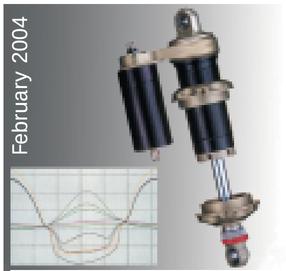


PENSKE RACING SHOCKS ENGINEERING

Quick Tech Sheet

Pressure Balancing of Shock Absorbers

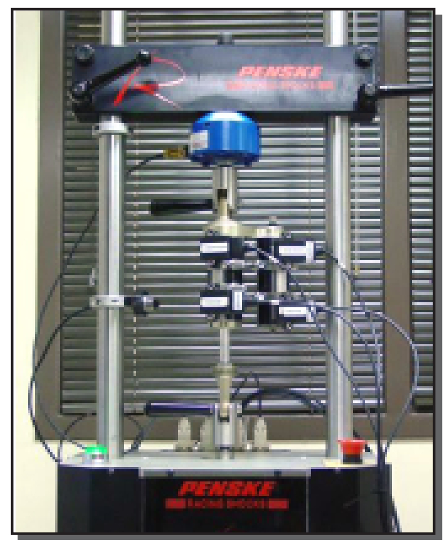
Introduction

The pressure balancing of shock absorbers is a new method of optimizing a particular damper set-up for a particular track or target velocity to reduce hysteresis and improve grip while still avoiding cavitation. Poor response of a damper can be equated to a lag in pressure across the main piston resulting from compliance in the damper including the compressibility of the oil. Hysteresis is reduced when pressure differences across the piston are reduced and when overall internal pressure levels are lowered. Reduction of hysteresis improves response of the damper and therefore enhances grip.

What is Hysteresis?

Hysteresis is lag in response of a damper usually due to compressibility of damper fluid from high pressures in the damper.

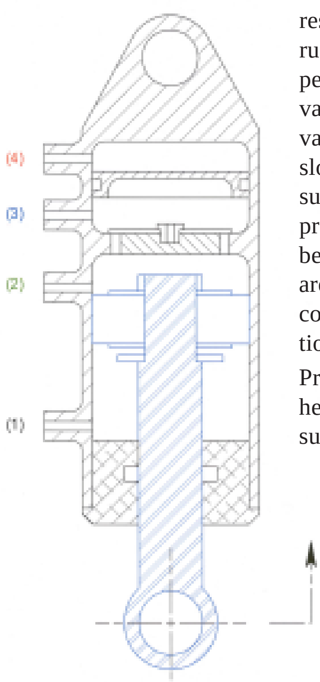
What is Cavitation?



A damper cavitates when the rebound pressure of the damper, while in compression, drops below the vapor pressure of the damper fluid or creates a vacuum. When this happens, dissolved bubbles in the fluid expand and cause voids in the damper fluid. These voids prevent the damper from functioning correctly because in order for fluid to flow through the piston, pressure must first build to a certain level. The pressure that is generated with shaft displacement must first collapse these voids before fluid flow happens which causes a lag or "dead spot" in the rebound damping during change of direction of the damper. The vapor pressure of most hydraulic damper fluids is approximately 0 psi. Rebound pressure of a damper can drop below 0 psi if a very heavy main compression stack is used on the piston without sufficient reservoir pressure, a head valve, or remote compression adjuster. This happens because the needed amount of fluid cannot pass through the piston in the time needed to replenish the void area and maintain oil pressure due to the stiffness of compression shims used. Instead of flowing through the piston, the "column" of fluid above the piston simply passes into the reservoir instead of being resisted and forced through the main piston to create force. If a damper continues to be used when cavitating, it will not produce consistent performance and the oil will eventually break down because of excessive shearing forces.

What is Pressure "Balancing"?

Pressure balancing is the method of making external and internal adjustments to the damper to achieve a symmetric pressure differential of compression and rebound pressures (i.e. the pressure differential across the main piston). This coincides with the percentage of overall compression force attributable to the head valve being **7-13%**. At 7% head valve damping, the damper will have the lowest hysteresis and quickest response while being able to run low gas pressures (50-70 psi). At 13% head valve damping, lower gas pressures may be run with less of a chance of cavitation then the 7% build. Ideally, 7% damping should occur at low velocities while the percentage ramps to 13% to avoid cavitation over bumps or high velocities while still running low pressures. A head valve producing **less than 7%** overall compression damping will cavitate unless higher gas pressure is used. A head valve producing **over 13%** will most likely never cavitate at any pressure used but will have increased hysteresis and slower response. This can be checked with a pressure-tapped shock as most dyno load cells will not have resolution at such low forces and friction may overshadow the results. When the pressure difference above and below the static pressure line is the same, it can be reasoned that they will both equalize in the same amount of time without one lagging behind the other. This improves response time of the damper which improves grip. Also, the less the overall pressures are, the quicker the pressure can be equalized and the quicker the response. The overall pressures in a head valve or compression adjustable damper tend to be less than a damper without because the needed gas pressure to avoid cavitation is less as well.



Pressure balancing is done by measuring pressure at 4 different locations inside the damper and making adjustments to head valve build, adjuster settings, main piston build, or a combination of all three to reduce internal pressures. Pressure tap locations are:

(1) Rebound side of the main piston (oil pressure) – between shaft bearing and piston

(2) Compression side of the main piston (oil pressure) – between main piston and head valve or CD housing

(3) Head Valve (oil pressure) – on exhaust side of head valve between compression shims of head valve or CD adjuster and reservoir piston

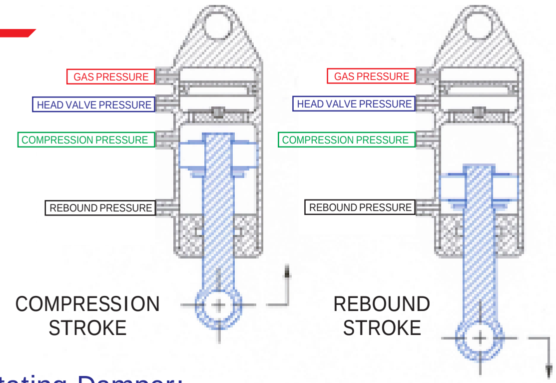
(4) Reservoir (gas pressure) – in gas reservoir

By evaluating pressure levels at these locations versus time while cycling the damper at a constant velocity, a good picture of dynamic pressure changes results. A graph of pressure versus time gives one direction in tuning the damper components to balance the damper.

KEY

GAS PRESSURE — COMPRESSION PRESSURE

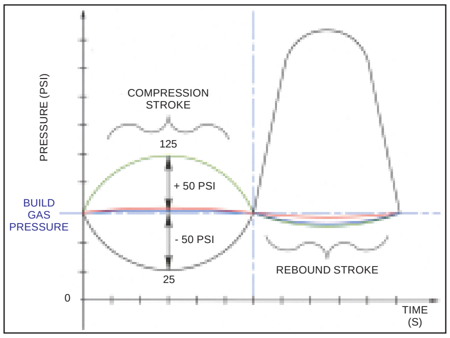
HEAD VALVE PRESSURE — REBOUND PRESSURE



Typical Pressure Balance Scenarios

1. (Ideal) Balanced Damper:

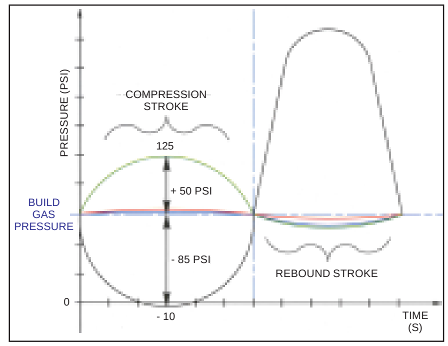
This set-up creates a symmetric damper curve with the rebound pressures above 0 psi. The curve shape is parabolic and smooth. Hysteresis is at a minimum.



Example: On the compression stroke, compression pressure increases to 125 psi from 75 psi while the rebound pressure decreases to 25 psi. A total pressure change across the piston is 100 psi. Rebound and compression pressures change by the same amount of 50 psi which is symmetric and maintains a low pressure which will keep hysteresis low and response time up.

2. Cavitating Damper:

This set-up may be somewhat symmetrical but the rebound pressures approach 0 psi. The damper will cavitate and is not optimized.

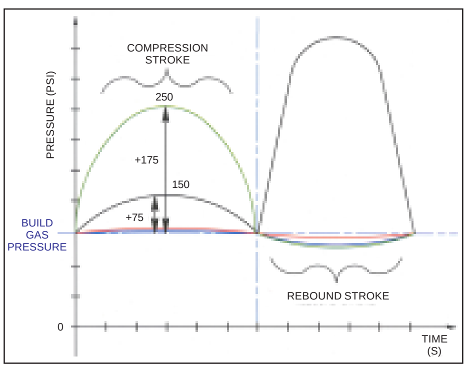


Example: On the compression stroke, compression pressure increases to 125 psi from 75 psi while the rebound pressure decreases to -10 psi. A total pressure change across the piston is 135 psi. Rebound and compression pressures change by different amounts and the rebound pressure drops below zero which causes cavitation.

Remedy: Add gas pressure/Stiffen Head Valve/Add High-Speed Compression

3. Excessive Head Valve Damper:

This set-up creates rebound pressures that are above the static gas pressure and is not symmetric because head valve stack is too stiff or compression adjuster setting is high. This damper will not be in much danger of cavitating but will have considerable hysteresis. May be an option for very smooth tracks and stiff springs with little damper displacement as low gas pressure can be run for reduced friction.

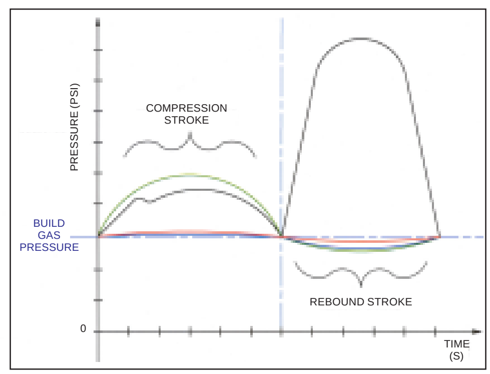


Example: On the compression stroke, compression pressure increases to 250 psi from 75 psi while the rebound pressure increases to 150 psi. A total pressure change across the piston is 100 psi. Rebound and compression pressures change by different amounts. Although the pressure differential across the piston is 100 psi as in the "ideal" damper, the pressures are much higher and they are not symmetric which will add hysteresis and slow response.

Remedy: Reduce Head Valve Stack/Soften High-Speed Compression Adjuster

4. Unstable Excessive Head Valve Damper:

This damper is very similar to the "Excessive Head Valve Damper" but has an unstable compression pressure curve. Usually, this can be attributed to a stiff head valve stack and a non-standard stack (all shims same diameter) or not sufficient bleed.

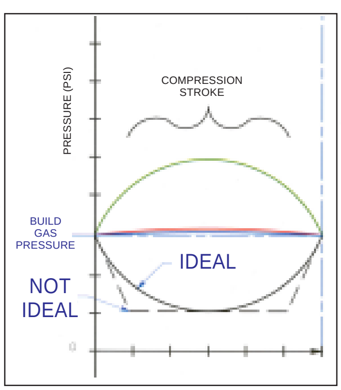


Remedy: Reduce Head Valve Stack/Soften High-Speed Compression Adjuster/Add Bleed

Other tips:

Curve Shape

Study the profile of the rebound pressure curve on the compression stroke. It is ideal to have a smooth, parabolic shape which indicates steady change in pressures. Abrupt, sharp slopes and corners or flat curve shapes indicate a harsh transition between pressures. Add bleed to adjust slope and shape.



Advantages of Pressure Balancing:

1.) Optimized Damper Response

2.) Reduced Hysteresis

3.) Increased Mechanical Grip

4.) Reduced Friction – Lower Static Rod Pressure (in most cases)

5.) Increased Oil Life

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