SUSPENSION SETUP

By Dave Sallberg

The majority of riders, including some very skilled ones, have very little knowledge of suspension setup. Everybody talks about tires, which ones work well etc, but rarely do riders give equal attention to suspension setup, which can be just as important. For less aggressive riders it is less critical, but the bike will feel better if properly set up. For very aggressive riders, it can be as important as tires.

When you buy a new bike, do you really trust the new helper who assembled it to carefully adjust it to factory specs? Is your weight the same as the average Japanese rider for which the suspension was designed? Or if you buy used, what did the misinformed former owner do to the suspension?

During a trip to TWO (Two Wheels Only) in northern GA, I encountered a dramatic lesson in the importance of setup. My son and I spent a day riding with two new friends found at TWO. One rider on a Honda VTR (very skilled – a former racer) was complaining about the new tires that he had just put on the bike. He didn't like the tires at all because the rear tire kept breaking loose. The other rider on a TL1000R complained of front end push in corners.

At the end of the day's ride, we held a suspension clinic and checked the setup of both bikes. They were both way off.

The VTR had way too much rear spring preload and rebound damping. Having had a VTR myself, I recognized that the springs, front and rear, were stiffer than stock. The stiffer springs were ok as the rider weighed 200 lbs. We made the proper adjustments, and the next day the tire worked ok. Apparently the stiff setup was not allowing the tire to follow the pavement.

On the TL1000R we found way too much front rebound damping. We corrected that and also made less dramatic adjustments to the other settings. The next day the push was gone. Whereas with the push condition he couldn't stay with me in corners, now he was right on my tail. Again, the tire needs to be able to follow the pavement.

These case histories illustrate that many riders think that stiffer is better. It is true that many stock bikes are too soft, but too stiff is just as bad (possibly worse as it tends to get aggressive riders in trouble – a soft suspension lets you know when you are pushing too hard).

Damping

Rather than jumping immediately into suspension setup, first I will give a simplified explanation of damping (and springs in the next section). Those with a good understanding of vehicle shock absorbers can skip this part. However, I suspect that many riders without a technical background do not really understand what the damping adjustments do. The following is a non-technical explanation.

Shock absorbers create a resistive force to movement of the vehicle suspension, i.e., up and down movement of the wheel relative to the chassis. This resistive force is sensitive to velocity (of the wheel relative to the chassis, not the velocity of the vehicle), becoming greater as the motion is faster. The force is created by pistons forcing hydraulic fluid through restrictions. The force is intentionally non-linear with velocity, with a blow-off valve limiting the damping force at higher velocities. The resistive force is called damping. In case somebody doesn't know, on most motorcycles the forks provide the shock absorber function at the front.

Without damping, a spring suspended vehicle would continuously bounce when driven as minor variations in the road would start oscillations that would not stop. The damping force of the shock absorbers controls the motion, preventing the continuous bouncing. When properly engineered, the ride can be well controlled without harshness.

When the vehicle hits a bump, the suspension compresses as the wheel moves up (or chassis moves down). The damping force in this direction is called compression damping. The wheel then rebounds or travels down (or chassis moves up). Damping in this direction is called rebound damping.

Compression damping in vehicle shock absorbers is lower than rebound damping. When the vehicle hits a bump, the wheel must be allowed to travel up rapidly (suspension compression) without applying too much force which would jolt the vehicle. Hence, intentional lower compression damping force.

When the suspension rebounds (wheel moving down), the damping force needs to be higher to control the motion. Otherwise, bouncing would result.

The damping adjustments on motorcycles generally affect the low speed damping only (low velocity of the suspension movement). The high speed damping is built into the internal valves. Therefore, for optimum performance it may be necessary to replace or modify the suspension components (more on that later).

The majority of motorcycles do not have compression damping adjustment. This is generally ok as the designed in compression damping is usually satisfactory for most street riders. Many high performance sport bikes do have adjustable compression damping.

This article will deal with setup of rebound damping which is adjustable to some extent on many motorcycles. There is not an equivalent simple method to adjust compression damping. If you have adjustable compression damping, my advice is to start at the setting recommended in the manual. I will deal with possible fine tuning.

If you did not follow the above confusing explanation, let it suffice to say that damping is necessary to control suspension movement. With too little damping, control of the bike will generally be poor, but with too much damping the wheel will not follow the road on bumpy pavement (not good).

Spring Rate and Spring Preload

Spring rate and spring preload are terms often confused and misused, particularly by non-technical journalists doing motorcycle test reports.

Spring rate is a measure of how much a spring force increases as it is compressed, expressed in pounds/inch. (or kg/mm). In other words, a spring with a rate of 100 lbs/in would increase its force an additional 100 pounds for each additional inch it is compressed. If this spring were compressed 2 inches from its free length, it would produce 200 pounds force.

Stiffness to an engineer means spring rate. Something with high stiffness takes a lot of force for a small deflection. This term is commonly used for structures as well as springs. A spring is nothing more than a particular structure with a designed in spring rate. The term stiffness is often applied to a motorcycle frame, where high stiffness (low deflection with load) is generally desirable.

Preload is the amount of force generated by a spring at its installed length. It is a totally separate from spring rate, although the two are related when the spring is installed in a particular application. However, it is possible to have a high preload with a low rate spring if the installed length compresses the spring a lot from its free length.

What is the significance of this to your motorcycle? First, the spring rates are selected by the design engineers to produce a desired suspension characteristic. The rear spring is usually around the shock absorber and the front springs are in the fork tubes. In order to change the spring rate, you have to change the physical springs.

Most motorcycles have spring preload adjustment at the rear (usually an adjustable collar around the shock) and many have adjustment at the front (adjusters at the top of the fork tubes).

What are you accomplishing when you change these adjustments? Technically, you are changing the spring preload at the suspension topped out condition. When the rider gets on the bike and the suspension compresses (called sag), equilibrium will be reached when the spring force equals the combined weight of the rider and bike as supported by that spring. The spring load with rider aboard will necessarily be the force needed to hold up the rider and bike. When you change the preload adjustment, you are actually changing the sag, i.e. the amount the suspension compresses from the topped out position with the rider on board. The end result is that you control the ride height (measured as sag) with spring preload.

Here is where the journalists often go astray in their articles. They often say they increased the spring preload to make the suspension stiffer. Actually, they are adjusting sag. This does affect handling and may give them the desired result, but they are not changing stiffness.

Additional terms related to motorcycle suspension are rising rate linkage and progressive or dual rate springs. These terms all refer to non-linear spring rate of the suspension. A non-linear spring has an increase in spring rate as it is compressed. For example, initial compression may require 50 lbs per inch, with an increase to 75 lbs/inch near full compression. Rising rate refers to rear suspension and the non-linear effect is achieved with the linkages driving the shock and spring. The spring is actually linear but the linkage gives the spring more leverage as the suspension is compressed. Since the fork springs act directly, the springs themselves must be made non-linear. This is done either by having some closely wound coils that come into contact, or by use of a stop tube which limits the compression of a section of spring. In either case, the effective length of the spring subject to further compression is reduced and it becomes stiffer. The purpose of non-linear suspension spring rate is to prevent bottoming out in extreme situations without resorting to stiff springs at normal riding conditions (primarily for comfort reasons). Most high performance specialists prefer linear springs which provide constant characteristics.

The motorcycle design engineer selects both damping and spring rates to produce the desired suspension characteristics. This necessarily is a compromise as the optimum values are a function or rider weight and the expected use of the motorcycle (cruising vs canyon carving, plush ride vs high performance). Further compromise results from budget constraints as high quality damping components are expensive.

Stock suspension setups are often on the soft side for aggressive riders, with the exception of some high performance sport bikes. Rear damping usually has sufficient adjustment range, but many bikes do not have adjustable damping in the front. The rear spring (on the shock absorber) is selected to handle two-up riding and therefore typically has reasonable stiffness. The fork springs are often softer than optimum for aggressive riding.

Setup of Sag and Rebound Damping

The following procedure will tell you how to set up the suspension on your bike. This is worthwhile doing for riders who like to smell the roses, and is essential for aggressive riders.

Sag

The first task is to set sag, which is a function of spring preload. This is a three-person job, so it works well to get together with friends and do a few bikes at the same time. One person holds the bike, the rider sits on the bike, and the third person takes the measurements.

Sag is the amount the suspension compresses from full topped out to the position occurring with rider in riding position. The first step is to get a topped out reading. The easy way to do this is to pull the bike toward the side stand which unloads the wheels (the weight of the bike usually creates some sag). Assuming we start at the rear, take a reference measurement (use a tape measure) between the fixed tail section and something that moves with the wheel. Make the measurement on a vertical line above the rear axle. If the body work doesn't have a convenient measuring point, a piece of masking tape makes a good reference line.

Next the rider (in full riding gear as the weight is significant) assumes a normal riding position (feet on pegs) with the helper #1 holding the bike up at the end opposite the measurement.
The rider should remain stationary in riding position while the measurements are made. Helper #2 first lifts the rear of the bike being measured by a small amount and lets the suspension settle without help. Make a measurement (helper #2) and record. Next push down on the bike, let it return, and measure again. The average of the two measurements is the value used to compute sag and the difference is the friction value.

The procedure at the front is basically the same, with the measurements made on the amount of fork compression between two convenient points (possibly the top of the seal to the triple clamp).

For convenience, the following is the procedure abbreviated.

L1 = measurement with suspension topped out.
L2 and L3 are the measurements on either side of the friction band with rider in place
L3 – L2 is the friction value
L4 = the average of L3 and L2
L4 – L1 = sag

What should the sag and friction be? Different references have a variety of numbers, so I will give you a range. These apply primarily to sport bikes and standards as the other types of bikes (dual purpose, touring bikes) may have a different design philosophy.

Rear: Sag 25 – 35 mm, optimum 28 – 30 mm for sport bike track setup
Friction 5 mm maximum

Front: Sag 30 – 50 mm, Optimum 33 – 40 mm for sport bike track setup
Friction under 10 mm good, up to 14 mm not uncommon

Note that a metric measuring tape should be used as it is far easier to compute differences in readings (decimal system – no fractions)

There should be a reasonable balance between the front and rear (both low or high in range), and the front sag should not be less than the rear sag.

Rear sag is normally adjustable via the preload of the spring on the rear shock. The rear usually can be adjusted to a reasonable sag.

The front adjusters (if they exist) are on the top of the forks. Due to limited range or lack of adjusters, it is not always possible to adjust the front to the desired sag. In that case, you either have to live with it or make hardware changes (springs or spacers). As there may be interaction, recheck both ends if large adjustments are made.

Friction obviously cannot be adjusted. If excessive at the rear, there is not an easy fix. If excessive at the forks, it may be improved by loosening everything, make sure the forks are at the same height in the triple clamps, and then retighten everything.

Damping

The next step is to set rebound damping. Unfortunately, it is difficult to describe this on paper. See the owners manual, if available, for the location and factory recommended settings of the damping adjustments. You will want to push down one end at time and observe the rebound. For the front, hold the brake and push down on the handlebars, then quickly hands off and observe the rebound. For the rear, straight down push somewhere above the rear wheel and again quickly hands off and observe. When released after pushing down, the rebound should be controlled and not be so fast as to bounce on top (overshoot and settle), but also not real slow (1 second to rebound is a bit too long). Generally, you want just enough damping to get controlled rebound without overshoot. Hence, in order to get a feel for this, you may want to go to minimum damping and observe the overshoot. Then add damping to get controlled motion without overshoot.

As mentioned previously, there is not a simple procedure for setting compression damping (adjustable only on high performance bikes). My recommendation is to start at the manufacturers recommend setting (or mid-range for aftermarket components). The section on fine tuning includes compression damping. This is not an easy seat-of –the pants adjustments.

Some people recommend a front to rear balance check at this point. This is done by pushing the bike down (theoretically at the center of gravity of rider plus bike) and observing the down and up reactions of the two ends (and making appropriate adjustments if not the same). A way to do this that seems to give reasonable results is to simultaneously push down on the left handgrip (with left hand), rear of gas tank (with right hand), and left foot peg (with right foot). On small bikes, it may be possible to just push down on the rear of the gas tank with both hands.

If adjusted per the above procedure, the bike setup will generally be satisfactory for street riding. A skilled rider may be able to do some fine tuning by feel. However, if the initial setup is not close, it is virtually impossible to do the entire job by feel as there are too many inter-related adjustments.

It is important to keep written notes of your settings. If you do further experimenting, it is essential to have a known baseline that you can return to.

Component Upgrade

What can you do if you go through the setup procedure and cannot achieve satisfactory setup? The adjustments may have insufficient range or there may be no adjustment. My VTR1000 was a good example of this. In stock form the front end dived excessively under braking. Clearly the stock fork springs and compression damping were too soft.

If you have the knowledge, time and patience you can approach this piece by piece. Companies such as Works Performance can supply springs based on the specific bike, the rider weight, and the intended use. It is possible to buy Race Tech Gold Valves and install them yourself. If you go this route, I would suggest an after-market shock.

For people in this category, let me give you an additional measurement which checks for satisfactory spring rate. The measurement is free sag, which is the sag from topped out condition due to the weight of the bike. Look for about 5 - 10 mm rear and 15 – 20 mm front (the rear is more critical – some setup experts ignore the front free sag). If you cannot get both the free sag and sag with rider in an acceptable range, the only cure is a revised rate spring.

One approach to upgrade is the integrated systems approach. Companies such as Race Tech determine by test the suspension setup that works on most common motorcycles. You give them the rider weight and intended riding style (canyon carving to cruising). They can then modify your forks and shock (damping and springs where necessary) and return them to you all adjusted and ready to bolt into place. I have done this with two motorcycles and have been satisfied with the results. It is fairly expensive (over $800 with shipping), but money better spent than on cosmetic accessories.

Other sources for suspension upgrade are (check online web sites for address):

Lindemann Engineering
GMD Computrack
Traxxion Dynamics

These sources typically rework the forks and replace the shock. In many areas there are also local sources for suspension upgrade.

If you want the best possible suspension (short of replacing the forks), get the forks modified and install a high quality aftermarket shock (Ohlins, Penske). Giving in to an extravagant urge, I bought a Penske shock for my VTR1000 (after already having the stock shock modified by Race Tech). Much to my delight, the difference was very apparent. It controlled better over bumps without hurting the ride.

If you purchase an aftermarket shock to install yourself, find out from the supplier if the length is pre-adjusted. The proper way to check or set the overall length is to measure from the rear axle to a reference point on the tail section directly above, with the original shock fully extended, before you make the change. Adjust the replacement shock for the same dimension (you will save time if you pre-adjust the length of the replacement shock to match the original as close as possible before installing). Note that a purchased pre-adjusted replacement shock may intentionally raise the rear for quicker steering. If that is the case, you want assurance from the supplier that the change is intentional. If not sure, set at the same length as the stock unit.

If the damping on the replacement shock has not been preset specifically for your application, initially set both compression and rebound damping to mid range. After installation, adjust the rebound damping by observing the rebound rate (a bit less than 1 second without bounce at top). Further fine tune after riding if necessary.

Race Tech also has authorized service centers (listed on their web site, www.race-tech.com) . For fork upgrade only this will avoid shipping charges. However, shock work is best done at Race Tech as machining is generally required.

For the ultimate setup, G.M.D. Computrack will upgrade the suspension and do a "sweet numbers" setup of the chassis. I had the full GMD rework and setup on both my 2000 RC51 and CBR600 F4. The improvement of the RC51 was dramatic as in stock form it did not want to turn. The results on the F4 were very good, but not as dramatic as it handled well in stock form.

Fine Tuning

Before you make any changes, make sure you follow the golden rule and keep notes. You may need to return to the baseline. Also, only make one change at a time.

<u>Tire Pressure</u>

Set the tire pressure before attempting to evaluate handling. You ask, what pressure should I use? You have just identified the first fine tuning issue. The bike manual is not much help on this one. Probably for liability reasons, the tire pressures listed in the manual are the tire manufacturers recommended pressure for maximum load carrying capacity (typically 36 psi front and 42 psi rear). If you plan on riding a significant distance on the Interstate two-up and with luggage, follow this recommendation. If you never push traction limits on corners and want maximum tire life, you can also use these numbers.

What if you have a sport bike and are interested in running Deal's Gap at a sporting speed? In this case you want to use a lower pressure. As tire pressure is lowered, the contact patch gets larger and this helps cornering traction. This suggests that the pressure should be reduced until some other undesirable factor provides a limit. The ultimate low limit would be loss of lateral stiffness from tire carcass flex, but heat buildup becomes a factor first. The tire has to flex to provide the larger contact patch, and this flexing causes heat buildup. If the tire becomes too hot, the traction diminishes and wear rate increases dramatically. Race teams work with the tire reps to determine the optimum pressures for a given set of conditions. WSB have monitoring of tire temperature while on the track. Street riders do not have this help, so must rely on general recommendations. For the sport bike rider above (aggressive cornering), 32 psi. front and 34 psi. rear is a reasonable level.

What if you are headed for a weekend including both touring and twisties? Ideally you should adjust the pressure for the task at hand, but this is often not convenient (the rest of the group may leave you at the gas station). In this situation I use compromise settings of 34f and 36r. There are many different opinions on tire pressure, so you need to decide what recommendation you want to follow. Note that these suggestions are for street tires only. For race tires you need to follow recommendations specific to the tire model.

Now you can try some fine tuning adjustments if you feel the need.

Steering

The basic suspension setup is done statically – i.e. without feedback from riding. A pro-level racer will make many fine adjustments after this in order to gain a few tenths of a second per lap when riding at the limit. For street riders, most of this is not necessary. Even spirited cornering on the street (short of being stupid) is far short of pushing the limit as a racer does. However, the rider should be aware of some basics.

When we set sag, we are merely adjusting the ride height so that the suspensions, front and rear, are in a desirable part of the working range with the rider on board. This adjustment can have a secondary effect as relative sag front to rear affects the rake angle of the forks (the angle of the forks relative to vertical). The rake angle affects steering, with some bikes more sensitive than others.

To check this, all you have to do is pay attention to steering effort when rounding a corner at typical road speeds (not parking lot speed). Ideally, the bike should turn easily and have neutral steering feel in the corner. If the bike doesn't seem to want to turn or if you have to hold constant counter-steer pressure on the bars to hold the corner line, then steering is slow. If the bike tends to fall into the turn, then the steering is quicker than desirable. If the steering just doesn't feel good (vague feeling), that is also likely an indication of too quick steering.

Slow steering is on the safe side, although it could make quick evasive maneuver more difficult. Rider preference is the guide here – if you are satisfied, leave it alone. Too quick steering is not desirable as it can get you into trouble, in the extreme case leading to front end tuck (followed by high-side get-off).

If the steering is slow and you want to make it quicker, you need to decrease the rake angle, accomplished by raising the rear and/or lowering the front. The purest would do this by raising the forks in the triple clamps (lowers the front) or raising the rear ride height if this adjustment is available. The easier way for us non-purest street riders is to modify the sag settings if they can still be maintained within an acceptable range (less sag at rear by increasing spring preload and/or more sag at front by decreasing spring preload). If the required sag settings would depart from the acceptable range, then better to adjust the forks or the rear ride height. An adjustment of 5 mm is significant.

The correction for too quick steering is obviously the opposite – lower the rear (more sag) and/or raise the front (less sag).

Note that tire profile (different with different brands) can also have a significant effect on steering. You may want to do another fine-tuning if you change tire brand. This also suggests that once you have a good setup, it is best to not arbitrarily change tire model.

Damping

The other parameter to think about is the damping adjustments. As a part of the static set-up procedure we check the rebound damping. If your damping is not adjustable, life is simple because you can't make any adjustment. If the rebound damping only is adjustable (no adjustment for compression damping), again life is fairly simple. The adjustment made by observing rebound is probably satisfactory (unless the shock or forks are bad and a good adjustment is not possible). If the ride seems harsh, try a little less rebound damping (CCW), if bouncy, add a little more. Keep notes on how much you modified the adjustment so that you can go back to baseline if you want to.

The following paragraphs address bikes with both rebound and compression damping adjustments, primarily high performance sport bikes.(The more casual rider can stop here.)

These bikes can be more difficult to get right as there is no easy way to statically check compression damping. I generally recommend starting at the manufacturers recommended setting and that is usually ok. However, there have been some examples of excessive compression damping, particularly on the forks, with factory settings (original RC51, some Kawasaki sport bikes). If the bike seems very harsh over small bumps (such as freeway joints), and the rebound damping has been set by observation, then I would suggest trying a little less compression damping, starting with the forks. You might want to also recheck the rebound damping (front and fear) to see if it was left it on the stiff side (slow return).

Another symptom of excessive damping at the rear is a tendency for the rear tire to break loose under acceleration. If this happens, first make sure the rebound damping is not on the stiff side, and then back off the compression damping. Best to go back off too far (until it feels bouncy or you feel loss of control), then put some back until it feels right.

Too much rebound damping can cause a phenomenon called packing-in. If the rebound rate is so slow that the suspension doesn't recover between bumps, then the ride height keeps getting lower and lower. When this happens predominately on one end, then the chassis attitude is upset. If the front becomes higher than the rear, understeer results (wants to run wide). If the front goes low, oversteer results (tendency to tuck-in).

As you can see, damping adjustments are not simple to sort out, so hopefully you do not have to go this far.

The settings given in "Sport Rider" magazine in conjunction with their tests can provide useful information. The fallacy of using these settings in total is that rider weight affects the proper settings. Sag adjustments in particular should be done with the actual rider. However, if after the normal static sag and rebound damping setup, you are not satisfied with results, look at their settings for clues on which direction to go with the settings, particularly the damping settings.

Additional Reference Information

The following is a list of symptoms and causes taken from various sources. These may be helpful in particular situations, but can also be very confusing as the same symptom can have multiple causes.

Forks – lack of rebound damping

- Plush ride, but when speed picks up feeling of control is lost. The fork feels mushy, and traction feel is poor.
- After hitting bumps at speed, the front tire tends to chatter or bounce.
- When flicking the bike into a corner at speed, the front tire tends to chatter and lose traction. This translates into an unstable feel at the clip-ons.
- Aggressive input at speed lessons control and chassis attitude suffers. Front end fails to recover after aggressive input into turn or over bumpy surface.

Forks – too much rebound damping

- Harsh ride, the front end feels locked up
- After the first bump, the bike will skip over subsequent bumps (the suspension packs-in). The suspension's reluctance to maintain tire traction through these sections erodes rider confidence. Entering a turn, it may feel like the front wants to tuck-in.
- Under hard acceleration exiting a bumpy corner, the front end wants to wiggle or tank slap. The front tire feels as though it is not staying in contact with the pavement when on the gas.

Forks – lack of compression damping

- Strong diving of the front during braking, may bottom out (soft springs also result in excessive dive)
- The front end has a mushy or vague feeling, similar to lack of rebound damping.

Forks – too much compression damping

- Feels harsh over bumps. Bumps felt directly through triple clamps with big bumps bouncing the front tire off the pavement.
- Front rides high in corners causing bike to steer wide.

Shock – lack of rebound damping

- The ride is plush at cruising speed, but as the pace increases, the chassis begins to wallow and weave through bumpy corners.
- Excessive chassis pitch through large bumps and dips at speed. The rear end rebounds too quickly, upsetting the chassis with a pogo stick action.

Shock – too much rebound damping

- Traction is poor over bumps during hard acceleration (the tire does not maintain contact).
- The rear wants to hop and skip when the throttle is chopped during aggressive corner entries.
- The rear will pack down, forcing the bike wide in corners (understeer).

Shock – lack of compression damping

- The rear may bottom, causing loss of control and traction.
- With excessive rear end squat when accelerating out of corner, the bike will steer wide
- Steering and control become difficult due to too much suspension movement.

Shock – too much compression damping

- Ride will be harsh, but not as severe as with excessive rebound damping
- Medium to large bumps are felt directly through the chassis. When a bump is hit at speed, the rear end kicks up.
- The rear wheel will tend to slide under acceleration.

The combinations of possible problems are endless, and there are multiple causes for some symptoms. If you get multiple adjustments way off, you will never sort it out by the seat of your pants.

Conclusion

Will you go faster if you optimize your suspension? That depends on your situation. If you are in the learning process on cornering, improved suspension will increase your confidence and help you go faster. If however you have reached the level where cornering speed on public roads is more a matter of prudence, you will probably not go faster. In this case, your safety margin will be increased. For that occasional track day, you will definitely appreciate the improvement.

Also, you will have the satisfaction of having a fine handling motorcycle. To many of us, that is important.