Regression equation

Penske Racing Shocks' latest development offers a new way of overcoming the age-old conundrum of hydraulic damping, with benefits for both lap time and tyre wear

BY SIMON MCBEATH

We ask an awful lot of the dampers on a racecar, or on any car come to that. We expect them to weigh nothing, cost less and yet perform a wholly contradictory set of critical functions that fundamentally control our racecars' handling and grip. And we expect all of this from a device based on a piston with holes in it, mounted on a shaft sliding to and fro in a sealed tube of fluid, the basic physical response of which is, in one sense, the opposite of what we really need.

Even the redoubtable Carroll Smith said in *Tune to Win* 'Sometimes I think that I would have enjoyed racing more in the days of the friction shock. Since you couldn't do anything much to them or with them I would have spent a lot less time being confused.' And that was in the days when double adjustable dampers were as sophisticated as you could get. With top-of-the-range dampers now offering four-way adjustability, as well as a wide range of force vs piston velocity ('damping') curves, the potential for confusion would seem to have increased. But the impetus for multiple adjustability and non-linear damping curves

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goes back to a basic and somewhat unhelpful property of the hydraulic damper – that fundamentally it is sensitive to the velocity of the piston through the fluid. And this is exactly where Penske Racing Shocks' (PRS) latest development has been brought to bear.

Before we get to that, let's just briefly and simplistically re-visit why this velocity sensitivity works against us. When a wheel runs over a sharp bump or a kerb the damper piston moves at relatively high velocity (probably in excess of 15in/sec (381mm/sec) and possibly up to 40in/sec (1016mm/sec). When the car rolls or pitches it moves at much lower velocity (up to 5in/sec/127mm/sec might typically be seen during chassis movements). So when hitting a bump a very simple damper with a linear damping curve would exert a high damping force, but when rolling or pitching it would exert a much lower force. If the damper were then made to provide just the right level of damping for dealing with bumps, it would be grossly under-damped for the slow velocity movements like roll and pitch, and our racecar would handle very sloppily indeed.

Conversely, if the dampers were made to provide the correct roll and pitch damping, which provides the driver with a taut-feeling, responsive car that is generally much preferred, when hitting bumps the dampers would be far too stiff. This would provide not only a very harsh, choppy ride but also a loss of tyre compliance and grip, potential symptoms being wheel patter, lack of traction, premature sliding and wheel lock up as the dampers are unable to even out the vertical loadings and keep the tyres on the track surface.

Therefore, what we ideally want is a level of damping that provides responsive, confidence-inspiring handling, but which also enables the wheels to maintain optimum contact with the track. As our late and lamented friend and colleague, Allan Staniforth, put it in *Competition Car Suspension*, we are 'seeking the strongest control of suspension movement and spring forces that can be achieved without some unacceptable penalty'. Clearly, this is not easy to achieve.

DIGRESSIVE DAMPING

But it didn't actually require external adjustability to start to find better ways of addressing the problem. The first step was to provide 'blow offs' within the damper, generally in the form of shims that, above a certain pressure, would open up more holes in the piston and reduce the damping force

THE CURVES

Figure 1

Typical linear and digressive damping curve shapes

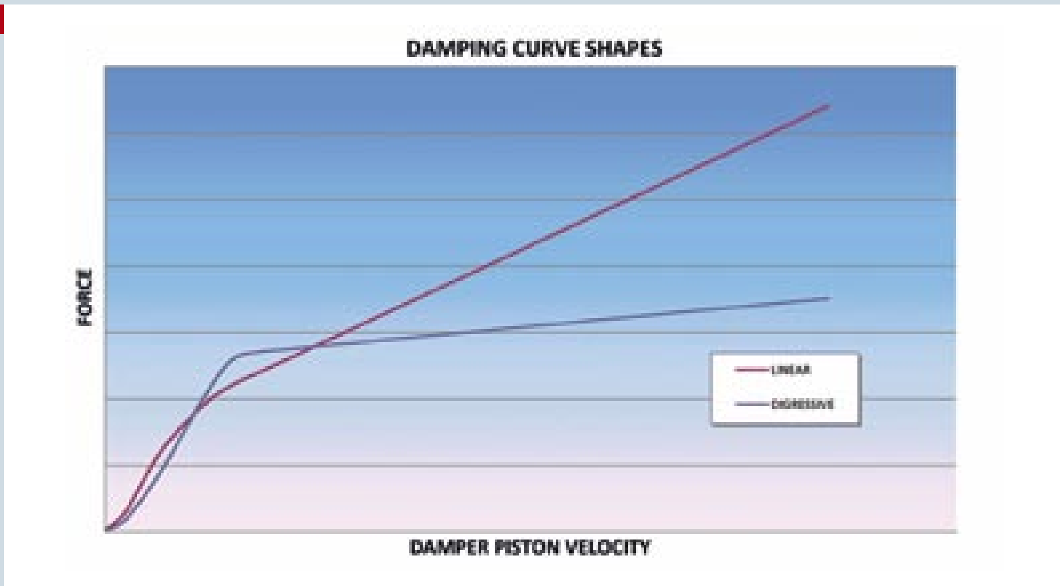
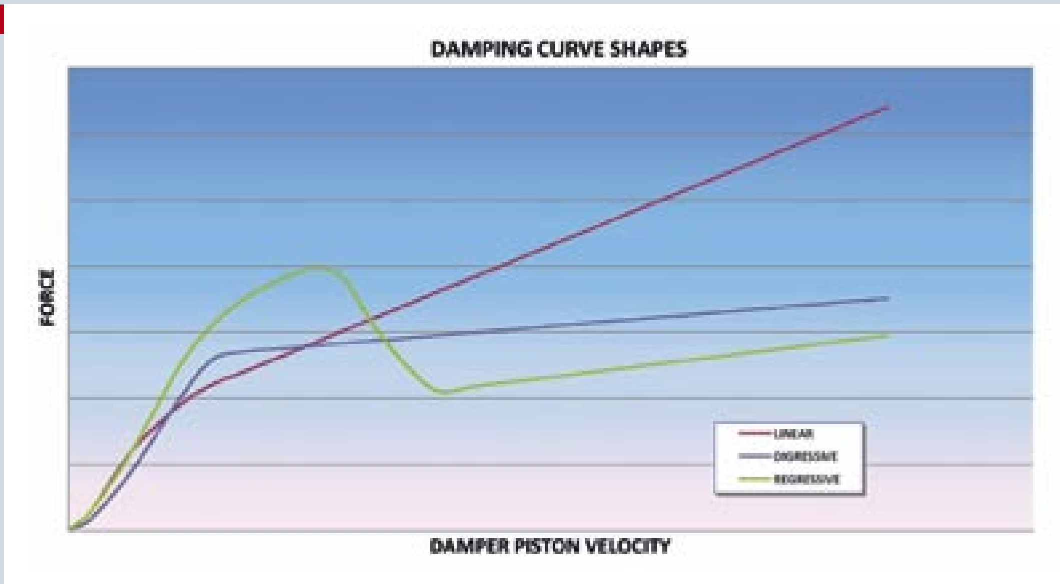


Figure 2

A regressive damping curve contrasts with the linear and digressive curves



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at higher piston speeds. This provided what became known as a digressive damping curve in which the slope of the force vs velocity damping curve reduced above a certain piston speed (see figure 1). Changing the shims internally enabled alterations to the transition point at which the damping rate went from the low-speed to the high-speed rate. This then enabled higher damping rates to be run in the low-speed region to provide better chassis control without immediately compromising the ability to deal with track imperfections and kerbs, so digressive damping was a very useful step forward.

So far, no distinction has been made between bump (compression) damping and rebound (droop) damping, and the foregoing applies principally to compression in order to illustrate the general principle. We will take a look at rebound later.

Of course, the advent of independent adjustability of bump and rebound and then, in around 1990, of high-speed bump (then high-speed rebound) from low-speed damping brought with it even greater potential for confusion, but also the ability to tune the car much better to a given track. The basic problem though still remained – it wasn't possible to run the high-speed damping at low enough rates in many instances.

A STEP FORWARD

In *Racecar Engineering* V17N2 Andy Thorby described an approach from Koni, who Andy was working with during the 2006 season on the Formula 3 Euroseries Dallaras at Manor Motorsport. This was Koni's 'Frequency Selective Damper' (FSD) valve, which was able to distinguish between suspension movement events according to the rate (frequency) at which they happened. A long duration (low frequency) increase in damper pressure closed off the path to flow control shims, and instead forced fluid through ports with a high damping level. Short duration inputs meant that the pressure increase did not have time for this sequence to invoke, and instead the flow control shims were deflected, leading to low damping forces. It was stated that, once fine tuned, FSD improved grip on most tracks, especially where there were bumps and kerbs in critical places. So this appeared to be a way around the traditional conundrum, and a useful step forward from conventional digressive damping.

"we needed our valve to be much more dynamic in its operation"

REGRESS TO PROGRESS

And so enter PRS's latest development, known as the 'regressive valve'. This uses a rather different principle (on which a patent is pending) to achieve a similar end, which is to provide lower damping rates at higher damper piston speeds (see figure 2). Indeed, the company says its new approach is 'about 180 degrees from the Koni FSD', adding provocatively that 'it was purely based on what a racecar needs.' Penske's Bill Gartner explains the background in full: 'When only linear damping curves were available, increasing the low-speed portion of the curve for good driver feedback meant drastic increases in mid to high-speed compression damping forces. So it was a case of balancing driver confidence against loss of grip or harshness over bumps. Digressive compression curves were likely developed to allow more aggressive low-speed compression damping to improve driver feel without the resulting [excessive] high-speed compression damping.

'However, high-speed damping levels with a digressive-style piston still could only be reduced down to the low-speed damping level because pressure and flow were linked. Therefore, low-speed damping levels could still only be increased to a point where the higher speed damping started to erode performance. For some applications a very flat digressive curve worked fine, but this didn't go far enough for some.

'The idea behind regressive damping began in Formula 1, where kerb strikes caused extremely high damper shaft velocities. During a kerbing event, the F1 teams want their suspension to allow the wheel to move quickly without upsetting the chassis, and to allow the driver to get back on the throttle immediately after hitting the corner apex. Regressive damping was meant to provide the requisite level of low and mid-speed compression damping for good driver feel and small bump absorption, but then cause drastic reductions in compression damping levels at higher shaft speeds when hitting kerbs.'

It seems that some years ago Penske's engineers devised some clever solutions to achieve regressive damping using complicated bypass tubes linked to the head valve pressure differential. 'These made for some complex and quite expensive dampers,' admitted Gartner. 'However, this was the heyday of spending in F1, when money was no object and complexity was almost revered!' he joked. And although regressive damping was a dream for more general racecar applications, the cost at the time was prohibitive, and kerb strike events not nearly so dramatic as in F1.

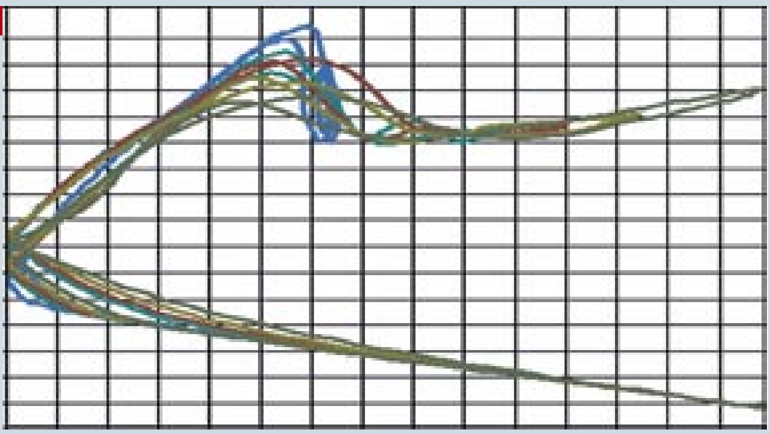
Fast forward to more recent times, and Gartner picks up the tale again: 'After yet another request by one of the F1 teams for regressive damping, our new regressive valve was devised. It uses variable pressure areas, and the concept is roughly similar to a latch valve in hydraulics, which locks itself open after a certain pressure is applied. However, we needed our valve to be much more dynamic in its operation. So we carefully matched the flow and pressure areas to create an extremely responsive valve that could not only blow completely open during the acceleration phase of a bump, but could also close during the deceleration phase toward the peak of a bump.

'After some testing we quickly realised that the rapid, stable response of the new valve could be useful for much more than kerb strikes! We started to test the valve with much lower velocity blow-off points, and much greater low-speed damping levels with good results. The increased low-speed damping provided the driver with such great feedback and chassis support that ultra-stiff springs

THE CURVES

Figure 3

Some actual regressive test data showing some of the available choice



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LAT

Dario Franchitti's Ganassi Racing Dallara Indy Car finished third at Mid-Ohio fitted with Penske's regressive dampers

were no longer necessary to control the vehicle. Softer rate springs were fitted, together with reductions in rebound damping, yielding instant gains in traction and decreased tyre wear.'

Gartner goes on to emphasise this latter point with a simple example of how the Penske regressive valve operates: 'If you can imagine a nicely shaped 'sine wave' bump [encountered in a cornering situation], when the tyre begins to climb the first part of the bump the low-speed compression damping helps to 'plant' the tyre, initially maintaining grip and providing the driver with good feedback.

At the middle of the ramp the highest [damper shaft] velocity occurs, and here the regressive valve blows off, dramatically reducing lateral tearing of the tyre surface. The accelerations leading to that area [of the curve], however, have a lot to do with how the valve responds through its frequency sensitivity.

In the next phase, the compression movement begins to decelerate towards the top of the bump. While other regressive arrangements may remain locked open at this point, our valve is responsive enough to close again and regain low-speed damping support. So a good regressive damper set up can feel like a very stiffly set up car with great support and responsiveness, but also allows the car to feel as though the tops of the bumps have been shaved off.'

FREQUENCY SENSITIVITY

So has Penske achieved damping nirvana? Well, further claims are made that certainly make it sound like a significant step forward, including the fact that the regressive valve also seems to exhibit frequency response sensitivity, too. The Penske engineers have included a small bleed jet in the valve that controls how quickly the pressure across the valve can equalise. With velocity held constant, a longer duration, lower frequency sine stroke will allow the pressure to equalise across the valve, the valve does not open, and the low-speed [higher damping rate] support is maintained. However, a shorter duration, higher frequency event such as a square-edged bump sees pressure quickly build up on the valve – it opens very rapidly and high damping forces are 'never really felt by the driver'. This bleed jet is tuneable by adjusting the jet orifice size – a larger hole providing a slower reaction, while a small hole gives a fast-acting valve.

And finally, Penske has also found that the regressive set up can overcome other downsides of a traditional digressive arrangement. Apparently, linear damper pistons that have been dished to provide low-speed damping support, and which are seemingly preferred by drivers, can once again be used because it's the regressive valve that now provides the blow off at the transition to the high speed [lower] damping levels. 'Previously, one of the potential negatives of a digressive arrangement has always been how sharply the low-speed force builds (via orifice damping) and then how quickly the shims open to flatten off the compression damping curve.

'Using the regressive valve teams can once again revert to a dished linear piston and then simply use the regressive blow-off point to chop out the high-speed damping that they don't want.

'We have also developed a rebound regressive valve that can allow the same low-speed rebound control, along with drastically reduced mid- to high-speed damping. We find that some racing teams like to use low-speed rebound damping for chassis control in certain roll and heave situations. However, excessive high-speed rebound forces are never good for tyre grip, and the rebound regressive option helps to ease this compromise. Our regressive damping options are also being evaluated in Stock Car racing to help with the safety vs speed conundrum, where extreme levels of rebound damping are used to tie cars down to their bump rubbers at 200mph.'

> **"the regressive valve seems to exhibit frequency response sensitivity, too"**

Finding the right damper set up is never easy, and Gartner acknowledges that 'getting the right set up with regressive damping can be a bit challenging, finding the correct blow-off point and the correct level of low-speed damping. However, we are planning an externally adjustable version to help with development. We have also successfully developed regressive curves using our active damper system on a test rig, and plan to offer on track active services to help with development for teams as well.'

But the claims are bold: 'In test after test the regressive valve has allowed suspension tuners to unlock hidden performance in a wide range of racing categories.' And in case you don't believe the manufacturer's own claims, the following testimonial might just make you think: 'The PRS regressive valve opens up a new dimension in tuning opportunities by enabling a falling rate response. And PRS has provided us with useful guidance on the dynamic considerations involved when implementing the device. The regressive valve has certainly found a place in our damper tuning "tool chest".' The source of this quote? Target Chip Ganassi Racing's 'shock man', Mike Cicciarelli.

Time alone will tell if this is simply another step forward in damper development or a major breakthrough. Meantime, as well as the compression and rebound options already being worked on, one might imagine developments that incorporate multiple regressive valves that provide more than one transition point so that idealised damping levels can be provided at more than just two or three damper shaft speed ranges. Fanciful? Perhaps, but so would regressive damping have been when hydraulic dampers were first developed...

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