.3.3 12v Power Supply Unit

In our project we are using step down transformer for providing a necessary supply for the electronic circuits. In our project we are using a 0-12 transformer.

5.4.4 Filters

The out voltage is essentially constant. We filter the pulsating voltage by using RC filter. The capacitor is made sufficiently large to present very low impedance to the ripple frequency and infinite impedance to DC prefers. The shunt path through C and the steady current (IDC) is forced through R developing a DC voltage drop across it. The ripples are reduced by R&C.

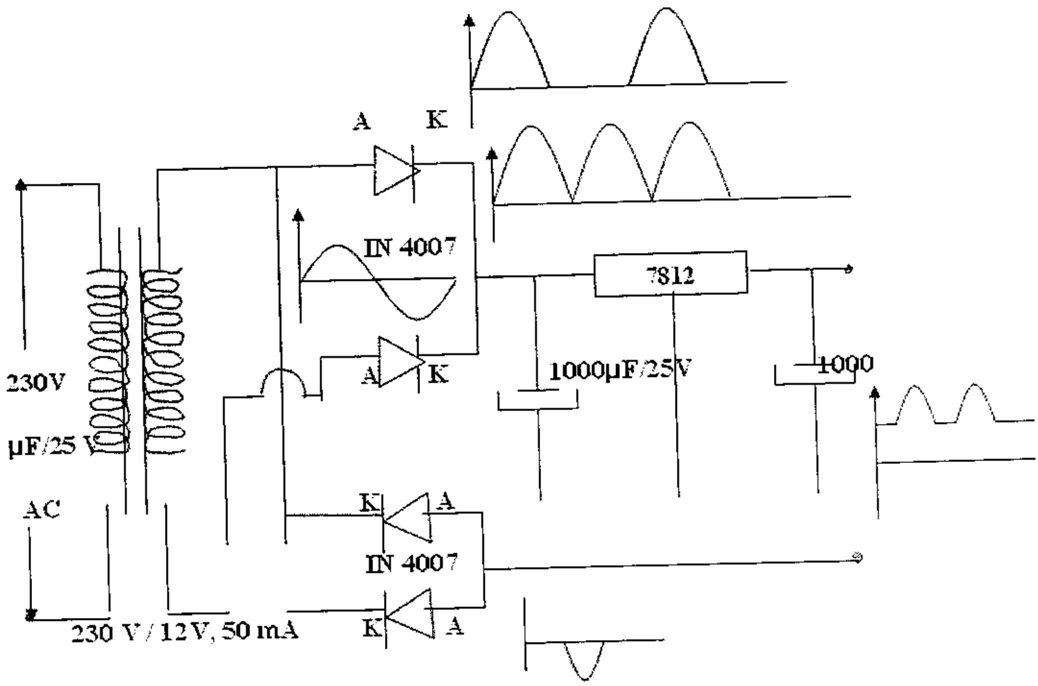


FIG 5.19 FILTERS

5.4.5 Voltage Regulator (IC 78xx Series)

The series 78 regulators provide fixed regulated from 5 to 24V. An unregulated input voltage Vi is filtered by capacitor C1 and connected to the IC's IN terminal. The IC's OUT terminal provides a regulated +12V which is filtered by capacitor C2. The third IC terminal is connected to ground. While the input voltage may very over some permissible voltage range, and the output load may vary over some acceptable range, the output voltage remains constant within specified voltage variation limits. The 7812 IC then provides an output is a regulated +12V DC.

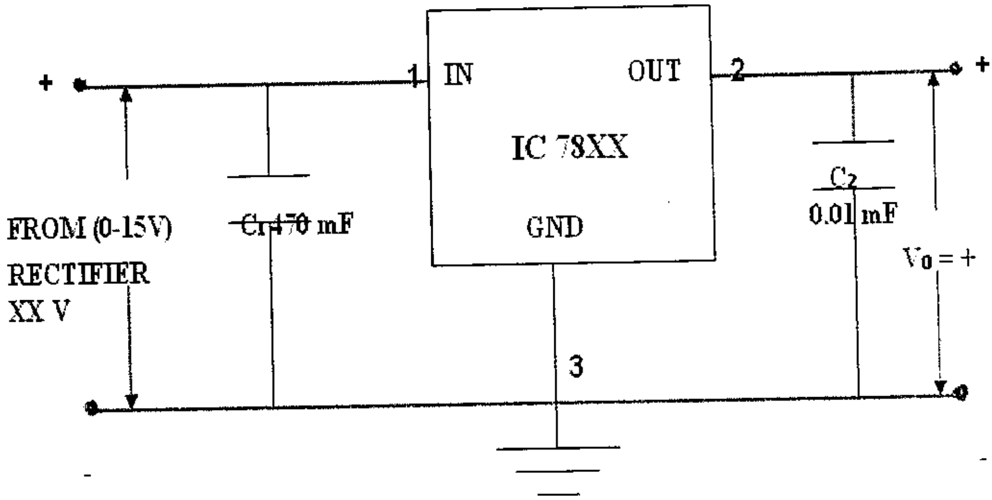


FIG 5.20 VOLTAGE REGULATOR

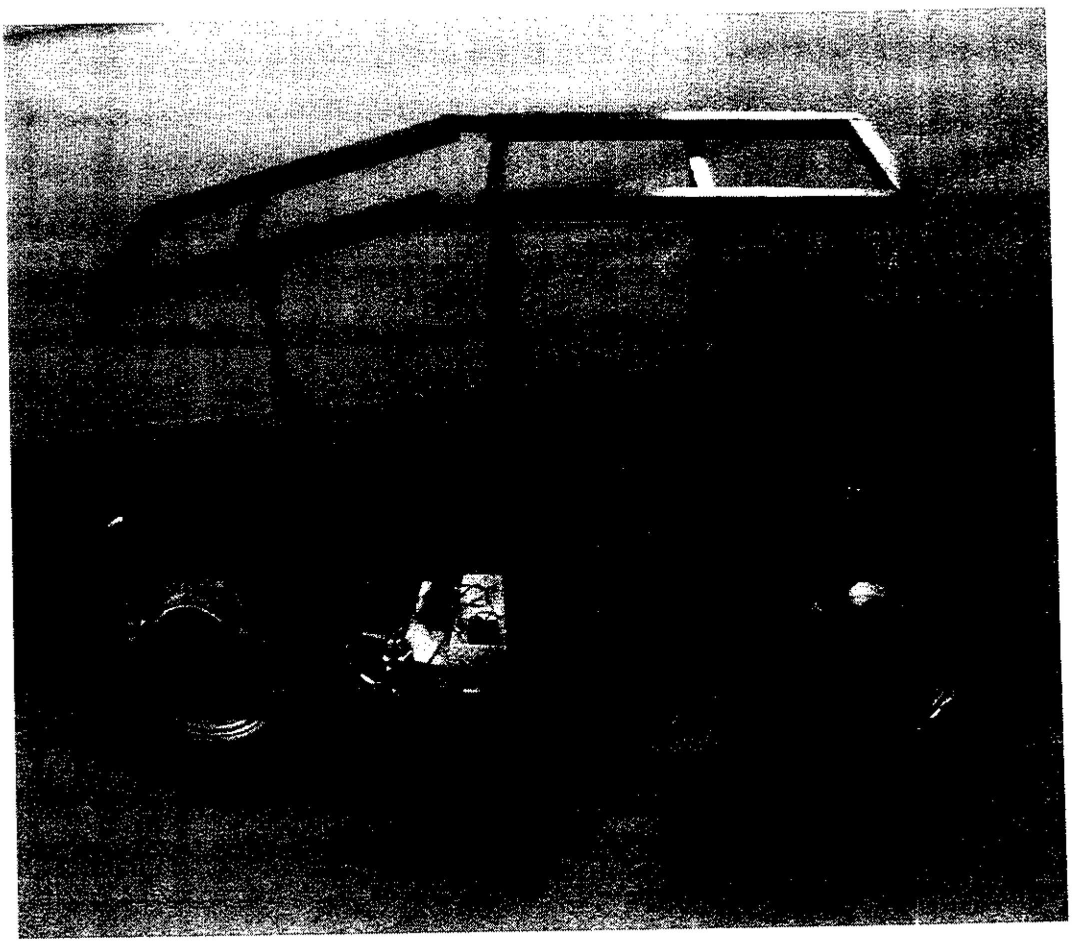


FIG. 5.21 ACTIVE SUSPENSION SYSTEM-MODEL

5.5 Advantages of the System

- Improves driver control, safety and stability with or without a load.
- Absorbs the load, rather than resisting it, thereby ensuring a much more comfortable and safer ride.
- Eliminates sway and reduces roll on corners.
- Improves Hard Braking & Acceleration.
- Reduces Dangerous Roll in Cornering.
- Reduce driver fatigue over long hauls.

5.6 Scope for Improvement

We have designed and fabricated a complete working model of an active suspension system for motorbikes, working on pneumatics.

1. Appropriate air compressor system that would be light, cheaper and that one which is mobile.
2. Sufficient and proper power source for operating the compressor.
3. Load sensor can be installed at the rear and the suspension suitably adjusted.
4. Progressive limit sensors can be installed at the front.

CHAPTER 6

CONCLUSION

CONCLUSION

A traditional or a conventional suspension system is a passive system. Once it has been installed in the bike, its character changes very little. This has certain advantages and limitations. On the down side, once the system has reached these limits, it has no way of compensating for situations beyond its design parameters. Thus shock absorbers bottom out, struts overextend and springs respond sluggishly.

The active suspension system that has been developed has the capability to adjust itself continuously to changing road conditions. It "artificially" extends the design parameters of the system by constantly monitoring and adjusting itself, thereby changing it's character on an ongoing basis. With advanced sensors and microprocessors feeding it information all the time, it's identity remains fluid, contextual, and amorphous. By changing its character to respond to varying road conditions, active suspension offers superior handling, road feel, responsiveness and safety.

The only limitation in implementing this technology in a live motorcycle is the lack of a small, mobile and a cheaper compressor that could blend with the structure of the bike. The compressors available in the market that are complying with our specifications are way too costly. However automobile companies can make this possible by designing a compressor exclusively for this purpose and when it is produced in large scale, it is obvious that the cost would come down. They can even deliver it either as a stock fitment or as an after market fitment. By this facility, the customer gets to decide among the choices available to him.

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