Brembo North America
High Performance Division

Performance Braking

> A FedEx Championship Series car and a passenger car are running side-by-side at 100 miles per hour. At exactly the same point, both cars jam on the brakes. By the time the race car has come to a complete stop, the passenger car is still doing 60 miles per hour.
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> Brakes on a race car work on the same principle as a passenger car with force on the brake pedal causing fluid in the brake lines to clamp the pads on the disc. The friction between the pads and the disc stop the vehicle. However, the materials, costs and operating temperatures are entirely different.
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> "Power Braking" Championship Racing; November 2000

The above excerpt obviously illustrates what most would expect to be true; a race car outperforms a standard passenger vehicle. When one thinks of racing, speed usually comes to mind. So to should stopping power. Of course this is expected of a purpose built race car, it can also be true however of a street vehicle converted or used in racing or performance situations.

In times past, what was seen on the track and in the environment of racing was quite often very different from that which was seen on the street. The distinction between the two uses is beginning to blend more and more. Cars are being used in performance driving situations, whether this be auto crossing, club events or true race sanctioned series. Engine improvements, suspension upgrades as well as brake system upgrades are being performed on street vehicles to bring them up to the level of a true track worthy vehicle.

Does improved braking really contribute to increasing average speed and decreasing overall lap times? The answer to this question is yes, though it will vary from track to track depending on the proportion of time spent in the corners versus time spent on the straights. More than that, a driver's confidence in the braking system also translates into that driver carrying a lot of speed into the entry of a turn and then threshold braking to make the pass. The more the driver gets consistent braking performance from the brake system, the more the driver is able to use the same braking markers, the better the modulation the driver has with the pedal then the better the result is going to be under braking. Modulation and control can be more important than the ultimate power of the brakes. If the brakes lock, a driver has to be able to sense this in the pedal and effectively release the pressure until the point that the tire(s) begin(s) rotating

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again. Threshold braking, or braking at the limit of the tire's adhesion, is what is desired.

This brings up a very key point. The effectiveness of the brakes is still going to be constrained by the adhesion coefficient that the tire delivers. Ultimately, budgets permitting, tires, wheels and brakes should be looked at as a package. While keeping the unsprung mass to a minimum, efforts should be made to seek increased adhesion from the tire while also increasing the effective brake torque that the braking system can deliver.

What do your brakes actually do? As you may have or have not heard, they do not stop the car; ultimately your tires accomplish this task. Brakes convert the kinetic energy of the vehicle into heat energy. It is the interaction of the brake pads and the rotor that converts this kinetic energy into thermal or heat energy. The rotor serves another function however in that it both absorbs this heat energy and then dissipates it. Without the rotor dissipating the heat, the pads would have to be able to provide effective friction at an ever-increasing operating temperature. This is a tall task to ask of any friction material. The rotor's design and effectiveness at both absorbing and dissipating heat is very key. Similarly, the ability of the pad to work at the temperature ranges seen in either a "cold" state (initial braking after starting the vehicle or at the end of long straights) as well as in high temperature environments is also a very important consideration. Tradeoffs can be made to sacrifice the low temperature capabilities of the pad if the vehicle is only going to be used in a track environment where high temperatures are going to be the norm. The "track" friction materials available today come in many different formulations to allow tailoring to the driver's preference for feel and performance. The high performance street pads available today have a very broad temperature range that deliver performance both at cold temperatures as well as the higher temperatures seen during performance driving situations. High performance street pads do however sacrifice performance when operated for extended lengths of time at the higher operating temperatures seen in true track environments. For performance demands, track specific friction choices are available.

So, with the general reasoning for why you would want to upgrade your brakes to a performance system, what does a high performance braking system consist of?

Calipers- The calipers used in the High Performance division at Brembo are all fixed-mounted, cast aluminum calipers. The advantage of an aluminum caliper stems from its reduction in weight and the effect that this has upon the unsprung mass of the vehicle. With a fixed-mounted caliper, that is in essence rigid, there is less flex that occurs when the brakes are applied. Contrast this with the sliding caliper systems that are standard on most production vehicles and you will begin to see the effectiveness of the fixed caliper. The sliding caliper does just that, it slides during the braking movement and exhibits flex due to the tortional forces that are being exerted upon it. This has the effect of diluting some of the pedal effort that the driver is exerting resulting in less feel and modulation of the pedal as well as reduced force exerted by the caliper through the pads to the rotor.

Rotors- The rotors used in the High Performance division at Brembo are primarily all two-piece floating rotor systems. The advantages of the two-piece floating rotor are many. First and foremost, the billet aluminum hat contributes to the overall weight savings of the rotor assembly and hence contributes to reducing the unsprung mass as well as reducing the rotating inertia. Second, the floating setup allows for heat to be effectively dissipated. This is accomplished by allowing the rotor to grow and contract in size (yes cast iron rotors will actually grow in size) as it heats up without being constricted at the points where it is attached to the hat. Another advantage to a floating rotor is that the rotor is able to find a centerline between the pads in the caliper. This is beneficial because without this feature the suspension components and knuckles that are stressed and flex during high load turns etc. would force a one-piece fixed rotor to rotate off-center in relation to the face of the brake pads

Development of the cross-drilled rotor - Earlier brake pads generated a certain amount of gases (off-gassing). This primarily consisted of a thin gas layer given off when the pad came into contact with the rotor surface. This layer of gas, when compressed between the face of the pad and the rotor, effectively reduced the coefficient of friction. Furthermore, the existence of this gas layer at the extreme temperatures seen in performance driving situations as well as track uses contributes toward “glazing” of the pads. When pads glaze, the friction material hardens, thus further reducing the coefficient of friction between the pad and rotor surface. Cross-drilling was developed as a means to remove the buildup of this gas layer between the pad face and the rotor surface. Cross-drilling and slotting effectively refresh the pad face deleting the buildup of the accumulated gas layer. While the better friction materials that are in use today produce significantly less off-gassing under even the most extreme uses, cross-drilling and slotting still provides a tangible benefit in refreshing the pad face and providing the optimum bite between the mating of the pad and rotor surface.

Brake Pads- The pad materials that are used in the upgrades all consist of high performance friction compounds that exhibit broad operating temperature ranges

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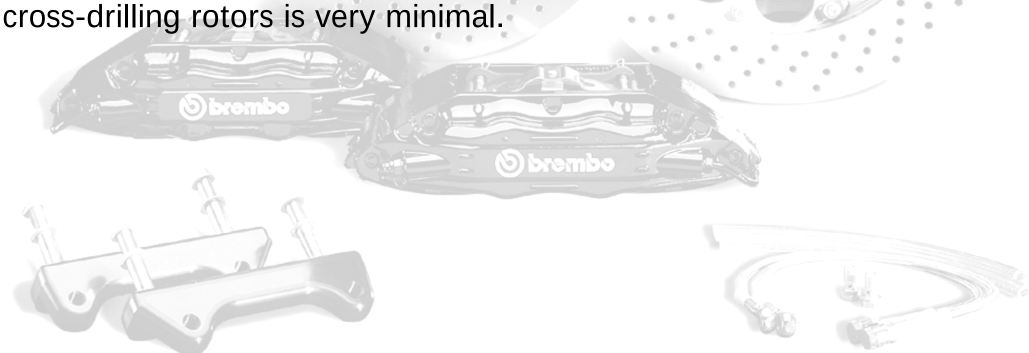
from very low temperature all the way up the high temperatures seen with limited track use.

Steel-braided brake lines- The upgrades are completed with steel-braided brake lines. The function of the steel-braided brake line is more than just that of aesthetics. A steel-braided line helps to reduce compliance in the braking system. Most standard production vehicles are delivered with soft rubber coated nylon brake lines. These however will tend to increase in size and diameter as brake fluid is put under pressure during a braking movement. This translates to reduced pedal feel and a loss of efficiency in the system. The steel-braided brake line decreases these compliance issues.

You may have noticed in discussing the components of the high performance brake system, a consistent desire to keep the unsprung mass of the vehicle, to a minimum. Why is this you ask? What are the benefits? Reducing the unsprung mass of each corner helps to dramatically improve the performance of the vehicle by reducing the mass that the shock absorbers and suspension must attempt to control. Reducing the unsprung mass makes it easier to keep the tires in contact with the road at a constant force, thus increasing performance. Reducing the mass of the rotor assembly is beneficial as well due to rotational inertia. Rotating mass requires additional energy to increase or decrease its speed of rotation. The lighter the rotating mass the more effective a given amount of brake torque will be in relation to its deceleration. As a sidenote, the modern day contribution to reducing the unsprung mass of each corner assembly from cross-drilling rotors is very minimal.



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