1. INTRODUCTION

Car manufacturers worldwide are vying with each other to invent more reliable gadgets thereby coming closer to the dream of the ‘Advanced safety vehicle’ or ‘Ultimate safety vehicle’, on which research and development has been going on for the past several years. Most of the newer vehicle models offer ABS as either standard or optional equipment. Wheel lockup during braking causes skidding which in turn cause a loss of traction and vehicle control. This reduces the steering ability to change direction. So the car slides out of control. But the road wheel that is still rotating can be steered. That is what ABS is all about. With such a system, the driver can brake hard, take the evasive action and still be in control of the vehicle in any road condition at any speed and under any load. ABS does not reduce stopping distance, but compensates the changing traction or tire loading by preventing wheel lockup.

During panic braking when the wheels are about to lockup, sensors sense that the wheel has just begun turning slower than others on the vehicle. So they momentarily reduce braking force on the affected wheel. This prevents sliding of the wheels on the pavement. When the wheel resumes rolling, full braking force is again applied. ABS repeats the process until there is no longer any need for modulated braking. ABS acts faster than any driver could, pumping the brakes several times per second. Depending on the type of system, ABS adjusts the braking force at each wheel or set of wheels, whereas a driver’s foot on the brake pedal operates all the brakes at once in normal braking.
2. CONCEPT OF ABS

The theory behind anti-lock brakes is simple. A skidding wheel (where the tire contact patch is sliding relative to the road) has less traction than a non-skidding wheel. If the vehicle have been stuck on ice and if the wheels are spinning then the vehicle have no traction. This is because the contact patch is sliding relative to the ice. By keeping the wheels from skidding while you slow down, anti-lock brakes benefit you in two ways: You'll stop faster, and you'll be able to steer while you stop. Good drivers have always pumped the brake pedal during panic stops to avoid wheel lock up and the loss of steering control. ABS simply gets the pumping job done much faster and in much precise manner than the fastest human foot.
3. PRINCIPLES OF OPERATION OF SIMPLE HYDRAULIC BRAKING SYSTEM.

A simple braking system consists of a master cylinder, and four wheel cylinders. Every wheel cylinder contains two pistons which move outwards when the hydraulic fluid flows from the master cylinder to the wheel cylinders through the suitable pipes or lines.

Springs are used to hold the brake shoes on all four wheels. When the brake pedal is pressed the piston in the master cylinder forces the liquid out of the cylinder. This liquid presses the two pistons in the wheel cylinders outwards. These two pistons push the brake shoes outwards. The brake shoes in turn press against the brake drums; this stops the brake drum which will be rotating.

When the brake pedal is released the master cylinder is pushed backwards. This is done by a spring fitted in the master cylinder. The springs of
the brake shoe brings the shoes closer. The liquid in the wheel cylinder is pushed outwards through the pipes. It returns through the pipes to the master cylinder. This is how the hydraulic system of the four wheels operates.

3.1 Master cylinder

![Inside the Master Cylinder](image)

It consists of a reservoir feedhole, bypass port, primary piston, secondary piston. The liquid in the reservoir flows through bypass port to the master cylinder. When the pedal is pressed the primary piston moves to the left. When it crosses the bypass port, the liquid is forced along the pipe lines to the wheel cylinders. When the pedal is released the primary piston is moved back wards. It is the spring, which pushes the piston back wards. At the same time a partial vacuum is developed in the space previously occupied by the spring.
4. PRINCIPLES OF ABS

The brakes of vehicle not equipped with ABS will almost immediately lock the wheels, when the driver suddenly applies the brake. In this case the vehicle slides rather than rolls to a stop. The skidding and lack of control was caused by the locking of wheels. The release and reapply of the brake pedal will avoid the locking of the wheels which in turn avoid the skidding. This is exactly what an antilock braking system does.

4.1 Pressure modulation

When the brake pedal is pumped or pulsed the pressure is quickly applied and released at the wheels. This is called pressure modulation. Pressure modulation works to prevent the wheel locking. ABS can modulate the pressure to the brake as often as 15 times per seconds. By modulating the pressure to the brakes the friction between the tires and the road is maintained and the vehicle is able to come to the controllable stop.
Steering is another important consideration. As long as a tire doesn’t slip it goes only in the direction in which it is turned. But once it is skid it has little or no directional stability.

The Maneuverability of the vehicle is reduced if the front wheels are locked and the stability of the vehicle is reduced if the rear wheels are locked.

ABS precisely controls the **slip rate** of the wheels to ensure maximum grip force from the tyre and it there by ensures maneuverability and stability of the vehicle. ABS control module calculates the slip rate of the wheels based on the vehicle speed and speed of the wheels, and then it controls the brake fluid pressure to attain the target slip rate.

During ABS operation, the target slip rate can be from 10 to 30%. 0% slip means the wheel is rolling freely, while 100 % means the wheel is fully locked. A slip rate of 25 % means the velocity of a wheel is 25 % less than that of a freely rolling wheel at the same vehicle speed.
5. ABS COMPONENTS

Many different ABS are found on today’s vehicles. These designs are varied by their basic layout, operation and components. The ABS components can be divided into two categories.

1. Hydraulic components
2. Electrical/electronic components

Besides these normal and conventional brake parts are part of the overall brake system.

5.1 Hydraulic components

- Accumulator

An accumulator is used to store hydraulic fluid to maintain high pressure in the brake system and provide the residual pressure for power assisted braking. Normally the accumulator is charged with nitrogen gas and is an integral part of the modulator unit.

- Antilock hydraulic control valve assembly

This assembly controls the release and application of the brake system pressure to the wheel brake assemblies. It may be of integral type and non integral type. In integral type the unit is combined with the power boost and master cylinder unit into one assembly. The non integral type is mounted externally from the master cylinder /power booster unit and is located between the master cylinder and wheel brake assembly. Both types generally contain solenoid valve that control the releasing, holding and applying of brake system pressure.
• **Booster pump**

  The booster pump is an assembly of an electric motor and pump. The booster pump is used to provide pressurized hydraulic fluid ABS. The pump motor is controlled by systems control unit.

• **Booster/Master cylinder assembly**

  It is referred as the hydraulic unit, contains the valves and pistons needed to modulate hydraulic pressure in the wheel circuit during the ABS operations.

• **Fluid accumulator**

  Different than a pressure accumulator, fluid accumulator temporarily store brake fluid, that is removed from the wheel brake unit during ABS cycle. This fluid is then used by pump to build pressure for the brake hydraulic system.

• **Hydraulic control unit**

  This assembly contains solenoid valve, fluid accumulator, pump and electric motor. The unit may have one pump and one motor or it have one motor and two pumps.

• **Main Valve**

  This is a two position valve and is also controlled by ABS control module and is open only in the ABS mode. When open pressurized brake fluid from the booster circuit is directed into the master circuit to prevent excessive pedal travel.

• **Modulator unit**

  The modulator unit controls the flow of pressurized brake fluid to the individual wheel circuits. Normally the modulator is made up of solenoid that open and close valves, several valves that control flow of fluid to wheel brake units and electrical relays that activate or deactivate the solenoids through the
commands of the control module. This unit may also be called the hydraulic actuator, hydraulic power unit or the electro hydraulic control valve.

- **Solenoid valves**
  
The solenoid valves are located in the modulator unit and are electrically operated by signals from the control module. The control module switches the solenoids on or off to increase, decrease, or maintain the hydraulic pressure to the individual wheel units.

- **Wheel circuit valves**
  
  Two solenoid valves are used to control each circuit or channel. One controls the inlet valve of the circuit, the controls the outlet valve. The position is determined by the control module. Outlet valves are normally closed and inlet valves are normally open. Valves are activated when abs control module switches 12 volts to the circuit solenoids. During normal driving the circuits are not activated.

**5.2 Electrical\ electronic components**

- **ABS control module**
  
  This small computer is normally mounted inside the trunk on the wheel housing, mounted to the master cylinder or is part of the hydraulic control unit. It monitors system operation and controls antilock function when needed. The module relies on input from the wheel speed sensors and feedback from the hydraulic unit to determine if the abs is operating correctly and to determine when the anti lock mode is required.

- **Brake pedal sensor**
  
  The antilock brake pedal sensor switch is normally closed. When the brake pedal exceeds the antilock brake pedal sensor switch setting during an antilock stop, the antilock brake control module senses that the antilock brake pedal sensor switch is open and grounds the pump motor relay coil. This
energizes the relay and turns the pump motor on. When the pump motor is running, the hydraulic reservoir is filled with high pressure brake fluid and the brake pedal will be pushed up until antilock brake pedal sensor switch closes. When the antilock brake pedal sensor switch closes, the pump motor is turned off and the brake pedal will drop some with each abs control cycle until the antilock brake pedal sensor switch opens and the pump motor is turned on again. This minimizes pedal feedback during abs cycling.

- **Pressure differential switch**
  It is located in the modulator unit. This switch sends a signal to the control module whenever there is an undesirable difference in the hydraulic pressures within the brake system.

- **Relays**
  Relays are electromagnetic devices used to control a high current circuit with a low current switching circuit. In abs relays are used to switch motors and solenoids. A low current signal from the control module energizes the relays that complete the electrical circuit for the motor or solenoid.

- **Toothed ring**
  It can be located on an axle shaft, differential gear or a wheels hub. This ring is used with conjunction with the wheel speed sensor. The ring has a number of teeth around its circumference. As the ring rotates and each tooth passes by the wheel speed sensor, an ac voltage signal is generated between the sensor and tooth.

- **Wheel speed sensor**
  It is mounted near the different toothed ring. As the rings teeth rotate past the sensor an ac voltage is generated. As the teeth move away from the sensor, the signal is broken until the next tooth comes close to the sensor. The end result is a pulsing signal that is sent to the control module. The control module translates the signal into wheel speed. The sensor is normally a small coil of wire with a permanent magnet in its center.
6. TYPES OF ANTILOCK BRAKE SYSTEMS

One of the classifications of abs is integral and non integral type.

Integral type they combine the master cylinder, hydraulic booster and abs hydraulic circuit in to single hydraulic assembly.

In non integral type they use a conventional vacuum-assist booster and master cylinder. In addition they can be classified according to the control they provide.

6.1. Four channel, four sensors ABS

This is the best scheme. There is speed sensor on all four wheels and a separate valve for all the four wheels. With this set up the controller monitors each wheel individually to make sure it is achieving maximum braking force.

6.2. Three channel, three sensor ABS

This scheme is commonly found on pick up trucks with four wheels ABS, has a speed sensor and a valve for each of the front wheels, with one valve and one sensor for both rear wheels. The speed sensor for the rear wheel is located in the rear axle.

This system provides individual control of the wheels, so they can both achieve maximum braking force. The rear wheels however are monitored together, they both have to start to lock up before the abs will activate on the rear. With this system, it is possible that one of the rear wheels will lock during a stop, reducing brake effectiveness.
6.3. One channel, one sensor abs

This scheme is commonly found on pick up trucks with rear wheel abs. It has one valve, which controls both rear wheels, and one speed sensor, located in the rear axle. This system operates the same as the rear end of the rear channel system. The rear wheels are monitored together and both have to start to lock up before the abs kicks in. In this system is also possible that one of the rear wheels will lock reducing brake effectiveness.

7. FOUR WHEEL SYSTEM

The hydraulic circuit for this type of system is an independent four channel type. One for each wheel. The hydraulic control unit is a separate unit. Normal braking is accompanied by conventional vacuum power assist brake system.

The system prevents wheel lock up during an emergency stop by modulating brake pressure. It allows the driver to maintain steering control and stop the vehicle in the shortest possible distance under most conditions. During ABS operation the driver will sense a pulsation in the brake pedal and clicking sound.

7.1 Operation

The ABS control module calculates the slip rate of the wheels and control the brake fluid pressure to attain the target slip rate if the control module senses that the wheel is about to lock based on input sensor data, it pulses the normally open inlet solenoid valve closed for that circuit. This prevents any more fluid from entering that circuit. ABS control module then
looks at the sensor signal from the effected wheel again. If that wheel is still decelerating faster than other three wheels it opens the normally closed outlet solenoid valve for that circuit. This dumps any pressure that is trapped between the closed inlet valve and the brake back to the master cylinder reservoir. Once the effected wheel returns to the same speed as the other wheel, the control module returns the valve to the normal condition allowing fluid flow to the effected brake.

Based on the input from vehicle speed and the wheel speed sensor, the control module calculates the slip rate of each wheel, and transmits a control signal to the modulator unit solenoid valve when the slip rate is high.

Wheel speed at each wheel is measured by variable reluctance sensors and sensor indicators. The sensors operate on magnetic induction principles.
As the teeth on brake sensor indicators rotate past the sensors, ac current is generated. The ac frequency changes in accordance with the wheel speed. The ABS control unit detects the wheel sensor signal frequency and thereby detects wheel speed.

7.2 FUNCTIONAL DIAGRAM OF FOUR CHANNEL ABS
8. ADVANCEMENTS IN ABS

Some systems, which work with the ABS, are Automatic traction control and Automatic stability control, which are discussed below.

8.1 AUTOMATIC TRACTION CONTROL (ATC)

Automatic traction control systems apply the brakes when a drive wheel attempts to spin and lose traction. The system works best when one drive wheel is working on a good traction surface and the other is not. The system also works well when the vehicle is accelerating on slippery road surfaces, especially when climbing hills. ATC is most helpful on four wheel or all wheel drive vehicles in which loss of traction at one wheel could hamper driver control.

During road operation the ATC system uses an electronic control module to monitor the wheel speed sensors. If a wheel enters a loss of traction situation, the module applies braking force to the wheel in trouble. Loss of traction is identified by comparing the vehicle speed to the speed of the wheel. If there is a loss of traction the speed of the wheel will be greater than expected for the particular vehicle speed. ABS and ATC systems can be integral and uses the common valves.

These systems are designed to reduce wheel slip and maintain traction at the drive wheels when the road is wet or snow covered. The control module monitors wheel speed. If during acceleration the module detects drive wheel slip and if brakes are not applied, the control module enters into the traction control mode. The inlet and outlet solenoid valves are pulsed and allow the brake to be quickly applied and released.
In some systems when a loss of traction is sensed, it not only cycles the brakes but signals the engine control module to retard ignition timing and partially close the throttle as well, which in turn reduces engine output.

Many systems are equipped with a dash mounted warning light to alert the driver that the system is operating. There will also be a manual cut off switch so that the driver can turn off ATC operation.
8.2 AUTOMATIC STABILITY CONTROL

Like ATC, the stability control systems are linked with the ABS. It can also be called Electronic Stability Programme (ESP). Stability control systems momentarily apply the brakes at any one wheel to correct over steer or under steer. The control unit receives signals from the typical sensors plus a yaw, lateral acceleration (G-force) and a steering angle sensor.

The system uses the angle of the steering wheel and the speed of the four wheels to calculate the path chosen by the driver. It then looks at lateral G-forces and vehicle yaw to measure where the vehicle is going. (Yaw is defined as the natural tendency for a vehicle to rotate on its vertical center axis). So it is also called Yaw control.
Under steer is the condition in which the vehicle is slow to respond to steering changes. Over steer occurs when the rear wheels try to swing around causing the car to spin. When the system senses under steer in a turn the brake at the inside rear wheel is applied. During over steer the outside front brake is applied. Relaying on the input from the sensors and computer programming the system calculates if the vehicle is going exactly in the same direction in which it is being steered. In case of any difference between what the driver is asking and what the vehicle is doing, the system corrects the situation by applying one of the right or left brakes.
9. ADVANTAGES OF ABS

- It allows the driver to maintain directional stability and control over steering during braking
- Safe and effective
- Automatically changes the brake fluid pressure at each wheel to maintain optimum brake performance.
- ABS absorbs the unwanted turbulence shock waves and modulates the pulses thus permitting the wheel to continue turning under maximum braking pressure.

Disadvantages

- It is very costly
- Maintenance cost of a car equipped with ABS is more.
10. CONCLUSION

ABS has been so far developed to a system, which provides rapid, automatic braking in response to signs of incipient wheel locking by alternatively increasing and decreasing hydraulic pressure in the brake line.

Statistics show that approximately 40% of automobile accidents are due to skidding. These problems commonly occur on vehicles with conventional brake systems which can be avoided by adding devices called ABS.

If there is an ABS failure, the system will revert to normal brake operation. Normally the ABS warning light will turn on and let the driver know there is a fault.
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ABSTRACT

Anti-Lock Braking Systems (ABS) are designed to maintain driver control and stability of the car during emergency braking. Locked wheels will slow a car down but will not provide steering ability. ABS allows maximum braking to be applied while retaining the ability to 'steer out of trouble'

The theory behind anti-lock brakes is simple. A skidding wheel (where the tire contact patch is sliding relative to the road) has less traction than a non-skidding wheel. By keeping the wheels from skidding while you slow down, anti-lock brakes benefit you in two ways: You'll stop faster, and you'll be able to steer while you stop.

An ABS system monitors four wheel speed sensors to evaluate wheel slippage. Slip can be determined by calculating the ratio of wheel speed to vehicle speed, which is continuously calculated from the four individual wheel speeds. During a braking event, the function of the control system is to maintain maximum possible wheel grip on the road - without the wheel locking - by adjusting the hydraulic fluid pressure to each brake by way of electronically controlled solenoid valves.
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