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TECHNICAL WHITEPAPER:

Brake Caliper Move-Out Kits

Potential Benefits and Concerns in Implementation

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Caliper move-out kits, also known as caliper relocations kits or plus-size kits, have become an increasingly popular brake system modification in recent years. A caliper move-out kit typically includes larger-diameter rotors of the same thickness as the original rotors, brackets to relocate the caliper outward to accommodate the larger disc, and required additional fasteners. In addition to the aesthetic impact of the larger rotors, the goal of these kits is to provide a low-cost means of achieving the increased thermal capacity associated with a complete big brake kit. Manufacturers of caliper move-out kits typically claim a reduction in brake fade and stopping distance. While the implementation of a pair of brackets may appear simple, careful attention must be paid to both mechanical design and the effect on vehicle performance at the system level.

Mechanical Design Concerns

At the heart of the move-out kit is the caliper relocation bracket. Obviously, the brackets must be sufficiently strong to be safe (the bracket doesn't bend or break) and maintain as much as possible of the original caliper mounting's resistance to flex under braking forces. Besides the potential for uneven pad wear, reduced caliper mounting stiffness could allow vibrations that would lead to noise, typically squealing when the brakes are applied. Another mechanical concern is that if the caliper's position is changed with respect to the brake line supporting hardware at the suspension upright, or the end of the hard line at the body side of the flexible line, changes to the brake line itself may be required for a safe installation.

Thermal Capacity

One manufacturer has claimed that shorter stopping distances result from increased thermal capacity. Greater thermal capacity and increased cooling inherent with larger rotors (assuming technologies for cooling such as vane design remain equivalent) should reduce the maximum temperature reached by the rotor, whether in a single stop or in a series of stops. This may prevent the brake system from exceeding the maximum operating temperature of the brake pad when it otherwise would have. At that point, the increase in stopping distance caused by pad fade will be avoided, but there is no reason that a vehicle's best single-stop performance will be improved by a caliper move-out kit.

Brake System Force Amplification

The entire purpose of the braking system, from the bottom of the driver's shoe acting on the brake pedal to the tire contact patch acting on the road surface, is to multiply (or amplify) the force applied by the driver and convert it into a deceleration force acting on the vehicle. A detailed description of each component's idealized function can be found in the StopTech white paper "The Physics of Braking Systems", available on the web at http://www.stoptech.com/tech_info/The%20Physics%20of%20Braking%20Systems.pdf .

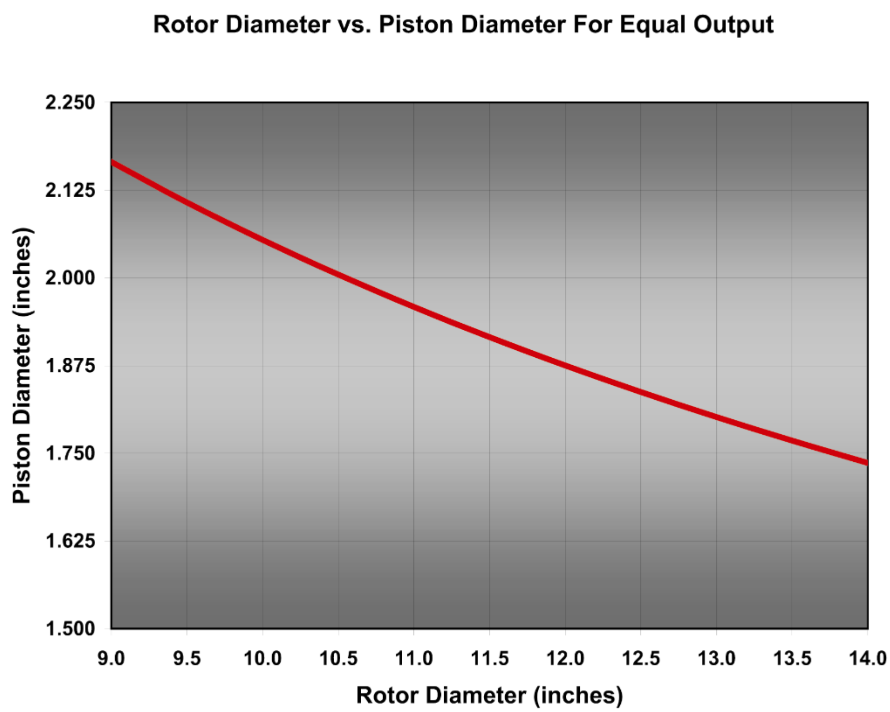
For our discussion of caliper move-out kits, it is useful to focus on he torque produced at the wheel, which is governed by the following equation, presented in the StopTech white paper "Formulas for Vehicle Braking Dynamics" and available on the web at http://www.stoptech.com/tech_info/formulas%20_vehicle_braking_dynamics.pdf .

Torque created by the caliper on the rotor (at the wheel) = T_W

$$T_W = P_S \times A_P \times \mu \times 2 \times R_E$$

- P_S = Pressure of system (instantaneous circuit pressure at the caliper);
- A_P = Total area of pistons in one half of caliper (one side of opposed type or active (piston) side of sliding or floater type);
- μ = Friction coefficient of the pads against the rotor;
- x 2, since there are two sides of the rotor that the pads are exerting force against;
- R_E = Effective Radius of clamping force

Assuming P_S is controlled by the driver's input to the brake pedal and μ is fixed by brake pad selection, we are interested in the effects of changing A_P and R_E. Specifically, in order to maintain torque at the wheel (or the system's force amplification) constant for a given circuit pressure, A_P must decrease as R_E increases, as plotted in Figure 1:



The only thing a caliper move-out kit changes in the equation is the Effective Radius of the clamping force:

R_E is increased while A_P remains the same. So, for a given system pressure, P_S, determined by the amount of force the driver applies to the brake pedal, torque at the wheel, T_W, is increased in proportion to R_E.

Brake Bias and Stopping Performance

We must understand that the tires stop the car, not the brakes. The shortest stopping distance is achieved when all four tires are working at the maximum of their ability to stop the car. Correct balance of brake torque between front and rear axles is the only path to maximum performance. A deeper explanation of these issues can be found in the StopTech white paper "Brake Bias and Performance", available on the web at: http://www.stoptech.com/tech_info/wp_brakebiasandperformance.shtml.

To illustrate the effect of an over amplified front brake "upgrade," consider a simplified, idealized vehicle model. Suppose that with all the physical aspects of the vehicle considered, the front axle is capable of a maximum deceleration of 8 arbitrary braking units (ABUs), and the rear axle is capable of contributing a maximum deceleration of 4 ABUs.

The total deceleration available from the vehicle is 12 ABUs. This maximum deceleration, which is governed by the tires' available grip, is reached with a brake pedal force of 75 pounds. We assume that the factory brake system is perfectly implemented.

Now, suppose a front-axle big brake kit is installed, which delivers 25 percent more force output (T_W) than the stock front brakes at a given circuit pressure. The maximum deceleration contribution of 8 ABUs from the front tires will be reached with a force on the brake pedal of 75 / 1.25 = 60 pounds. The driver may feel as if the brakes are "more powerful" and could deliver greater deceleration if he increased the force on the brake pedal. But the front tires will never deliver more than 8 ABUs, and if he presses harder, they will lock and deliver significantly less. Maximum deceleration will be achieved with 60 pounds on the pedal. The rear tires will at that point be contributing only 4 / 1.25 = 3.2 ABU of deceleration to the vehicle. Thus, the total deceleration available from the vehicle will be 8 + 3.2 = 11.2 ABU. The over-amplified front brake upgrade has actually decreased available braking performance by 6.7 percent.

If we choose a different vehicle, in which the original contributions are 9 front and 3 rear ABUs, then the total available braking performance with a 25 percent overamplified front system would be 11.4 rather than 12 ABUs, a decrease of five percent. If the stock vehicle took 110 feet to stop from 60 mph, the modified vehicle would take 115.8 feet to stop.

An anti-lock brake system (ABS) can counteract this effect to some extent by resisting the tendency of the over amplified wheels to lock, allowing greater brake pedal force to be applied and the other wheels to do more work. Due to mechanical differences and ABS tuning differences, different vehicles are able to accommodate different amounts of variation from the correct balance, but any excessive dependence on ABS control negatively impacts performance, with a difference that can be measured at the test track. Vehicle stability control systems are more dependent on stock-like brake system response characteristics, because they rely on a pre-calculated response to a greater degree than the ABS function does.

Furthermore, with an over-amplified front brake system, the front axle is called on to do a disproportionate share of the braking work any time ABS intervention is not present, leading to accelerated wear on the front pads and rotors. In track driving, the increase in thermal capacity that is the primary objective of a caliper move-out kit will be undermined.

Additionally, vehicle handling will be impacted. Because the front tires will be nearer the limits of their grip for a given vehicle deceleration, they will be less able to sustain steering forces. On the street, the driver's ability to steer around an obstacle while braking will be reduced, with obvious potential implications for safety. In autocross or track driving, the ability of the car to enter a corner, or begin turning under braking, will be reduced. In the language used by performance enthusiasts, the car will have poor trailbraking performance.

Caliper Move-Out Kit Results

So, say we have built sufficiently strong and stiff caliper mounting brackets, we have addressed brake line length and attachment angle sufficiently, and we have built our caliper move-out kit with reasonable attention paid to maintaining the balance of the brake system by proportionally increasing effective radius at both front and rear axles. What have we accomplished?

Thermal capacity of the brake system will likely be increased, due to greater mass of the brake rotor, a probable increase in cooling airflow, and increased rotor surface area for greater radiation. That will let us do more braking, for longer, before reaching the maximum operating temperature of a given brake pad. We have also increased brake system force amplification, which many drivers view as positive.

Comparison to Big Brake Kits

Is a caliper move-out kit the same as a balanced big brake kit that includes well-designed, opposed-piston calipers? In a word, no. Calipers such as StopTech's ST-40, ST-60 and ST-22 are much stiffer than typical OE calipers and provide better pedal feel and driver control. Stiff calipers with differential piston sizes maintain even pad wear for longest life and preserve good pedal feel throughout the life of a set of pads. A balanced big brake kit can usually achieve the required increase in thermal capacity for a street car on just the front axle, while a caliper move-out kit must include both front and rear axles.

An additional benefit of the StopTech calipers mentioned above is that they are designed around standard pad shapes used widely in both racing and OE applications, so there are many more choices for brake pad compounds for street and track use than for most OE calipers. Big brake kits sold by StopTech feature the company's patented AeroRotor vane design, and competitors' brake kits typically include quality, industry-standard racing vane designs. There is little indication that most manufacturers of caliper move-out kit upgrades have so far paid any special attention to rotor vane design beyond that typical of OE rotors.

Some caliper move-out kits provide two-piece rotors. This can reduce weight, possibly maintaining the caliper move-out kit system weight at or below the original brake system's weight. Two-piece rotors also often reduce heat transferred from the brake rotor into the hub. However, most caliper move-out kits with two-piece rotors do not provide a floating mechanism to allow the rotor to expand separately from the hat as it is heated. This places stress on the mounting hardware, as well as promoting "coning" distortion of the rotor.

A Common Mistake

Note that a common mistake is adding a caliper move-out kit to the rear axle of a car equipped with a properly-balanced, front-axle-only big brake kit. Unfortunately, adding a caliper move-out kit to the rear could affect vehicle stability under braking in certain applications. This is especially of concern if the big brake kit was engineered to adjust the brake bias slightly rearward, as StopTech sometimes does in order to exploit an opportunity for improved performance revealed by thorough track testing.

Conclusion

In conclusion, a properly engineered caliper move-out kit can provide some real performance benefits at an affordable price. However, caliper move-out kits fall far short of achieving many of the advantages of a properly-engineered big brake system.

STOP TECH

Stoptech is the performance engineering and manufacturing division of Centric Parts. It is the leader in Balanced Brake Upgrades for production cars and has three patents in basic brake technology and one other pending. With a worldwide network of resellers, StopTech's product line includes Balanced Brake Upgrades for approximately 450 applications featuring StopTech's own six-, four- and two-piston calipers, two-piece AeroRotor Direct Replacement Kits, braided stainless steel brake lines and slotted and drilled original-dimension rotors. StopTech also stocks a wide range of performance brake pads. The company's website, www.stoptech.com, is a clearinghouse of performance brake information, and provides details on StopTech products.

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