How a Brake System Works

Brake systems were designed to slow the vehicle's wheel movement through friction. Today there are primarily two brake systems, ABS and non-ABS systems (anti-brake skid). One system is basic hydraulics that work with a master brake cylinder (which is connected to the brake pedal in the car) that supplies brake fluid pressure to the front brake calipers and rear brake wheel cylinders or brake calipers if so equipped.

A drum brake is a brake in which the friction is caused by a set of shoes or pads that press against the inner surface of a rotating drum. The drum is connected to a rotating wheel.

History

The modern automobile drum brake was invented in 1902 by Louis Renault, though a less-sophisticated drum brake had been used by Maybach a year earlier. In the first drum brakes, the shoes were mechanically operated with levers and rods or cables. From the mid-1930s the shoes were operated with oil pressure in a small wheel cylinder and pistons (as in the picture), though some vehicles continued with purely-mechanical systems for decades. Some designs have two wheel cylinders.

The shoes in drum brakes are subject to wear and the brakes needed to be adjusted regularly until the 1950s introduction of self-adjusting drum brakes. In the 1960s and 1970s brake drums on the front wheels of cars were gradually replaced with disc brakes and now practically all cars use disc brakes on the front wheels, with many offering disc brakes on all wheels. However, drum brakes are still often used for handbrakes as it has proved very difficult to design a disc brake suitable for holding a car when it is not in use. Moreover, it is very easy to fit a drum handbrake inside a disc brake so that one unit serves for both footbrake and handbrake.

Early type brake shoes contained asbestos. When working on brake systems of older cars, care must be taken not to inhale any dust present in the brake assembly. The Federal government began to regulate asbestos production, and there was a period of time where owners complained of poor braking with the non-asbestos linings. Eventually technology advanced to compensate. A majority of daily-driven older vehicles have been fitted with asbestos-free linings.

Servo design

Drum brakes, depending on the way the shoes are hinged, can have a "self-servo" characteristic. This increases stopping power without any additional effort by the driver because the rotation of the drum
Braking Systems

drags the shoes around with it, increasing the force holding them together. In rear brakes (as illustrated above) only one shoe will have this characteristic. Front drum brakes may use two actuating cylinders which allow both shoes to utilize the servo characteristic and which also increase the front axle braking force, required to compensate for forward weight shift and also to avoid premature rear-wheel locking. Servo action can be used to make a very powerful brake (as on the rear axles of large commercial vehicles), but it does reduce the ability of the driver to modulate the brakes sensitively. (The disc brake has no self-servo effect because the pads act perpendicularly to the rotating disc.)

Advantages

Drum brakes are still used in modern cars. There can be engineering and cost advantages. Drum brakes allow simple incorporation of a parking brake. They are often applied to the rear wheels since most of the stopping happens in the front of the vehicle and therefore the heat generated in the rear is significantly less. Drum brakes are also occasionally fitted as the parking (and emergency) brake even when the rear wheels used disk brakes as the main brakes. In this situation, a small drum is usually fitted within or as part of the brake disk.

An advanced technology hybrid car using drum rear brakes is the Toyota Prius. (4-wheel discs are used in certain markets - Hybrid vehicles greatly reduce everyday wear on braking systems owing to their energy recovery motor-generators, see regenerative braking).

Disadvantages

Drum brakes with internal shoes have a particular disadvantage; when the drums are heated by hard braking the diameter of the drum increases due to the expansion of the material and the brakes must be further depressed to obtain effective braking action. This is known as brake fade and can lead to driver panic and brake failure in extreme circumstances. Under normal driving conditions it is seldom noticed, especially when drums of appropriate size are fitted. The Pontiac GTO is one vehicle often cited as having undersized drums.

Before 1984, it was common to re-arc brake shoes to match the arc within brake drums; the machinery used has been phased out. This practice, however, was controversial as it removed friction material from the brakes and caused a reduction in the life of the shoes as well as creating hazardous asbestos dust. It is much better to use shoes for the proper diameter drum, and if the procedure was needed, the drums were so worn that they should have been replaced, as the thickness of the drum contributes to the strength and the heat absorption and dissipation ability of the drum.

Discs

Source: http://en.wikipedia.org/wiki/Disc_brake

The design of the disc varies somewhat. Some are simply solid cast iron, but others are hollowed out with fins joining together the disc's two contact surfaces (usually included as part of a casting process). This "ventilated" disc design helps to dissipate the generated heat and is commonly used on the more-heavily-loaded front discs.

Many higher performance brakes have holes drilled or cast through them. This is known as cross-drilling and was originally done in the 1960's on racing cars. Brake pads will outgas and under use may create boundary layer of gas between the pad and the disc hurting braking performance. Cross-drilling was created to provide the gas someplace to escape. Although modern brake pads seldom suffer from outgassing problems, water residue may build up after a vehicle passes through a puddle and impede braking performance. For this reason, and for heat dissipation purposes, Cross Drilling is still used on some braking components, but is not favored for racing or other hard use as the holes are a source of stress cracks under severe conditions.

Discs may also be slotted, where shallow channels are machined into the disc to aid in removing dust and gas. Slotting is the preferred method in most racing environments to remove gas, water, and de-glaze brake pads. Some discs are both drilled and slotted. Slotted discs are generally not used on standard vehicles because they quickly wear down brake pads; however, this removal of material is beneficial to race vehicles since it keeps the pads soft and avoids vitrification of their surfaces.
Braking Systems

A Mountain Bike Disc brake

On the road, drilled or slotted discs still have a positive effect in wet conditions because the holes or slots prevent a film of water building up between the disc and the pads. Cross drilled discs will eventually crack at the holes due to metal fatigue. Cross-drilled brakes that are manufactured poorly or subjected to high stresses will crack much sooner and more severely.

New technology now allows smaller brake systems to be fitted to bicycles, mopeds and now even mountain boards. The market for mountain bike disc brakes is very large and has huge variety, ranging from simple, mechanical (cable) systems, to highly expensive and also powerful, 6-pot hydraulic disc systems, commonly used on downhill racing bikes. Improved technology has seen the creation of the first vented disc rotors, for use on mountain bikes. The vented discs are similar to that seen on cars and have been introduced to help prevent heat fade on fast alpine descents.

Disc brake discs are commonly manufactured out of a material called grey iron. The SAE maintains a specification for the manufacture of grey iron for various applications. For normal car and light truck applications, the SAE specification is J431 G3000 (superseded to G10). This specification dictates the correct range of hardness, chemical composition, tensile strength, and other properties that are necessary for the intended use.

Disc damage modes

Discs are usually damaged in one of three ways: warping, scarring, and cracking. Machining the discs to correct these problems also leads to reduced life. It is usually cheaper just to replace the disc instead of repairing the parts.

Warping

Warping is primarily caused by excessive heat, which softens the metal and allows it to be reshaped. The main causes of overheating are: undersized/overmached brake discs, excessive braking (racing, descending hills/mountains), "riding" the brakes, or a "stuck" brake pad (pad touches disc at all times). Another cause of warping is when the disc is overheated and the vehicle is stopped. When keeping the brakes applied, the area where the pads contact the disc will cause uneven cooling and lead to warping.

Several methods can be used to avoid overheating brake discs. Use of a lower gear when descending steep grades to obtain engine braking will reduce the brake loading. Also, operating the brakes intermittently - braking to slower speed for a brief time then coasting will allow the brake material to cool between applications. Riding the brakes lightly will generate a great amount of heat with little braking effect and should be avoided. High temperature conditions as found in automobile racing can be dealt with by proper pad selection, but at the tradeoff of everyday driveability. Pads that can take high heat usually do best when hot and will have reduced braking force when cold. Also, high heat pads typically have more aggressive compounds and will wear discs down more quickly. Brake ducting that forces air directly onto the brake discs, common in motorsports, is highly effective at preventing brake overheating. This is also useful for cars that are driven both in motorsports and on the street, as it has no negative effect on driveability. A further extension of this method is to install a system which mists the rotors with cool water. Jaguar has reported great reductions in rotor temperatures with such a system.
Warping can also be caused by improperly torquing the lug nuts when putting on a wheel. The manual will indicate the proper pattern for tightening as well as a torque rating for the bolts. The tightening pattern varies little between manufacturers and most mechanics are familiar with them. Lug nuts should never be tightened in a circle. Some vehicles are sensitive to the force the bolts apply and tightening should be done with a torque wrench.

Warping will often lead to a thickness variation of the disc. If it has runout, a thin spot will develop by the repetitive contact of the pad against the high spot as the disc turns. When the thin section of the disc passes under the pads, the pads move together and the brake pedal will drop slightly. When the thicker section of the disc passes between the pads, the pads will move apart and the brake pedal will raise slightly, this is pedal pulsation. The thickness variation can be felt by the driver when it is approximately 0.007 inch (0.017 cm) or greater.

Not all pedal pulsation is due to warped discs. Brake pad material operating outside of its designed temperature range can leave a thicker than normal deposit in one area of the disc surface, creating a "sticky" spot that will grab with every revolution of the disc. Grease or other foreign materials can create a slippery spot on the disc, also creating pulsation.

Cracking
Cracking is limited mostly to drilled discs, which get small cracks around outside edges of the drilled holes near the edge of the disc due to the disc's uneven rate of expansion in severe duty environments. In the main small hairline cracks will appear in all cross drilled discs, this is normal. Manufacturers that use drilled discs as OEM are doing so for two reasons: looks, if they determine that the average owner of the vehicle model will not overly stress them; or as a function of reducing the unsprung weight of the brake assembly, with the engineering assumed that enough brake disc mass remains to absorb racing temperatures and stresses. A brake disc is a heat sink, so removing mass increases the heat stress it will have to contend with. Generally an OEM application that is not drilled will crack and could fail catastrophically if used over and above the original equipment design. Once cracked, these discs cannot be repaired.

Calipers
The brake caliper is the assembly which houses the brake pads and pistons. The pistons are usually made of aluminum or chrome-plated iron. There are two types of calipers: floating or fixed. A fixed caliper does not move relative to the disc. It uses one or more pairs of pistons to clamp from each side of the disc, and is more complex and expensive than a floating caliper. A floating caliper (also called a "sliding caliper") moves with respect to the disc; a piston on one side of the disc pushes the inner brake pad until it makes contact with the braking surface, then pulls the caliper body with the outer brake pad so pressure is applied to both sides of the disc.

Floating caliper (single piston) designs are subject to failure due to sticking which can occur due to dirt or corrosion if the vehicle is not operated regularly. This can cause the pad attached to the caliper to rub on the disc when the brake is released. This can reduce fuel efficiency and cause excessive wear on the affected pad.

Pistons and cylinders
The most common caliper design uses a single hydraulically actuated piston within a cylinder, although high performance brakes use as many as twelve. (Some pre-1969 Chrysler and General Motors vehicles had four-piston calipers - usually sought after by restorers.) Modern cars use different hydraulic circuits to actuate the brakes on each set of wheels as a safety measure. The hydraulic design also helps multiply braking force. The number of pistons in a caliper is often referred to as the number of 'pots', so if someone has six pot calipers they mean each caliper has six pistons in them.

Failure can occur due to failure of the piston to retract - this is usually a consequence of not operating the vehicle during a time that it is stored outdoors in adverse conditions. For high distance vehicles the piston seals may leak, which must be promptly corrected.

Brake pads
The brake pads are designed for high friction with brake pad material embedded in the disc in the process of bedding while wearing evenly. Although it is commonly thought that the pad material contacts the metal of the disc to stop the car, the pads work with a very thin layer of their own material and generate a semi-liquid friction boundary that creates the actual braking force. Of course, depending on the properties of the material, disc wear could be faster or slower than with other pads. The properties that determine material wear involve trade-offs between performance and longevity.
The brake pads must be replaced regularly, and most are equipped with a method of alerting the driver when this needs to take place. Some have a thin piece of soft metal that causes the brakes to squeal when the pads are too thin, while others have a soft metal tab embedded in the pad material that closes an electric circuit and lights a warning light when the brake pad gets thin. More expensive cars may use an electronic sensor. Although almost all road-going vehicles have only two brake pads per caliper, racing calipers utilise up to six pads, with varying frictional properties in a staggered pattern for optimum performance.

Early brake pads (and shoes) contained asbestos. When working on an older car's brakes, care must be taken not to inhale any dust present on the caliper (or drum).

**Brake squeal**

Sometimes a loud noise or high pitch squeal occurs when the brakes are applied. Most brake squeal is produced due to vibration (resonance instability) of the brake components especially the pads and discs. This type of squeal does not negatively affect brake stopping performance. Some simple techniques like adding chamfers to linings, greasing or gluing the contact between caliper and the pads (finger to backplate, piston to backplate), bonding insulators (damping material) to pad backplate, etc might help reduce squeal. Many times cold weather combined with high early morning humidity (dew) could make the brake squeal worse and vanishes when the lining reaches regular operating temperatures. However, some lining wear indicators are also designed to squeal when the lining is due for replacement. Overall brake squeal can be annoying to the vehicle passengers, passerby, pedestrians, etc especially as vehicles are designed to be more comfortable and quieter. Hence vehicle NVH (Noise, Vibration and Harshness) is one of the important priorities for today's vehicle manufacturers.

An age-old trick is to put a small amount of copper slip (copper grease) onto the back of the pads where they contact the brake caliper piston and on the pad shims, if present. While this will normally stop the squeal, getting grease on the pads or disks will affect braking performance.

Dust on the brakes may also cause squeal; there are many commercial brake cleaning products that can be used to remove dust and contaminants from the brakes.

Some high-performance brake pads, such as Hawk Performance pads, will always squeal during operation, and this does not indicate a problem.

Apart from noise generated from squeal, brakes may also develop a phenomenon called brake judder or shudder.

**Brake judder**

Brake judder is usually perceived by the driver as minor to severe vibrations transferred through the chassis during braking [1-9]. The judder phenomenon can be classified into two distinct subgroups; they are Hot (Thermal) or Cold Judder.

Hot judder is usually produced as a result of longer more moderate braking from high speed where the vehicle does not come to a complete stop [10]. It commonly occurs when a motorist decelerates from speeds of around 120-km/h to about 60-km/h, which results in severe vibrations being transmitted to the driver. These vibrations are the result of uneven thermal distributions believed to be the result of phenomena called Hot Spots. Hot Spots are classified as concentrated thermal regions that alternate between both sides of a disc that distort it in such a way that produces a sinusoidal waviness around its edges. Once the brake pads (friction material / brake lining) comes in contact with the sinusoidal surface during braking severe vibrations are induced as a result and can produce hazardous conditions for the person driving the vehicle [11-13,14].

Cold judder on the other hand is the result of uneven disc wear patterns or DTV. These variations in the disc surface are usually the result of extensive vehicle road usage. DTV is usually attributed to the following causes; waviness of rotor surface, misalignment of axis (Runout), elastic deflection, thermal distortion, wear and friction material transfers [3, 14,15].

**Brake Dust**

When braking force is applied, small amounts of material are gradually ground off the brake pads. This material is known as "brake dust" and usually deposits itself on the braking system and the surrounding wheel. Brake dust can badly damage the finish of most wheels if not washed off. Different brake pad formulations create different amounts of dust, and some formulations are much more damaging than others.
How Braking Systems Work

We all know that pushing down on the brake pedal slows a car to a stop. But how does this happen? How does your car transmit the force from your leg to its wheels? How does it multiply the force so that it is enough to stop something as big as a car?

When you depress your brake pedal, your car transmits the force from your foot to its brakes through a fluid. Since the actual brakes require a much greater force than you could apply with your leg, your car must also multiply the force of your foot. It does this in two ways:

- **Mechanical advantage** (leverage)
- **Hydraulic force multiplication**

The brakes transmit the force to the tires using friction, and the tires transmit that force to the road using friction also. Before we begin our discussion on the components of the brake system, we'll cover these three principles:

- Leverage
- Hydraulics
- Friction

**Leverage and Hydraulics**

In the figure below, a force $F$ is being applied to the left end of the lever. The left end of the lever is twice as long ($2X$) as the right end ($X$). Therefore, on the right end of the lever a force of $2F$ is available, but it acts through half of the distance ($Y$) that the left end moves ($2Y$). Changing the relative lengths of the left and right ends of the lever changes the multipliers.
The pedal is designed in such a way that it can multiply the force from your leg several times before any force is even transmitted to the brake fluid.

The basic idea behind any hydraulic system is very simple: Force applied at one point is transmitted to another point using an incompressible fluid, almost always an oil of some sort. Most brake systems also multiply the force in the process.

**Friction**

Friction is a measure of how hard it is to slide one object over another. Take a look at the figure below. Both of the blocks are made from the same material, but one is heavier. I think we all know which one will be harder for the bulldozer to push.

To understand why this is, let's take a close look at one of the blocks and the table:

Because friction exists at the microscopic level, the amount of force it takes to move a given block is proportional to that block's weight.

Even though the blocks look smooth to the naked eye, they are actually quite rough at the microscopic level. When you set the block down on the table, the little peaks and valleys get squished together, and some of them may actually weld together. The weight of the heavier block causes it to squish together more, so it is even harder to slide.

Different materials have different microscopic structures; for instance, it is harder to slide rubber against rubber than it is to slide steel against steel. The type of material determines the coefficient of friction, the ratio of the force required to slide the block to the block's weight. If the coefficient were 1.0 in our example, then it would take 100 pounds of force to slide the 100-pound (45 kg) block, or 400 pounds (180 kg) of force to slide the 400-pound block. If the coefficient were 0.1, then it would take 10 pounds of force to slide to the 100-pound block or 40 pounds of force to slide the 400-pound block.
So the amount of force it takes to move a given block is proportional to that block's weight. The more weight, the more force required. This concept applies for devices like brakes and clutches, where a pad is pressed against a spinning disc. The more force that presses on the pad, the greater the stopping force.

**Coefficients**

An interesting thing about friction is that it usually takes more force to break an object loose than to keep it sliding. There is a coefficient of static friction, where the two surfaces in contact are not sliding relative to each other. If the two surfaces are sliding relative to each other, the amount of force is determined by the coefficient of dynamic friction, which is usually less than the coefficient of static friction.

For a car tire, the coefficient of dynamic friction is much less than the coefficient of static friction. The car tire provides the greatest traction when the contact patch is not sliding relative to the road. When it is sliding (like during a skid or a burnout), traction is greatly reduced.

How Master Cylinders and Combination Valves Work

To increase safety, most modern car brake systems are broken into two circuits, with two wheels on each circuit. If a fluid leak occurs in one circuit, only two of the wheels will lose their brakes and your car will still be able to stop when you press the brake pedal.

The master cylinder supplies pressure to both circuits of the car. It is a remarkable device that uses two pistons in the same cylinder in a way that makes the cylinder relatively failsafe. The combination valve warns the driver if there is a problem with the brake system, and also does a few more things to make your car safer to drive.

**The Master Cylinder**

Here is where you'll find the master cylinder:
In the figure below, the plastic tank you see is the brake-fluid reservoir, the master cylinder's brake-fluid source. The electrical connection is a sensor that triggers a warning light when the brake fluid gets low.

As you'll see here, there are two pistons and two springs inside the cylinder.

When you press the brake pedal, it pushes on the primary piston through a linkage. Pressure builds in the cylinder and lines as the brake pedal is depressed further. The pressure between the primary and secondary piston forces the secondary piston to compress the fluid in its circuit. If the brakes are operating properly, the pressure will be the same in both circuits.

If there is a leak in one of the circuits, that circuit will not be able to maintain pressure.
When the first circuit leaks, the pressure between the primary and secondary cylinders is lost. This causes the primary cylinder to contact the secondary cylinder. Now the master cylinder behaves as if it has only one piston. The second circuit will function normally, but the driver will have to press the pedal further to activate it. Since only two wheels have pressure, the braking power will be severely reduced.

The Combination Valve
You will find a combination valve on most cars with front disc brakes and rear drum brakes.

The combination valve does the job of three separate devices:

- The metering valve
- The pressure differential switch
- The proportioning valve

Combination valve sections
Metering Valve
The metering valve section of the combination valve is required on cars that have disc brakes on the front wheels and drum brakes on the rear wheels. If you have read How Disc Brakes Works and How Drum Brakes Work, you know that the disc brake pad is normally in contact with the disc, while the drum brake shoes are normally pulled away from the drum. Because of this, the disc brakes are in a position to engage before the drum brakes when you push the brake pedal down.

The metering valve compensates for this, making the drum brakes engage just before the disc brakes. The metering valve does not allow any pressure to the disc brakes until a threshold pressure has been reached. The threshold pressure is low compared to the maximum pressure in the braking system, so the drum brakes just barely engage before the disc brakes kick in.

Having the rear brakes engage before the front brakes provides a lot more stability during braking. Applying the rear brakes first helps keep the car in a straight line, much like the rudder helps a plane fly in straight line.

Pressure Differential Switch
The pressure differential valve is the device that alerts you if you have a leak in one of your brake circuits. The valve contains a specially shaped piston in the middle of a cylinder. Each side of the piston is exposed to the pressure in one of the two brake circuits. As long as the pressure in both circuits is the same, the piston will stay centered in its cylinder. But if one side develops a leak, the pressure will drop in that circuit, forcing the piston off-center. This closes a switch, which turns on a light in the instrument panel of the car. The wires for this switch are visible in the picture above.

Proportioning Valve
The proportioning valve reduces the pressure to the rear brakes. Regardless of what type of brakes a car has, the rear brakes require less force than the front brakes.

The amount of brake force that can be applied to a wheel without locking it depends on the amount of weight on the wheel. More weight means more brake force can be applied. If you have ever slammed on your brakes, you know that an abrupt stop makes your car lean forward. The front gets lower and the back gets higher. This is because a lot of weight is transferred to the front of the car when you stop. Also, most cars have more weight over the front wheels to start with because that is where the engine is located.

If equal braking force were applied at all four wheels during a stop, the rear wheels would lock up before the front wheels. The proportioning valve only lets a certain portion of the pressure through to the rear wheels so that the front wheels apply more braking force. If the proportioning valve were set to 70 percent and the brake pressure were 1,000 pounds per square inch (psi) for the front brakes, the rear brakes would get 700 psi.

How Drum Brakes Work
Drum brakes work on the same principle as disc brakes: Shoes press against a spinning surface. In this system, that surface is called a drum.
Many cars have drum brakes on the rear wheels and disc brakes on the front. Drum brakes have more parts than disc brakes and are harder to service, but they are less expensive to manufacture, and they easily incorporate an emergency brake mechanism.

In this edition of *HowStuffWorks*, we will learn exactly how a drum brake system works, examine the emergency brake setup and find out what kind of servicing drum brakes need.

Let's start with the basics.

**The Drum Brake**

The drum brake may look complicated, and it can be pretty intimidating when you open one up. Let's break it down and explain what each piece does.

Like the disc brake, the drum brake has two brake shoes and a piston. But the drum brake also has an adjuster mechanism, an emergency brake mechanism and lots of springs.

When you hit the brake pedal, the piston pushes the brake shoes against the drum.

As the brake shoes contact the drum, there is a kind of wedging action, which has the effect of pressing the shoes into the drum with more force.
The extra braking force provided by the wedging action allows drum brakes to use a smaller piston than disc brakes. But, because of the wedging action, the shoes must be pulled away from the drum when the brakes are released. This is the reason for some of the springs. Other springs help hold the brake shoes in place and return the adjuster arm after it actuates.

**Brake Adjuster**

For the drum brakes to function correctly, the brake shoes must remain close to the drum without touching it. If they get too far away from the drum (as the shoes wear down, for instance), the piston will require more fluid to travel that distance, and your brake pedal will sink closer to the floor when you apply the brakes. This is why most drum brakes have an **automatic adjuster**.

As the pad wears down, more space will form between the shoe and the drum. Each time the car stops while in reverse, the shoe is pulled tight against the drum. When the gap gets big enough, the adjusting lever rocks enough to advance the adjuster gear by one tooth. The adjuster has threads on it, like a bolt, so that it unscrews a little bit when it turns, lengthening to fill in the gap. When the brake shoes wear a little more, the adjuster can advance again, so it always keeps the shoes close to the drum.

Some cars have an adjuster that is actuated when the emergency brake is applied. This type of adjuster can come out of adjustment if the emergency brake is not used for long periods of time. So if you have this type of adjuster, you should apply your emergency brake at least once a week.

**Servicing**

The most common service required for drum brakes is **changing the brake shoes**. Some drum brakes provide an inspection hole on the back side, where you can see how much material is left on the shoe. Brake shoes should be replaced when the friction material has worn down to within 1/32 inch (0.8 mm) of the rivets. If the friction material is bonded to the backing plate (no rivets), then the shoes should be replaced when they have only 1/16 inch (1.6 mm) of material left.
Just as in disc brakes, deep scores sometimes get worn into brake drums. If a worn-out brake shoe is used for too long, the rivets that hold the friction material to the backing can wear grooves into the drum. A badly scored drum can sometimes be repaired by refinishing. Where disc brakes have a minimum allowable thickness, drum brakes have a **maximum allowable diameter**. Since the contact surface is the inside of the drum, as you remove material from the drum brake the diameter gets bigger.

![Figure 10. Brake drum](image)

**How Disc Brakes Work**

Most modern cars have disc brakes on the front wheels, and some have disc brakes on all four wheels. This is the part of the brake system that does the actual work of stopping the car.

![Disc brake](image)

The most common type of disc brake on modern cars is the **single-piston floating caliper**. In this article, we will learn all about this type of disc brake design.

**Disc Brake Basics**

Here is the location of the disc brakes in a car:
The main components of a disc brake are:

- The brake pads
- The caliper, which contains a piston
- The rotor, which is mounted to the hub

The disc brake is a lot like the brakes on a bicycle. Bicycle brakes have a caliper, which squeezes the brake pads against the wheel. In a disc brake, the brake pads squeeze the rotor instead of the wheel, and the force is transmitted hydraulically instead of through a cable. Friction between the pads and the disc slows the disc down.
A moving car has a certain amount of kinetic energy, and the brakes have to remove this energy from the car in order to stop it. How do the brakes do this? Each time you stop your car, your brakes convert the kinetic energy to heat generated by the friction between the pads and the disc. Most car disc brakes are vented.

Vented disc brakes have a set of vanes, between the two sides of the disc, that pumps air through the disc to provide cooling.

Self-Adjusting Brakes

The single-piston floating-caliper disc brake is self-centering and self-adjusting. The caliper is able to slide from side to side so it will move to the center each time the brakes are applied. Also, since there is no spring to pull the pads away from the disc, the pads always stay in light contact with the rotor (the rubber piston seal and any wobble in the rotor may actually pull the pads a small distance away from the rotor). This is important because the pistons in the brakes are much larger in diameter than the ones in the master cylinder. If the brake pistons retracted into their cylinders, it might take several applications of the brake pedal to pump enough fluid into the brake cylinder to engage the brake pads.

Older cars had dual or four-piston fixed-caliper designs. A piston (or two) on each side of the rotor pushed the pad on that side. This design has been largely eliminated because single-piston designs are cheaper and more reliable.

Emergency Brakes

In cars with disc brakes on all four wheels, an emergency brake has to be actuated by a separate mechanism than the primary brakes in case of a total primary brake failure. Most cars use a cable to actuate the emergency brake.
Some cars with four-wheel disc brakes have a separate drum brake integrated into the hub of the rear wheels. This drum brake is only for the emergency brake system, and it is actuated only by the cable; it has no hydraulics.

Other cars have a lever that turns a screw, or actuates a cam, which presses the piston of the disc brake.

**Servicing Your Brakes**

The most common type of service required for brakes is changing the pads. Disc brake pads usually have a piece of metal on them called a wear indicator.
When enough of the friction material is worn away, the wear indicator will contact the disc and make a squealing sound. This means it is time for new brake pads.

There is also an inspection opening in the caliper so you can see how much friction material is left on your brake pads.

Sometimes, deep scores get worn into brake rotors. This can happen if a worn-out brake pad is left on the car for too long. Brake rotors can also warp; that is, lose their flatness. If this happens, the brakes may shudder or vibrate when you stop. Both of these problems can sometimes be fixed by refinishing (also called turning or machining) the rotors. Some material is removed from both sides of the rotors to restore the flat, smooth surface.

Refinishing is not required every time your brake shoes are replaced. You need it only if they are warped or badly scored. In fact, refinishing the rotors more often than is necessary will reduce their life. Because the process removes material, brake rotors get thinner every time they are refinished. All brake rotors have a specification for the minimum allowable thickness before they need to be replaced. This spec can be found in the shop manual for each vehicle.

How Power Brakes Work

If you've ever opened the hood of your car, you've probably seen the brake booster. It's the round, black cannister located at the back of the engine compartment on the driver's side of the car.
Back in the day, when most cars had drum brakes, power brakes were not really necessary -- drum brakes naturally provide some of their own power assist. Since most cars today have disc brakes, at least on the front wheels, they need power brakes. Without this device, a lot of drivers would have very tired legs.

The brake booster uses vacuum from the engine to multiply the force that your foot applies to the master cylinder. In this article, we'll see what's inside the black cannister that provides power braking.

The Vacuum Booster
The vacuum booster is a metal canister that contains a clever valve and a diaphragm. A rod going through the center of the canister connects to the master cylinder's piston on one side and to the pedal linkage on the other.

Another key part of the power brakes is the check valve.
The photo above shows the check valve, which is a **one-way valve** that only allows air to be sucked *out* of the vacuum booster. If the *engine* is turned off, or if a leak forms in a vacuum hose, the check valve makes sure that air does not enter the vacuum booster. This is important because the vacuum booster has to be able to provide enough boost for a driver to make several stops in the event that the engine stops running -- you certainly don't want to lose brake function if you run out of gas on the highway.

### The Booster in Action

The vacuum booster is a very simple, elegant design. The device needs a **vacuum source** to operate. In *gasoline-powered* cars, the engine provides a vacuum suitable for the boosters. In fact, if you hook a hose to a certain part of an engine, you can suck some of the air out of the container, producing a partial vacuum. Because *diesel engines* don't produce a vacuum, diesel-powered vehicles must use a separate vacuum pump.

On cars with a vacuum booster, the brake pedal pushes a rod that passes through the booster into the master cylinder, actuating the master-cylinder piston. The engine creates a **partial vacuum** inside the vacuum booster on both sides of the diaphragm. When you hit the brake pedal, the rod cracks open a valve, allowing air to enter the booster on one side of the diaphragm while sealing off the vacuum. This increases pressure on that side of the diaphragm so that it helps to push the rod, which in turn pushes the piston in the master cylinder.

As the brake pedal is released, the valve seals off the outside air supply while reopening the vacuum valve. This restores vacuum to both sides of the diaphragm, allowing everything to return to its original position.