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WELCOME

Mark Ortiz Automotive is a chassis consulting service primarily serving oval track and road racers. This newsletter is a free service intended to benefit racers and enthusiasts by offering useful insights into chassis engineering and answers to questions. Readers may mail questions to: 155 Wankel Dr., Kannapolis, NC 28083-8200; submit questions by phone at 704-933-8876; or submit questions by e-mail to: markortiz@vnet.net. Readers are invited to subscribe to this newsletter by e-mail. Just e-mail me and request to be added to the list.

BRAKING/DOWNSHIFTING TECHNIQUE

I'm track-engineer on a Porsche 996 Biturbo. When I talk with our drivers, and also drivers of other teams and cars, and we are talking about braking, the drivers are always telling me that they brake on the engine, by downshifting and releasing the clutch. I ask them why they are doing it that way. They explain that they can brake harder with the engine and brakes together than with the brakes alone.

I disagree with them on this. In my opinion, the maximum braking force of a car is determined by the coefficient of friction between the tires and the track surface. How this force is generated doesn't matter. It can be generated by the brakes or the engine. But if the brakes are big enough, they can lock all four wheels by themselves, or get the ABS working. So why lose time downshifting, when the shortest braking distance possible can be achieved using the brakes alone?

Braking technique is controversial, among drivers, driving instructors, and engineers. There is no single best way for all cases. However, there are factors that will logically cause us to favor one approach or another, with a particular car, for a particular turn or situation. The tradeoffs are fascinating, and are a good example of the complexities that make racing a thinking person's sport.

Factors governing braking technique, including downshifting, include:

- The adequacy of the brakes, for the actual situation. That is, are we considering only one application, or a long race? Is fade a factor? Is pad wear a factor?
- The amount of flywheel inertia in the engine, relative to compression, friction, and pumping work on closed throttle, and relative to the car's ability to slow using the brakes and aerodynamic drag. Does the engine actually try to slow the car, or drive it?
- Brake bias, relative to the optimum for the level of deceleration being attempted. Does adding engine braking at the driven wheels improve brake bias, or impair it? Does ABS make the issue irrelevant?
- The need to be in a particular gear when we finish braking. Also, the need to be in gear, with revs

matched to road speed, at the end of braking.

- Handling properties of the car when trailbraking. Does it like to brake and corner at the same time, or not? There may be more than one answer to this, depending on speed range.
- Properties of the transmission. Will it tolerate being being disengaged during braking, and simply stuffed directly into the gear needed after braking, or will this destroy the dogs or synchros? Is the shifter H-pattern or sequential?
- What is before and after the turn. Is an in-slow-out-fast line the best, or an in-fast-out-slow line? Or is there no turn? Are we trying to bring the car to a halt for a pit stop, or for some other reason?
- Tactical considerations. Are we trying to pass under braking? Pass after braking? Avoid being passed under braking? Avoid being passed on exit?
- Driver preference. Race driving isn't easy. It is difficult to use any braking technique to the absolute limit of its potential, and this makes it difficult for a driver to change from one technique to another as circumstances vary, or even to adapt to different cars. In general, a less-than-optimal technique executed well will beat a theoretically better technique executed poorly.

Until the advent of disc brakes, it was quite easy to use up any car's brakes in almost any road race, and often on short ovals as well. Stability in braking was uncertain, especially with the self-energizing (leading-shoe) drum brakes used on road cars. Racing drum brakes often were made with a minimum of self-energizing effect, or were even self-de-energizing (some or all shoes trailing), to minimize this instability, at the expense of high pedal effort.

With drum brakes, it was therefore imperative to brake in a straight line, at least most of the time. It was also imperative to use the engine to slow the car, just to have any brakes left at all late in the race.

When disc brakes arrived late in the 1950's, it became possible to use the brakes much harder, and also to trailbrake – carry the braking process into the first part of the turn. Oval track racers have always trailbraked, if they used the brakes at all. It is not uncommon in oval racing for a driver not to lift until the turn-in point, and do all braking in a curved path.

Trailbraking was one of the keys to Stirling Moss's competitive edge. It was further developed by Mark Donohue, who often used cars with spool rear ends to allow him to brake harder while turning, without getting oversteer. Donohue is also credited with being among the first to figure out that it pays to leave braking until really late, apex early, do a lot of braking in a curved path, and give up exit speed, if the turn is preceded by a straightaway and followed by another turn.

Even with discs, it was possible to use up the brakes, especially in sports cars. It still is in many cars, notoriously NASCAR stockers on road courses. And it was still universal to heel-and-toe down through the gears, although some cars now had close enough ratios so that the driver could skip-shift – go two or even three gears down at once.

By the early 1970’s, some classes of cars – notably Formula 1 and other large formula cars – had sprouted huge wings and fat, sticky slicks. At speeds above 100 mph, such cars with a high-downforce setup can exceed 1.0g rearward acceleration without using the brakes at all, mainly because they are so draggy. They also have vast amounts of downforce, and when the driver does use the brakes, the car may decelerate at more than 4.0g!

At this point a school of thought developed which held that the brakes and the drag could decelerate the car faster with the engine disengaged, and that the engine’s rotating inertia was such that it was actually trying to drive the car even with the throttle closed, and was fighting the brakes rather than assisting them. Advocates of this view held that it was best to disengage the engine while braking, and then try to find the right rpm and gear for the turn from that state right at the end of braking. Among the drivers using this technique was Francois Cevert. When the driver got it right, it worked pretty well. However, there was also a greater risk of not succeeding in snagging that gear at the last moment, in which case the driver was caught out of gear when the car needed power, and the car might easily leave the road, or at best lose a lot of speed.

This school of thought never gained universal acceptance. Older drivers still went down through the gears as they had always done, although the rapidity of the cars’ braking made skip-shifting attractive – in which case the “old” method started to resemble the “new” method, for many turns.

Of course, this controversy was only relevant for cars that had big tires and wings, and H-pattern gearchanges. Production cars, NASCAR stockers, and production-based endurance racing sports cars still decelerated at closer to 1.0g or 2.0g than 4.0g, and still needed to conserve their brakes, and their gearboxes. And in the last decade or so, sequential gearchanges have become universal in the faster classes. With a sequential transmission, skip shifting is not possible. Computer control has made rev-matching nearly foolproof, and overrevving due to a premature downshift is prevented as the computer will forbid the shift until the road speed is correct. So we again see, and hear, all the cars rapidly going down through the gears as they approach a turn. In many cars, the driver has the option of having downshifts and upshifts occur either manually or automatically. A popular choice is to downshift manually (with the computer still having veto power) and let the car upshift automatically.

With extremely powerful brakes, the question of whether the engine assists or fights the brakes is mainly relevant to brake balance rather than ultimate braking power.

Regardless of how we get down to the gear we need for the turn, this much is certain: we better catch that gear by the time we need to turn in, except maybe if the turn-in is very gentle, in which case we may do one last shift early in our trail-braking if we feel confident with this. Once we have initiated the turn, we will need to be very smooth with the brakes and steering, rolling out of the brakes as we wind in more steering, keeping the car as close as possible to the

perimeter of the traction envelope. This is hard enough without trying to shift at the same time. As soon as we're done braking, we need to smoothly apply power to balance the car and accelerate out of the turn. We can't be pausing to engage the right gear after braking. We need to be in it already. Therefore, we have to do our downshifting before the turn, while braking, whether it's theoretically best for braking distances or not, simply because we can't afford to take a hand off the wheel, and upset the car with a shift, while we're cornering at the limit, nor can we afford to have the car out of gear or in too high a gear when we need power to control it. In short, we must downshift while braking because it's the only time we can.

All of this assumes that we are slowing for a turn, and will need an appropriate gear as soon as we finish braking. Suppose we are braking for a pit stop, or panic-stopping to avoid a wreck or a deer, or doing a brake test?

If we just want to get the car stopped as fast as possible, most of us will simply stand on the brakes, modulating them if we don't have ABS and have sufficient presence of mind, and just try to remember to declutch soon enough to avoid killing the engine. If we're doing a brake test, we may be able to do comparison runs with the clutch engaged and disengaged for most of the stop. In any case, we won't try to downshift in any modern car.

When pitting, we will usually have a pit road speed limit. To avoid violating this limit, we will need to be in a specific gear – usually a lower one, maybe first – and at a specific rpm. Therefore, when entering pit road we are under much the same constraints as when entering a turn. We need to delay braking as late as possible, we need to be at a specific speed in a specific gear right where the speed limit starts, and we need to be at that speed, in that gear, the instant we finish braking. Therefore, we have to downshift while braking. When we reach the pit stall, our object is to brake as late as possible, not overshoot the pit, position the car precisely to help the crew do the stop efficiently, and have the car ready to make a good launch at the conclusion of the stop.

This last concern may impose varying constraints in terms of getting the car in first gear before it comes to rest, depending on the design of the gearbox, and depending on whether we're in first already due to the speed limit. In most cases it will be desirable, though not absolutely essential, to get first gear while still in motion, and declutch during the stop.

To summarize, downshifting while braking may or may not be necessary to get the car slowed down and to allow the brakes to survive. This varies with the car, the event, even the weather. But downshifting while braking remains necessary regardless of this in many cases, to prepare the car for what we need it to do once we're done braking.