Design Update: Shocks

Damper development and testing is one of the main interests of this year. With the recent acquisition of the Roehrig Engineering 2VS Shock Dyno, testing will be much easier than in the past. The 2VS is a valuable tool and incredibly easy to use. This shock dyno is a crank dyno run by an electric motor. Because it is a crank dyno, the stroke is fixed at either one or two inches. In order to change the maximum velocity of each test the frequency is changed. Several different measurements are taken during a dyno test. A load cell measures the force generated by the damper, an infrared thermocouple measures the temperature of the shock body, a linear potentiometer measures the shaft displacement and a velocity sensor measures the speed at which the shaft moves.

Based on these measurements the dyno produces force versus velocity and force versus displacement plots. Both of these plots display the characteristics of the damper being tested. This dyno is capable of two different types of testing, continuous velocity plot (CVP) and peak velocity plot (PVP). Continuous velocity plots collects data over a total revolution of the crank while the peak velocity plot runs the damper at several different peak speeds and only collects the maximum force at each speed. The PVP tests are mainly used by mass manufacturers when general behavior of a damper is more than enough information. CVP tests contain much more information and are much more beneficial when true damper performance is of interest. All of the tests run in house are CVP.

The tests seen in the following four figures were by Cane Creek and run on a Roehrig dyno using the same Shock6.0 software that is used in-house. They are CVP tests, and only show one half revolution of the crank. One total revolution of the crank is divided into four sections which can be seen on a plot of a whole CVP test. Starting with the crank at bottom dead center, the first 90 degrees of crank rotation is the compression open phase, the next 90 degrees is the compression closed phase. During the compression open phase the shock is accelerated from 0ips at bottom dead center to the max speed specified for the test, and during the compression closed phase the damper velocity goes to from max speed to 0ips at top dead center. The rebound open phase is the next 90 degrees where the shock accelerates from 0ips at top dead center to the max speed of the test. The final 90 degrees is the rebound closed phase where the shock decelerates to 0ips.

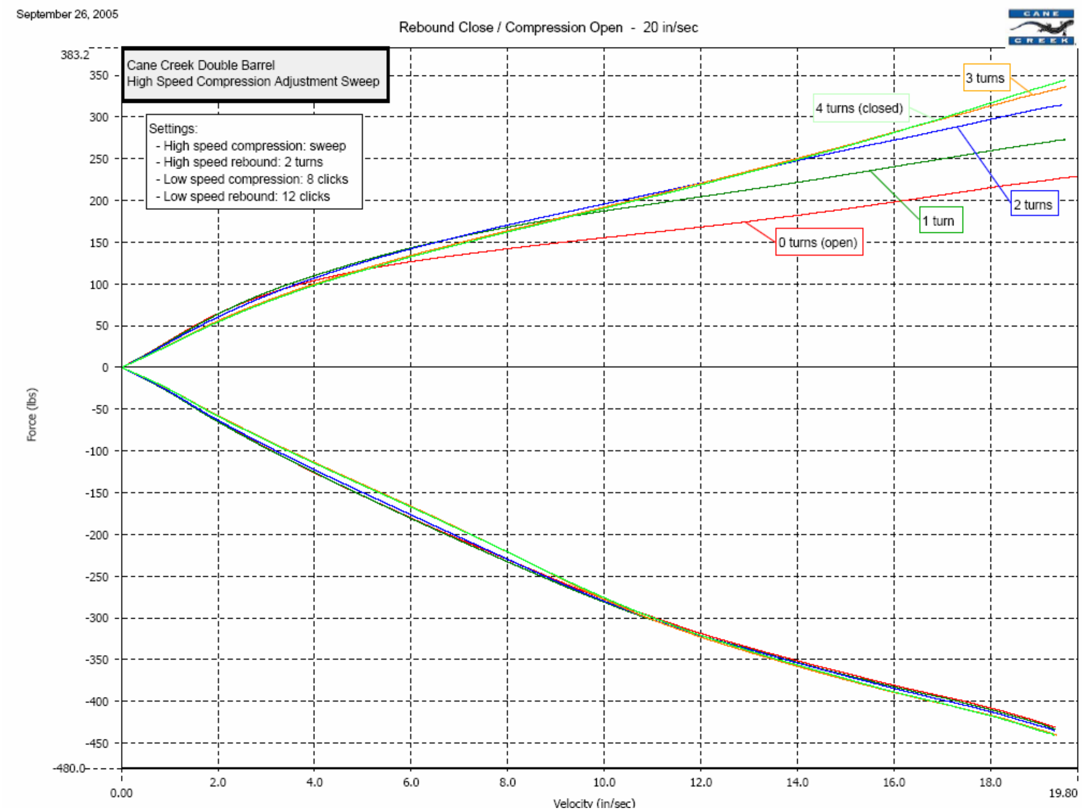

Figure 1. High Speed Compression Adjustment Sweep

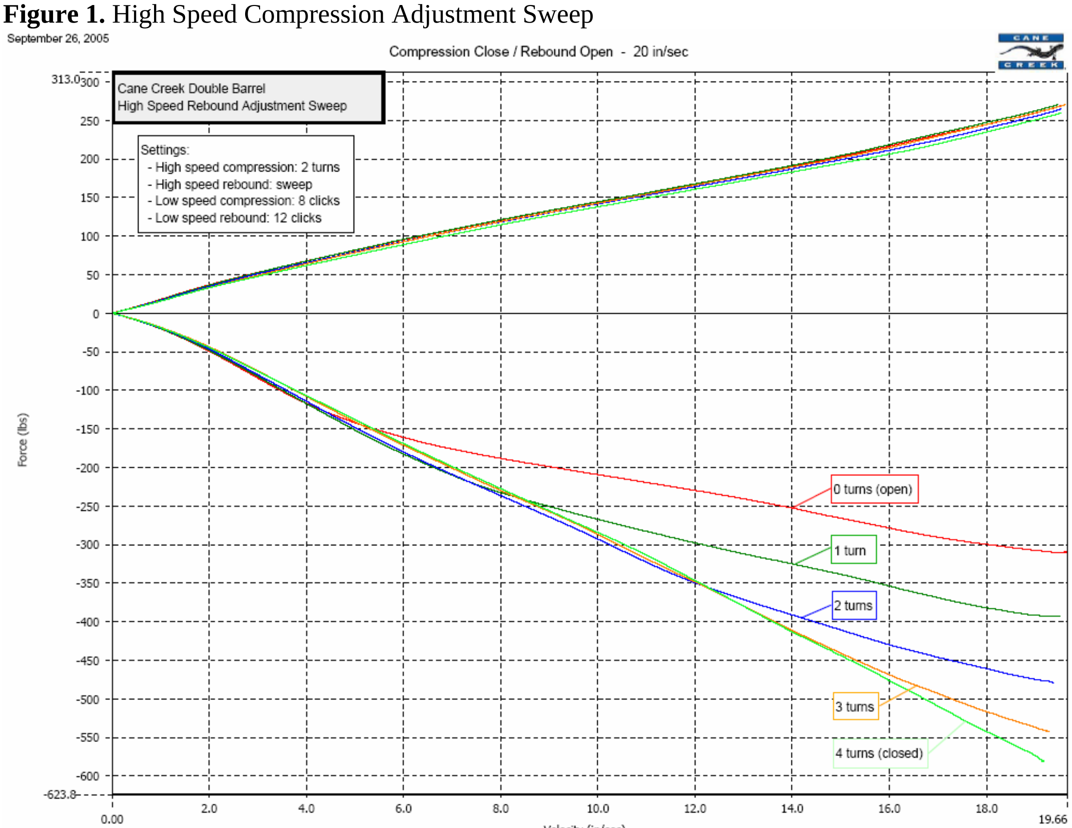

Figure 2. High Speed Rebound Adjustment Sweep

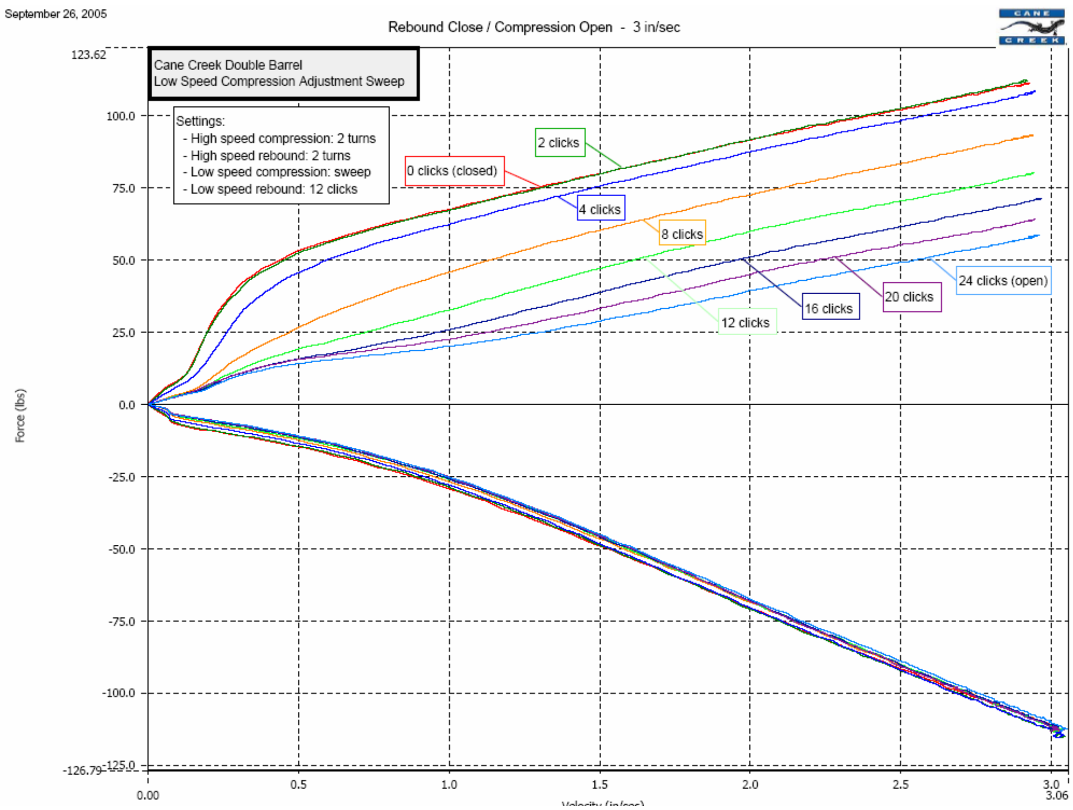

Figure 3. Low Speed Compression Adjustment Sweep

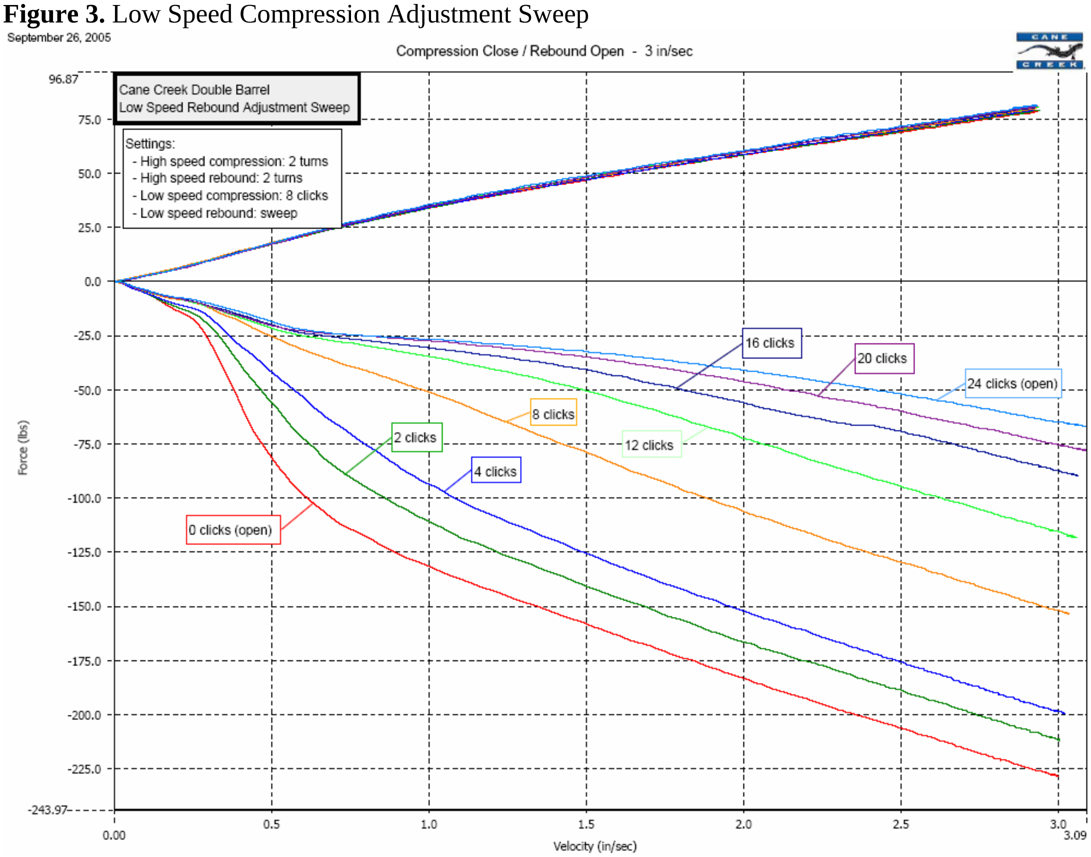

Figure 4. Low Speed Rebound Adjustment Sweep

It is very important to study both phases of the compression and rebound curve in order to understand the actual behavior of the damper. Comparing the opened and closed phases of either compression or rebound can display the behavior of the fluid and shims and, possibly, the effects of cavitation or hysteresis.

In addition to CVP and PVP tests, the dyno also has the ability to test the gas pressure and the seal drag of the damper internals. The gas pressure is an important addition to each test run on the dyno. Many shocks have a gas-filled reservoir which acts like a spring as the piston compresses. This spring force can be measured by the dyno using a quasi-steady-state test. The dyno pauses at 90 degrees from bottom dead center and 270 degrees from top dead center and measures the force at each of these points. Based on the diameter of the shaft, the pressure in the reservoir is calculated from the force data.

The seal drag test is used to measure the internal friction of the moving components of the shock. Through a small displacement window and a very low speed, for example a 0.15” window and a speed of 0.05ips, the change in force is measured both on the compression and rebound strokes. This test is best run with essentially an empty shock meaning the shims are removed and the adjusters are fully opened. This is done in order to remove all other possible sources of a force change inside the damper and allows for a better estimation of just the force generated from the friction of the moving parts.

Shock testing up to this point has involved the shocks from Proof and one spare damper from Rooster. The Proof shocks were taken down to the Haas Racing Shop at the end of October and were re-valved so the shocks would match each other on the same axle. This produced some interesting results in terms of how each shock was constructed to give the same force-velocity curve. The curves that were produced exhibited a great amount of cavitation and very choppy curves. The final products of this day’s work were two pairs of dampers that displayed similar curves and characteristics. The figure below shows the final FV plot for the two rear dampers. The top half of the plot shows the compression forces while the bottom half of the plot shows the rebound forces. The compression open line is the lower of the compression curves and the compression closed line is the upper part of the curve. The rebound open is the upper part of the rebound lines and the rebound closed is the lower part. This is the same for all plots and this convention will be used throughout the report to describe the dyno plots.

As seen in the plot of the rear shocks from the Haas trip, the compression closed line maintains almost a constant force as the velocity decreases; this is a sign of cavitation within the damper. The source of the cavitation could be many factors including a low gas pressure, air in the fluid and general poor assembly. The rebound closed curve also displays similar behavior. The compression open and rebound open curves on this plot are compound, this can be indicative of issues with air in the fluid or unwanted shim stack behavior. With air in the fluid, there could be little to no damping force when the shock is closer to extended length. The compound curve could also be a result of the shim stack not operating properly because of several different variables including incorrect thickness, incorrect order or poor assembly.

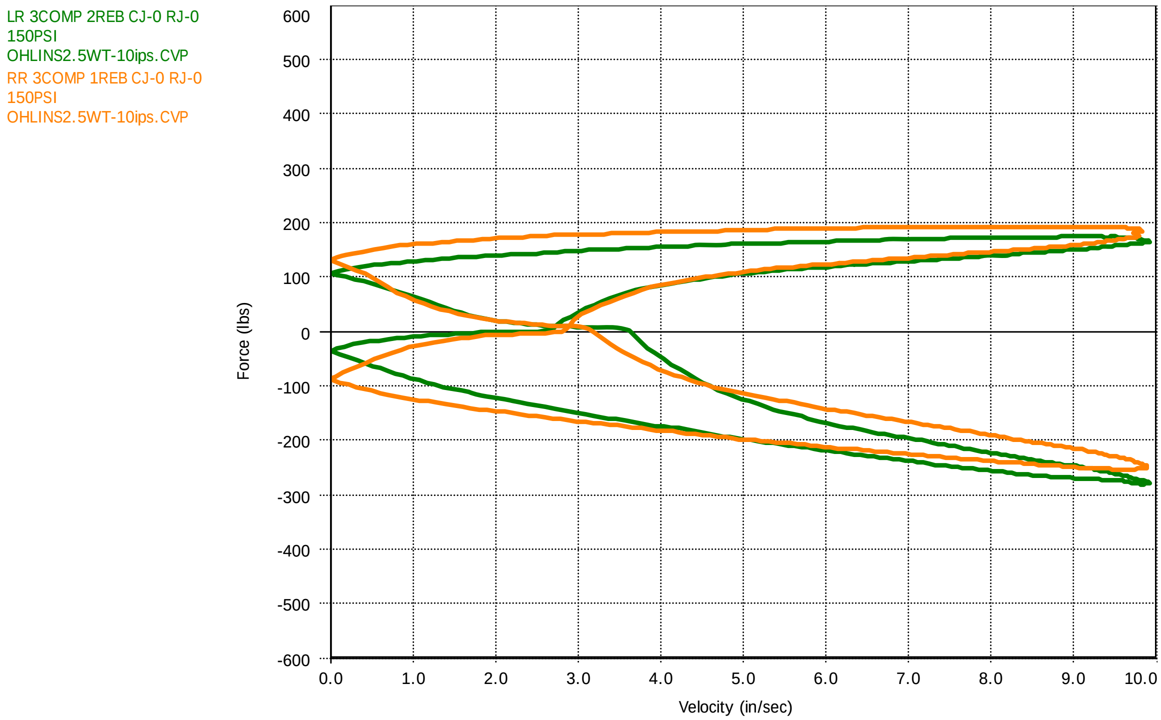

Figure 5. FV plot of rear dampers after trip to Haas (10/29/05)

Once the Roehrig dyno arrived on November 16th, in house testing was able to begin. On November 16th, the dampers setup at Haas were run on the dyno. The purpose of this testing was to become familiar with the operations of the dyno as well as rerun the dampers to compare with the plots from Haas. Several different tests were run in order to become accustomed to designing tests and using the dyno. The results from these tests did not seem to match the curves received from Haas. The following plot compares the right rear (RR) shock data from Haas versus the same shock data from the first set of in house testing. The curve from the in house testing looks much better than the Haas curve. This example is representative of each shock. The testing from November 16th shows the dampers generating less compressive force and more rebound force than the Haas plots. This could be because the tests at Haas did not measure the gas pressure which affects the forces throughout the range tested. Based on the many unknown variables from the Haas testing, those results will be ignored and the November 16th tests will be the current baseline for the dampers.

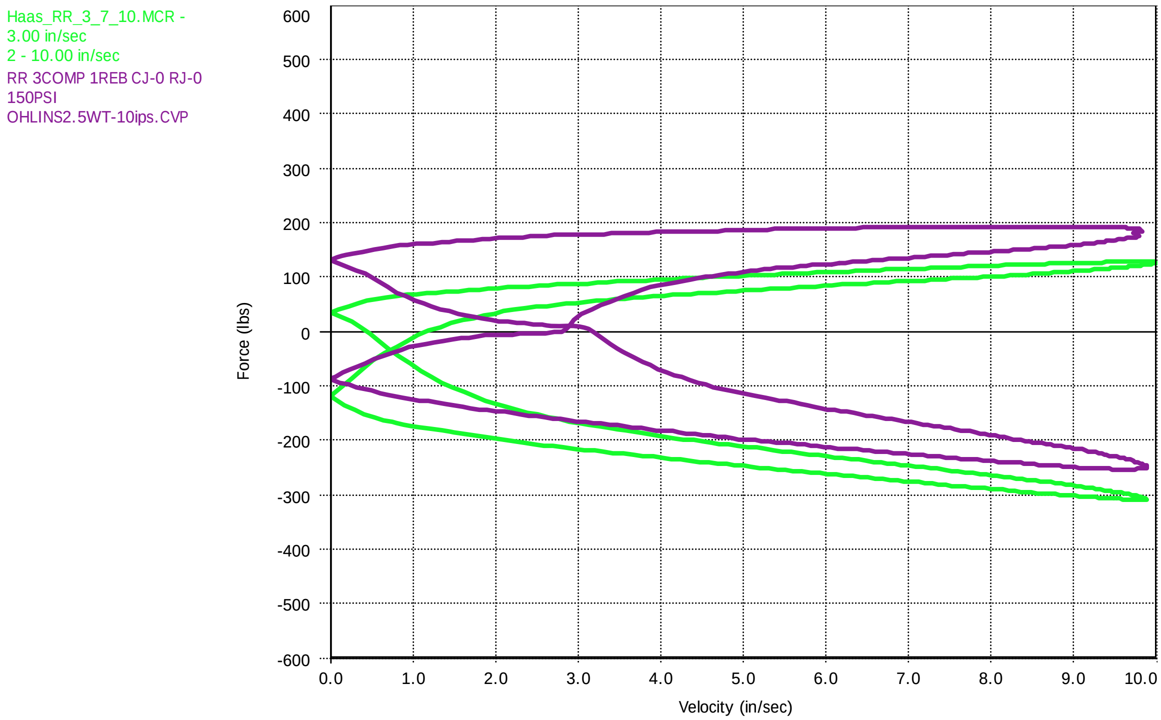

Figure 6. Comparison FV plot of RR shock tested at Haas and RR shock tested in house.

One of the features of the dyno that was not explored during the November 16th tests was the seal drag test. As stated earlier the seal drag test measures the friction force acting upon the damper in a quasi-steady-state test. This is best done with a damper with the shims and any other flow obstructions removed in order to accurately measure the drag created by the seals around the piston and shaft. The spare damper from Rooster was disassembled and the shims on the piston and foot valve were removed for this test. Several different shock fluids were looked into with this damper setup. The fluids involved were the Ohlins 2.5wt, Penske 2.5wt, Honda 5wt and Honda 7.5wt. The results for this testing are documented in the design binder under November 28, November 29 and November 30 testing.

Another observation from this testing is the consistency of the shock curves. Although the shock curves are not close to ideal by any means, they are somewhat repeatable. Qualitatively, the shocks are very similar to each other for each different set of testing. The following plot illustrates the consistency of the left front (LF) damper. One of the curves was taken from the November 16 testing, one from November 28 and the last from November 29. The rebound curves slightly vary, but the compression curves are almost identical. Each of the shocks behaves similarly to this plot. Based on these observations, given a shock that is not changed, the performance of it can be assumed to be the same as its last dyno test. Eliminating the variable of inconsistency greatly simplifies the testing process and design of experiments because the results from previous tests become valid comparisons.

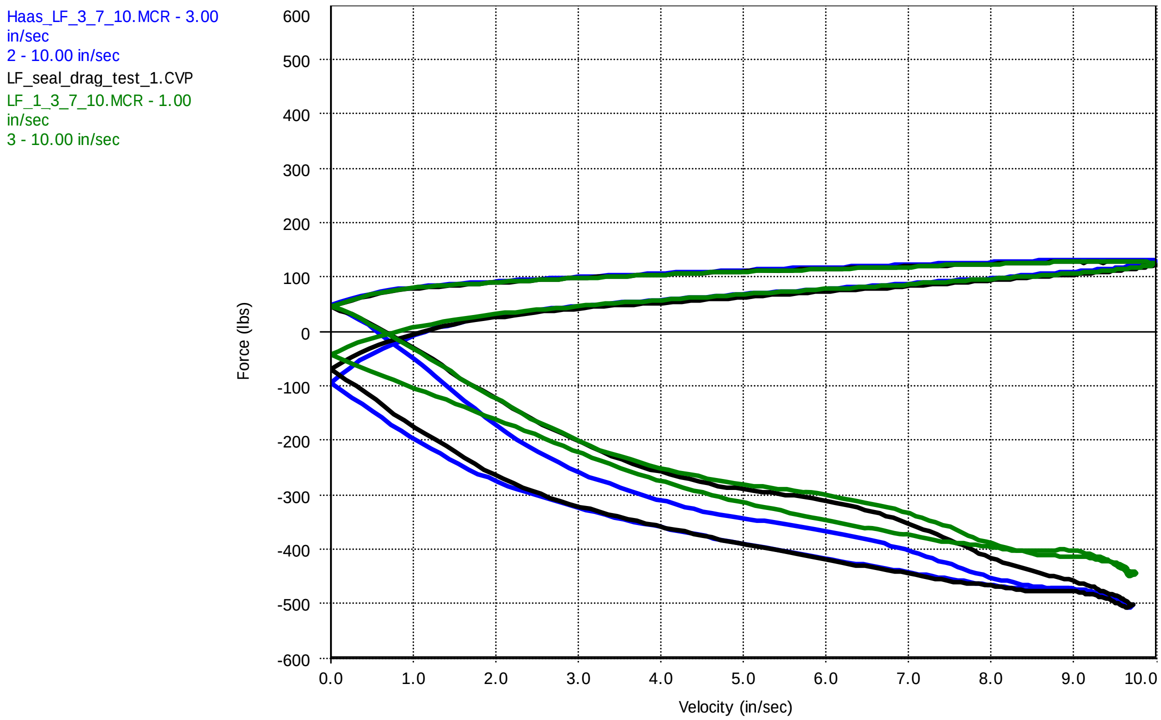

Figure 7. Comparison plot of LF damper from three different test days.

The main purpose of this testing is to aid in the production of better dampers. There are several ways to improve the performance of these dampers. The following plot is an example of how simple changes will improve the performance of the damper. This plot shows two separate tests of the LF damper still in the same setup as when it left Haas. The first test was one of the first tests run after the dyno arrived here. The second test was run after changing the oil in the damper and slightly lowering the rebound adjustment. The second curve exhibits much less cavitation and the damping curves are more linear than the first curve. This small improvement on the dyno can translate into a much greater feel of the car during driving. This improvement was done without adjusting the internals of the damper to any extent. Without the dyno, this type of improvement would not be easily recognized. This testing lays the groundwork for future research and development with all that has been learned about these dampers during the course of testing this far.

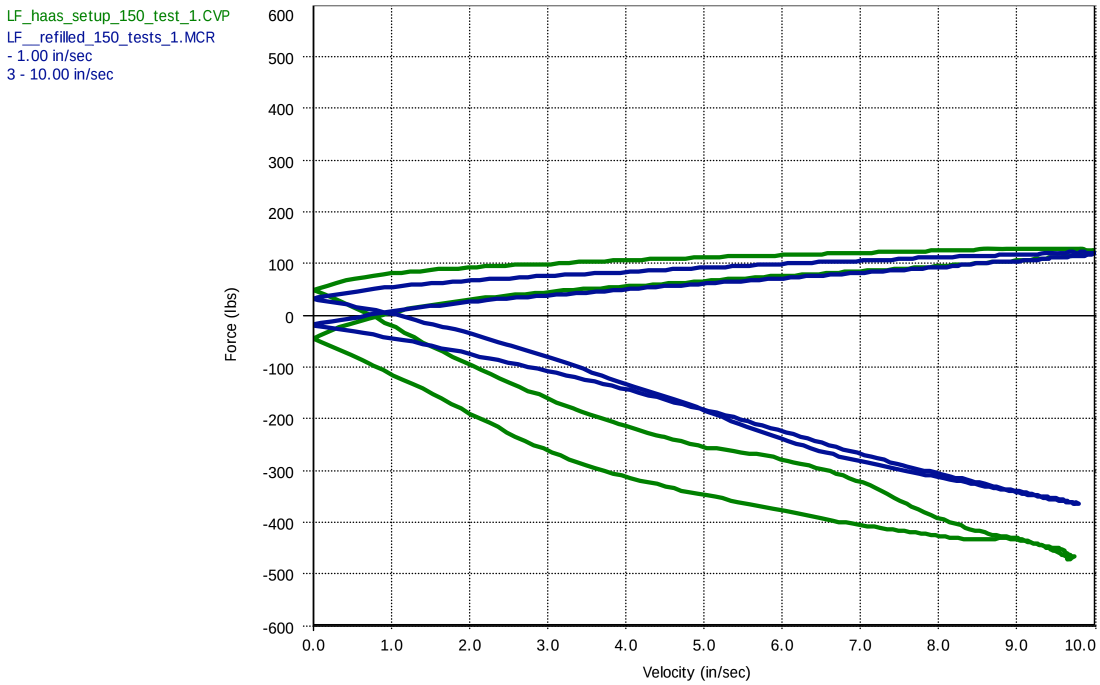

Figure 8. Comparison of LF damper before and after oil change and adjustment.

The Cane Creek Double Barrel dampers arrived at the beginning of January and were tested the following week. The plots gathered in-house match the plots previously provided by Cane Creek. Dyno plots of each individual damper were also provided. The following plots show the low-speed and high-speed adjustment range of the Double Barrel.

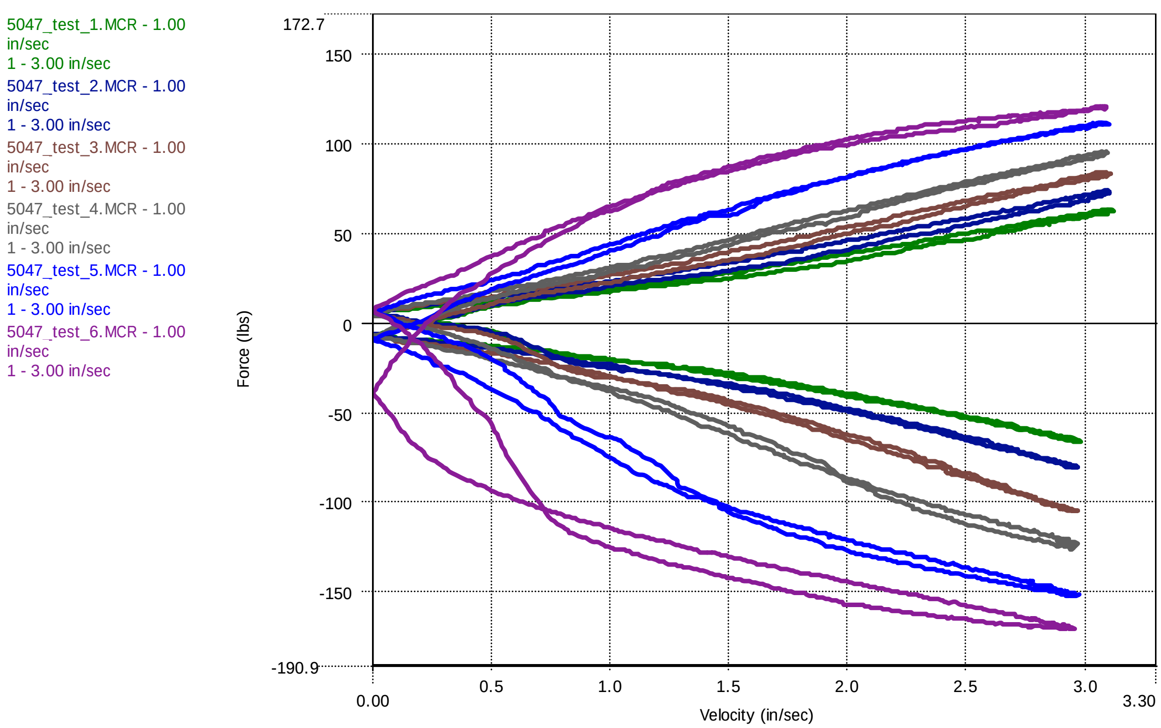

Figure 9. Double Barrel low-speed adjustability.

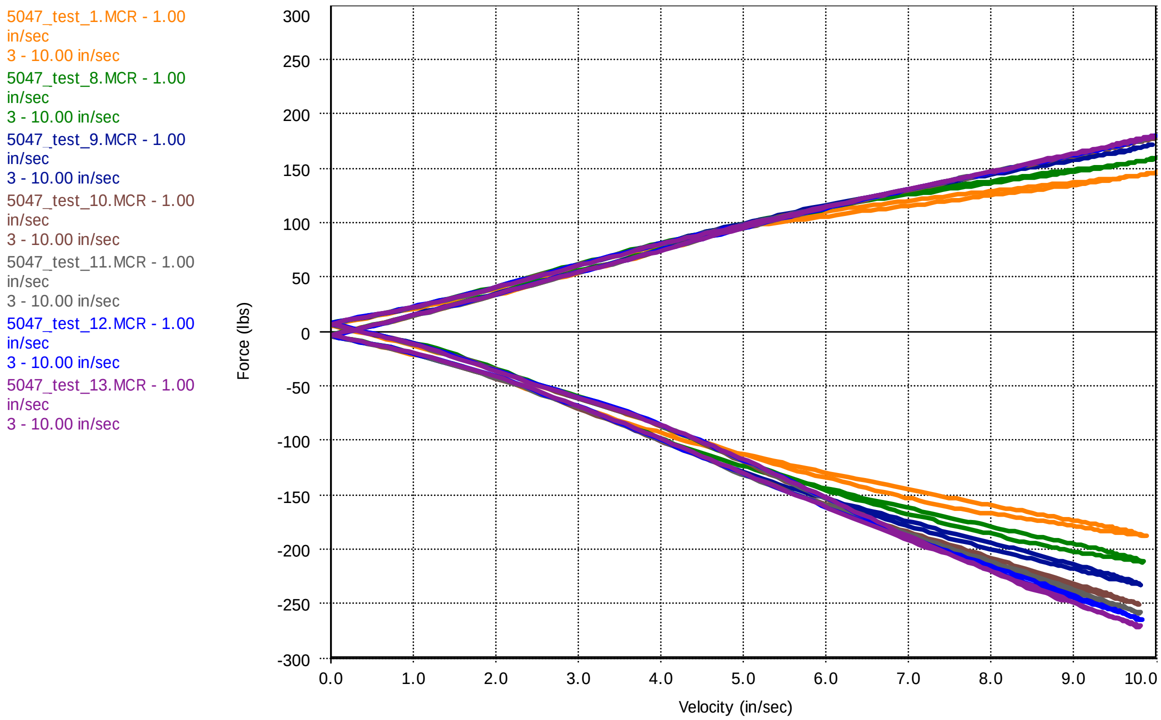

Figure 10. Double Barrel high-speed adjustability.

As can be seen in the previous two plots, the adjustability of these dampers is very well defined. Based on previous calculations and simulation the adjustment range of these dampers places them in the ideal range for the planned spring rates and suspension setup. This will allow much better fine tuning of the suspension and much better transient handling of the car. We are excited to be using these dampers for the 2006 car.