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Antilock Braking System (ABS) in Automobiles

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Abstract:- Sudden braking causes the car's imbalance and accidents & one of the most important reasons why it happens is that the wheels lose their maneuverability by locking. ABS has been developed in order to prevent the brakes from being locked. It has helped greatly to reduce fatal accidents. So, ABS can be called as lifesaving system/Vehicle safety in Automobiles. In motor vehicles ABS plays a vital role for the safety of the driver and passengers. While the car is in the driving condition, suddenly any other vehicle or person or object can come out in front of the vehicle and in such case the driver may have to apply brakes suddenly. That's where ABS comes into play. In this article, readers/audience will find an opportunity to get to know the ABS braking system more closely. Briefly, this article describes all about how this system works exactly, what the role of it in vehicles is, and how ABS vehicles differ from the vehicles without ABS.

Keywords:- *Antilock Braking System, ABS, Antilock Brakes, Advance Braking System, Vehicle Stability Control, Valves, Wheel speed sensor, Vehicle safety.*

I. INTRODUCTION

ABS (Anti-lock Braking System) is an automobile safety system that ensures full the steering wheel control by preventing the locking of wheels in sudden braking situations at all speeds & in all road conditions. ABS system is developed in order to prevent the locking of the wheels on motor land vehicles. In Anti-lock Braking System, electronic control unit which is called Brake Control Module (BCM or EBCM) is used to control the change in the number of revolutions of each wheel. During driving, because of the various obstacles that appear in front of the car there may be a need to urgently press the brake pedal. In such cases, in order to stop the car both the brake pedal and the clutch or only brake pedal must be pressed at the same time very strongly. Otherwise, the car might hit the object, or maybe it could lead to an accident that can result into a huge damage.

When the brake pedal is pressed suddenly, the wheels of vehicles which does not have an ABS system lose their connection with the steering wheel and gets locked. As a result, in this case the wheels cannot sense the instructions from the steering wheel. The vehicle's maneuverability is reduced to zero due to these locked wheels. However, vehicles with an Anti-lock Braking Systems do not lock the wheels of vehicles in sudden braking situations. So by turning the steering wheel light slightly even while the car is skidding the driver can easily get rid of the car in a simple maneuver.

ABS is a system that does not lose the connection between the wheels and the steering wheel even after the brake pedal is pressed. It stops the wheels by sending a command to the wheels with a very short intervals, and after a very short time again it sends the command in order to deactivate the squeezed brake calipers. This state of sequence is repeated up to twenty times in a second. The aim is; when a car is at a high speed it cannot stop suddenly, and due to its moment of inertia it cannot stay where at the same position. So, it continues to move forward. At this time, if there is no ABS then the passengers inside the vehicle can even jump out of the windshield. However, ABS slows the wheels of the vehicle and stops the car in a very controlled way. Anti-lock braking system (ABS) allows the wheels on a motor vehicle to maintain tractive contact with the road surface according to inputs of the driver while braking, avoiding uncontrolled skidding and preventing the wheels from locking up.

In ABS, the system is running under the control of computers. The driver only presses the brake pedal and, if necessary, maneuvers the car by steering wheel. Any inexperienced driver with an ABS vehicle as compared to the experienced driver who uses the vehicle without ABS, stops the car in a much safer and more comfortable way and also gets rid of an accident. In the ABS working system, as soon as the sensors detect that the wheels are starting to slip, it immediately sends a command to the brake to cut the stopping power immediately. Here it can be understood that the working formula of the ABS system is based on the pressure limitation. Below Figure 1 shows braking compression of ABS and without ABS car.

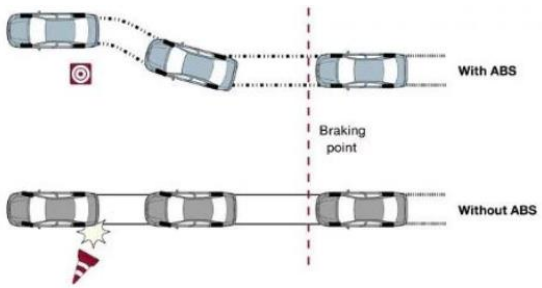

Fig. 1. With ABS, the car gets better stability and control while braking

Vehicles with ABS stop at a very shorter distance as compared to other vehicles, also with more stability and safety. Especially ABS plays a vital role when there is sudden entry into curved roads and when emergency braking is required. All the vehicles with ABS can safely brake and maneuver because of its maneuverability, but in the same case the vehicle without ABS is at risk of slipping and being

thrown out of the road. Because the vehicle with ABS continues to be under the control of the driver in curved roads.

II. HISTORY OF ABS

The first motor vehicles were developed in the year 1769 and the first driving accidents took place in the year 1770, since then engineers have been determined to reduce accidents due to driving and increase the safety of vehicles. It is clear that, the accidents are reduced by the efficient design of the brake systems. In 1928 the German engineer Karl Wessel invented the first patented system, however Wessel could not develop a working model of ABS. In 1930 Engineers developed the first mechanical anti-lock braking system (ABS) system which is designed and manufactured in the aviation industry, the first ABS was used in Boeing's B-47 bomber aircraft in 1945 in order to prevent the tires from blowing out during braking. Afterwards this braking systems were widely used on other aircrafts in the 1950s. With the arrival of the 1960s, in order to control the rear wheels ABS began to be tested on cars only. With the rapid progress of electronic and computer technology, this system started to spread widely in cars in 1980s. Today, on most of the latest car models on both wheels and even on some motorcycles ABS can be found.

While looking at the history of ABS in cars; in the 1960s for the first time fully mechanical ABS started to be used experimentally in the Ferguson P99 race car. When it came to 1970's, Chrysler and Bendix Corporations also started using this system in the Imperial model and it was named as "Sure Brake". A few years later, in 1975 Ford marketed this system with the name of "Sure-Track". Also, under the name of "Trackmaster" General Motors began using this technology only for rear-wheels and was offered as an option. In the same year, an automotive supplier Japanese Denso company, developed under the name of “EAL” an electronic locking prevention system in Nissan President Model. In 1971, for the first time the Italian automotive company Fiat started using ABS in trucks. In 1986, the ABS system on the heavier vehicles was developed by the American company WABCO and named it as "EBS" and carried this technology to the market.

In 1978 Mercedes-Benz became the first company to produce a four-wheel controlled anti-lock braking system with Bosch. In 1988, for the first time on the BMW K100 model BMW started using this technology on motorcycles. Later American Lincoln firm took the marketplace in 1993 and made ABS a standard feature for all four wheels.

III. THEORY AND PRINCIPLES OF ABS

As already mentioned, the main aim of the ABS is to stop the vehicle as quickly as possible within a shorter distance in a controlled manner as soon as the braking is applied. During the braking of non-ABS vehicles, one or more than one wheels of the vehicle can be locked, which results in a longer brake distance, also losing steering wheel control of the vehicle and in the worst case, there could be an accident.

ABS consists of Hydraulic control unit, wheel spped sensor, deceleration sensor, valves, hydraulic pump and ABS control module. This system receives information from the sensors and as soon as it receives the information it effects the hydraulics of the brakes. When a rapid lock of the wheels is detected, the anti-lock braking system reduces the hydraulic pressure in the brake cylinders, in order to release the brakes and to prevent the wheels from locking. The master cylinder in the system is used to control the hydraulic pressure in the brake cylinder. The master cylinder is connected to the brake cylinder by the hydraulic system. The hydraulic fluid has to be passed through a chamber so that it reaches master cylinder and brake cylinder. During the normal use of brakes, the valve is in open condition and the pressure in the reservoir is the same as that of the pressure in the main cylinder and in this case since there is no rapid braking the anti-lock braking system does not work.

When there is sudden braking, the sensor detects and the control valve moves. The control valve is used to determine the pressure in the actuator. When there is larger pressure in the chamber upstream of the actuator it causes back slip and closes the valve between the chamber and master cylinder. As the actuator moves backwards, the volume of the fluid increases in the reservoir. Due to this the hydraulic fluid pressure is reduced and brakes are released which prevent locking.

A. Physics of ABS

The force due to the weight of the vehicle: F_N
The side force generated due to steering effect: Fs
The traction force generated by the engine: Fv

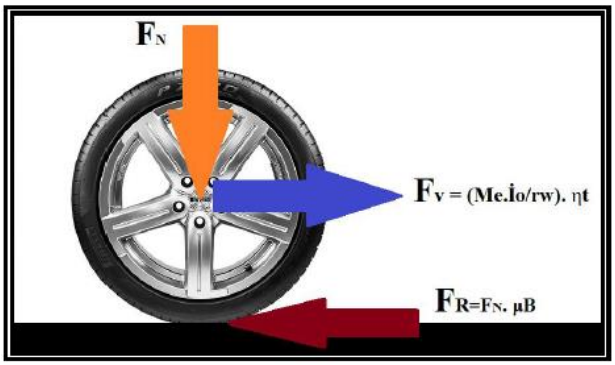

Fig. 2. Forces acting on tire during driving.

If $F_V > F_R$ wheel-spinning occurs which is shown in Fig. 2

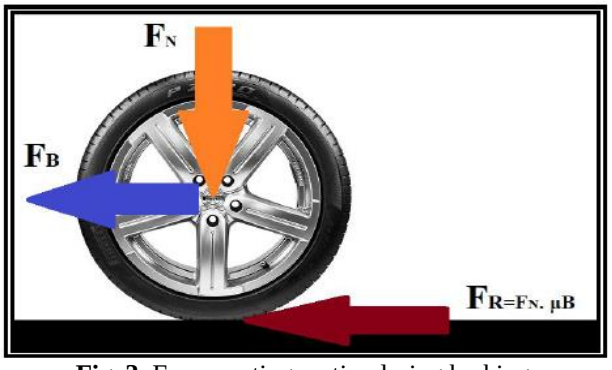

Fig. 3. Forces acting on tire during braking.

If $F_{VB} > F_R$ wheel-spinning.
If $F_{VB} > > F_R$ locking which is shown in Fig. 3

Assuming a vehicle with a weight of 9810 N, the vehicle's grip force on the icy and dry road will be as follows ($\mu B = 0.07$ on ice, $\mu B = 0.9$ on dry road and there is equal axle distribution and the safe slip limit is assumed to be 20%)

For icy road:
$F_R = (9810/4) \times 0.07 = 171.675$ N
$\lambda = (F_V - F_R) / F_V$
$F_V = F_R / (1 - \lambda) = 171.675 / 0{,}8 = 214.5937$ N

For dry road:
$F_R = (9810/4) \times 0.9 = 2207.25$ N
$\lambda = (F_V - F_R) / FV$
$F_V = F_R / (1 - \lambda) = 2207.25 / 0{,}8 = 2759.0625$ N

IV. MAIN COMPONENTS OF ABS

A. Hydraulic Control Unit

The main function of the hydraulic unit is to adjust the brake cylinder pressure of each wheel with the instructions/commands coming from the engine control unit (ECU). Solenoid valves are used, during this adjustment. The main brake is positioned between the wheel brake cylinders and the master cylinder where the car's engine is located. Thus, there is short connections to the brake center cylinders and the links to the wheel brake cylinders. The hydraulic units consists of inlet and outlet solenoid valves for controlling the pressure of each wheel. The engine control unit plays an important role in this part and with the help of control functions it fulfills all electronic and electrical tasks of the system. Figure 4 shows the location of the Hydraulic Control Unit in the car engine.

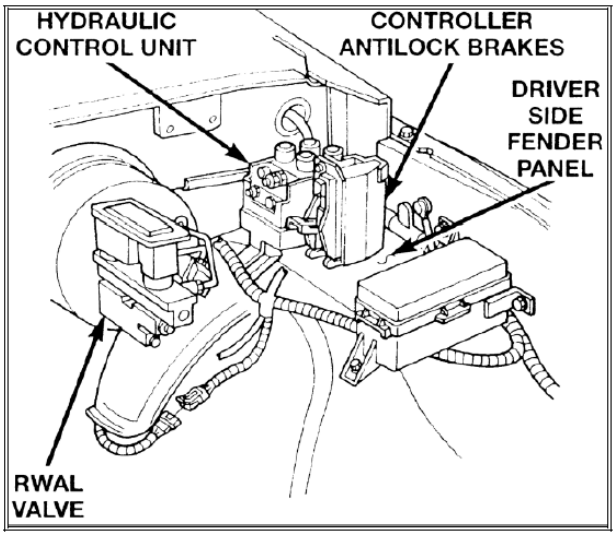

Fig. 4. Location of the Hydraulic Control Unit in the car engine.

B. Whee Speed Sensor

Wheel speed sensors send the signals to the ECU or engine control unit in order to calculate the speed of the car's wheels. There are two principles - active and passive wheel speeds. Whether active or passive, both speeds measure the speed of the wheels of the vehicle with the magnetic field, without touching the wheels of the vehicle. Nowadays more active sensors are used in the vehicles. Active sensor variants can control both the speed of the wheels and the direction of rotation of the wheels. Figure 5 shows the location of wheel speed sensors in the car.

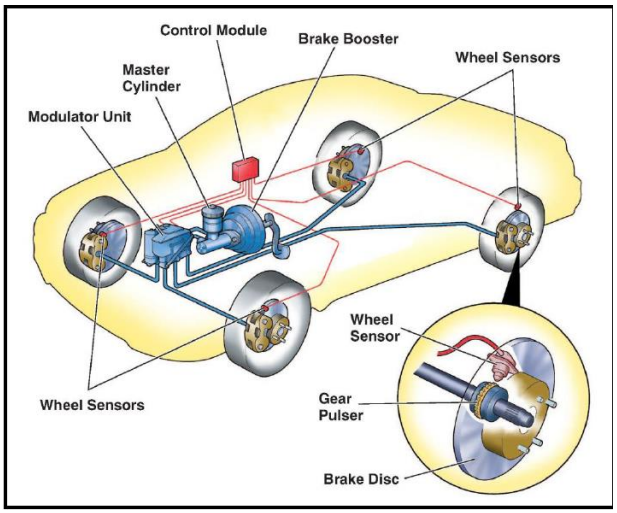

Fig. 5. Location of the wheel speed sensors, Master Cylinder, Control module in the car.

C. Deceleration Sensor

During braking of the four-wheel-drive vehicles, Deceleration Sensor detects the rate of vehicle's deceleration and sends these signals to the ECU. The ECU uses these signals received by the sensor to determine precisely the surface conditions of the road and makes the required control measurements. In passenger cars the deceleration speed sensor is located in the luggage compartment whereas in other vehicles it is located in the engine compartment. Deceleration sensor contains of two pairs of LEDs (light emitting diode), signal conversion circuit and one channel with photo transistor plate.

When there is a change in vehicle's deceleration rate, the channel plate is rocked along the vehicle's longitudinal direction in accordance with the deceleration rate. The photo transistor is opened and closed by the channels on the channel plate of the Deceleration sensor by cutting off the light which comes from the photo-transistor from the LEDs. The transistors turn on and off rate is divided into four levels, which are signaled to the ECU.

D. Valves

The valves are continuously active in the system and are controlled by the Hydraulic Control Unit.

The main functions of valves are;
1. In the first position, valves are open; the pistons in the caliper are braked with full power.
2. In the second position, valves are close; it cuts off the hydraulic flow of the line which leads to the piston and even when the pedal is pressed there is no power transmitted.
3. In the third position, valves are half open; in this condition a certain amount of hydraulic fluid is allowed to pass and partial

pressure is applied to the pistons and the line is not completely opened while the brake force is kept under control.

E. Hydraulic Pump

When there is the stoppage of flow of the valve line, the pump releases the hydraulic pressure in order to regain the lost pressure. This process is repeated each and every time when the hydraulic pressure decreased due to valve openings. It is situated on the hydraulic unit. The ABS is deactivated in the fault condition and the ABS warning lamp lights up.

F. ABS Control Module

ABS Control Module is a microprocessor used to evaluate the information transmitted by the wheel speed sensors and with the help of this information it controls the ABS system in the vehicles by giving the necessary commands to the actuators. Generally, it is situated under the hydraulic unit. In some vehicles it has been mounted at a different location. The ABS and the connected systems are disabled during the event of a fault, some failures in the system may cause problems with other systems, and the ABS warning lamp is turn on.

V. TYPES OF ABS

A. Four-wheel ABS and Rear-wheel ABS

The four-wheel ABS provides maximum stability in the car's stopping conditions and maneuverability of the driver. In the vehicles having ABS on all four wheels, the braking systems of that cars prevent the locking of wheels on all four wheels. The vehicle can be controlled by the driver better and to keep the vehicle under control is easier. At this time, the required braking pressure for braking is set. In case of trucks, minibuses and sports cars it is usually found that the rear two wheels have ABS. In such cases the vehicle is prevented from locking only on the rear two wheels.

If the ABS system is available on only the rear two-wheel and when the driver presses the brake pedal and locks the wheels, he must know that the braking system is installed only on rear two wheels and it is not as effective as the four-wheel ABS. In this case, the pressure on the brake pedal is to be adjusted manually by the driver. Thus, the driver can provide safe driving & can conveniently orient the car in the desired direction. Figure 6 shows Four-channel, Three-channel and one-channel ABS respectively.

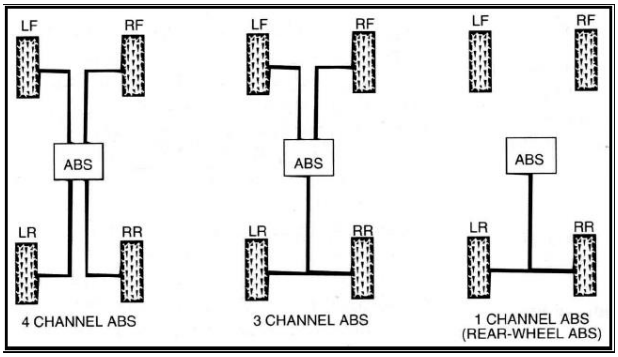

Fig. 6. Four-channel, Three-channel and one-channel ABS.

B. Four-channel Four-sensor ABS

As name suggests it has sensors on all four-wheels and four hydraulic control channels. Each wheel is independently controlled. Therefore steering safety as well as stopping distance are protected on all road conditions. In the vehicles which have front-wheel drive, most of the weight of the vehicle is on the front wheels as the transmission system and engine are located in front of the vehicle. Almost 70% of the brake force is controlled by front wheels. And for the protection of the stability of the vehicle it is very important to provide the remaining 30% of the braking force on the rear wheels. The speed difference that is caused due to yawing moment on the rear axle on different surfaces of the road can cause the vehicle to be out of balance. Due to this reason, on the rear wheels of the vehicles having four-channel ABS have a low-logic choice in order to maintain the balance of the vehicle.

C. Three-channel Three-sensor ABS

The three speed sensors is used to measure the number of revolutions of both the wheel and differential sun gear. The solenoid valves adjust the braking force on the front wheels and the single solenoid valve regulates braking force of the rear wheels. This type of hydraulic units are mostly used in parallel brake circuits.

D. Two-channel ABS

This type of hydraulic units are mostly used on heavy vehicles such as trucks. In this case only the rear two wheels of the vehicles are controlled.

E. One-channel One-sensor ABS

This type of hydraulic units are usually found in SUVs, VANs and pickups. As name suggests there is only one valve and one sensor, which is used to control the rear wheels. The way of operation is similar to the three-channel ABS system.

VI. ADVANTAGES AND DISADVANTAGES OF ABS

A. Advantages of ABS

The anti-lock braking system has the following advantages:

a. The vehicle is stable under all kinds of braking conditions.
b. It ensure optimum braking without losing the steering wheel control.
c. Optimizing the braking distance by optimum braking with maximum road holding, thus bringing it to the optimum braking distance.
d. During emergency braking the steering is under control.

B. Disadvantages of ABS

The anti-lock braking system has the following disadvantages:

a. The stopping distance increases in poor road conditions.
b. It is very expensive when it comes to repair and maintenance
c. It increases the overall cost of the vehicle

VII. CONCLUSION

This study has been attempted to assess how the working of ABS system, its history, the function of ABS parts, the components of ABS and the advantages & disadvantages of ABS. When a vehicle travels at a constant speed, both the speeds the speed of the wheels and the speed of the car are same. But when the driver presses the brake pedal, there is gradually decrease in the speed of the wheels and hence differs with the speed of the vehicle. When the difference between the speed of the vehicle & the wheel speed increase to a certain point, slip occurs between the tires and the road surface. In such situations, the ABS ECU calculates the changes in the rotational speeds of the wheels. The vehicle speed is determined by the ECU and according to this, it supplies the brake pressure to the wheels in the required amount in order to provide a safer driving.

ABS is a safety system that provides both comfort and safety which performs all these complex operations without waiting for commands or anything from the driver.

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