The Low-Down on Bike ABS, Linked and EVO Brakes

By Steve Makohin

14th June 2006

Link To Article at www.nabble.com

Hello,

I have written this article for people who are new to motorcycle ABS or to other brake technologies (linked brakes and servo brakes), and for those who may not be aware of some of the potential "gotchas" that are lurking with bike ABS. This article is divided into sections to allow semi-interested readers to skip parts they don't care about As always, the "Delete" button is at your disposal.

The sections are:

- Overview
- Why ABS exists
- How ABS works
- ABS Reduces Stopping Distance (in most cases)
- Motorcycle ABS Shines (in most cases)
- The ABS Safety Net
- When ABS Doesn't Shine
- ABS is the Future of Motorcycling, Available Today
- Linked or "Integral" Brakes
- Combining ABS, Links, and EVO
- Epilogue The Low-Down on Bike ABS, Linked and EVO Brakes (or "Why ABS Shines, and Sometimes Sucks")

Overview:

This article explains three separate brake technologies:

1) ABS,
2) Linked and Semi-Linked brakes, and
3) EVO brakes, also known as servo-controlled brakes or "whizzy" brakes.

It includes a brief, non-technical overview of each technology, and it focuses on the benefits and some of the negatives of these technologies.

Why ABS Exists:

Understanding why ABS exists and its purpose will help you understand what to expect of ABS, as well as to appreciate some of its limitations. It will also help you understand why ABS behaves as it does. Without this information, you may be surprised to find yourself in a situation in which you believe you "have no brakes" or your ABS "caused an accident".
ABS is an acronym for Anti-lock Brake System. The ABS systems on bikes, like those on cars, are designed to do one thing, and one thing only: to help prevent wheel lockup which could result in a skid and subsequent loss of vehicular control. That is the one mission that ABS is designed to fulfill. ABS on a motorcycle is arguably even more important than ABS on a car because the consequences of loss of

control on a motorcycle typically results in the bike being "dropped", thereby causing damage to the machine, and exposing the rider to the risk of personal injury.

How ABS Works:

ABS is a hydraulic brake system with a few extra components. Most motorcycle ABS have independently functioning sensors on the front and rear wheels. These sensors measure the speed at which each of the wheels are rotating, and they report that information to an ABS computer. The ABS computer is continuously running an application (software) that evaluates the wheel rotation information and combines it with other information, and then applies certain rules to determine if a wheel is at risk of locking up. Different manufacturers, such as BMW and Honda, have different "logic", or principles that are used to determine exactly what constitutes an "impending lockup" condition at a specific wheel. Some highly simplified examples of the logic that may be used are as follows:

- IF front brake is ON AND front wheel rotation speed is less than rear wheel rotation speed THEN front wheel is at risk of lock-up

- IF rear brake is ON AND rear wheel rotation speed is less than front wheel rotation speed THEN rear wheel is at risk of lock-up

Note that one of the conditions for sensing an "impending lockup" is always "brake is on" - ABS may activate only while the vehicle operator has the brake applied.

The wheel rotation sensors and the ABS computer do their work very quickly, on the order of making tens of evaluations per second, so they can detect an "impending lock-up" condition and respond to it much more rapidly than any human can. They can also respond to changes in conditions much quicker, and much more precisely than humans.

When the ABS computer determines that a wheel is in a state of "impending lock-up", it takes action to alleviate that condition. It does this by reducing or releasing brake pressure at the affected wheel in order to give the tire a chance to re-establish its grip with the road (i.e., no skid). The ABS computer then reapplies the brake to that wheel to resume stopping power. In resuming the application of brake force, the ABS computer may still detect the "impending lock-up" condition, in which case it repeats the cycle by temporarily reducing or releasing brake pressure at the affected wheel, and then reapplying the brake force. This cycling of releasing and applying the brakes happens very quickly, occurring several times per second. Some systems are slow enough that the operator feels a vibration as the ABS is engaged, while others may not give any tactile feedback at all. It depends on the system.

ABS Reduces Stopping Distance (in most cases):

As mentioned earlier, ABS is designed to perform one function, and that is to help prevent wheel lockup which could result in a skid and subsequent loss of vehicular control. Even though ABS was designed to prevent loss of control, it also affects stopping distances - shortening them under most conditions, and sometimes lengthening them in others.

Maximum stopping power, that is the greatest rate of deceleration, can be attained just *before* a wheel lockup. There are a variety of human challenges, especially on a motorcycle, in trying to rapidly apply brakes to quickly attain this threshold, and then to vary brake pressure as conditions change throughout the stop. The dynamics start within a fraction of a second of applying your brakes as your bike's momentum shifts the weight bias forward, thereby lightening the downward force on the rear wheel (and in doing so, making it more prone to lockup and skid) and increasing the downward force on your front wheel (and in doing so, giving it more traction and allowing you to apply still greater brake pressure before it locks up).

This means if you want to attain maximum stopping power, you must manually and continuously vary the brake pressure independently at both wheels to compensate for changing conditions. And that's not easy to do.

Extremely good riders, such as professional world-class racers, are well-versed at threshold braking. Repeated testing with a variety of riders and motorcycles, under a variety of conditions, have concluded that a non-ABS bike can attain a shorter stopping distance than the identical ABS-equipped bike, providing that all six of following criteria are met:

1) The exercise takes place on a high-traction surface.
2) The high-traction surface does not have any variables that vary the available traction.
3) The rider knows the traction limits of the test bike on the test track (this requires multiple attempts to hone the perfect stop).
4) The rider is mentally and physically readied for the braking exercise. (i.e., no surprises)
5) The rider is well-trained at threshold braking, and well-practiced
6) No human error occurs during the execution of the exercise.

However, on the street, most of the time you will experience considerably different conditions than those in the "perfect braking scenario" at the track:

- Tire temperatures vary to provide more or less grip
- Tires wear throughout their lifetime to provide different handling, so the maximum grip you got three months ago may not be the same as you get today.
- Tire pressure may be a few pounds off from your previous threshold braking session.
- Road surfaces vary as do the level of traction they offer.
- Road surfaces may be further affected by debris such as sand or gravel, oil or gasoline, or even being slicked with rain.

Any or all of the items above make it difficult, if not impossible for a human to quickly ascertain (without exceeding) the actual traction limits that are available to them on a first attempt at threshold braking. To make matters worse, the conditions may change suddenly and significantly during the braking, such as starting the braking on smooth, dry, fresh asphalt (superb grip), and then crossing onto older, glazed asphalt (reduced grip), or encountering a little sandy patch (severely reduced grip). Worse still is the fact that in an emergency situation, even the best-trained and well-prepared human brains tend to simplify, and focus on a very few things.

This contrasts sharply with the multitasking that is required to execute threshold breaking well.

Extensive research in the field of motorcycle braking, some of it dating back to the Hurt Report (the most extensive study of motorcycle incidents to date), tells us that in the vast majority of motorcycle incidents in which emergency braking was required or in which it was a viable option, the rider did not apply the brakes hard enough. For fear of locking up a wheel, skidding, and losing control of the bike, riders increase their stopping distances, in some cases dramatically, and as a result, they "ride into" danger -- an obstacle, another vehicle, or off the road.

Motorcycle ABS performs extremely well in emergency braking situations by allowing the rider to apply brakes hard and fast without worrying about locking up a wheel and skidding. ABS will use up all the available traction to provide maximum stopping power. And because ABS responds so quickly, it continuously adjusts to account for changing tractions conditions, such as running across a sandy patch or transitioning from grippy fresh asphalt to much less grippy glazed asphalt or an unpaved shoulder.

Motorcycle ABS Shines (in most cases):

ABS performs so well on the street, that with very few exceptions, it provides shorter stopping distances as compared to an identical non-ABS bike. This reality has far-reaching consequences: Under the vast majority of street motorcycling scenarios, an average rider with motorcycle ABS can attain shorter stopping distances than the most skilled motorcyclists can (e.g., a professional, world-class racer, etc.) on an identical, non-ABS bike. This is true even when the pros are given multiple opportunities to shorten their distances. Not surprisingly, even the pros can shorten their stopping distances when they switch over to an ABS-equipped bike on the street. Numerous tests by a variety of organizations have proven this, time and again. Scenarios like the well-prepared, well anticipated, non-panic, perfect threshold braking exercise on a high-traction non-variable track are the rare exception when riding on the street.

Stopping distances are shortened with bike ABS for two distinctly different reasons:

1) The rider is able to apply the brakes hard and fast without the fear of a lockup and skid. Doing so lets you use significantly more of your brake's potential stopping capabilities, sooner. In other words, ABS lets you convert much more of your bike's potential stopping power into actual stopping power.

2) ABS continuously monitors changing traction conditions, and it rapidly adjusts to compensate for those dynamic conditions. This helps to keep your brakes close to their limits of maximum stopping throughout the stop.

The ABS Safety Net:

Motorcycle ABS offers a considerably increased safety margin. However, if you use up that safety margin, you may put yourself at even greater risk than by not having ABS. For example, if you get into the habit of riding in closer proximity to other vehicles, or at higher speeds because of the belief that ABS will be able to rescue you when you call upon it, then the additional safety margin offered by ABS may be insufficient to overcome the higher risks you have introduced through your change in riding style.

When you ride an ABS-equipped bike, be aware when the ABS engages. When it does, consider it a warning that you have already exceeded the limits of your motorcycle and/or your riding abilities, and that it has prevented a skid. Adjust your riding style to avoid repeated ABS engagements. And ride as though you did not have the benefit of ABS available to you.

When ABS Doesn't Shine:

If your bike has ABS, then your motorcycle's owner manual will likely have a section that duly warns you that ABS does not do some things well, or at all. One of those things is circumventing the laws of physics. If you want to get the most enjoyment out of your ABS-equipped bike, reduce risks, and avoid potential pitfalls, it is important that your understand not only what ABS does (as described earlier) but also what ABS does not do, and the conditions under which ABS may not do what you want it to do.

In most cases, ABS cannot be faulted for not doing something it was not designed to do. In other cases, ABS has inherent characteristics that may surprise unprepared riders.

The first group of issues relate to the limits of traction. Each motorcycle has a finite traction limit, which is influenced by a variety of conditions. The full amount of traction can be distributed between steering and braking -- the greater the steering, the less the braking, and vice versa. You can see this principle in action in a car without ABS that is in a full wheel lockup. The full limit of traction is being expended on braking, and the car will not steer under these conditions. Similarly, on a motorcycle, when you are executing a turn at or near the limits of traction (all or virtually all traction is being expended on turning), the application of brakes may push your machine past its limits of traction resulting in a skid. In this case, one or both wheels will slide out from under the bike to produce what is commonly called a "low side." ABS simply cannot do anything in this example because as soon as the skid is initiated, the bike is already leaning beyond the point of recovery, so releasing the brakes has no effect. In other words, an ABS-equipped bike fairs similarly to a non-ABS bike.

The above example is an extreme one, because most street riders do no ride at their motorcycle's performance limits in graceful sweepers. A more realistic scenario is one in which the rider is executing a turn in which they have a considerable traction reserve (e.g., 25%), and an unexpected event is introduced (e.g., a deer crossing the road), and the rider responds by applying brakes that exceed the traction limits. Once loss of traction occurs and the bike is beyond the recoverable lean angle, a "low-side" occurs, with ABS or without. For ABS riders, the important thing to note is that the more vertical your bike, the greater the safety margin offered by ABS. Another group of issues arises in scenarios in which a very short (transient) skid is preferred as compared to ABS's momentary release of brake pressure.

A real-world example is applying brakes, moderately on a smooth, level, good-traction surface, and then encountering a recessed man-hole cover. At the moment when the front wheel steps over the high-traction road and momentarily descends an inch to a lower-traction metal plate, the ABS system may detect the reduced wheel spin and trigger an "impeding skid" condition, and pulse the front brake. This results in a reduction of brake force and a lengthen stopping distance. Without ABS, the wheel would very briefly reduce its spin rate, and then resume its effective braking, likely without the rider even noticing a chirp from the tires.

A similar condition arises under moderate or hard braking on a road whose surface is wavy. Such is the case with "frost heaves" in the northern United States and in Canada, or on roads in a poor state of repair. Another example is braking over a bump that throws the bike and rider upwards. In such scenarios, the ABS may detect a momentary reduction in wheel spin, and pulse the brakes. These conditions are exacerbated when riding down-hill, because you have gravity adding to the forward momentum of your bike, so when ABS engages, not only will it lengthen stopping distance as compared to a non-ABS bike, the rider may interpret this as a "lunge forward", or the brakes failing and then suddenly re-engaging.

By being aware of these characteristics, you can adjust your riding style accordingly. In some extreme cases, where a rider spends much of their time in these conditions, ABS may prove to be detrimental by doing the "wrong thing" most of the time. Fortunately, some motorcycle models have switchable ABS that allows you to turn ABS off when you know you will be spending a fair bit under these conditions, and back on again when you're out of them.

ABS is the Future of Motorcycling, Available Today:

BMW was an early adopter of motorcycle ABS, and they have learned a lot from the time they spent in the saddle. For example, the BMW GS series of dual-sport bikes are available with switchable ABS to accommodate dirt riding where deliberate rear-wheel skids are commonly induced (called "trail braking"). BMW's newest R1200S sport boxer has available switchable ABS for track days, to accommodate performance riding purists. All of BMW's motorcycles either have ABS available, or standard.

But BMW is just a small manufacturer. Honda, on the other hand, is the world's largest motorcycle manufacturer by a wide margin. In late 2005, they announced that within a few years, every road-going Honda motorcycle will have available ABS, and in many cases, ABS will be standard. This strong endorsement tells us that motorcycle ABS is here to stay, and it will soon be the norm rather than the exception. Other manufacturers are expected to follow suit. Even the venerable Harley-Davidson is reported to be developing their own ABS system, only to meet the demands for higher safety amongst American police forces.

Linked or "Integral" Brakes:

Linked braking systems link both the front and rear brakes to the motorcycle's brake controls such that both the front and the rear brakes are applied when only the front brake lever or the rear brake pedal are actuated by the rider. In the case of fully-linked brakes, both brakes are always applied, whether you use your front brake (right hand lever) or rear brake (right foot pedal). With semi-linked brakes, the hand lever affects both brakes while the foot pedal affects only the rear brake.

In many cases, linked brakes has been proven to reduce stopping distances, especially when teamed with ABS. For the shortest stopping distances, both front and rear brakes should be applied up to the traction limits (i.e., threshold braking). This threshold varies depending on a number of factors ranging from the rate at which the brakes are applied, to whether a pillion is available to apply additional weight to the rear tire, and therefore additional stopping power.

BMW's linked brakes, according to the manufacturer, are "intelligent" in that they apply the "correct" proportions of front versus rear brake pressure, depending on the circumstances. They are especially useful with the cruiser crowd who frequently apply only the rear brake, which coincidentally provides the least stopping power and is most prone to lockup. With linked brakes, both brakes are applied when the cruiser rider actuates the rear brake pedal, thereby providing much more stopping power.

Linked brakes do have their enemies, though. Authority motorcycles frequently find themselves in low speed maneuvres, so it is desirable to apply the rear brake alone ("trail braking") while also applying throttle. Similarly, in performance riding it is useful to trail brake as you enter a corner in order to elongate the chassis and stabilize the suspension. In these cases, semi-linked brakes allow you to apply the rear brake alone, as desired. Linked brakes have proven to be a benefit in emergency stops, because a rider does not always do the right thing in a panic scenario. Sometimes, they apply only one brake, typically favoring the front brake (cruise riders often favor the rear). In these scenarios, without linked brakes, the unused brake ends up as unrealized potential stopping power, and stopping distances increase unnecessarily.

Servo-Controlled Brakes:

The final attribute to BMW's brake technology is "EVO," which is most easily understood as power-assisted brakes. EVO provides its assist only while the ignition is in the ON position, and just like power brakes in a car, it provides much more stopping power with less brake lever or brake pedal effort.

Current motorcycles already have awesome brakes enabling a front wheel lockup or a stoppie with just two fingers of braking force applied to the right lever, so one may ask why bother boosting the braking power at all?

The real benefit, as claimed by the manufacturer, is in the EVO braking computer, which senses the rapid application of brakes, thereby detects an emergency braking condition and it can take appropriate action.

When the EVO computer senses this condition, BMW says that the brakes are pumped up to full pressure about 1/10 of a second quicker than any human can accomplish the same feat. This translates into a stopping distance from 60 mph to zero that is almost 9 feet shorter with EVO assistance than without. Though 9 feet over a stopping distance of over 100 feet may not appear meaningful, it may make the difference between connecting with an obstacle or not. Or connecting at a lower speed, thereby reducing or eliminating personal injuries.

Early releases of EVO brakes were criticized for being "grabby", or providing much more stopping power than you would expect with little control effort. Current BMW EVO-equipped bikes have been updated to be more compliant to users' expectations, though they still may need some "getting used to." Also, like a car, the power assistance disappears when the ignition is switched to the OFF position, which surprises new EVO-equipped bike owners when they roll their bike with the engine off only to discover that they need to apply much more brake lever pressure than they expected to stop the bike. BMW bikes are not the first to take advantage of this "emergency stop" program. Mercedes-Benz cars have had it for years, as do some BMW cars.

Combining ABS, Links, and EVO:

When you combine all three BMW brake technologies, you have the potential to provide a much-enhanced braking experience. In a real-world scenario, a rider is about to pass an SUV whose inattentive driver suddenly veers into the rider's lane. From force of habit, the rider rapidly applies his rear brake pedal. EVO brakes sense the rapid application of the brake pedal and they determine an emergency braking maneuver has started. They pump up the brakes to full pressure at least 1/10 of a second faster than the rider could do so himself. Fully-linked brakes take the rear brake pedal control signal and use it to apply both front and rear brakes. The linked brake system senses the additional available traction at the rear wheel because a pillion is on board, and distributes the brake force in appropriate proportions across the front and rear brakes, using all the available traction at both wheels and translating it into actual stopping power. Sensing an impeding lock-up, ABS kicks in to prevent both wheel from locking, thereby averting loss of control while providing rapid deceleration. All this happens in the blink of an eye with confidence-inspiring precision and control.

Epilogue:

No matter what brake technology your bike has, it behooves you (N.B.: is in your interests) to develop superb riding and braking skills. These technologies, however, offer dramatic gains in improved safety, especially in panic stops, and in the case of ABS, when braking on streets whose traction is less than perfect, or on which traction varies.

This is the real world, full of imperfections. And even the best riders with the most highly developed braking skills can't come close to guaranteeing that they will be able to meet all six criteria that are essential to executing the perfect threshold braking maneuver, thereby outbrake a non-ABS bike.

Steve Makohin

'01 R1100S/ABS

Oakville, Ontario, Canada