

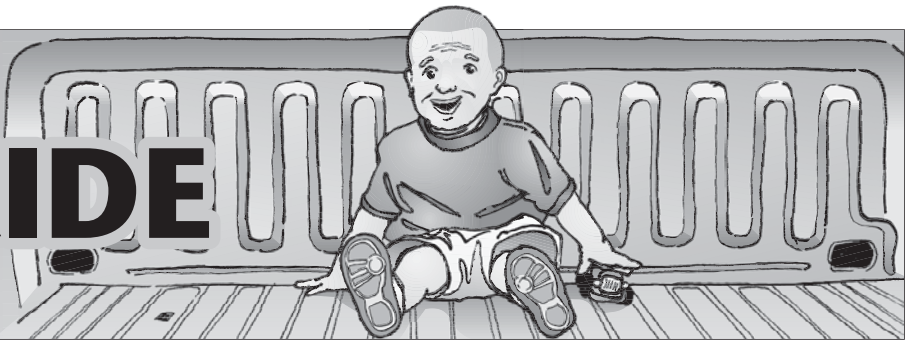
**ISSUE 50**

**Nov/Dec/Jan**

**2005-06**



# FIRST RIDE



In case you haven't guessed by now, the theme of Issue 50 is, "My Favorite Truck Accessory." This is supposed to give your humble writing staff a chance to share our wisdom, insight, and lessons learned from our own trucks with you, the TDR audience.

I know this is going to be a shocker to some of you, but I plan to cover brakes (insert applause here). Since we have already covered brake system basics in Issue 40, brake pad selection in Issue 41, brake fluid in Issue 43, brake balance in Issue 44, and proportioning valves in Issue 45, I have chosen a topic near and dear to practically anyone who has ever driven a truck that shook their fillings out when the brakes were applied—brake vibration.

Now, you may be asking yourself, "How does that relate to this issue's theme?" Well, I'm not really sure that it does, but if you do a poor job in selecting your brake pads, break them in incorrectly, or damage them during use then they certainly would not be your favorite accessory, now would they?

## BRAKE UTOPIA

Quite simply brake vibrations are never a good thing. In fact, a common saying in the brake industry is, "The best brake system is an invisible brake system." Let's try to understand why this can sometimes be difficult to achieve.

You press the brake pedal and your truck slows down. There's no squealing, no shaking, and no vibration. You have arrived at brake utopia.

Unfortunately, brake utopia can sometimes be in another area code.

Pick your favorite brake system malady: brake roughness, pulsation, shudder, hot judder, shake, vibration, or the all-time favorite, rotor warping. To the brake engineer these all have slightly different meanings, but to the average consumer they are all simply a problem that has to be addressed.

Few vehicle problems are as annoying as a problematic brake system. While usually not a detriment to brake system effectiveness at first, none of these conditions can be considered desirable; and, if ignored long enough they can have legitimate performance impacts.

So what causes these conditions, and what can be done to prevent them in the first place? We'll get there, but first we should briefly review what we learned about brakes back in Issue 40.

## The Brakes Don't Stop the Truck!

What does the brake system do? The brake system's primary responsibility is to convert the kinetic energy of the truck in motion into thermal energy, or heat. If there is available tire traction (tire-to-road friction) the truck certainly may decelerate, but the brakes do not stop the truck. That's the job of your tires.

No tire traction, no tire force, no deceleration. Hello, tree. Thud!



Regardless of how large, colorful, or sexy your braking system components, it's still the tires that stop the truck!

If we look in more detail at the brake pad and rotor interface, we discover that this is where most of the energy conversion takes place. It is the friction between the brake pad and the spinning rotor that creates heat while simultaneously building torque in the rotating brake parts. Over the next few paragraphs we will be dissecting this dynamic interface.

As the saying goes, you paid for the whole seat, but you'll only need the edge!

## The Two Types of Friction

Who takes the time to worry about how the stationary brake pad and the spinning rotor generate friction? Odds are this question has never passed through your mind, but it is paramount to understanding brake vibrations.

Brake pads engage in two distinctly different types of dynamic friction: abrasive friction and adherent friction. The details should be left to the PhD community, but in general the two modes operate as follows:

In the abrasive mode, friction is generated as a result of interference between the microscopic high and low spots on the brake pad face and the spinning rotor. In very simple terms, this is similar to holding a block of wood on a belt sander. As the high and low spots are slowly machined away (much slower than the wood on the belt sander, of course), this breaking of molecular bonds creates a force which resists the rotation of the rotor. It also heats up the materials involved. Breaking molecular bonds has a tendency to do that.

Presto! We have converted kinetic energy into thermal energy by breaking a bunch of molecular bonds. Not too surprisingly, this is the mode that most people naturally envision when asked to explain how brake pad friction operates.

Adherent friction is quite different in nature. In the adherent mode, pressure and temperature collaborate to deposit a thin layer of brake pad material, or a transfer layer, on the rotor face. Subsequently, as the caliper squeezes the brake pads against the rotor, the pads contact the transfer layer, not the rotor itself.

As the pressure increases, molecular bonds are then very quickly formed between the similar materials of the brake pad and the transfer layer. Just as quickly, however, those very same bonds are broken as the rotor continues to move relative to the brake pad. As a result, heat is generated and the brake pad material wears away.

In summary, abrasive friction can be found between the brake pad and the rotor itself, slowly wearing away both materials, breaking bonds, and generating heat and torque in the process. With adherent friction, however, the rotor never actually wears. Because all of the bonding-breaking action is occurring between molecules of the brake pad material, only the pad itself wears away over time.

### But Wait, There's More!

Although we have talked about abrasive friction and adherent friction as if they were mutually exclusive from one another, all brake pads operate in both modes, and sometimes simultaneously. Typically most pads will operate in a primarily abrasive mode when they are cold and will then transition to an adherent mode as the brake temperature increases. This is why some brake pads (for example, many racing brake pads) require warming up before they will be operating properly—they need to “go adherent” before they exhibit their desired performance.

For the weekend racers in the audience, if you have ever used the Hawk Blue 9012 pads, then you know exactly what we're saying here. This material operates like a brake lathe (mega-abrasive mode) until it gets hot enough to stop on a dime (ultra-adherent mode). It's also why you shouldn't run Hawk Blue brake pads on the street—the brake temperatures will never get hot enough to get out of the abrasive mode and the rotors will pay the ultimate price.

A final interesting note on adherent friction: when race teams select adherent pads for their race cars, chances are that their rotors will actually be thicker than new when the time comes to replace them

at the end of the season. Why? Because of the added thickness of the transfer layer material. The rotors may still need replacing due to cracking or other thermally-induced maladies, but rarely are race rotors replaced because they have worn too thin. They simply heat-cycle themselves to death.

### Brake v-v-i-i-b-b-r-r-a-a-t-t-i-i-o-o-n-n

So, now we can talk about brake vibration. As you read, you will find the underlying theme will revolve around preventing brake vibration, not curing it. But first, let's purge the phrase “warped rotors” from your vocabulary.

### Rotors Do Not Warp!

In nearly every single case, warped rotors are not physically warped at all. The common misconception is that the rotors get hot enough to distort and then, upon cooling, end up looking like a pretzel.

Contrary to popular belief, rotors simply do not warp in this fashion. The vibration that is felt in the steering wheel and floorboard is almost always caused by rotor thickness variation (TV), and the physical pulsing in the brake pedal is nearly always a direct result of the caliper piston extending and retracting as it tries to follow a rotor of varying surface thickness.

Take a second and re-read those last two paragraphs. They are that important!

TV is generally created in one of three ways. The least glamorous, yet most common form of TV is initiated when a truck is parked in the same place for an extended period of time. While it is sitting, a thin layer of corrosion (ferrous oxide, or rust) can form between the brake pad surface and the rotor. As you can probably imagine, sitting in humid or damp environments can greatly accelerate the corrosion.



Pad printing is due to corrosion while parked. This is classic TV in the making, and pulsation is only a few miles away.

When the truck is ultimately moved, there will be a localized high spot (an unintended transfer layer of corrosion) on the rotor which will wear at a different rate than the surrounding material. At first

the condition is undetectable, but it will get worse over time as the rotor wears unevenly, creating high spots (thicker areas) and low spots (thinner areas).

For trucks which experience extreme brake use (Towing without a trailer brake comes to mind, not that you would ever do that, would you?) another common mode of TV is initiated by an uneven transfer layer of brake pad material on the rotor face. Without going into a doctoral dissertation on the subject, overheating the brake pad can generate an uneven transfer layer as the pad material breaks down and “splotches” (a highly technical term which one should not use without proper training and certification) on the rotor.

These uneven transfer layer deposits will wear at a different rate than the surrounding rotor material. On and on it goes until the high spots and low spots on the rotor face are severe enough to feel in the pedal. How much can be felt? In most cases, even less than 0.001” can be downright annoying.

The third most common source of TV begins with the overheating of the rotor itself. If a rotor gets really, really hot, it can develop evenly spaced, localized areas along its face which are much hotter than the surrounding rotor material. These hot spots will wear quicker than the cooler surrounding material, creating a thick and thin wear pattern on the rotor face. As the rotor cools, these thick and thin spots remain and will propagate with use until the TV is finally felt by the driver.

### How to Keep the Evil TV Monster at Bay

So now that we know what causes TV and the ensuing brake vibration, what can be done to prevent it in the first place? Don't worry if you don't have the answer already—we're professionals and can help you through this.

First, make absolutely sure to cool your brakes after extreme use (and NEVER stop while they are hot with your foot still on the brake pedal)! Anytime hot brakes are allowed to sit motionless, molecular bonds may continue to form between the brake pad and the existing transfer layer material (adherent friction in action). The result is nearly instantaneous TV generation.



A rotor which has been exposed to an overheated brake pad. Note the friction material deposits on the face.

Second, during extreme use, keep your brakes as cool as possible to reduce the opportunity for hot spots. A set of brake cooling ducts or an aftermarket exhaust brake goes a long way in this regard. Remember, cool brakes are happy brakes.

Third, if your truck is typically left outside for extended periods of time, it might be best to select a non-metallic brake pad. Non-metallic brake pads (also known as organic or ceramic brake pads) reduce the tendency to generate corrosion between the pad and the rotor. While they are not usually recommended for extreme-use applications, they don't rust as fast, and over time this may reduce the generation of TV.

Fourth, when installing your wheels and tires, be sure to tighten your wheel nuts in the manufacturer's recommended pattern and take several passes to reach maximum torque. In some cases, uneven tightening of the wheel nuts can physically distort the rotor enough that during normal driving thick and thin spots may develop on their own.

Finally, be sure to follow your manufacturer's recommended procedure for bed-in when installing new brake pads and/or rotors. These processes have been developed to reduce the opportunity for uneven brake pad material deposition on the rotor face when the pads and/or rotors are new.

### Bed-in Procedure? I'm Not Even Tired!

Whenever new brake pads and rotors are installed on your truck, you will need to properly develop a transfer layer. I bet nobody has ever told you that, have they?

The process of developing a transfer layer is typically referred to as brake pad bed-in (or more commonly known as break-in). In general, bed-in consists of heating a brake system to its adherent temperature to allow the formation of a transfer layer. The brake system is then allowed to cool without coming to rest, resulting in an even transfer layer deposition around the rotor circumference. This procedure is typically repeated two or three times in order to ensure that the entire rotor face is evenly covered with brake pad material.



A typical rotor before bed-in. Note the clearly defined machining marks on the rotor face.

Please note that the procedure that follows is completely generic and is only intended to introduce you to the theory of pad bed-in. Because this procedure is non-manufacturer specific, be sure to check with your brake pad supplier or vendor for any special considerations related to the bedding-in of your particular rotors and pads.

**James' Generic Bed-in Procedure**

For a typical stock brake system, a series of 6 to 8 braking events from about 60mph down to about 10mph will typically get the brake components warm enough to be considered one bed-in cycle. Each of the 6 to 8 braking events should be made at moderate to high deceleration (about 75% of the deceleration required to lock up the brakes and/or engage ABS) and should be made one after the other without allowing the brakes to cool in between.

These are not extreme panic stops. Don't go overboard here.

Once the brakes have faded a bit and/or you smell friction material in the passenger compartment, the cycle is complete and you should allow the system to cool by driving at steady speeds without bringing the truck to a complete stop. After cooling, repeat the braking event procedure listed above one more time, cool down again, and you're typically good to go. In some situations a third cycle is beneficial, but two are usually sufficient.



A typical rotor after bed-in. The soft gray haze on the rotor face is the transfer layer material.

And now a word from the lawyers: Note that these speeds and maneuvers are neither recommended nor acceptable on all public roads. While you need to get heat into the system to achieve a proper bed-in, you also need to exercise common sense and take responsibility for your actions. Drive smart, please.

**But I Already Have a Brake Vibration . . .**

And what if brake vibration is already present in your truck? Well, that's a different story.

In select cases where brake vibration has just begun, it may be possible to remove any uneven transfer layer deposits from the rotor face by using a super-abrasive brake pad for a short while.

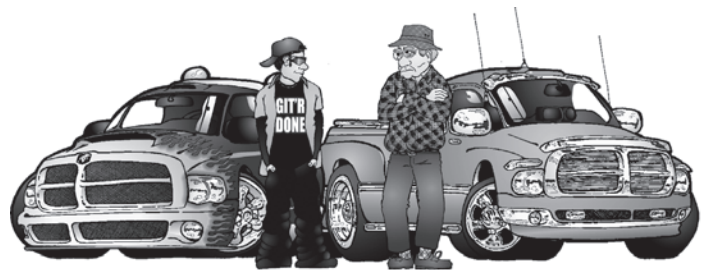
This is a hit-and-miss strategy, and if uneven rotor wear has already started, then it's too late anyway. Remember, abrasive brake pads cannot make a rotor flat again—they can only smooth off uneven pad deposits.

Turning rotors can also alleviate the vibration situation, but may not be a viable long-term solution. If the rotor has been heated to the point that the chemistry of the rotor has changed (specifically, if localized areas of cementite have formed due to heat, yet another topic for the PhD's), then the vibration will come right back as the softer areas of the rotor face wear away more quickly. (Note that in some cases turning the rotors may not cure the vibration even for a short time, as these hard spots can deflect the brake lathe cutting tool making for an uneven cut on the rotor face.)

Unfortunately, the only known long-term solution to purging vibration is to replace the rotors themselves and properly bed-in the new parts, assuring an even transfer layer. It may sound like a brute-force approach, but desperate times call for desperate measures. Just be sure to learn from your mistakes to keep the evil TV monster from rearing its ugly head again.

What it all boils down to is that, in the war against brake vibrations, the best offense is a good defense. Until next time, I hope you are vibration free!

**James Walker, Jr.**  
TDR Writer



YOUNG BUCKS IN FAST TRUCKS MEET GRAY-HAIRED TRAILER TRASH



TURBO DIESEL TECH 2006 • COLUMBUS, INDIANA  
DHRA DIESEL NATIONALS • INDIANAPOLIS, INDIANA

Turbo Tech 2006  
57 Pages Ahead (page 132)