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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.

ANALYZING SHOCK TRACES

I am an aspiring race engineer – currently work for a professional sports car team – as well as a mechanical engineering student. I am learning to use data acquisition. I was hoping you could give me some insight into reading the shock velocity traces from the data system. Should they be compared to the dyno charts to make sure they are operating in the correct range? What can be deduced as far as oversteer/understeer characteristics?

This is a fairly complex subject, and one that has seen its share of hype and mystification, particularly in stock car racing. A few years ago, shock technology went through a "trick of the week" phase. Teams suddenly discovered that it was worth paying attention to, and shocks went from almost a non-factor to a perceived panacea practically overnight. Suddenly people were trying to fix every problem with shocks. This is a wrong approach. The first thing to remember about shocks is that they are only one element of the total package, not a holy grail.

The second thing to remember is that you need a rapid sampling rate to get shock traces that are accurate enough to be meaningful. Once you have a good shock position trace, it can look quite different depending on how you filter it. This is because shock velocities and accelerations undergo dramatic, continual change, especially on a bumpy surface. What sampling rate is good enough? Opinions vary, but anything under 100/sec is definitely too slow. 250/sec is a common general-purpose recommendation. 500/sec is fast.

Sampling rate makes more difference on a rough surface than on a smooth one. This is also true of filtering. Sampling rate also becomes more critical if you want to differentiate the position trace to obtain a velocity trace, and even more if you want to differentiate the velocity trace and look at acceleration. Inaccurate information can be worse than none at all.

The shock traces, taken alone, actually tell you more about the track and the rest of the setup than they do about the shocks themselves, at least in normal circumstances. The wheel motion will be reduced some as you stiffen up the damping, but ordinarily the track surface and the spring rates mainly determine how the wheels move. (An exception occurs when a shock is grossly undervalved or overvalved, or is leaking, sticking, or otherwise malfunctioning.) The shock valving determines the forces the shock generates when it goes through those motions, and those forces affect wheel loadings.

To know the force a shock is generating at a particular instant, you need to know the instantaneous velocity, which you get from on-car data, and the force the shock can be expected to generate at that velocity, which you get from shock dyno data.

Shocks are also acceleration-sensitive. The degree of acceleration sensitivity can vary widely. To get the best assessment of what forces the shock is producing at a particular point on the track, we need to reproduce both the velocity and the acceleration on the shock dyno. To do this requires a high-cost shock dyno that can be programmed to either produce a particular acceleration, or to play back motion recorded on-car. This means the dyno must be controlled fully electronically – usually with with high-powered hydraulics providing the actual force – rather than the more common variety with a scotch yoke drive that always produces a sinusoidal motion.

If we don't have access to such a dyno, we can at least get some idea of whether we have a highly acceleration-sensitive shock by looking at a full-cycle trace from a sinusoidal dyno. In a plot where absolute velocity is the horizontal coordinate and force is the vertical coordinate, a full cycle trace will have two points or noses at the left (zero velocity) edge of the graph. These represent the "turn-around" points in the cycle – full compression, and full extension. If the two noses have dramatically different shapes, the shock is probably displaying acceleration sensitivity, particularly if all shocks of the same design show this pattern. If just one shock shows such a pattern, that suggests a malfunction on that individual unit.

Another way to get some indication of a shock's acceleration sensitivity is to look at its construction. If the valving includes relatively massive chunks of metal that see big accelerations when the unsprung mass does, that's a strong indication that the valving will be acceleration-sensitive. Examples include: dual-tube shocks with foot valves having coil-spring-loaded discs or spools, where the shock body is down or moves with the wheel; and gas shocks with coil-spring-loaded discs or spools on the piston, where the shock body is up or the piston moves with the wheel. Deflective-disc valving has minimal acceleration sensitivity.

Acceleration sensitivity is not necessarily a performance disadvantage. It may even be helpful in some instances. However, it does complicate the process of inferring shock forces from on-car traces, based on sinusoidal dyno testing.

Merely knowing whether the shock is highly acceleration-sensitive does not allow us to know actual forces in combinations of acceleration and velocity that our dyno can't reproduce, but it does at least let us make informed guesses as to whether we can assume dyno data to be representative for a specific instant picked from an on-car trace.

Fortunately, we can accomplish a lot without knowing exact shock forces. Provided we know what portion of the valving is active at the instant in question, we can at least qualitatively predict what will happen to our wheel loadings if we soften or stiffen that portion of the valving. And from that, we can predict whether such a change will move the car toward oversteer or toward understeer (loosen it or tighten it) at that point in the lap.

To meaningfully discuss such predictions, we have to break track surfaces down into rough ones and smooth ones. Rough surfaces are ones where there are enough bumps so that the bumps cause most of the suspension movement. Smooth surfaces are ones that are smooth enough so that most suspension movement is caused by sprung mass motion. Shock velocities will be much greater, and will change much more, on a rough surface than on a smooth one.

On a rough surface, damping affects tire loads in two basic ways. First, the amount of damping affects the wheel's ability to ride the bumps with minimum load variation at the contact patch, and minimum non-contact (airborne) time. Second, the balance between compression (bump) damping and extension (rebound) damping affects the suspension's tendency to jack up or down when riding a series of bumps. Jacking down is by far the more common of these two possibilities.

Looking at the first of these issues, the suspension behaves better over bumps when lightly damped *except when the bumps excite the suspension at the unsprung mass natural frequency, or a simple multiple or fraction (harmonic) of that frequency*. In such instances, the suspension performs better if stiffly damped. Excitation at a vulnerable frequency is the worst-case situation, the scenario most likely to send the car out of control due to being upset by bumps. Therefore, there is a strong case for erring on the stiff side when in doubt; the car will be worse on "friendly-frequency" bumps, but will be less upset by the patches to which it is most vulnerable.

Looking at the second issue, if all four corners of the car jack down a bit, this may have little effect on cornering balance. However, if only one wheel jacks its suspension down, or if three do and one doesn't, or if two diagonally opposite wheels do and the other two don't, then the jacking will change the car's instantaneous diagonal percentage (percentage of tire loading on the outside front and inside rear, or right front and left rear for oval track). If instantaneous diagonal is increased, that moves the car toward understeer (tightens it); if instantaneous diagonal is decreased, that moves the car toward oversteer (loosens it).

On bumpy surfaces, medium to high speed valving is at work. On smooth surfaces, only low-speed valving is relevant. These terms are relative. On a stiffly suspended car, as in F1 or CART, "low speed" might mean below 1 in/sec (.025 m/sec). In stock cars or moderate downforce sports cars, "low speed" is commonly taken to mean below 2 in/sec (.05 m/sec). In passenger cars or off-road cars, "low speed" can be a lot higher. In any of these contexts, low

speed damping means the velocity range that can be attained by driving the car violently on a smooth surface. Usually, low speed damping is governed by bleeds and preloads in the valving.

On a surface smooth enough to allow sprung mass motion to be the main input, we can control corner entry and exit oversteer/understeer properties with the low-speed damping. The basic rules for this are:

1. Whenever a damper's velocity is in the extension direction, stiffer extension (rebound) valving reduces load on that tire and the diagonally opposite one, and increases load on the other two tires.
2. Whenever a damper's velocity is in the compression direction, stiffer compression (bump) valving increases load on that wheel and the diagonally opposite one, and decreases load on the other two.
3. We get the greatest effect from changing the shocks that are have the highest velocity at the instant or point on the track that we seek to affect.
4. Effects on oversteer/understeer balance can be predicted by examining the effect on instantaneous diagonal percentage; more diagonal = tighter car.

We can write troubleshooting charts for various types of cars and tracks, and these can get quite long and complex. However, the four principles above can be used for all cars, and with data acquisition, you don't have to infer or guess at shock velocities.

So, returning to your question regarding whether we can deduce oversteer or understeer from shock velocity, the answer is that we cannot, but knowing shock velocity can help us predict changes to balance that will result from changes in valving. We determine the presence of understeer or oversteer by examining steering position, or a calculated speed-corrected steer channel. We also make sure we talk to the driver, because what really counts is whether the car is looser or tighter than the driver wants it. Also, a tight car can exhibit oversteer if the driver is purposely driving it loose to make it turn. Data acquisition is a tool to supplement human senses and brains, not a substitute for them.

As to what we compare to dyno traces or tabular charts, comparison to dyno data is done to infer forces, as noted above. We compare our dyno data to the manufacturer's if we have data from the manufacturer for the build spec we're using. We also compare our dyno traces to traces from shocks in our own inventory with identical build specs. We use these comparisons to make sure we don't have leakage or sticking, and to make sure we really built what we thought we built. It's surprisingly easy to include an extra disc, or leave one out, or grab the wrong diameter or thickness.

Finally, we compare dyno data for different shocks to evaluate the effect of a change to the build spec – to see what velocity range it affected and how much. We then compare this to the on-car velocity data to predict the handling effect of the build spec change, applying the four rules listed above.