SPRINGS

The primary & most relevant trait of all springs is a term called ***'rate'*** . Rate is the indicator of stiffness or softness of any given spring. Specifically, rate is the amount of force (or weight) it takes to deflect, or compress, the spring a given distance. It's form is force/distance. I tend to still use **lb/in,** but feel free to express rate in the form that suits you, **Kg/cm** or **N/mm** is the ***SI*** standard.

Lets consider a relatively stiff racecar suspension spring fig. 1

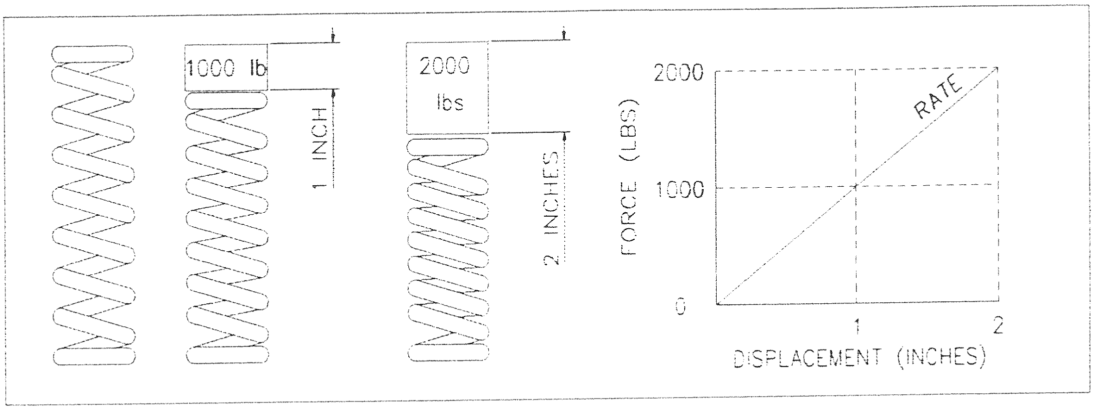


Fig. 1

The free length of the spring is measured & considered as zero. A load of 1000 lb is applied to the spring & the displaced length is measured & found to be 1 inch. A load of 2000 lb is applied, re-measured & found to be 2 inches. Each time we remove the load or re-apply the load the displacements are duplicated. If we plot the results on a force vs displacement graph. It will give the results shown in fig. 1.

As we mentioned before, the results duplicate one another each time we re-test, whats more, the results are same when we apply the load, as they are when we remove it. This simple test teaches us two fundamental rules, one, the force of the spring is proportional to it's displacement, a law that was first discovered in 1676 by Robert Hooke & is now referred to as ***'Hookes law'***. Two, because the displacement is the same as we remove the load the spring is said to have little or no ***'Hysteresis'***. Most springs & torsion bars if not stressed past their elastic limit usually portray these two ***'linear'*** & reliable laws.

The need for dampers on vehicles becomes evident when considering the continuous ***'oscillations'*** of motion portrayed by a simple extension spring and the momentary displaced mass connected to the spring as shown in fig. 2

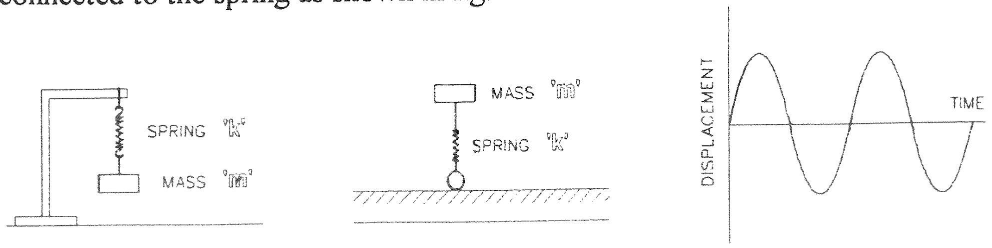


Fig. 2 a b c

This is called ***'simple harmonic motion'*** and occurs at the ***'natural frequency'*** and is common in many engineering situations.

The need to reduce this motion is why dampers play an important role.

Remember the famous VW advert that shows a Golf dropped from about 2 metres, well had this vehicle not had dampers, theoretically, and ignoring friction, the vehicle would returned to its initial dropped height and what's more would have continued to do so. In reality mechanical friction and friction due to a body passing through air ***(aerodynamic drag)*** would've slowed these motions - eventually.

Try it! Find a relatively soft extension spring & hang a mass that gives it an approximate 50% length increase at rest. Next, hang the extension spring from a stable hook, or similar, displace the the mass gently & let go go. Notice the motion of the system relates to the graph shown in fig.2c. With a stop watch, count the amount of cycles completed in 10 seconds, repeat this 3 or 4 times and record the results. Average your results and then divide the answer by ten. This gives 'cycles per second' also known in engineering as ***'Hertz'***.
Change the mass hanging from the spring & re-evaluate.

DAMPING

Dampers play a significant role in suspension systems.

If we add a damper to the system shown in fig. 2, the results can be clearly seen in fig.3c This type of decrease in motion, velocity and force is commonly known as ***'decay'***.
The rate of decay can be altered by increasing or decreasing the damping.

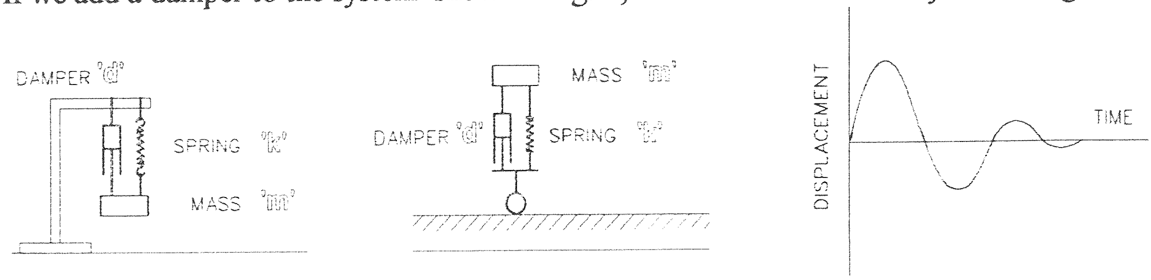


Fig. 3 a b c

Orifice damping is one of the ways of creating a resistance to motion which is dependant on the speed at which you pump the fluid through a hole. More or less, we can consider the oil as an 'incompressible fluid' or a near solid, this means we don't need to worry out the 'springyness' of the fluid. If we pump fluid through an orifice (fig. 4) the type of characteristic given by the system would be such that the force would increase with velocity. In fact, the force increase is proportionate to the square of the velocity i.e. F/V^2 This is commonly referred to as an ***'exponential'*** characteristic (fig. 4).

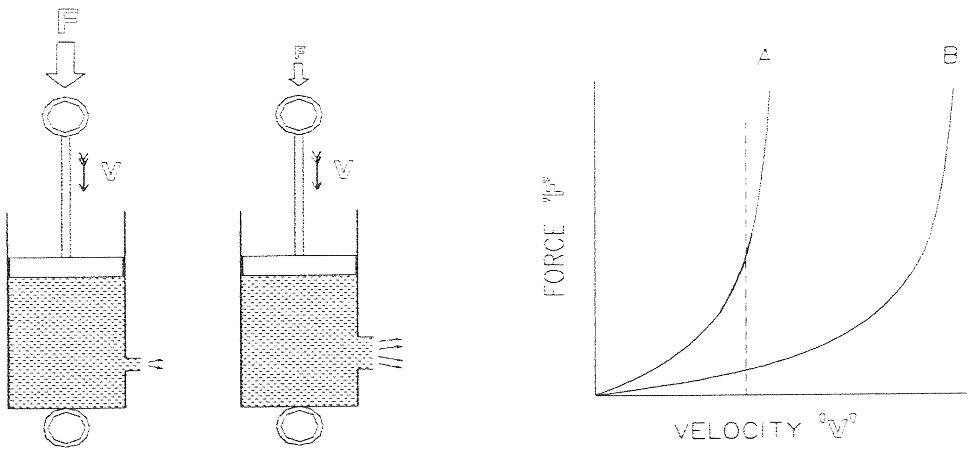


Fig. 4 a b c

If we reduce the size of orifice, an increase in force at the same velocity is shown, this can clearly be seen in fig. 4c by the dotted line.

As the fluid is compressed heat is generated in just the same way as a bicycle pump warms during the compression of air. This heat is then 'hopefully' dispersed around the system and finally dissipated into the airstream surrounding the unit. This is termed as 'energy transfer'. *Generally speaking,* the energy required to slow the motion of spring and mass system is converted to heat and cast into the atmosphere.

Unfortunately, pure orifice damping, or exponential damping is not the 'be all' or 'end all' of suspension systems.
Consider the VW Golf with exponential damping. The moment the vehicle hit the floor the orifice would quickly 'choke' due to high velocity of the whole car decelerating. All that force would be transmitted through the dampers and into the damper mounting points leading to deformations & possibly breakages. So, we need a way of controlling the high speed damping with not quite so high increases in force, and have the ability of altering it for different spring and mass arrangements. This is introduced into the damper in this form of spring steel shims and can be shown pictorially as shown in fig. 5. The approximate effects are also given.

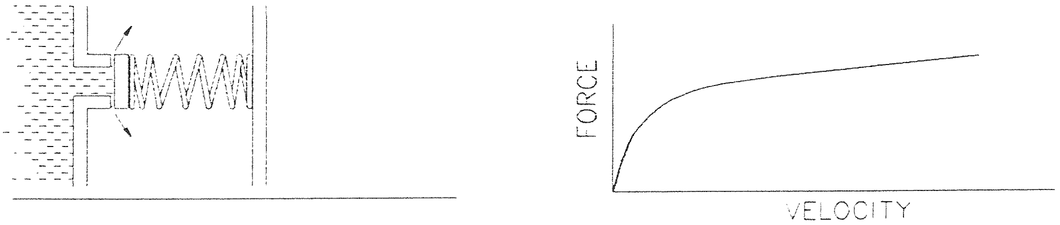


Fig. 5 a b

Combine exponential (orifice) damping with high speed (shim and port) damping and one arrives at the conventional 'Race Car' damper as seen commonly today.
A pictorial portrayal of each / and is given in fig.6

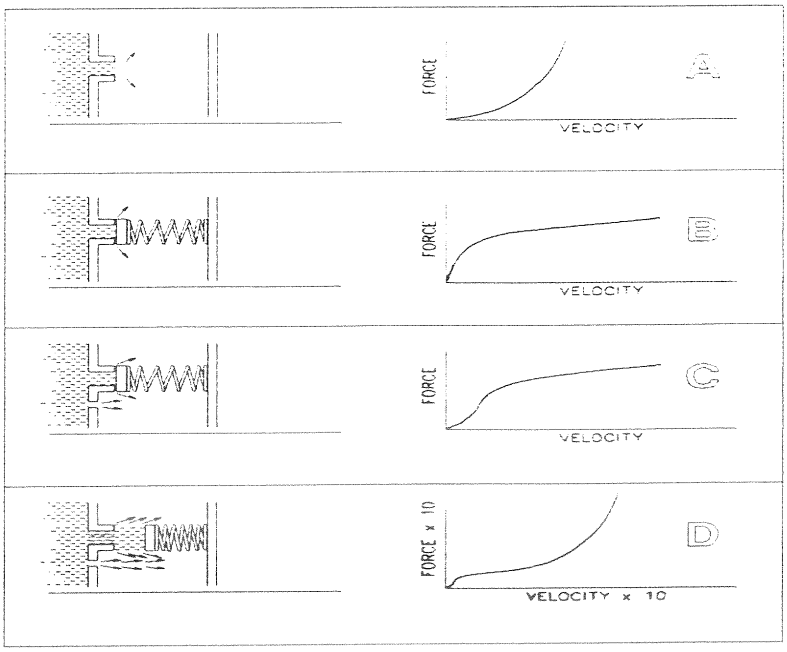


Fig. 6

As you can see, a system such as that shown in fig.6c might be what you expect from a typical Dynamic Suspensions damper. Fig 6d shows the effect of the damping when the ports in the main piston eventually choke. Such characteristics are of importance when considering high velocity applications such as rallying or Moto cross.

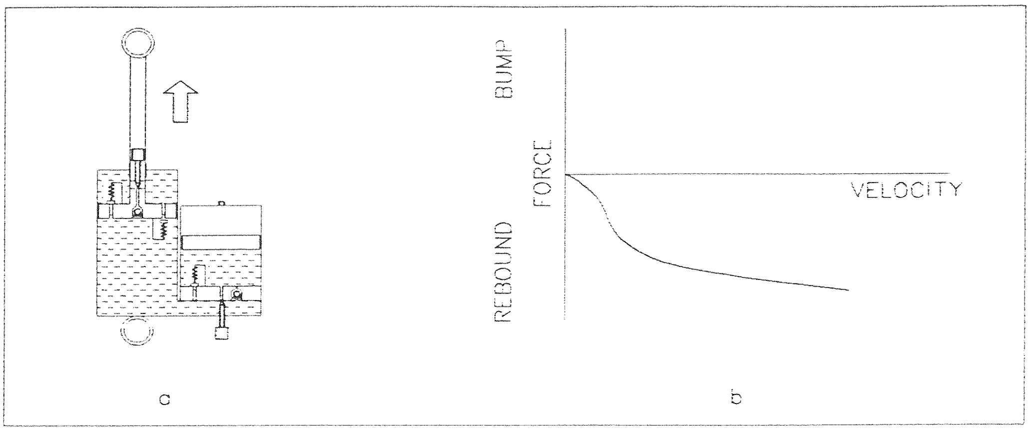


Fig. 8

QUESTION: This might look similar to rebound as fig.8 but, why does this (fig. 6c) look nothing like our compression damping?
ANSWER: If we were to consider the CV only then this would be exactly the same type of characteristic apart from it being on a much lesser scale due to the fluid movement being only that equal to the shaft volume displaced.

Try it ! **fill a glass to the brim with water and place into a measuring jug. Place a utensil into the glass and imagine this represents the shaft of a damper entering the body. The fluid that overflows the glass and is now in the jug represents 'shaft volume displaced fluid' and something we have to constantly consider.**
Change the diameter of the utensile & re-evaluate. Note the difference in volumes. This difference is one we have to consider when using different shaft diameters.

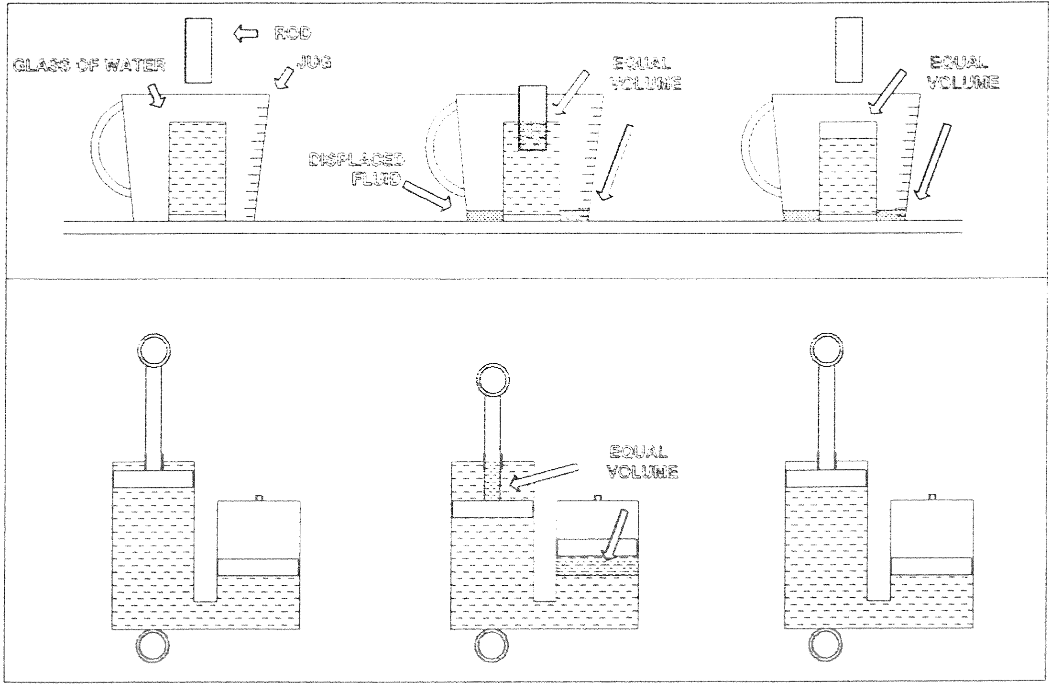


Fig. 7

In compression, if we consider the CV only, it would again compare nicely to fig.6a, b and c. But we've added another flow path restriction in terms on main piston valving. Fig.9.

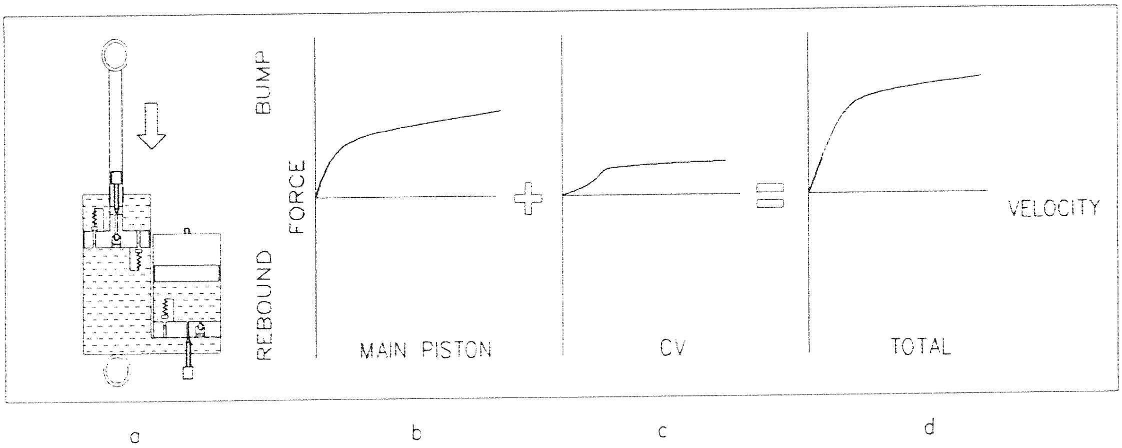


Fig. 9

In general terms **CV** + **main piston** = **resultant curve**. When we add all these elements together in compression it becomes difficult to understand which part of the damper effects which part on the resultant curve, but not impossible

WHERE TO LOOK

Firstly let's consider some of the common problems that occur in all sorts of dampers Fig.10 shows general areas that needle and jets operate within a damper.

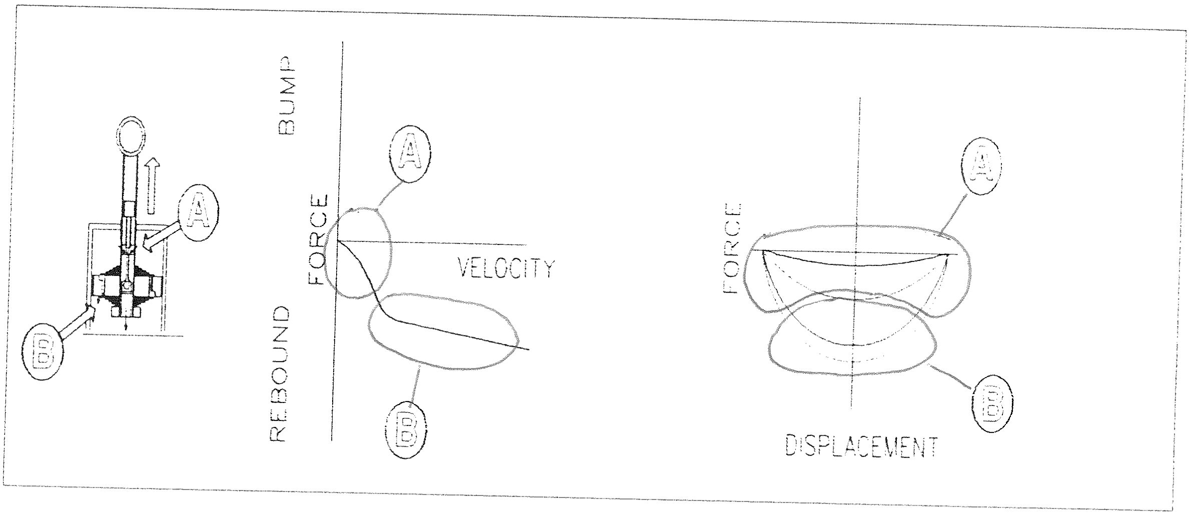


Fig. 10 a b c

TROUBLE SHOOTING

Let's consider some problems in rebound: fig. 11 and 12

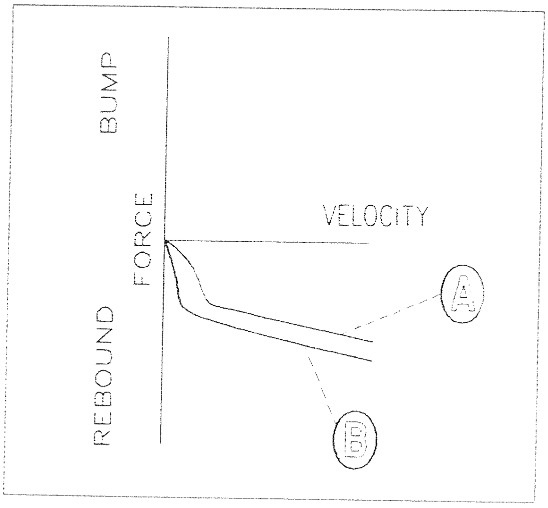


Fig. 11

A has been an overall parallel offset to **B.** This clearly shows that **A** appears to have a slightly larger bleed past the piston (could be in the form of an incorrect click on the adjuster or even a piece of debris under the shim pack valving).

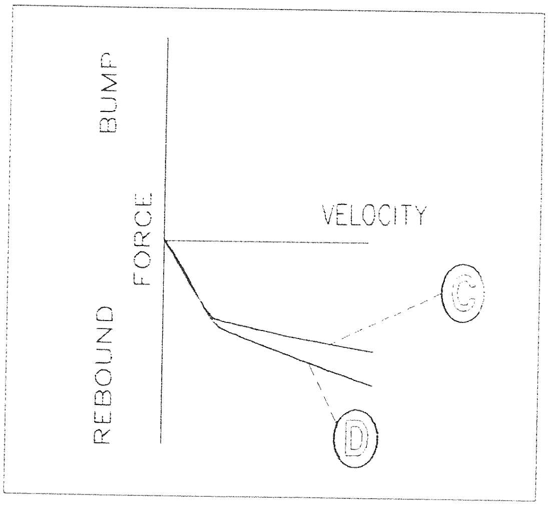


Fig. 12

At low speeds the bleeding past the main piston of **C** and **D** is quite comparable. However, at high speed the rate of high speed damping has changed.

This shows that the internal 'high speed' valving is stiffer in **D** compared to **C**. This can be caused by an incorrect thickness of one of the shims or the point at which the shims are bending is shorter or the effective area acting upon the shims is smaller.

Too stiff high speed damping

Fig. 14 shows the possible causes for stiffer rate high speed damping.

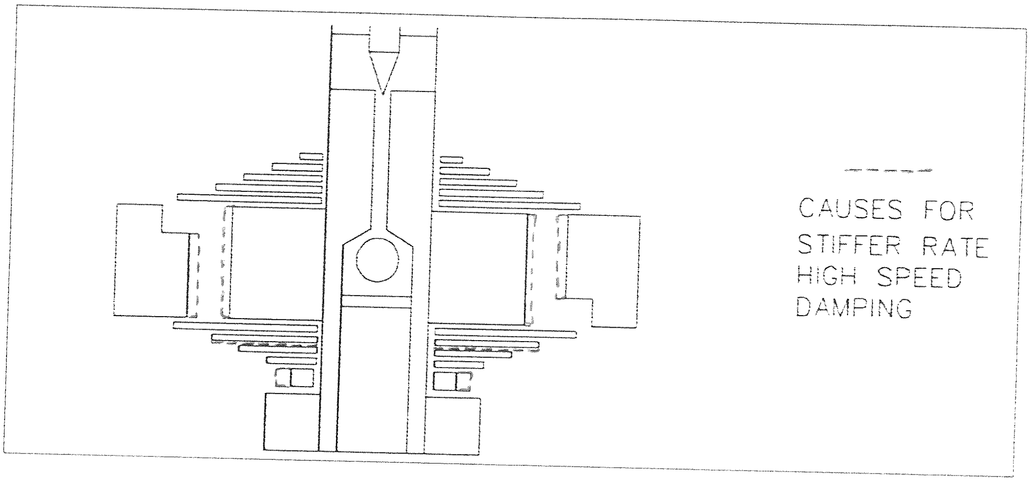


Fig. 14

To analyse problems in compression some fore thought is required. We have established in fig.9 that main piston and CV damping equals the resulting compression characteristic.

To best analyse the compression characteristic, first we have to isolate it between the main piston and the CV, ideally the CV is tested alone using a shimless and ported main piston. Also all needles and jets must be first flow-checked prior to initial assembly. Unfortunately time doesn't always allow a complete strip-down of the damper and individually test. Bear in mind that to have a ported piston and shaft readily available for each shaft and piston diameter could prove a useful tool to firstly test CV's. Should time be of the essence, one way of approximately testing 'main piston only' damping is to open (to make soft) as much as possible the CV damping, thus making the flow path restriction as little as possible.

Jacking of reservoir piston

A common complaint found in 'in-line' dampers is the effect of 'jacking' of the reservoir piston. The secondary effect of this is cavitation on the low pressure side of the main piston. Two arrangements are shown in fig.16.

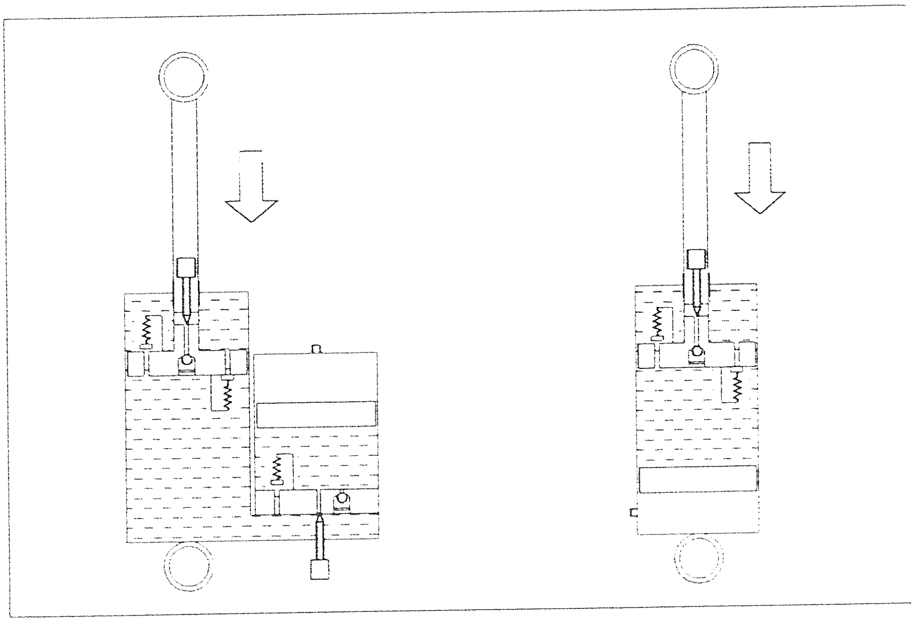


Fig. 16 a b

In fig.16a a restriction exists between the main body & the remote reservoir seperator piston in the form of the CV arrangement.

This restriction creates a pressure drop between the main body & the reservoir piston, thus reducing the force acting on the seperator piston. On an 'in-line' damper there is no restriction & so a large pressure drop across the main piston can lead to a depression above the main which then in turn jacks the reservoir piston.

Rebound check ball not sealing

Should the rebound check ball become worn, the seating land not smooth or a piece of debris become logded between the ball and it's seat the following characteristics might be shown as in fig.17 B.

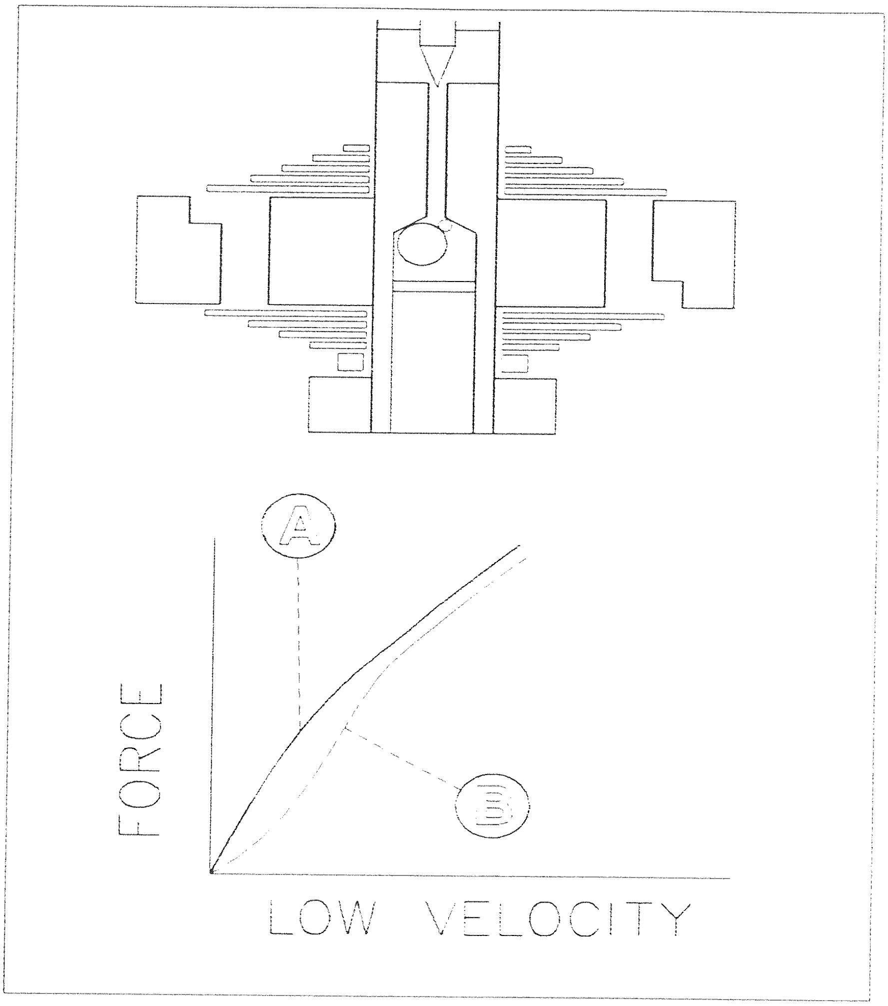


Fig. 17

In compression A shows a fully seated check valve, however B shows a trend of bleed bypass.

Squeeze film

Some early designs of pistons have a large areas of land on which the shims lay. This leads to a problem called ***'Squeese film'*** . The shimpack is pressed against the area of land on the piston and forms a sealed joint. Similar to the effect of 'ringing' two slip gauges together. As the force acts upon the shim pack through the piston the seal is eventually broken & high speed damping resumes as normal. This effect is clearly seen on force vs displacement graphs at very low velocities in the form of a ***'spike'*** as shown in fig.18.

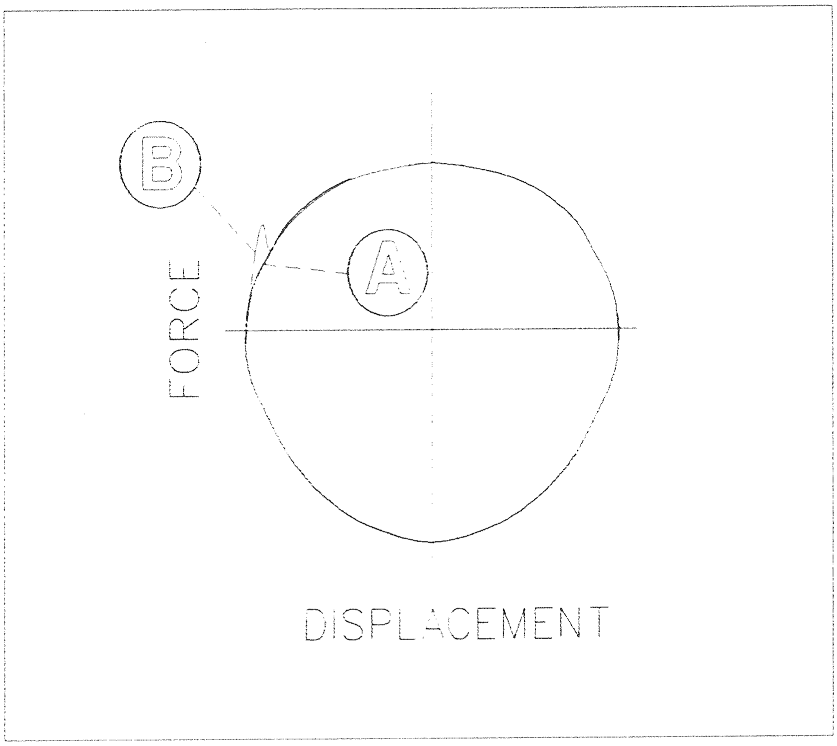


Fig. 18

Curve **B** shows the characteristic of the *spike* & where to look for it should one be concerned this problem might possibly exist. Curve **A** shows the characteristic of the same piston with a great deal of seating land removed.

CV inconsistencies

Widersprüche

bewerten

As discussed earlier CV's & main piston valving characterisics can be assessed seperately if you understand the areas in which they operate. Fig.19 shows a problem with damping at a fu stiff setting. At full soft the damping characteristics of the two dampers are comparable. The CV valve is wide open at this stage & has little effect over the damping range. At full stiff (induced by the CV valve) the curves of the two dampers are different, suggesting the difference in damping is in the CV valve itself.

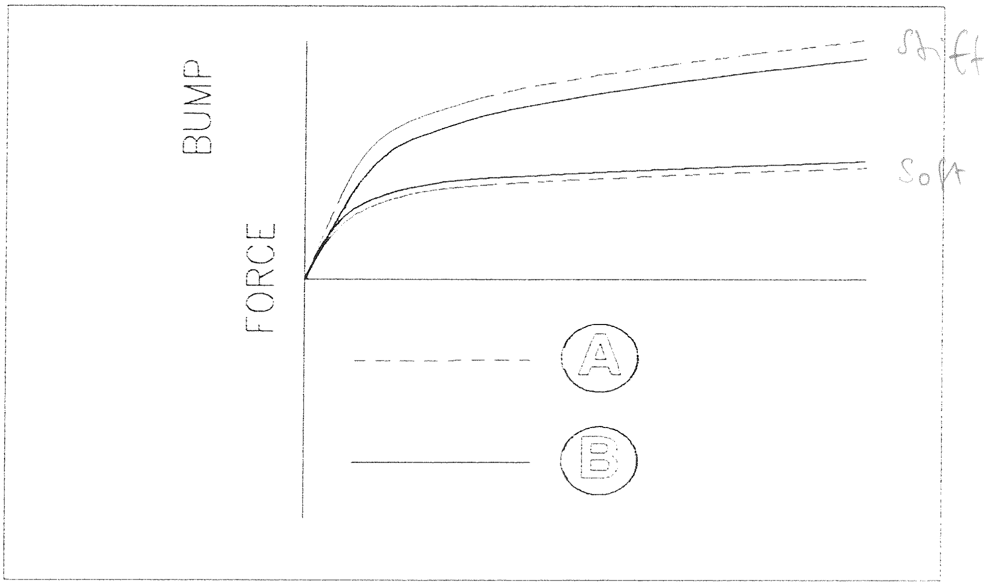


Fig. 19

Reservoir volume too small

Should the volume of the gas chamber be relatively small compared to that of the shaft then an additional spring rate can be noted on the force vs displacement graph. The force at BDC & TDC should be identical. Should there be an increase in force at TDC then the damper is said to have an additional spring rate. Most dampers have a slight spring rate due to the volume of nitrogen gas being compressed. The amount of acceptable rate depends on the application. Fig.20 show two examples of small **(A)** & large **(B)** spring rates incurred by this effect.

Zusätzliche

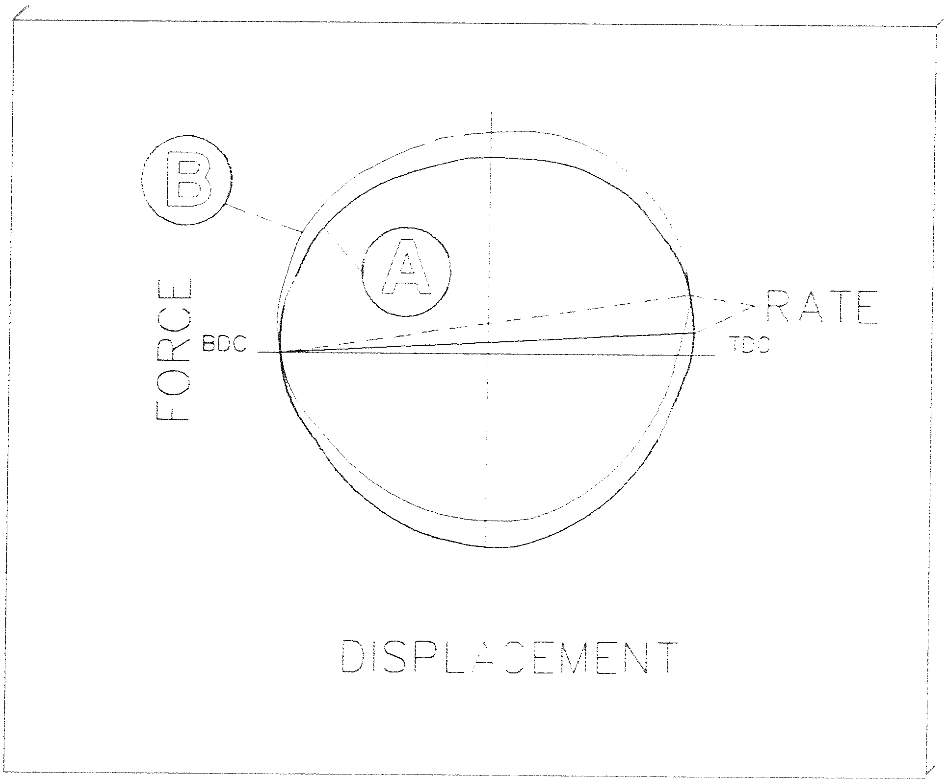


Fig. 20

Abgenutzte Kanäle

Worn porting in main piston

Shims bend off the main piston very little at high velocities. As the velocities reach over 200 mm/sec the piston port area becomes more critical. Worn ports **(A)** tend to show a drop in high speed damping compared to **(B)** as shown in fig.21.

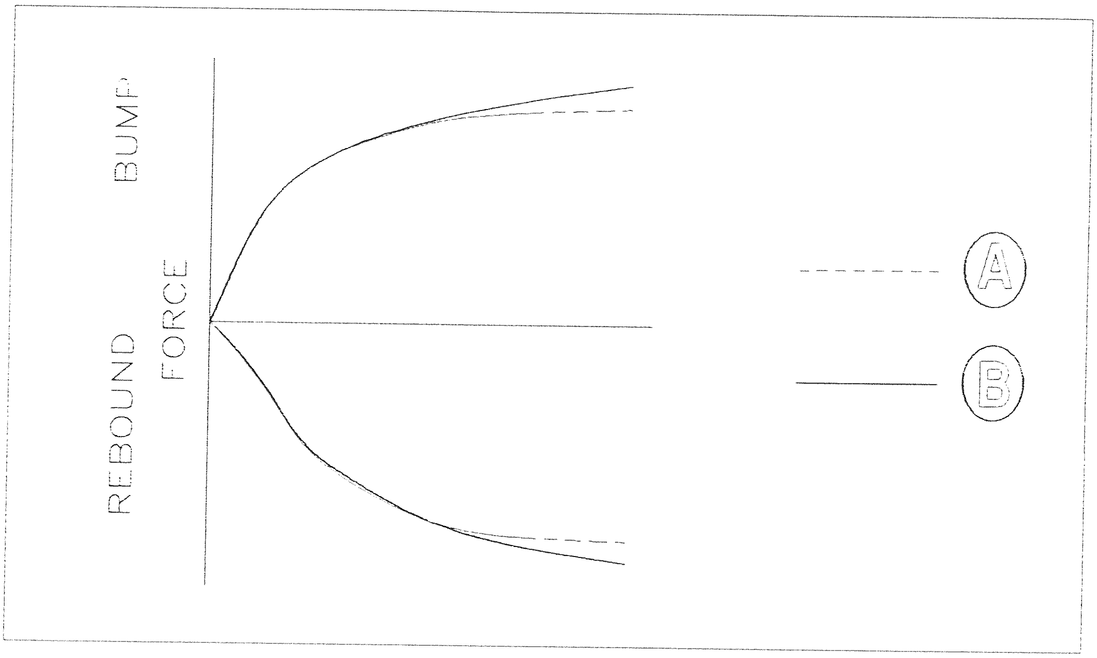


Fig. 21

Cavitation

Cavitation of the internals of dampers can be reduced by increasing the 'back-pressure' of the system. Should cavitation become evident in dampers the characteristic may look like fig.22. To limit this effect to the minimum increase the reservoir gas pressure.

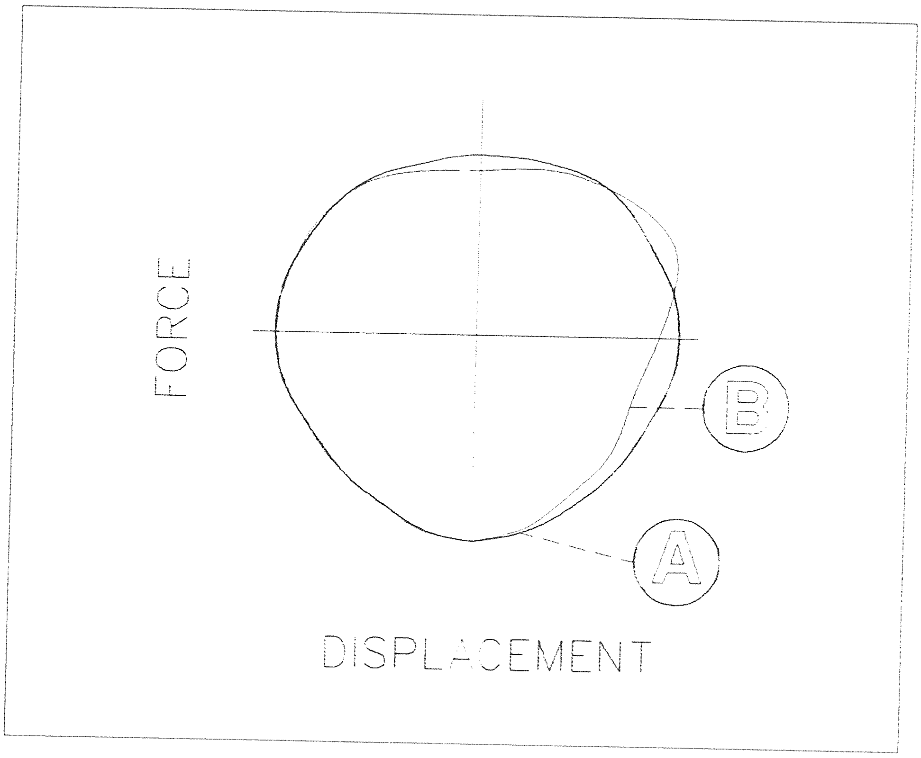
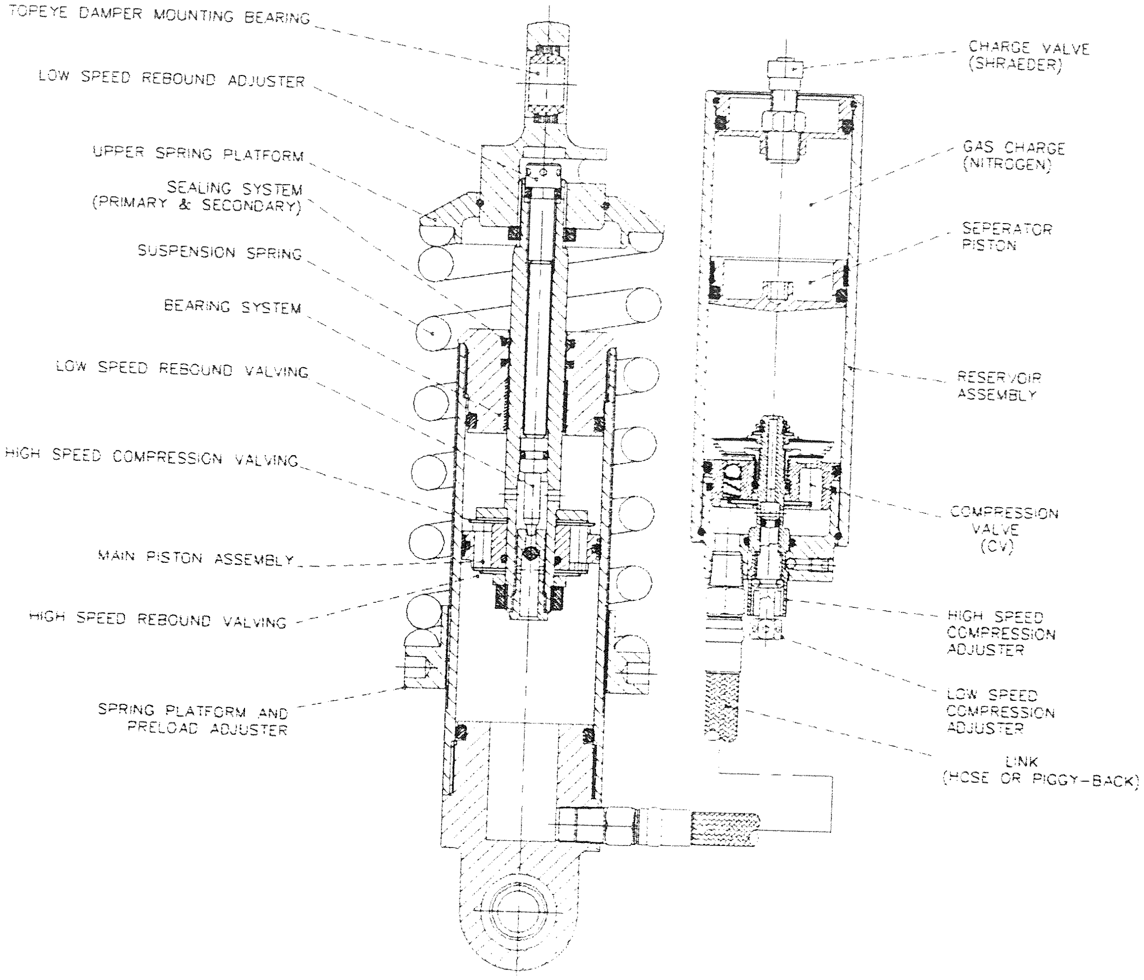


Fig. 22

A typical assembly of a 3-Way damper



DYNAMIC SUSPENSIONS - GLOSSARY

ACCELERATION - The rate of change of velocity, or how quickly an object speeds up.

AERATION - The condition when air bubbles are present throughout a liquid.

AIR SPRING - A device that uses air's natural ability to be compressed & used as a spring.

BLEED - Piston valving bypass.

BUMP - See Compression.

CAVITATION - Vaporising of fluid in the throat of an orifice due to insufficient back pressure.

COIL BOUND - The condition when a spring coil bears against the next coil.

COMPRESSION DAMPING - The resistance of a shock absorber to being pushed together at a given speed.

CONTACT PATCH - The foot-print of a tyre on the ground.

COMPRESSION VALVE - The valving usually housed in the reservoir assembly, which meters the fluid flow displaced by the shaft into the reservoir.

DAMPING - A hydraulic means of creating a resistance to motion & converting that energy to heat.

DECELERATION - The rate of slowing down of an object.

DOWN FORCE - Total load at, for example, the tire contact patch.

DROOP - Suspension movement in the down direction. Wheel moves away from fender.

DYNAMOMETER - (Shock Dyno) A test machine for working a shock and measuring the loads it produces at various velocities/frequencies.

EXTENSION DAMPING - See Rebound.

FADE - An unwanted reduction in damping, caused by overheating.

FORCE - An influence (as a push or pull) that causes motion or a change in motion.

FREQUENCY - Number of vibrations completed per second. Expressed in Hertz.

"g" - The acceleration due to gravity.

HERTZ - See frequency.

HYSTERESIS - Difference in load between the loaded & unloaded curve.

LOAD CELL - Device which produces an electric signal when loads are applied.

MASS - The mass of a body is the same everywhere. The weight of a body on the surface of the earth has a slight dependance where it is, and would have considerably different values at other places in the universe.

MECHANICAL PRELOAD - The amount either in force or displacement, a spring is compressed when fitted to an extended shock absorber.

ORIFICE - A passage, of exact and pre-determined size, for metering shock absorber fluid.

POTENTIOMETER - Device to sense movement and give an electric signal.

PRELOAD - See definitions of "mechanical" and "static" preload.

REBOUND - The extension or return direction of the shocks or suspension.

SECONDARY SPRING - The short spring of a dual spring system.(sometimes called a 'Helper'.)

SHOCK ABSORBER - See damping.

SEAL FRICTION - Mechanical drag of the seal on a rod or tube.

SPRING RATE - The amount of force required to deflect a spring a given distance.

STATIC PRELOAD - The mechanical preload plus the additional amount the spring compresses when it is supporting the chassis while at rest.

TORSION - A turning effect about a point. Usually measured in stiffness, like a spring.