WORKS

Choosing baseline damper curves for ride.

Last time, we discussed the process of choosing proper baseline spring rates. In this paper, we will continue the discussion on suspension components by simplifying the process of choosing appropriate baseline damper settings for ride.

What is damping?

In a spring-mass system, any displacement and release of the mass from its equilibrium position will cause the mass to oscillate. If the system were ideal, the mass would continue vibrating at a given frequency (its natural frequency) indefinitely with unchanged amplitude. Introducing damping into the system causes the oscillation to trail off and forces the system to reach a steady state value.

Going back to physics, the simplest equation of a damper is $F = CV$, where F is the force exerted by the damper, C is the damping coefficient, and V is the velocity of the damper.

So why did we go through all this? In order to introduce the **damping ratio** – this is where you want to start in determining what kind of damper to use.

Damping ratio

The damping ratio, usually designated as ζ, is defined as the ratio of actual damping coefficient to the critical damping coefficient. The reason why we work with damping ratios instead of actual damping coefficients is so that we can normalize the discussion for all dampers.

Choosing a damping ratio is a generally a tradeoff between response time and overshoot (you want to minimize both). Typically, passenger cars will use a damping ratio of around 0.25 to maximize ride comfort. For a racecar, the damping must be considerably higher for road holding and control of the unsprung mass motion. Data has shown that **for racecars, a good baseline for damping ratio is between 0.65 and 0.70.**

Transmissibility

There is one more concept that should be understood before introducing the damping curve – the concept of transmissibility. Transmissibility is defined as the ratio between output and input amplitude. In our application, the input amplitude will be the height of a road irregularity and the output amplitude is the vertical movement of the car body. For a spring-mass-damper system, **transmissibility is**

actually a function of frequency. Whether you realize it or not, most of you actually know this already from driving cars on the street.

We all know that if you hit a speed bump going very slowly, the car moves vertically almost as much as the wheels. But if you were to go over the same bump going quickly, the body of the car doesn't move nearly as much. Depending on the speed at which you hit the speed bump, the car body's response changes. The cause of this phenomenon is that the response of the system – the car and its suspension – is a function of the frequency of the input.

Transmissibility also changes with damping. Included below is a plot of the transmissibility of a spring-mass-damper system for various damping ratios:

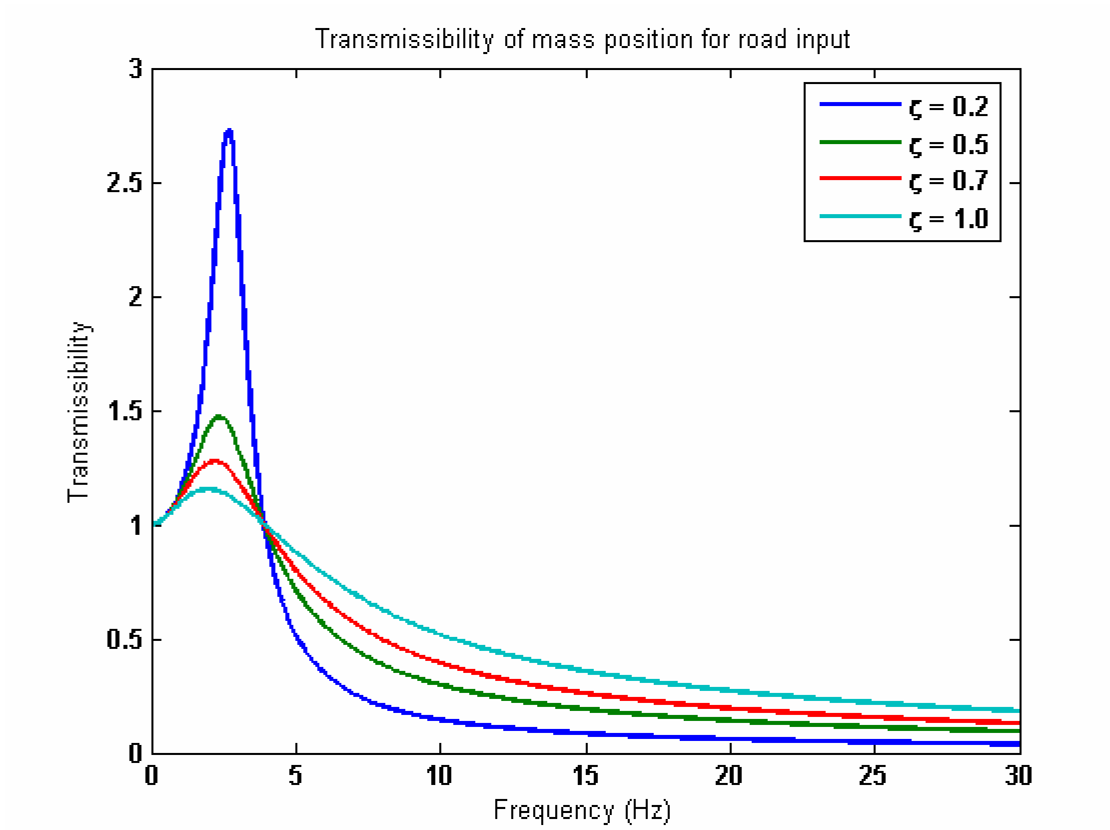


Figure 1. Transmissibility for different damping ratios
(*Courtesy of OptimumG*)

For maximum grip, we want to minimize the change in forces that the springs are seeing. This is achieved with minimal body movement. Thus, we want the lowest transmissibility possible. At low frequencies, you can see from the plot that we want higher damping ratios. However, the tradeoff occurs after the crossover frequency, throughout which we would like a lower damping ratio. Corresponding low frequencies to low shock speeds, and high frequencies to high shock speeds, you can see that we need high damping ratios for low speeds and low damping ratios for high speeds. This concept will be used in determining baseline damper curves.

Determining Baseline Ride Damper Curves

STEP 1: Calculate the slope of the initial damper curve. This slope applies to both compression and rebound damping.

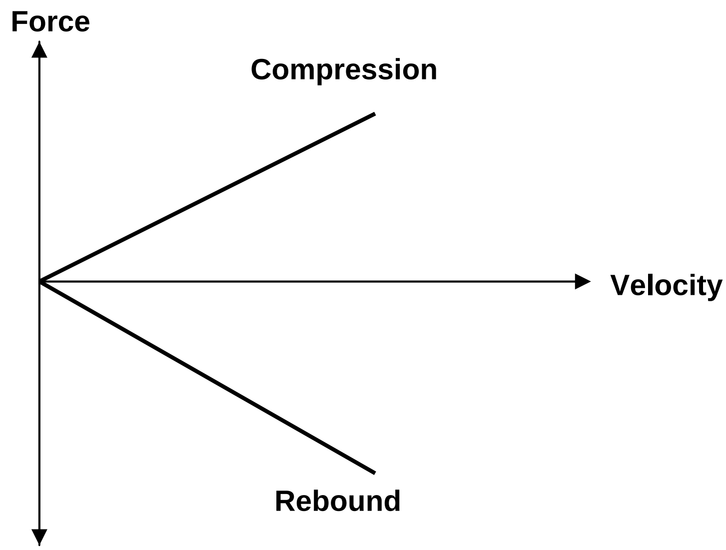
$$Initial\ Slope = (1/12)4\pi\zeta\omega m \qquad [\text{lbf/(in/s)}]$$

where…

ζ is the desired damping ratio in ride
ω is the desired ride frequency in Hz
m is the sprung mass supported by the damper at that corner in lbm

Side note: This formula for the damping slope comes from the damping term in a simple damped harmonic oscillation.

Here is what the damper curve looks like at this point:



STEP 2: Now we will make some modifications to our initial damper curve.

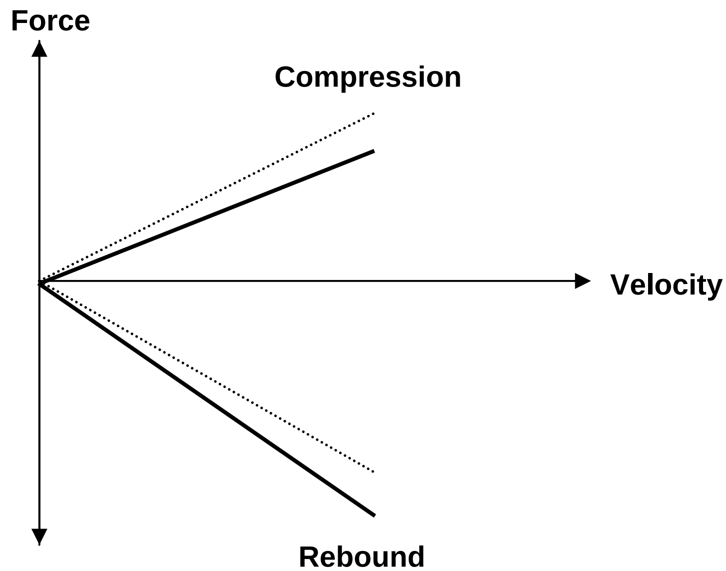
In compression, energy is "taken up" by the spring, effectively decreasing the damping requirement of the shock in that direction. However in rebound, the potential energy stored in the spring to compress it is released, thus requiring higher damping of the shock in that direction.

This is the reason that shocks typically have a steeper slope in rebound than in compression. Quantitatively, wheel velocities in the compression direction have been measured to be higher than the rebound direction by a factor of about two. Thus, we will modify the slopes by making the rebound slope twice as steep as the compression slope. However, we also want to modify it such that the average slope matches the initial slope that we originally calculated:

*Compression Slope = (2/3)*Initial Slope*

*Rebound Slope = (4/3)*Initial Slope*

Here is what the damper curve should look like now:



<u>STEP 3:</u> If you remember our discussion on transmissibility, you will note that our damper curve is still not complete – the damping needs to be lowered for high shock speed to minimize the transmissibility there. A good rule of thumb is to reduce the slope by half. The split point between low and high shock speed can be determined based on testing and experience. (Hint: you can also correlate the crossover point on the transmissibility plot to a damper velocity to determine a split point to start from.)

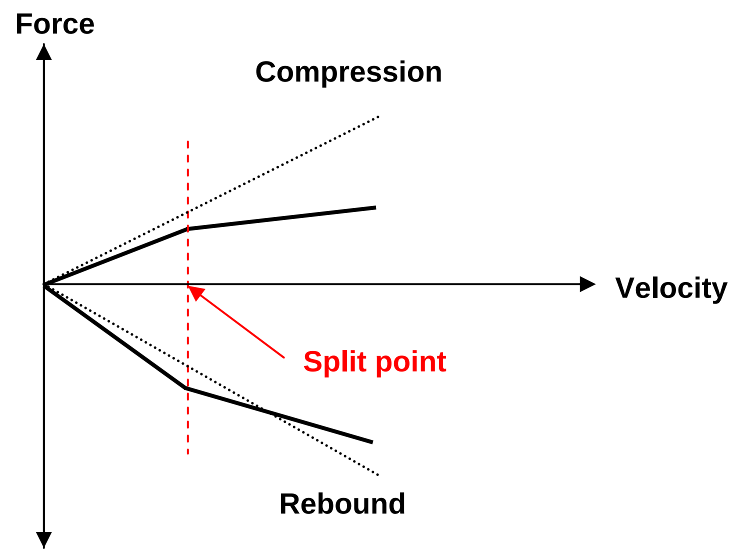
*Low Speed Compression Slope = (2/3)*Initial Slope*

*High Speed Compression Slope = (1/3)*Initial Slope*

*Low Speed Rebound Slope = (4/3)*Initial Slope*

*High Speed Rebound Slope = (2/3)*Initial Slope*

Here is what the baseline ride damper curve looks like finally:



Side note: The damping curve shown above displays an abrupt transition from high to low damping which for some racing applications may not be optimum, as such a sudden transition can upset the dynamics of the car. One advantage with some Öhlins shocks is that they utilize a **PCV (parallel compression valve)** system that allows a smoother damping transition around the split point as shown by the figure below:

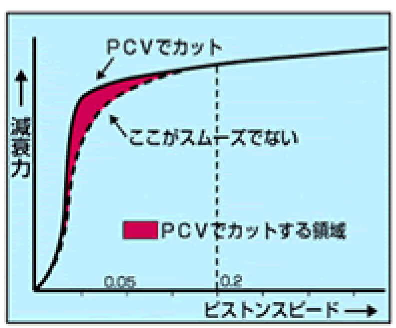


Figure 2. Illustration of PCV Effects *(Courtesy of Öhlins)*

Hopefully you have found this damper information easy to understand and educational. Please stay tuned for more white papers published by WORKS in the future.

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References:

Brisson, Samuel & Giaraffa, Matt. “Tech Tip: Spring & Dampers, Episode Four”. OptimumG, Denver, CO.

Milliken, Douglas L. & Milliken, William F. Race Car Vehicle Dynamics. Society of Automotive Engineers, Warrendale, PA, 1995.