

UNIT 4 SUSPENSION AND BRAKING SYSTEM

4.5.Suspension system;

Suspension system is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels . It is basically cushion for passengers protects the luggage or any cargo and also itself from damage and wear.

Sir **William Brush** is the father of suspension system in automobiles.

The main role of suspension system are as follows:

- It supports the weight of vehicle .
- Provides smoother ride for the driver and passengers i.e. acts as cushion.
- Protects your vehicle from damage and wear .
- It also plays a critical role in maintaining self driving conditions.
- It also keeps the wheels pressed firmly to the ground for traction .
- It isolates the body from road shocks and vibrations which would otherwise be transferred to the passengers and load.

Principle :

When a tire hits an obstruction, there is a reaction force. The size of this reaction force depends on the unsprung mass at each wheel assembly.

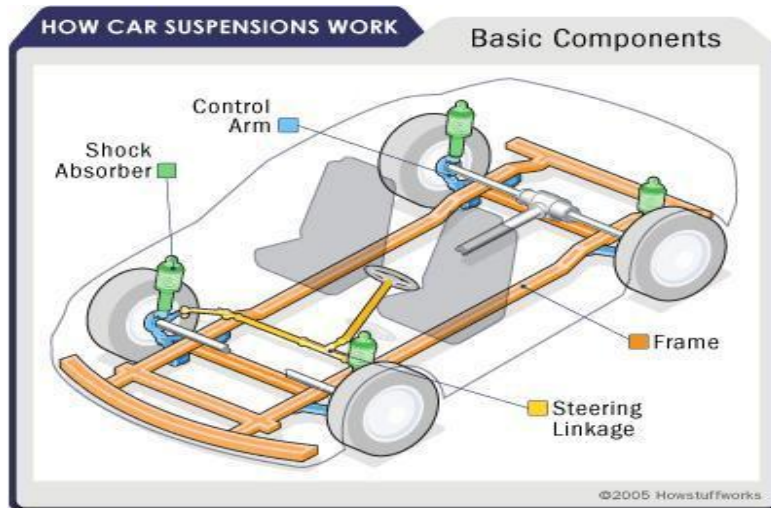
In general, the larger the ratio of sprung weight to unsprung weight, the less the body and vehicle occupants are affected by bumps, dips, and other surface imperfections such as small bridges. A large sprung weight to unsprung weight ratio can also impact vehicle control.

No road is perfectly flat i.e. without irregularities. Even a freshly paved highways have subtle imperfections that can be interact with vehicle's wheels. These are the imperfections that apply forces on wheels.

According to **Newton 's law 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. Thus, either the wheel experiences a vertical acceleration as it passes over an imperfection.

The suspension of a car is actually part of the chassis, which comprises all of the important systems located beneath the car's body. These system include :

- Frame
- Suspension system
- Steering system
- Tires or Wheels

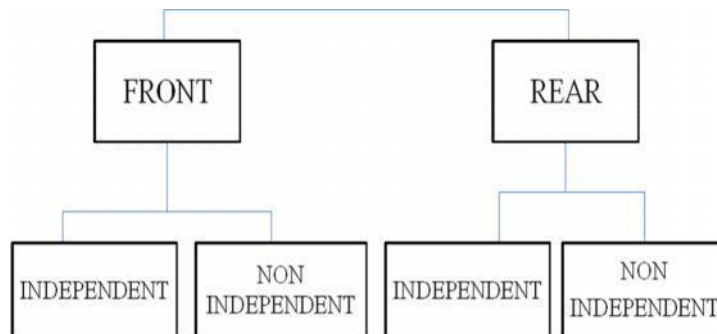


Components of Suspension system;

There are three fundamental components of any suspension system .

- Springs
 - Coil spring
 - Leaf springs
 - Air springs
- Dampers
 - Shock Absorbers
 - Struts:-
 - Anti-sway Bars
- Anti sway bars.

Types of Suspension system;



Advantages;

- Comfort to passengers
- Good handling
- Shields the vehicle from damage
- Increases life of vehicle
- Keeps the tires pressed firmly to ground.

4.6. Braking System;

A brake is a mechanical device which inhibits motion, slowing or stopping a moving object or preventing its motion. The rest of this article is dedicated to various types of vehicular brakes.

Most commonly brakes use friction between two surfaces pressed together to convert the kinetic energy of the moving object into heat, though other methods of energy conversion may be employed. For example regenerative braking converts much of the energy to electrical energy, which may be stored for later use. Other methods convert kinetic energy into potential energy in such stored forms as pressurized air or pressurized oil. Eddy current brakes use magnetic fields to convert kinetic energy into electric current in the brake disc, fin, or rail, which is converted into heat. Still other braking methods even transform kinetic energy into different forms, for example by transferring the energy to a rotating flywheel.

Brakes are generally applied to rotating axles or wheels, but may also take other forms such as the surface of a moving fluid (flaps deployed into water or air). Some vehicles use a combination of braking mechanisms, such as drag racing cars with both wheel brakes and a parachute, or airplanes with both wheel brakes and drag flaps raised into the air during landing.

Since kinetic energy increases quadratically with velocity ($K = mv^2/2$), an object moving at 10 m/s has 100 times as much energy as one of the same mass moving at 1 m/s, and consequently the theoretical braking distance, when braking at the traction limit, is 100 times as long. In practice, fast vehicles usually have significant air drag, and energy lost to air drag rises quickly with speed. Almost all wheeled vehicles have a brake of some sort. Even baggage carts and shopping carts may have them for use on a moving ramp. Most fixed-wing aircraft are fitted with wheel brakes on the undercarriage. Some aircraft also feature air brakes designed to reduce their speed in flight.

Notable examples include gliders and some World War II-era aircraft, primarily some fighter aircraft and many dive bombers of the era. These allow the aircraft to maintain a safe speed in a steep descent. The Saab B 17 dive bomber and Vought F4U Corsair fighter used the deployed undercarriage as an air brake. Friction brakes on automobiles store braking heat in the drum brake or disc brake while braking then conduct it to the air gradually. When traveling downhill some vehicles can use their engines to brake.

When the brake pedal of a modern vehicle with hydraulic brakes is pushed, ultimately a piston pushes the brake pad against the brake disc which slows the wheel down. On the brake drum it is similar as the cylinder pushes the brake shoes against the drum which also slows the wheel down. Brakes may be broadly described as using friction, pumping, or electromagnetic. One brake may use several principles: for example, a pump may pass fluid through an orifice to create friction: Frictional brakes are most common and can be divided broadly into "shoe" or "pad" brakes, using an explicit wear surface, and hydrodynamic brakes, such as parachutes, which use friction in a working fluid and do not explicitly wear. Typically the term "friction brake" is used to mean pad/shoe brakes and excludes hydrodynamic brakes, even though hydrodynamic brakes use friction.

Friction (pad/shoe) brakes are often rotating devices with a stationary pad and a rotating wear surface. Common configurations include shoes that contract to rub on the outside of a rotating drum, such as a band brake; a rotating drum with shoes that expand to rub the inside of a drum, commonly called a "drum brake", although other drum configurations are possible; and pads that pinch a rotating disc, commonly called a "disc brake".

Other brake configurations are used, but less often. For example, PCC trolley brakes include a flat shoe which is clamped to the rail with an electromagnet; the Murphy brake pinches a rotating drum, and the Ausco Lambert disc brake uses a hollow disc (two parallel discs with a structural bridge) with shoes that sit between the disc surfaces and expand laterally. Pumping brakes are often used where a pump is already part of the machinery. For example, an internal-combustion piston motor can have the fuel supply stopped, and then internal pumping losses of the engine create some braking. Some engines use a valve override called a Jake brake to greatly increase pumping losses. Pumping brakes can dump energy as heat, or can be regenerative brakes that recharge a pressure reservoir called a hydraulic accumulator.

Electromagnetic brakes are likewise often used where an electric motor is already part of the machinery. For example, many hybrid gasoline/electric vehicles use the electric motor as a generator to charge electric batteries and also as a regenerative brake. Some diesel/electric railroad locomotives use the electric motors to generate electricity which is then sent to a resistor bank and dumped as heat.

Types of Braking system in Automobile;

- By applications –
 1. Foot Brake,
 2. Hand brake.
- By Method of power –
 1. Mechanical brake,
 2. Hydraulic brake.
 3. Vacuum brake,
 4. Electrical brake and
 5. Air brake.
- By method of operations –
 1. Manual brake,
 2. Servo brake.
 3. Power operation.
- By construction –
 1. Drum type brake,
 2. Disc type brake.

4.7. Anti-lock braking system (ABS)

Anti-lock braking system (ABS) is an automobile safety system that allows the wheels on a motor vehicle to maintain tractive contact with the road surface according to driver inputs while braking, preventing the wheels from locking up (ceasing rotation) and avoiding uncontrolled skidding. It is an automated system that uses the principles of threshold braking and cadence braking which were practiced by skillful drivers with previous generation braking systems. It does this at a much faster rate and with better control than a driver could manage.

ABS generally offers improved vehicle control and decreases stopping distances on dry and slippery surfaces for many drivers; however, on loose surfaces like gravel or snow-covered pavement, ABS can significantly increase braking distance, although still improving vehicle control.

Since initial widespread use in production cars, anti-lock braking systems have evolved considerably. Recent versions not only prevent wheel lock under braking, but also electronically control the front-to-rear brake bias. This function, depending on its specific capabilities and implementation, is known as electronic brake force distribution (EBD), traction control system, emergency brake assist, or electronic stability control(ESC).

Operation

The anti-lock brake controller is also known as the CAB (Controller Anti-lock Brake).

Typically ABS includes a central electronic control unit (ECU), four wheel speed sensors, and at least two hydraulic valves within the brake hydraulics. The ECU constantly monitors the rotational speed of each wheel; if it detects a wheel rotating significantly slower than the others, a condition indicative of impending wheel lock, it actuates the valves to reduce hydraulic pressure to the brake at the affected wheel, thus reducing the braking force on that wheel; the wheel then turns faster.

Conversely, if the ECU detects a wheel turning significantly faster than the others, brake hydraulic pressure to the wheel is increased so the braking force is reapplied, slowing down the wheel. This process is repeated continuously and can be detected by the driver via brake pedal pulsation. Some anti-lock systems can apply or release braking pressure 15 times per second.^[17] Because of this, the wheels of cars equipped with ABS are practically impossible to lock even during panic braking in extreme conditions.

The ECU is programmed to disregard differences in wheel rotating speed below a critical threshold, because when the car is turning, the two wheels towards the center of the curve turn slower than the outer two. For this same reason, a differential is used in virtually all road going vehicles. If a fault develops in any part of the ABS, a warning light will usually be illuminated on the vehicle instrument panel, and the ABS will be disabled until the fault is rectified.

Modern ABS applies individual brake pressure to all four wheels through a control system of hub-mounted sensors and a dedicated micro-controller. ABS is offered or comes standard on most road vehicles produced today and is the foundation for electronic stability control systems, which are rapidly increasing in popularity due to the vast reduction in price of vehicle electronics over the years.

Modern electronic stability control systems are an evolution of the ABS concept. Here, a minimum of two additional sensors are added to help the system work: these are a steering wheel angle sensor, and a gyroscopic sensor. The theory of operation is simple: when the gyroscopic sensor detects that the direction taken by the car does not coincide with what the steering wheel sensor reports, the ESC software will brake the necessary individual wheel(s) (up to three with the most sophisticated systems), so that the vehicle goes the way the driver intends. The steering wheel sensor also helps in the operation of Cornering Brake Control (CBC), since this will tell the ABS that wheels on the inside of the curve should brake more than wheels on the outside, and by how much.

ABS equipment may also be used to implement a traction control system (TCS) on acceleration of the vehicle. If, when accelerating, the tire loses traction, the ABS controller can detect the situation and take suitable action so that traction is regained. More sophisticated versions of this can also control throttle levels and brakes simultaneously.

Components of ABS

There are four main components of ABS:

- Speed sensors,
- Valves,
- Pump, and
- Controller.

Speed sensors

A speed sensor is used to determine the acceleration or deceleration of the wheel. These sensors use a magnet and a coil of wire to generate a signal. The rotation of the wheel or differential induces a magnetic field around the sensor. The fluctuations of this magnetic field generate a voltage in the sensor. Since the voltage induced in the sensor is a result of the rotating wheel, this sensor can become inaccurate at slow speeds. The slower rotation of the wheel can cause inaccurate fluctuations in the magnetic field and thus cause inaccurate readings to the controller.

Valves

There is a valve in the brake line of each brake controlled by the ABS. On some systems, the valve has three positions:

In position one, the valve is open; pressure from the master cylinder is passed right through to the brake.

In position two, the valve blocks the line, isolating that brake from the master cylinder. This prevents the pressure from rising further should the driver push the brake pedal harder.

In position three, the valve releases some of the pressure from the brake.

The majority of problems with the valve system occur due to clogged valves. When a valve is clogged it is unable to open, close, or change position. An inoperable valve will prevent the system from modulating the valves and controlling pressure supplied to the brakes.

Pump

The pump in the ABS is used to restore the pressure to the hydraulic brakes after the valves have released it. A signal from the controller will release the valve at the detection of wheel slip. After a valve release the pressure supplied from the user, the pump is used to restore a desired amount of pressure to the braking system. The controller will modulate the pumps status in order to provide the desired amount of pressure and reduce slipping.

Controller

The controller is an ECU type unit in the car which receives information from each individual wheel speed sensor, in turn if a wheel loses traction the signal is sent to the controller, the controller will then limit the brake force (EBD) and activate the ABS modulator which actuates the braking valves on and off.

Use

There are many different variations and control algorithms for use in ABS. One of the simpler systems works as follows,

The controller monitors the speed sensors at all times. It is looking for decelerations in the wheel that are out of the ordinary. Right before wheel locks up, it will experience a rapid deceleration.

If left unchecked, the wheel would stop much more quickly than any car could. It might take a car five seconds to stop from 60 mph (96.6 km/h) under ideal conditions, but a wheel that locks up could stop spinning in less than a second.

The ABS controller knows that such a rapid deceleration is impossible, so it reduces the pressure to that brake until it sees an acceleration, then it increases the pressure until it sees the deceleration again. It can do this very quickly, before the tire can actually significantly change speed. The result is that the tire slows down at the same rate as the car, with the brakes keeping the tires very near the point at which they will start to lock up. This gives the system maximum braking power.

This replaces the need to manually pump the brakes while driving on a slippery or a low traction surface, allowing steering even in the most emergency braking conditions.

When the ABS is in operation the driver will feel a pulsing in the brake pedal; this comes from the rapid opening and closing of the valves. This pulsing also tells the driver that the ABS has been triggered. Some ABS systems can cycle up to 16 times per second.

4.8. Hydraulic braking system

The disc brake or disk brake is a device for slowing or stopping the rotation of a wheel while it is in motion. A brake disc (or rotor in U.S. English) is usually made of cast iron, but may in some cases be made of composites such as reinforced carbon-carbon or ceramic-matrix composites.

This is connected to the wheel and/or the axle. To stop the wheel, friction material in the form of brake pads (mounted on a device called a brake caliper) is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop. Brakes (both disc and drum) convert motion to heat, but if the brakes get too hot, they will become less effective because they cannot dissipate enough heat. This condition of failure is known as brake fade.

Construction of Braking system;

The most common arrangement of hydraulic brakes for passenger vehicles, motorcycles, scooters, and mopeds, consists of the following:

- Brake pedal or lever
- A pushrod (also called an actuating rod)
- A master cylinder assembly containing a piston assembly
- Reinforced hydraulic lines

Brake caliper assembly usually consisting of one or two hollow aluminum or chrome-plated steel pistons (called caliper pistons), a set of thermally conductive brake pads and a rotor (also called a brake disc) or drum attached to an axle. The system is usually filled with a glycol-ether based brake fluid (other fluids may also be used).

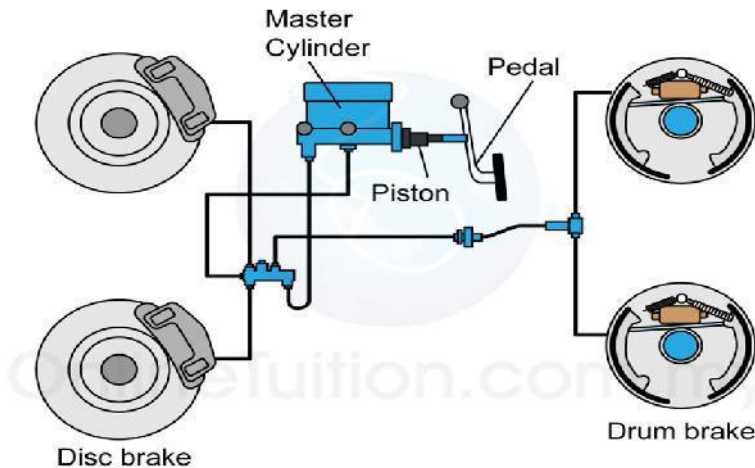
At one time, passenger vehicles commonly employed drum brakes on all four wheels. Later, disc brakes were used for the front and drum brakes for the rear. However disc brakes have shown better heat dissipation and greater resistance to 'fading' and are therefore generally safer than drum brakes. So four-wheel disc brakes have become increasingly popular, replacing drums on all but the most basic vehicles. Many two-wheel vehicle designs, however, continue to employ a drum brake for the rear wheel. The following description uses the terminology for and configuration of a simple

In a hydraulic brake system, when the brake pedal is pressed, a pushrod exerts force on the piston(s) in the master cylinder, causing fluid from the brake fluid reservoir to flow into a pressure chamber through a compensating port. This results in an increase in the pressure of the entire hydraulic system, forcing fluid through the hydraulic lines toward one or more calipers where it acts upon one or two caliper pistons sealed by one or more seated O-rings (which prevent leakage of the fluid).

The brake caliper pistons then apply force to the brake pads, pushing them against the spinning rotor, and the friction between the pads and the rotor causes a braking torque to be generated, slowing the vehicle. Heat generated by this friction is either dissipated through vents and channels in the rotor or is conducted through the pads, which are made of specialized heat-tolerant materials such as kevlar or sintered glass.

Subsequent release of the brake pedal/lever allows the spring(s) in my master cylinder assembly to return the master piston(s) back into position. This action first relieves the hydraulic pressure on the caliper, then applies suction to the brake piston in the caliper assembly, moving it back into its housing and allowing the brake pads to release the rotor.

The hydraulic braking system is designed as a closed system: unless there is a leak in the system, none of the brake fluid enters or leaves it, nor does the fluid get consumed through use.



4.9. Pneumatic braking system

An air brake or, more formally, a compressed air brake system, is a type of friction brake for vehicles in which compressed air pressing on a piston is used to apply the pressure to the brake pad needed to stop the vehicle.

Air brakes are used in large heavy vehicles, particularly those having multiple trailers which must be linked into the brake system, such as trucks, buses, trailers, and semi-trailers in addition to their use in railroad trains.

George Westinghouse first developed air brakes for use in railway service. He patented a safer air brake on March 5, 1872. Westinghouse made numerous alterations to improve his air pressured brake invention, which led to various forms of the automatic brake. In the early 20th century, after its advantages were proven in railway use, it was adopted by manufacturers of trucks and heavy road vehicles.

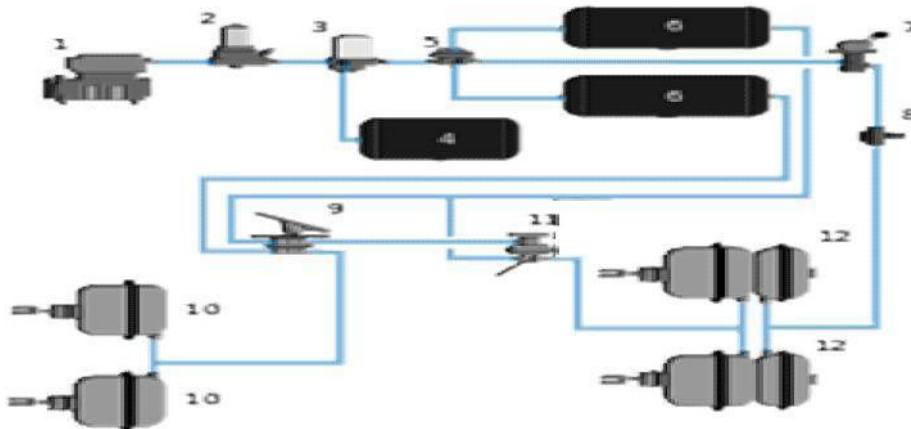
Construction of Braking system;

Air brake systems are typically used on heavy trucks and buses. The system consists of service brakes, parking brakes, a control pedal, and an air storage tank. For the parking brake, there is a disc or drum brake arrangement which is designed to be held in the 'applied' position by spring pressure.

Air pressure must be produced to release these "spring brake" parking brakes. For the service brakes (the ones used while driving for slowing or stopping) to be applied, the brake pedal is pushed, routing the air under pressure (approx 100–120 psi or 690–830 kPa) to the brake chamber, causing the brake to be engaged. Most types of truck air brakes are drum brakes, though there is an increasing trend towards the use of disc brakes in this application. The air compressor draws filtered air from the atmosphere and forces it into high-pressure reservoirs at around 120 psi (830 kPa).

Most heavy vehicles have a gauge within the driver's view, indicating the availability of air pressure for safe vehicle operation, often including warning tones or lights. Setting of the parking/emergency brake releases the pressurized air in the lines between the compressed air storage tank and the brakes, thus allowing the spring actuated parking brake to engage. A sudden loss of air pressure would result in full spring brake pressure immediately.

A compressed air brake system is divided into a supply system and a control system. The supply system compresses, stores and supplies high-pressure air to the control system as well as to additional air operated auxiliary truck systems (gearbox shift control, clutch pedal air assistance servo, etc.).



Highly simplified air brake diagram on a commercial road vehicle (does not show all air reservoirs and all applicable air valves). The air compressor is driven by the engine either by crankshaft pulley via a belt or directly from the engine timing gears. It is lubricated and cooled by the engine lubrication and cooling systems.

Compressed air is first routed through a cooling coil and into an air dryer which removes moisture and oil impurities and also may include a pressure regulator, safety valve and smaller purge reservoir. As an alternative to the air dryer, the supply system can be equipped with an anti-freeze device and oil separator. The compressed air is then stored in a reservoir (also called a wet tank) from which it is then distributed via a four way protection valve into the front and rear brake circuit air reservoir, a parking brake reservoir and an auxiliary air supply distribution point. The system also includes various check, pressure limiting, drain and safety valves. Air brake systems may include a wig wag device which deploys to warn the driver if the system air pressure drops too low.

Control system

The control system is further divided into two service brake circuits: the parking brake circuit and the trailer brake circuit. This dual brake circuit is further split into front and rear wheel circuits which receive compressed air from their individual reservoirs for added safety in case of an air leak. The service brakes are applied by means of a brake pedal air valve which regulates both circuits.

The parking brake is the air operated spring brake type where its applied by spring force in the spring brake cylinder and released by compressed air via hand control valve. The trailer brake consists of a direct two line system: the supply line (marked red) and the separate control or service line (marked blue). The supply line receives air from the prime mover park brake air tank via a park brake relay valve and the control line is regulated via the trailer brake relay valve. The operating signals for the relay are provided by the prime mover brake pedal air valve, trailer service brake hand control (subject to a country's relevant heavy vehicle legislation) and the prime mover park brake hand control.

Advantages of Air Brakes;

Air brakes are used as an alternative to hydraulic brakes which are used on lighter vehicles such as automobiles. Hydraulic brakes use a liquid (hydraulic fluid) to transfer pressure from the brake pedal to the brake shoe to stop the vehicle. Air brakes have several advantages for large multitrailer vehicles:

- The supply of air is unlimited, so the brake system can never run out of its operating fluid, as hydraulic brakes can. Minor leaks do not result in brake failures.
- Air line couplings are easier to attach and detach than hydraulic lines; there is no danger of letting air into hydraulic fluid. So air brake circuits of trailers can be attached and removed easily by operators with little training.
- Air not only serves as a fluid for transmission of force, but also stores potential energy. So it can serve to control the force applied. Air brake systems include an air tank that stores sufficient energy to stop the vehicle if the compressor fails.
- Air brakes are effective even with considerable leakage, so an air brake system can be designed with sufficient "fail-safe" capacity to stop the vehicle safely even when leaking.

4.10. Loss of Traction:

One undesirable side effect of a differential is that it can reduce overall torque - the rotational force which propels the vehicle. The amount of torque required to propel the vehicle at any given moment depends on the load at that instant - how heavy the vehicle is, how much drag and friction there is, the gradient of the road, the vehicle's momentum and so on. For the purpose of this article, we will refer to this amount of torque as the "threshold torque".

The torque on each wheel is a result of the engine and transmission applying a twisting force against the resistance of the traction at that wheel. Unless the load is exceptionally high, the engine and transmission can usually supply as much torque as necessary, so the limiting factor is usually the traction under each wheel. It is therefore convenient to define traction as the amount of torque that can be generated between the tire and the ground before the wheel starts to slip. If the total traction under all the driven wheels exceeds the threshold torque, the vehicle will be driven forward; if not, then one or more wheels will simply spin.

To illustrate how a differential can limit overall torque, imagine a simple rear-wheel-drive vehicle, with one rear wheel on asphalt with good grip, and the other on a patch of slippery ice. With the load, gradient, etc., the vehicle requires, say, 2000 N-m of torque to move forward (i.e. the threshold torque). Let us further assume that the non-spinning traction on the ice equates to 400 N-m, and the asphalt to 3000 N-m.

If the two wheels were driven without a differential, each wheel would push against the ground as hard as possible. The wheel on ice would quickly reach the limit of traction (400 N-m), but would be unable to spin because the other wheel has good traction. The traction of the asphalt plus the small extra traction from the ice exceeds the threshold requirement, so the vehicle will be propelled forward.

With a differential, however, as soon as the "ice wheel" reaches 400 N-m, it will start to spin, and then develop less traction ~300 N-m. The planetary gears inside the differential carrier will start to rotate because the "asphalt wheel" encounters greater resistance.

Instead of driving the asphalt wheel with more force, the differential will allow the ice wheel to spin faster, and the asphalt wheel to remain stationary, compensating for the stopped wheel by extra speed of the spinning ice wheel. The torque on both wheels will be the same - limited to the lesser traction of 300 N-m each. Since 600 N-m is less than the required threshold torque of 2000 N-m, the vehicle will not be able to move.

An observer simply sees one stationary wheel and one spinning wheel. It will not be obvious that both wheels are generating the same torque (i.e. both wheels are in fact pushing equally, despite the difference in rotational speed). This has led to a widely held misconception that a vehicle with a differential is really only "one-wheel-drive". In fact, a normal differential always provides equal torque to both driven wheels (unless it is a locking, torque-biasing, or limited slip type).

Traction control system (TCS),

A **traction control system (TCS)**, in German known as **Antriebsschlupfregelung (ASR)**, is typically (but not necessarily) a secondary function of the anti-lock braking system (ABS) on production motor vehicles, designed to prevent loss of traction of driven road wheels. TCS is activated when throttle input and engine torque are mismatched to road surface conditions.

Intervention consists of one or more of the following:

- Brake force applied to one or more wheels
- Reduction or suppression of spark sequence to one or more cylinders
- Reduction of fuel supply to one or more cylinders
- Closing the throttle, if the vehicle is fitted with drive by wire throttle
- In turbocharged vehicles, a boost control solenoid is actuated to reduce boost and therefore engine power.

Typically, traction control systems share the electro hydraulic brake actuator (which does not use the conventional master cylinder and servo) and wheel speed sensors with ABS.