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TECHNICAL WHITEPAPER:

Brake Pad Knockback

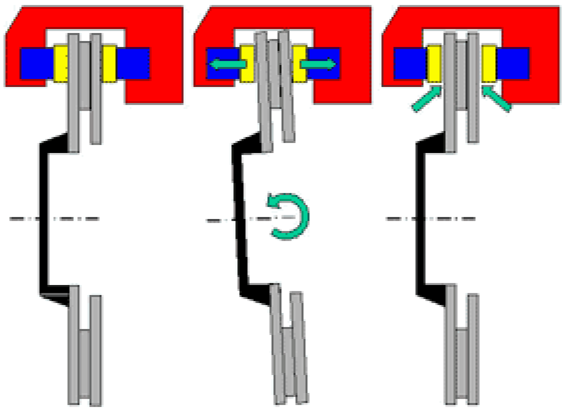
A Common Racing Phenomenon

The concept of pad knockback is pretty simple to explain. When a car is running straight down the road and the brakes are in good repair, the brake pads and rotor are rather parallel to one another. In a perfect world all of the driver's input at the brake pedal would be translated into pressure, but the reality is that some fluid must be used to take up the clearances that exist between the pistons, pads, and rotor before building pressure. A properly designed caliper piston seal will allow the pistons, pads, and rotor to stay relatively close to one another so that when the brake pedal is pressed this dead play in the system is minimized, but it can never be reduced to zero.

However, racetracks are rarely composed of just straightaways. To keep things interesting, there are usually a handful of turns thrown in the mix, some faster than others. These dynamic events create lateral loads on the vehicle chassis that are reacted by the tires, wheels, hubs, bearings, uprights, and so on. This is what makes driving on racetracks so enjoyable, but these loads are negatively impacting our braking system behind the scenes.
Naturally, none of the components on our cars are 100% rigid. Therefore, as these dynamic lateral loads are applied, all of the components reacting the cornering forces must deflect to some degree. In English, when we throw our cars into a corner, stuff bends. It's not desirable, but that's the reality of the situation. You can pay more money to make stuff bend less, but it will always bend to some degree. This is where knockback is born.

As the wheel, hub, and wheel bearing deflect during cornering, the rotor hat sandwiched in-between is forced to go along for the ride. Because the caliper (red in the illustration) is attached to a more rigid suspension component – the upright – the parallelism between the rotor face (gray in the illustration) and the brake pads (yellow in the illustration) is altered. In so many words, the deflection of the rotor relative to the brake pads actually forces the brake pads away from one another. This spreading action pushes the caliper pistons (blue in the illustration) back into their bores a tiny amount (horizontal green arrows in the center illustration) so that when the deflection goes away (when the cornering event is over) there is not enough springback in the piston seal to push everything back together again (green arrows in the rightmost illustration). The pads are now pushed off the rotor and will stay put until the brakes are next applied.

Knockback in action – before, during, and after cornering



Unfortunately, the next time the brakes are applied the initial travel will be used exclusively to push the pistons back up against the pads and rotor. This requires forcing fluid into the system, so the pedal feels as if it drops away toward the floor. Because this action does not build any line pressure, no torque is generated and for a brief moment the car will not slow down. Yikes!

Flashback: October, 2002, Watkins Glen, New York

So there I was at the historic Watkins Glen International road course. It was to be the first time that my 1995 Cobra was to be put on track. Prior to the event (I was instructing at a Shelby Club school) I of course had gone through the suspension bit by bit, changed the vital fluids, and had inspected the things that one inspects on a Mustang. The car was locked and loaded, so to speak, for two days of high-speed classroom work.

As part of the preparation, I had been asked to install a prototype STOPTECH big brake kit (the official Mustang application was still under development at the time). The kit consisted of 332mmx32mm AeroRotors, ST40 front calipers, STOPTECH braided brake lines, and Hawk Blue race pads. To maximize the potential of the new set-up we also mounted and balanced a new set of Hoosier 275/45 race rubber on 17”x9” Cobra-R wheels. The car was dialed!

Driving around the paddock the brake pedal felt just great. High, firm, confident – just like big brakes are supposed to be. Two warm up laps later I stepped up the pace and began to run up through the legendary Esses at speed. This gentle right-left-right sequence loaded the chassis nicely and shot the car onto the back straight in the neighborhood of 120mph. Shortly thereafter I whizzed by the braking markers for the Inner Loop – 600 feet, 500 feet, 400 feet, brakes!

Wham! Without prior warning the brake pedal dropped what felt like an inch before any brake torque was generated. Luckily the car had plenty of room to recover and ran the Inner Loop without incident, but something was wrong. Way wrong.

Driving at 5/10ths for the next lap, all was perfect once again. At every braking marker the pedal was high, firm, and confident. However, the very next time that the car was run through the Esses at speed the brake pedal fell away at the entrance to the Inner Loop. Big brakes shouldn't feel like that, should they?

I thought to myself, "Could this be knockback rearing its ugly head?" My front wheel bearings felt tight (although 50,000 miles old) and the rears had just been replaced, but there was only one sure way to know. After three fast laps with a low pedal I came out of the Esses and gently tapped the brake pedal with my left foot two times as I accelerated toward the braking zone. The braking markers whizzed by – 600 feet, 500 feet, 400 feet, brakes!

Unlike the previous three laps, I was pleasantly greeted with the best-feeling brake pedal I had ever experienced on track. Without a moment's hesitation the nose of the car seemingly planted itself against the pavement as the big Hoosiers shed the speed with amazing ease. In fact, I had hit the brakes way too early and had to lift off the brakes and coast to the turn-in point. Mystery solved – my Cobra had a classic case of knockback. But why had I not noticed it on the street?

Racetracks seem to change all the rules

Now, the Cobra had never exhibited knockback around town, regardless of how hard it was driven. Why would it only appear after the car was modified and put on track? The factors abound…

1. Knockback is directly related to cornering forces

Higher forces will always yield higher levels of knockback. More force = more deflection. Although the Cobra had never demonstrated knockback on the street, I was not using the super-sticky Hoosier race rubber either. While a stock Cobra may have been able to generate 0.85g's of cornering force, with race tires that number could have risen as high as 1.2g's – an increase in cornering force of about 40%! Deflection, and consequently knockback, surely would have followed suit.

2. Knockback is directly related to rotor diameter

For a given angular deflection at the hub face, the amount of knockback will increase linearly (on a percentage basis) with effective rotor diameter. More diameter = more deflection. The following example in tabular format summarizes it nicely.

Nominal Effective Radius	120mm	140mm (+17%)
Knockback at 1° Hub Deflection	2.09mm	2.44mm (+17%)
Knockback at 2° Hub Deflection	4.19mm	4.89mm (+17%)

3. Fixed calipers are too darn efficient

Most big brake upgrades include fixed calipers that are more efficient than the stock floating calipers they are replacing. While this is a good thing when the time comes to bring things to a halt, fixed calipers are more prone to allowing knockback to push all four pistons back into their bores. Why? The very bane of the floating caliper – the slider pins – make them more tolerant to rotor deflections.

Floating calipers will always have a small amount of play between the caliper body and the anchor bracket. This play stems from the radial clearances, which must exist between the sliders and their bores. When the rotor deflects and attempts to separate the pads, some of the force is used to simply realign the caliper body with the rotor in its new position, reducing the amount of pad knockback. When the cornering event is over, the sliders return to their at-rest position and allow the pads to run parallel to the rotor face once again.

In addition, the friction generated between the sliders and their guides will resist the knockback effect more so than the outboard caliper piston seals on a fixed unit. This may not seem like a large factor at first pass, but every little bit counts. Of course, every time you hit the brakes with a floating system that same friction force must be overcome as well, so it's not as if you are getting something for nothing.

Naturally, when comparing floating caliper knockback with fixed caliper knockback, the rotor diameter must be held constant to make the comparison meaningful. Because many fixed caliper conversions include the installation of larger diameter rotors, the effects can be confounding. It's all too easy to blame increased knockback on a caliper design, when in fact a majority of the increase may due to rotor diameter growth instead.

So, what can you do about knockback?

There are many schools of thought on addressing knockback, each with their own pros and cons. We'll list them here not in order of preference or recommendation, but rather to assist you, the reader, in making your own best decision.

1. Minimize wheel end deflections during cornering

While it may sound obvious, making sure that your wheel bearings are fresh and tight is the first major step toward addressing knockback. Following the wheel bearing itself, upgrading hubs and other suspension components to achieve less deflection during cornering will also serve to minimize knockback. At times, heavy-duty or race-specification components may be available for bolt-on installation. A little bit of research here can go a long way.

Most professional race teams will actually take the time to disassemble, blueprint, reassemble, and shim their wheel bearings prior to use. In addition to minimizing clearances and running gaps, the grease is upgraded as well to make sure that the bearing generates as little deflection as possible while on track.

Note that if you are experiencing knockback only after either right-hand or left-hand turns, it may be indicative of a single wheel bearing on the fritz. As right turns load left bearings and vise-versa, a little on-track analysis can sometimes lead you directly to the suspect component(s).

2. Tap-up the brakes when necessary

This practice may not sound glamorous, but you might be surprised to find how many professional road racers use this technique on a regular basis. All that is usually necessary is a one- or two-tap application of the brake pedal just moments before your braking zone arrives. It takes some practice to get used to, but like heel-toe downshifting eventually it just becomes habit. Note that if you are applying the brakes hard enough to feel the car decelerate you are applying too much pressure – you only need enough pressure to seat the components, not to build torque!

3. Install active knockback springs

In some applications the best solution is to install a spring behind the caliper piston to actively push the pad against the rotor face, even when the brake pedal is not applied. While this creates a situation where the running drag of the system goes up significantly (the brake are always applied!), it can be of great help in solving otherwise terminal knockback issues. It should be noted that this is not typically an applicable solution for street-driven vehicles – it's primarily found on track-only cars.

4. Increase master cylinder diameter and/or reduce caliper piston diameter(s)

Both of these changes will alter the hydraulic ratio of the braking system in such a way that for a given amount of deflection, the amount of fluid displaced is reduced. While this might sound like a good solution at first pass, keep in mind that the fundamental brake system characteristics will be impacted as well! Both of these changes will require the driver to apply more pedal effort for a given level of deceleration and will certainly impact the front-to-rear bias of the braking system at the same time.

5. Slow down and reduce cornering forces

Naturally, this solution is no fun and is not recommended.

Make improvements where you can

After returning home from Watkins Glen, I promptly went to my local Ford dealer and purchased a new pair of front hub and bearing assemblies for the Cobra. I was instructing at Gingerman the following week and needed to know just how big of a factor those bearings were on my knockback situation. They sure didn’t feel loose, but I also wasn’t tugging on the wheel by hand with all the force of a 3300-pound car cornering over 1g either.

To make a long story short, the knockback at Gingerman was drastically reduced, but not entirely gone. Tapping the brakes was still favored in a few braking zones, but not all. In particular, the pedal would drop going into turns three and ten – both of which followed significant sustained cornering sequences. No surprise there, as sustained cornering is a worst-case condition after all. However, the new stock replacement parts had all but cured the condition to my satisfaction.

Wrapping it up

Within practical limits, knockback will always be present to some degree on street cars that are used on the track. I resigned myself to living with my Cobra in its improved state, tapping the brakes a few times here and there as necessary. I guess that’s the price you pay for tracking a car designed in the late 70’s!

Ultimately, knockback is a wheel-end phenomenon that unfortunately manifests itself in the brake system hardware; however, you should not place blame on the braking system components, as they are just along for the ride. Address the root cause of the issue, deflection, and outbrake your competition all the way to the checkered flag!

by James Walker, Jr. of scR motorsports, exclusively for StopTech

James Walker, Jr. is currently the supervisor of vehicle performance development for brake control systems at Delphi Energy & Chassis. His prior professional experience includes brake control system development, design, release, and application engineering at Kelsey-Hayes, Saturn Corporation, General Motors, Bosch, and the Ford Motor Company. Mr. Walker created scR motorsports consulting in 1997, and subsequently competed in seven years of SCCA Club Racing in the Showroom Stock and Improved Touring categories.

Through scR motorsports, he has been actively serving as an industry advisor to Kettering University in the fields of brake system design and brake control systems. He also serves as a brake control system consultant for StopTech, a manufacturer of high-performance racing brake systems. In addition, Mr. Walker contributes regularly to several automotive publications focusing on brake system analysis, design, and modification for racing and other high-performance applications. He is a recipient of the SAE Forest R. McFarland Award for distinction in professional development/education. Mr. Walker has a B.S. in mechanical engineering from GMI Engineering & Management Institute.

To find out more about Mr. Walker and scR Motorsports, visit their website at www.teamscR.com

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