

Reading Shock Dynamometer Results

A fast race car is one that makes best uses of its tyres on a given race track. When a car hits a bump a tyre can unload and this reduces grip and increases tyre wear. Springs are used to absorb the energy from a bump so the tyre can work more effectively. A spring is an energy storage device that absorbs energy when it compresses then proceeds to release the energy in the opposite direction when it expands. A race car requires a shock absorber to both absorb energy from a bump, and dissipate the spring's stored energy over time. The force a shock absorber creates is dependent on the shaft velocity of the shock, and this shouldn't be confused with the velocity of the car itself.

The resistive force in a shock absorber is known as damping force and is measured in pounds force (lbf) or Newtons (N). The velocity of the shock absorber shaft is measured in inches per second (inch/s) or millimetres per second (mm/s). The conversions for these measures are shown below.

Initial Value	Desired Value	Multiply by
lbf	N	4.448
N	lbf	0.225
Inch/s	mm/s	25.4
mm/s	Inch/s	0.0394

A shock dynamometer (dyno) is a piece of equipment (Figure 1) used to display how the damping force of a shock changes with shaft velocity. The shock is fixed at one end, and attached to a vertical shaft on its opposing end. The vertical shaft is connected to a motor in such a way that as the motor turns, the shaft displaces vertically for a set distance. A load cell at the shock's fixed end is used to sense the amount of load on the shock and this is translated to a computer program. The motor runs through a set list of velocities, plotting how much force is being recorded at each velocity. The end result is a plot called the Force vs. Velocity Curve (Figure 2).



Figure 1 – Shock Dynamometer

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It is commonly accepted in circuit racing that shaft velocities between 0mm/s and 50mm/s are considered low speeds and contribute to driver feel and the car's body movements (sprung mass). Speeds between 50mm/s and 150mm/s are considered mid range shaft velocities and affect the car under braking, during fast changes of direction and ride harshness. Speeds from 150mm/s upwards are considered high speed shaft velocities and are concerned with absorbing energy from bumps and controlling energy from the vehicle's unsprung mass.

When a shock is compressed due to a bump, the damping force is called compression damping (or bump damping). When the shock extends due to the energy from the spring, this is called rebound damping. In our example of a Force vs. Velocity Curve (Figure 2), the compression damping is displayed in the top portion of the graph and the rebound damping in the bottom portion.

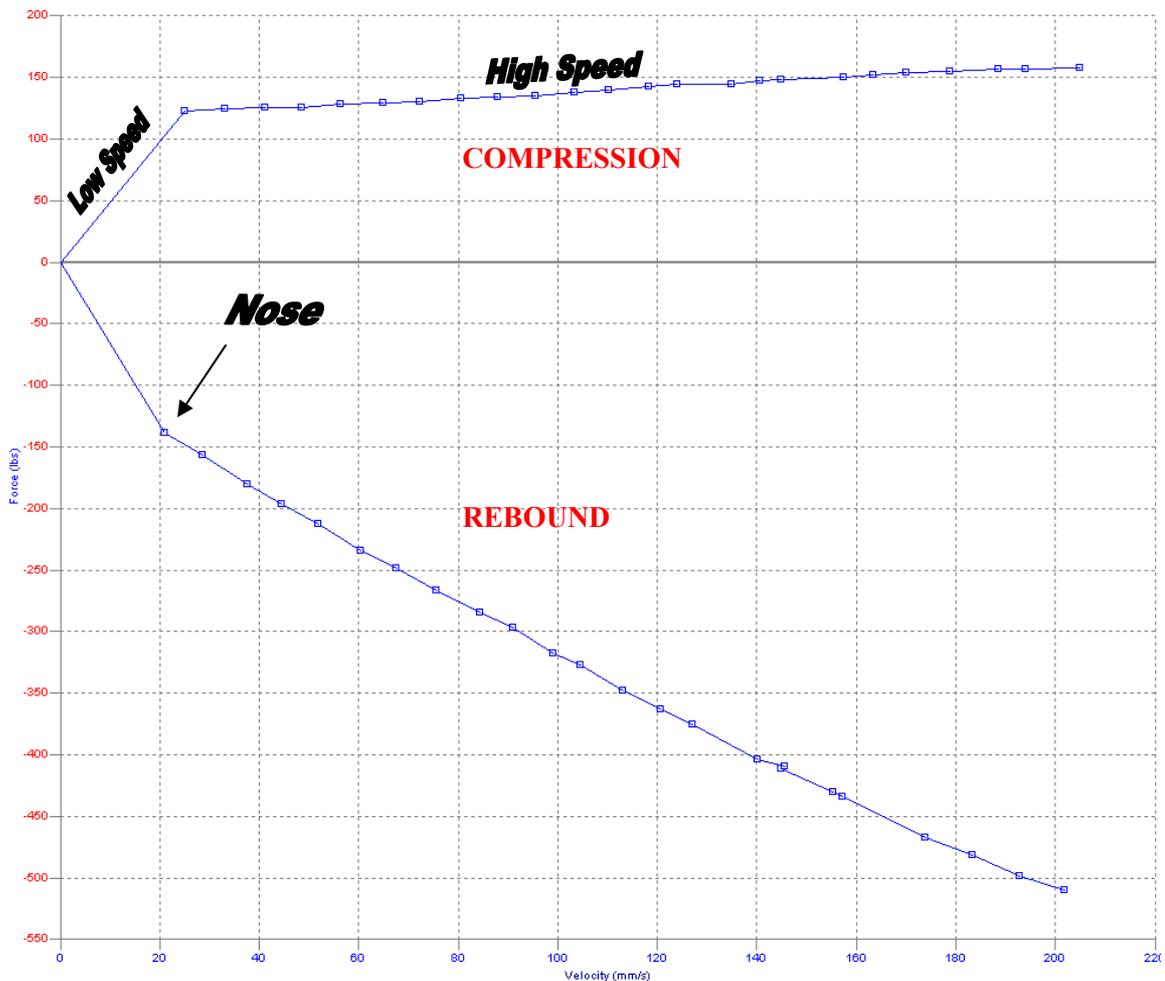


Figure 2 – Force vs. Velocity Curve

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The Force vs. Velocity curve shown in Figure 2 displays the Force on the vertical axis and the Velocity on the horizontal axis. As you read the velocity left to right the force will increase with velocity. The shape of the curve affects vehicle performance, driver feel and tyre longevity by improving tyre use, body control and bump control. The shape of the curve can be affected by a shock's piston type, internal shim arrangement, and adjusters that affect piston bleed and shim preload. The range of velocities displayed on the graph is not an indication of the maximum shaft velocities experienced by the shock absorber in practice, merely the range of most concern to a driver or engineer. A dyno can be set to display a larger or smaller range of velocities, and can display them in finer increments for more precise results (Figure 3).

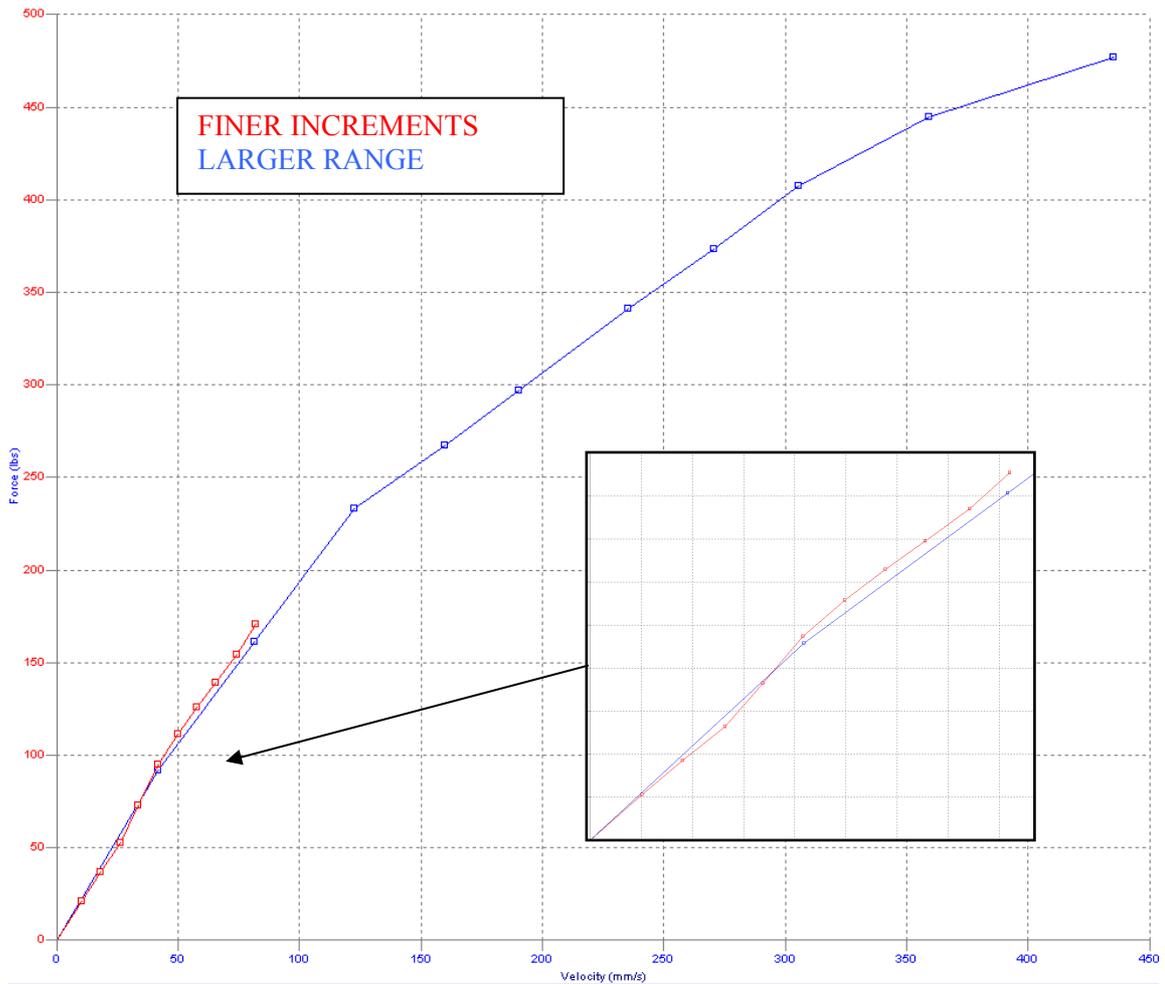


Figure 3 – Comparison of a curve showing a larger velocity range, and one showing finer increments

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The most notable characteristic from the Force vs. Velocity curve in Figure 2 is the curve has two different phases, or slopes. The first slope is the low speed phase of the curve, and the second slope is the high speed phase of the curve. The point of transition from the low speed curve towards the high speed curve is called the “nose”. The shock has this characteristic as a damping curve is a compromise between grip, support, tyre longevity and ride quality. Splitting the curve into two phases reduces the compromise leading to a more balanced and better performing vehicle. Figure 4 below shows how a shock splits the curve into two phases. For low shaft velocities, fluid is bled through a hole in the piston, and once the flow through this hole is choked, pressure then builds up on a shim stack located on the face of the piston, eventually forcing them open, allowing fluid to flow through a larger area, decreasing damping forces.

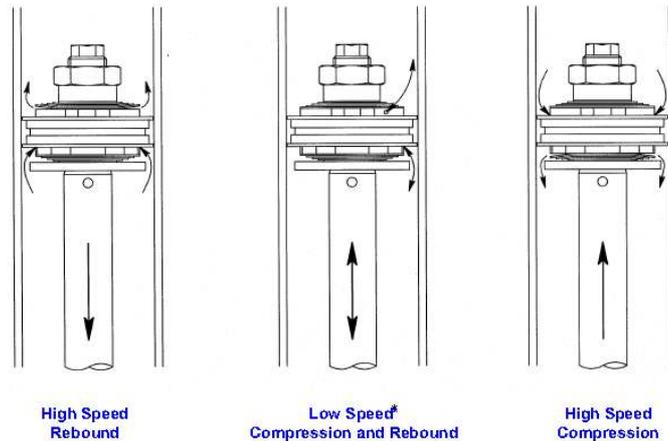


Figure 4 – Variation of low and high speed forces using a bleed orifice and shim activation

The curve characteristic can then be further tuned by using various types of pistons. The three most common are the linear, digressive and progressive pistons. A comparison of the curves these pistons create is shown below (Figure 5).

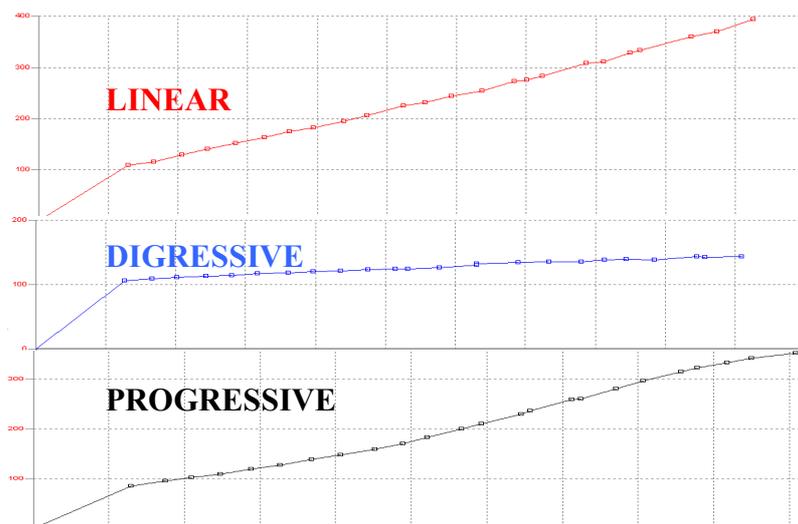


Figure 5 – Comparison of damping curves for linear, digressive and progressive pistons

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The dyno can also be used to output a Force vs. Displacement graph (Figure 6). This graph shows the force a shock generates as it travels through its motion in both the compression damping and rebound damping phases. Force is shown on the vertical axis, and is measured in lbf or N, and displacement is shown on the horizontal axis, measured in mm or inches. Quadrant A displays the shock's force as it is accelerated in bump, quadrant B as it is decelerated in bump, C as it is accelerated in rebound and D as it is decelerated in rebound. This plot can be used to troubleshoot a shock you are having issues with, or to ensure hysteresis levels are at an acceptable level. Hysteresis occurs when the damping forces are higher as the damper is decelerating compared to when it is accelerating, and will decrease the effectiveness of the shock. This effect can be seen in Figure 7, where the damping forces in quadrant B are higher than in quadrant A. Hysteresis is the primary reason that a shock should be valved to be used in the middle of its adjustment range, as hysteresis is significant when you use the stiffest adjustment settings.

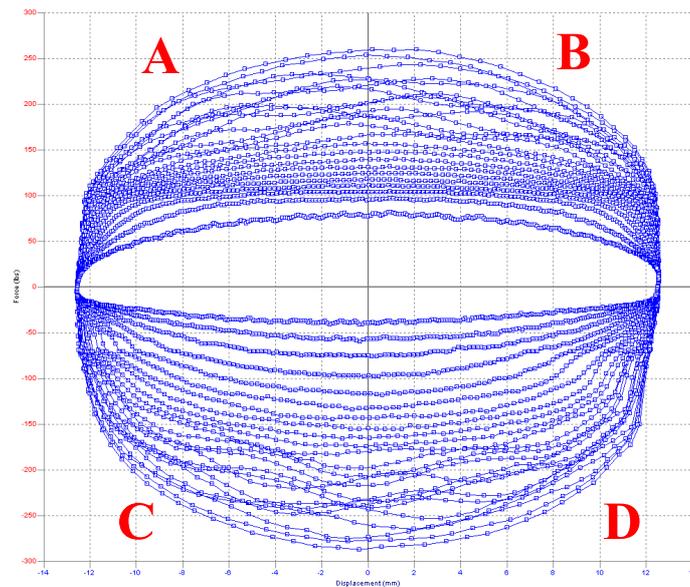


Figure 6 – Force vs. Displacement Plot

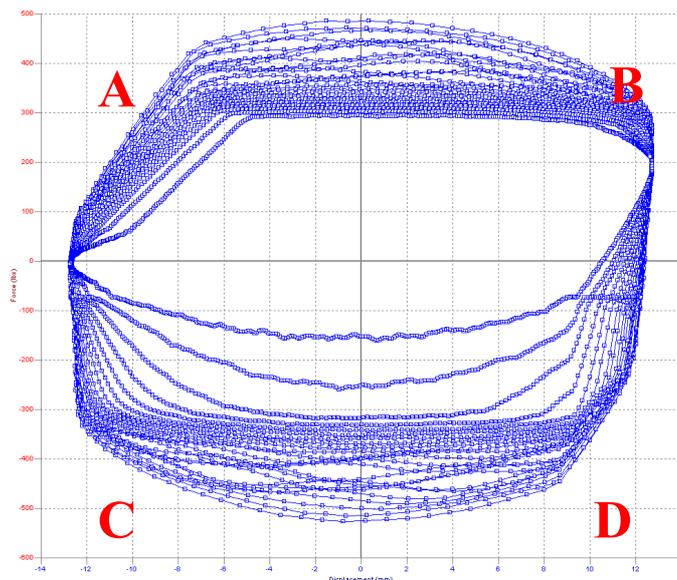


Figure 7 – Force vs. Displacement plot showing hysteresis

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The Force vs. Displacement plot can also be used to find a fault with your shocks. For example if the shock is damaged in a crash, bending the shaft slightly, then the plot will show a spike as it will take larger amounts of force to move the shock through the bent region of the shaft. Figure 8 shows a significant amount of resistance in the accelerating bump phase of the plot, indicating a significant problem with the shock. If a car is run with this shock it will experience grip issues on bumpy tracks in minor cases, and loss of vehicle control in major cases.

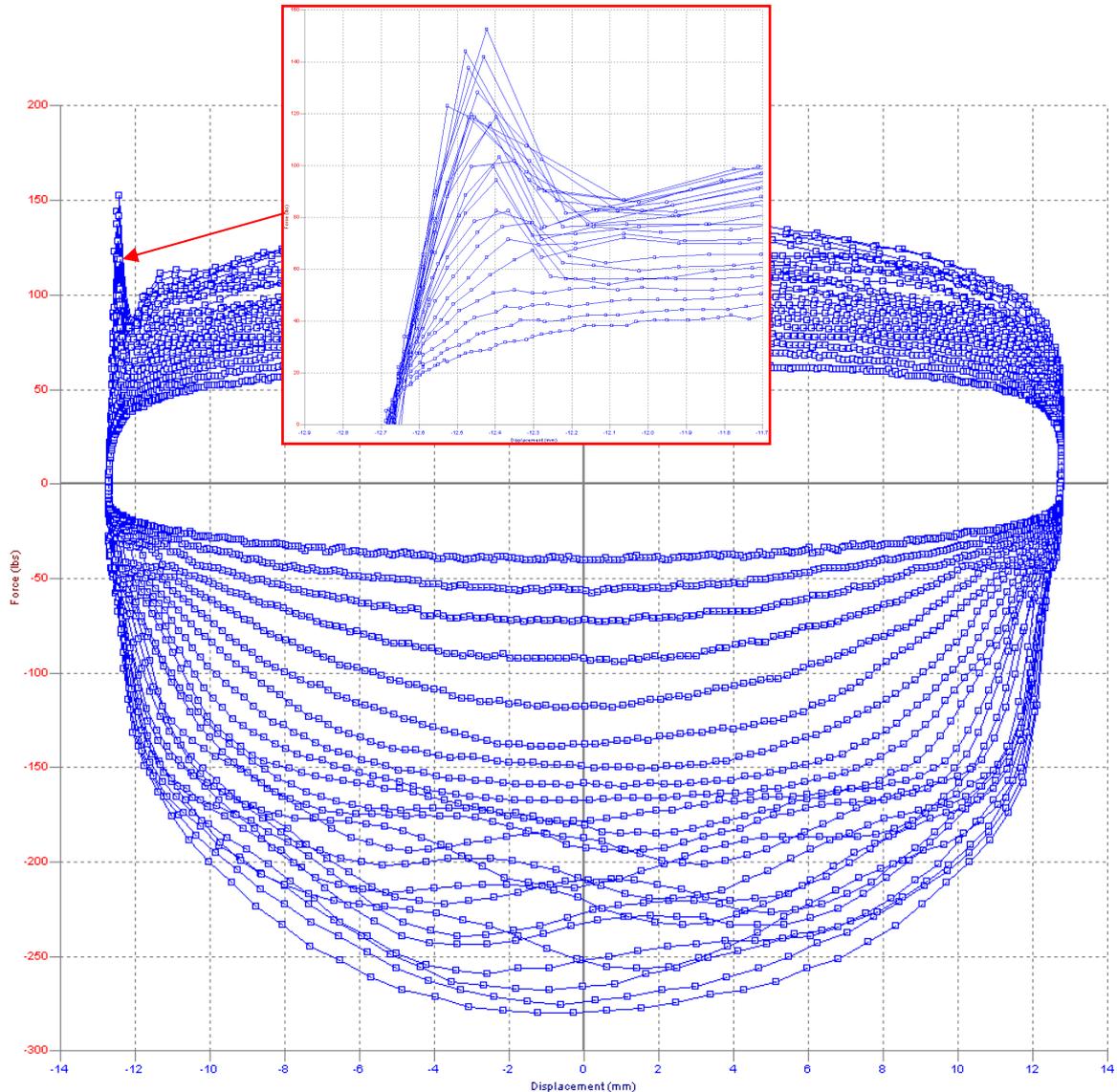


Figure 8 – Force vs. Displacement plot showing a problem with the shock

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The dyno can also be used to identify what sort of adjustment system your shock has and how those adjustments will affect the damping curve. The three main types of external adjustments are high speed preload on an external canister, low speed bleed on an external reservoir, and bleed adjustment.

The graph below (Figure 9) shows the results of changing a high speed adjuster, which will vary the preload of the shock's internal shims. You can see that as you increase the high speed adjustment, the slope of the high speed part of the curve stays the same, but the forces are becoming greater at each velocity. Also note that this adjustment raises the "nose" of the graph, affecting the low speed curve.

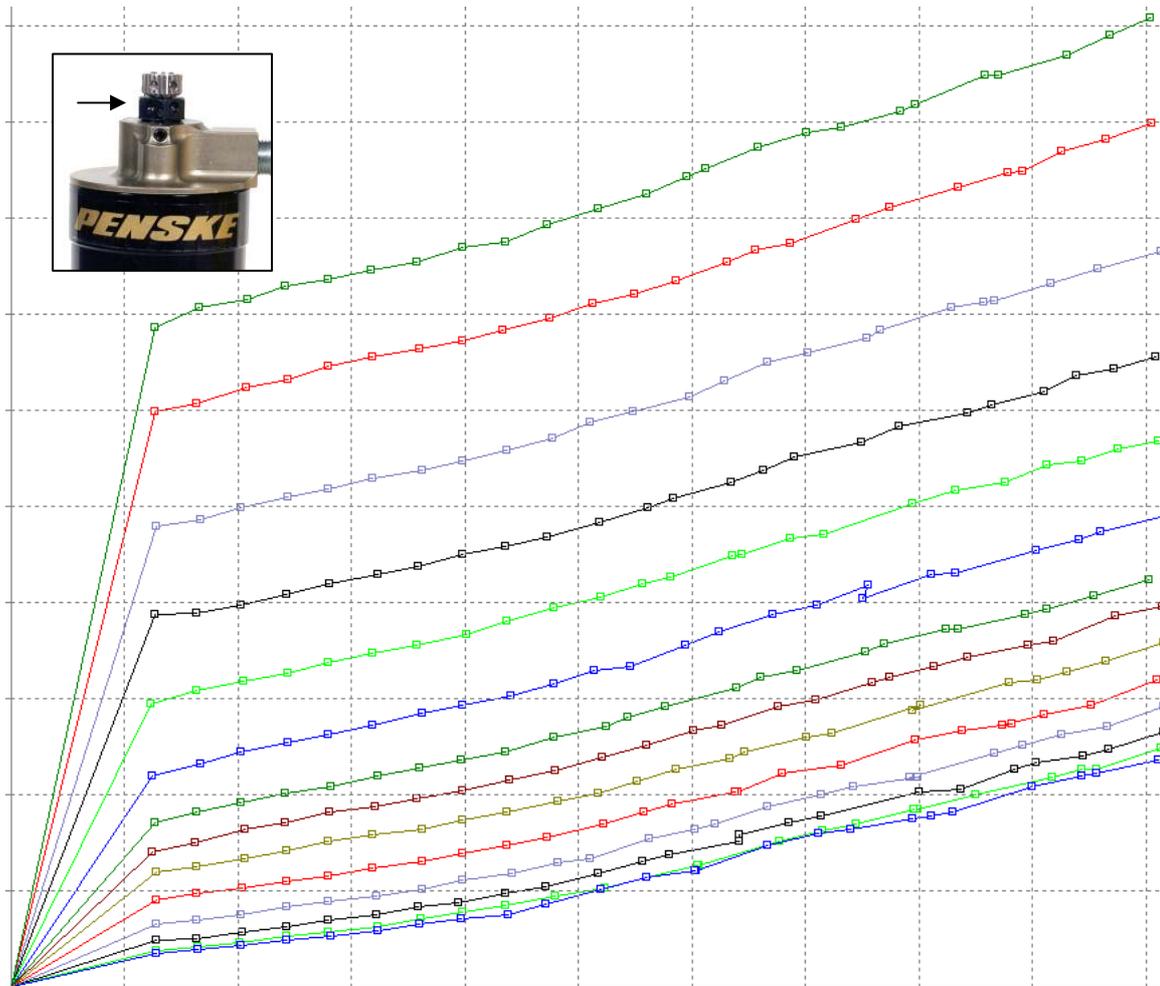


Figure 9 – Canister High Speed Preload Adjustment

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Now imagine you have set the high speed adjuster to a constant value, then the graph below (Figure 10) shows the effect of using a low speed bleed adjuster on an external canister. As the bleed adjuster is opened, the “nose” of the curve drops incrementally. This adjustment can help with controlling the vehicle’s rate of roll and pitch. As you can see, combining a preload adjuster with a bleed adjuster creates a very powerful tuning tool.

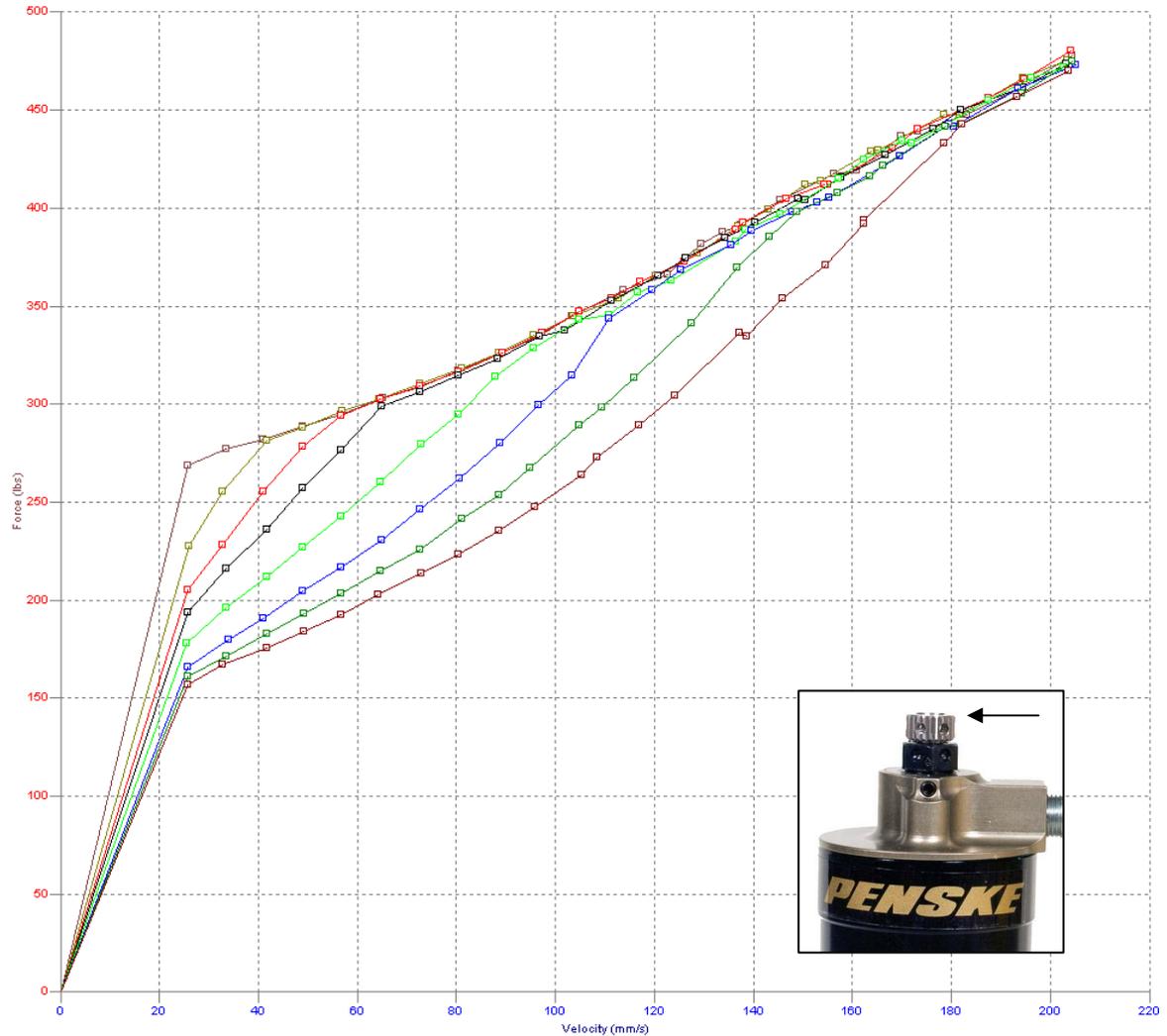


Figure 10 – Canister Low Speed Bleed Adjustment

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The next graph (Figure 11) shows the effects of changing piston face bleed via a shaft adjustment system. As the bleed jet is opened, the low speed part of the curve is changed significantly, allowing quick changes to be made from track to track to enhance grip in bumpy corners or provide more support on smoother tracks, without the need to revalve the shock.

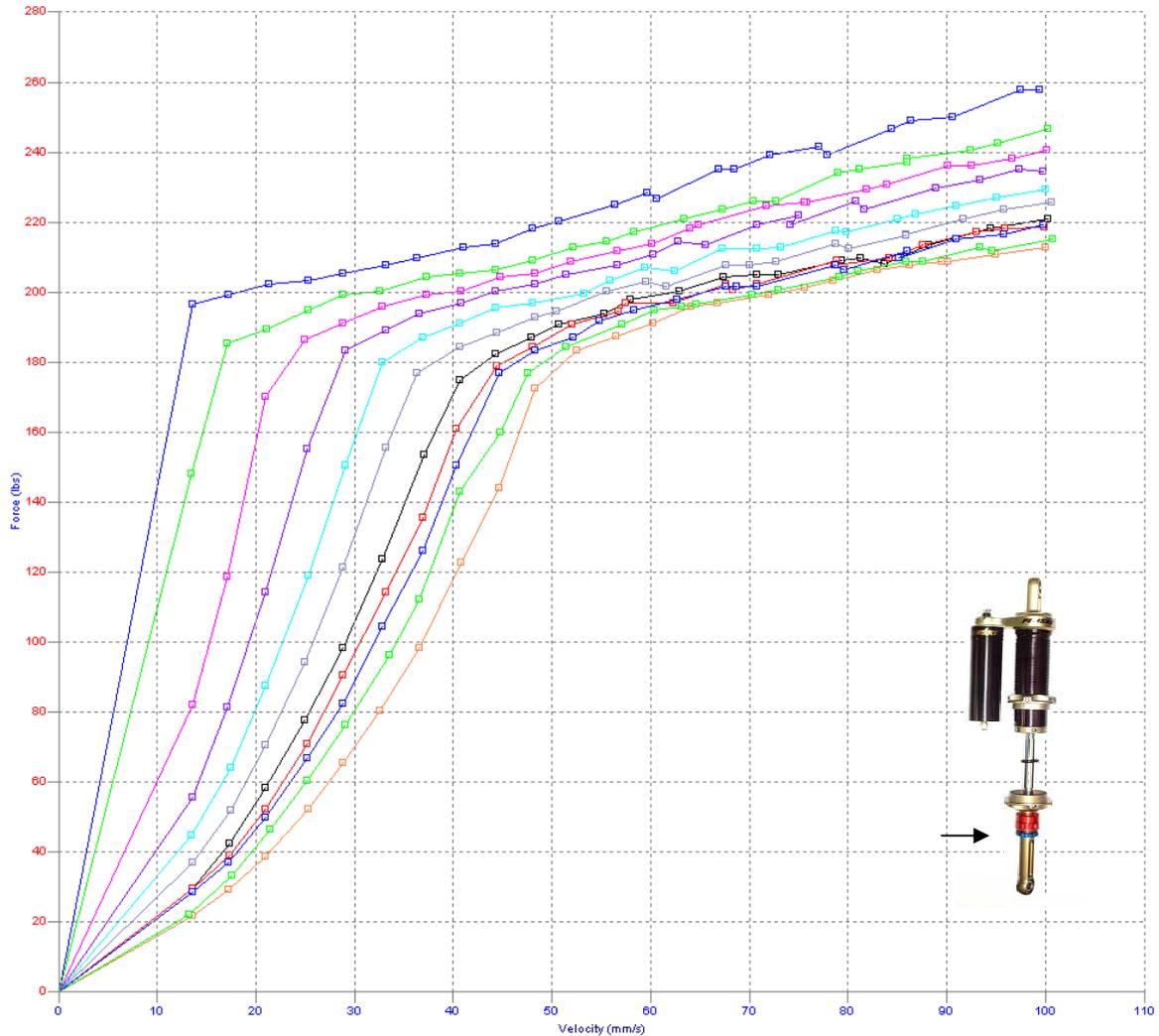


Figure 11 – Low Speed Shaft Bleed Adjustment

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When all three adjustments are combined into one shock, there is the opportunity to allow very significant changes to the Force vs. Velocity curve without the need to open the shock. The preload adjuster allows you to set the high speed damping, then canister bleed allows you to tune the car's low speed curve, and lastly the bleed adjuster allows to tune for initial low speed damping.

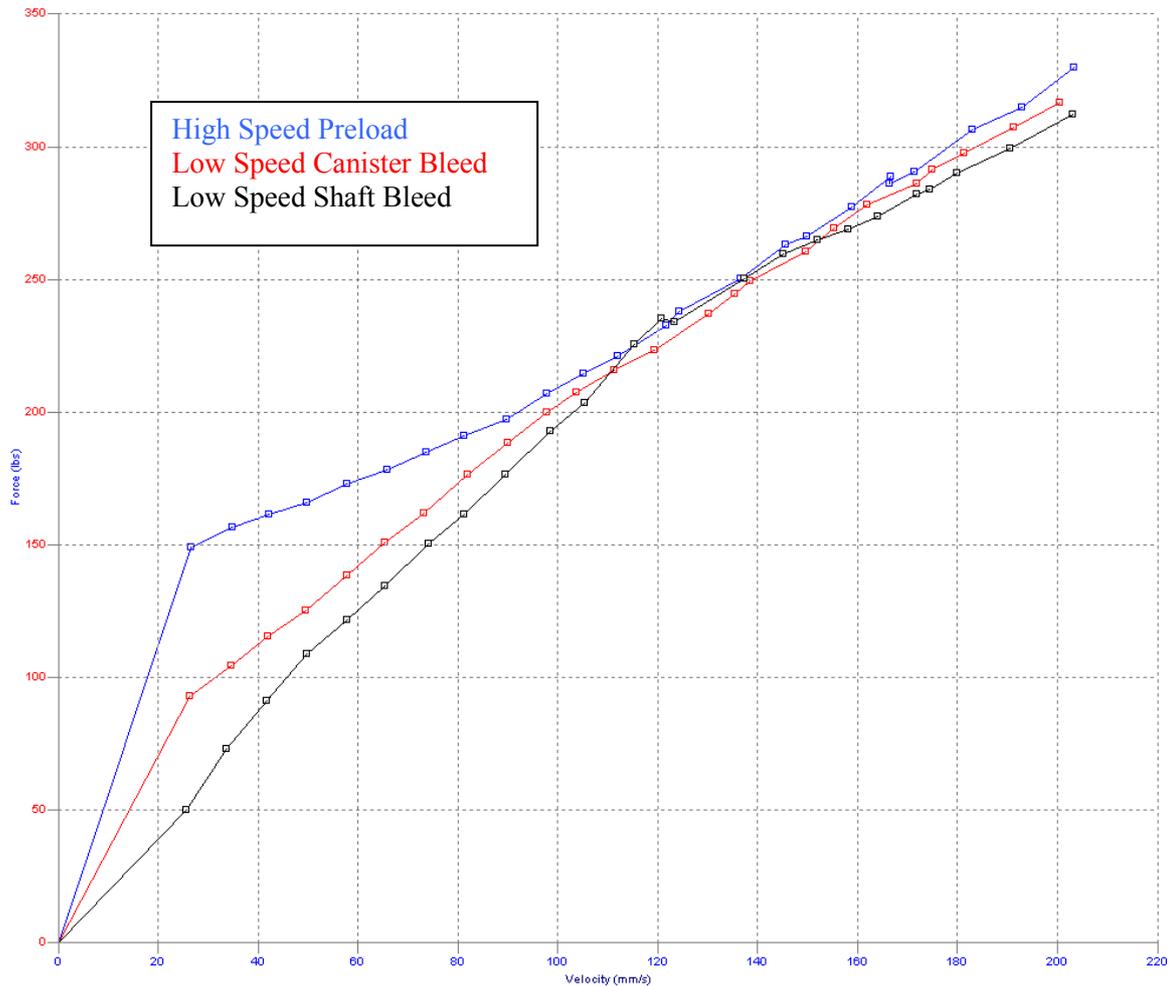


Figure 12 – Comparison of canister and shaft adjustments

If you have any questions or queries please ring (08) 8362 4417 or email to penske@nttyres.com.au