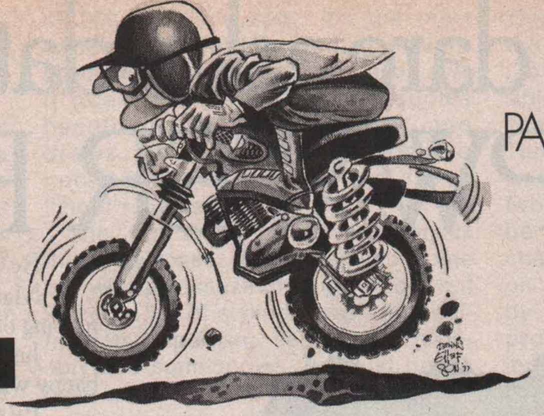
THE LONG AND SHORT OF SUSPENSION



PART TWO: IN REAR SUSPENSION, THE WHEEL RATE'S THE NAME OF THE GAME

By Bruce Burness

Last month we looked at motorcycle suspension in rather general terms in order to present some basic theory. This article will get right into specifics by covering the most controversial and talked about area of motorcycle suspension: the rear suspension on off-road bikes.

By now it has become pretty well accepted that longer wheel travel will get you over rough terrain more quickly. The first attempts at getting increased wheel travel were accomplished by moving the shock mounting position farther up the swing arm away from the rear axle. That wasn't exactly the ideal way to do things, but the available shocks were limited to 12 to 13 inches of overall length, and about three inches of travel. If you wanted six inches of travel at the rear wheel you had to find a way to double the amount of travel available in the shock absorber. Getting that amount of travel from a shock with only three inches of travel of its own meant that you had to create a mechanical advantage of two to one. That advantage is called the *leverage ratio.*

Moving the mounting position up the swing arm solved the problem of increasing wheel travel, but many more problems were created. Swing arms and frames bent and broke under the stress of forces they were not designed to accept. Spring selection also left many people baffled. It seemed logical that moving the shock mounting position halfway up the swing arm would require a spring twice as stiff, but a lot of experimentation proved that it was necessary to have a spring four times as stiff. Why? Take a look at **figure 1.** Illustrated is a swing arm with two different shock mounting positions. The rear mount will give a leverage ratio of 1:1, the forward mount will give a ratio of 2:1.

Let's say we want this suspension to resist with 100 pounds of force for every inch we raise the rear wheel. Using a 100-lb./in. spring in the rear mounting position will achieve that. But what spring rate in the front position will give the same resistance?

We know that the leverage ratio is 2:1, so it seems logical to use a 200-lb./in. spring. But let's move the wheel up one inch and look again. Because of the 2:1 leverage ratio we for sure need 200 pounds of force at the forward shock mounting to give 100 pounds at the wheel. If you measure the distance the shock mounting moves upwards when you move the wheel one inch, you will find that it is only ½ inch. If you compress our "logical" 200-lb./in. spring ½ inch you only get half of its spring rate, which works out to 100 pounds. That is only half of the amount we know we need to make 100 pounds at the wheel. In order to get 100 pounds at the wheel, we will have to double our "logical" spring rate with a 400-lb./in. spring. Now if you square our original leverage ratio of 2:1 (multiply it times itself), you get a ratio of 4:1, which, coincidentally, is the same as for our two alternate springs (400/100).

No matter what the leverage ratio you must square it before trying to compute springs to give a particular action. The chart in **figure 2** will make it clear that as you use higher and higher leverage ratios this "squaring" procedure becomes more and more important. Also, the accuracy when determining the exact leverage ratio is increasingly critical.

Look at the column for the 1.1:1 ratio. When it is squared the result is not much different from the original number. But, the ratio of 1.9 squared is almost twice as much. Small changes in shock mounting, when already dealing with high leverage ratios, will require much bigger adjustments in spring rate.

WHEEL RATE

Now that we know how to select the right spring for the job, how do we know what degree of "stiffness" or "softness" we want throughout the system? Suspension engineers use a term called *wheel rate* to allow riders to put a number on the type of feel they like in rear suspension. In the example we used we said we wanted a 100-pound force to move the wheel one inch, or a wheel rate of 100 lb./in. Wheel rate is the amount of force needed to move the wheel straight up one inch. No matter what type of suspension system is used, the wheel rate measurement allows you to know in advance what the bike will feel like. It is as though each rider carries a wheel rate figure tattooed to his brain. The closer a bike is to that rate, the better he likes it.

The outer limits of wheel rate are a low of 50 pounds

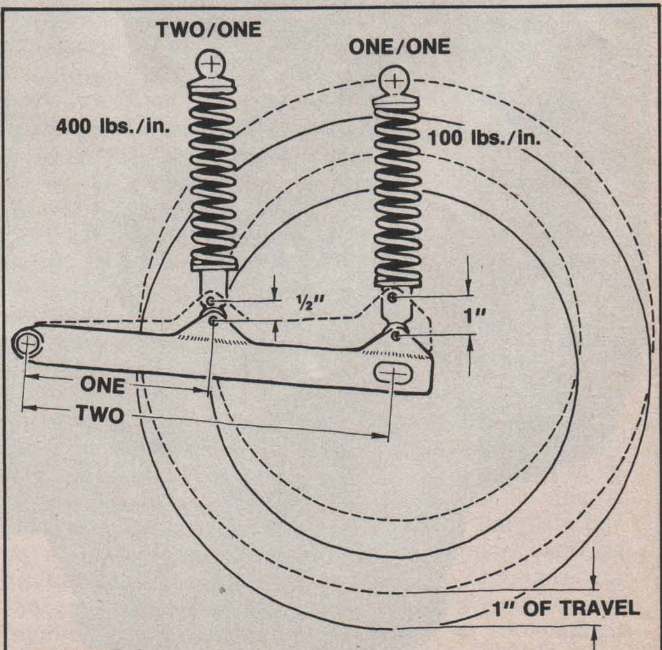


FIGURE 1

ILLUSTRATION: STEVE AMOS

Freelance contributor Bruce Burness is one of the most respected motorcycle suspension authorities in the U.S.

FIGURE 2

SPRING REQUIREMENTS FOR VARIOUS LEVERAGE RATIOS

	100%										200%		
LEVERAGE RATIO	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2
LEVERAGE RATIO^2	1.0	1.21	1.44	1.69	1.96	2.25	2.56	2.89	3.24	3.61	4.0	4.41	4.84
SPRING RATE REQUIRED TO MAINTAIN A CONSTANT 100 lb./in. WHEEL RATE	100	121	144	169	196	225	256	289	324	361	400	441	484
	100%										400%		

LEVERAGE RATIOS IN THIS RANGE ARE NOT UNCOMMON WITH TODAY'S MOTOCROSSERS.

NOTE THAT FOR AN INCREASE OF 100% IN LEVERAGE RATIO THE SPRING REQUIREMENT GOES UP 400% AND FOR LOW RATIOS THE SQUARING EFFECT IS NOT VERY PRONOUNCED.

and a high of 100 pounds. Actual rider preferences fit into a much narrower range of from 60 to 80 lb./in. There are several factors that can modify wheel rate preference.

A 125 racer will need less wheel rate than an open class bike and a 250 will fall somewhere in between. Big, rolling, sandy whoop-de-doos will require more wheel rate than hard washboard surfaces. Rider weight has a great deal of influence, too. If you stand up instead of sitting in the saddle you can lower the wheel rate, but if you lock your knees while standing the wheel rate will have to go up again. If you ride far forward on the gas tank the wheel rate can go down, and the converse is also true. The aggressiveness of your riding will likewise influence wheel rate. Still another factor is the amount of compression damping in the shock absorber. This is impossible for the individual to determine precisely, but some shocks are known to have more or less compression damping. A lot of compression damping will assist the spring and allow you to lower the wheel rate.

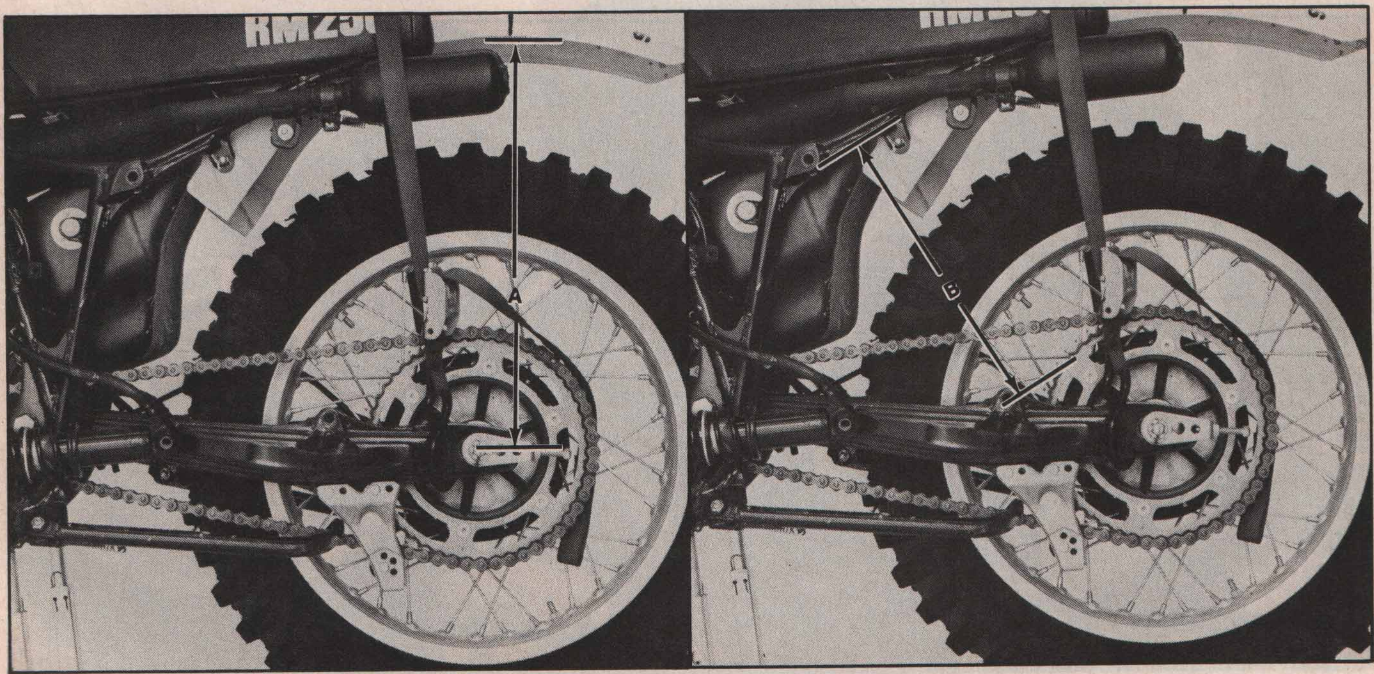
If you use these factors as guidelines and do some testing on your own motorcycle, you will arrive at a perfect wheel rate for your riding. If you already have a motorcycle with a perfect spring combination, work backwards with the formulas shown later on in this article to come up with your personal wheel rate. Then in the future, if you get a new motorcycle or change geometry, you can apply your personal wheel rate to select springs and be very close to optimum.

A few years ago we had the opportunity to have a National Motocross Champion, Gary Jones, test two bikes on the same day. The bikes were identical with the exception of the rear suspension; one had conventional shocks moved up to a forward mount, the other had longer shocks in a more laid-down position. After a long day of experimenting, we got both bikes to his liking. Even though the two suspension geometries were quite different and used different springs, the preferred wheel rate on both setups was 62 lb./in.

Working with another National Motocross Champ, Pierre Karsmakers, who was in the process of switching from a monoshocker to a conventional motocrosser, we found that what he preferred in the conventional rear suspension was within two pounds of the monoshocker in wheel rate. This time it was in the 80 lb./in. region, a rate that suited his riding style better than a softer one.

COMPUTING WHEEL RATE

Now that we know what wheel rate is, how do we find out what rate a given motorcycle has? The first thing you will have to know is the leverage ratio. We have already given a very simplified example of leverage ratio. In the real world shocks are positioned at a lot of weird angles, and the best method is to measure directly on the bike. To do so, put the bike on a steady centerstand. Remove both rear shock absorbers. Support the rear wheel so that it hangs in about the same position as when the shocks are installed **(figure 3).** Make a mark



PHOTOGRAPHY: DAVE EKINS

FIGURE 3

SUSPENSION BASICS

on the rear fender directly over the axle as a reference point. Measure the distance between the center of the axle and the mark on the fender. This distance will be referred to as *A*. Without moving anything measure the distance between the upper and lower shock mounts. This will be known as *B*. Now compress the suspension until the tire hits the fender (refer to **figure 4**). You can use a tie-down strap draped over the seat to hold the suspension up. Now make the same two measurements with the suspension compressed. We will call these dimensions *a* and *b*. Now subtract *a* from *A* and *b* from *B*. Divide the result of *b* from *B* into the result of *a* from *A* and you have your leverage ratio.

EXAMPLE
Measurements from motorcycle:
A = 15 in.
B = 13.5 in.
a = 7 in.
b = 9.5 in.

$$\text{Wheel travel} = A - a \text{ or } 15 - 7 = 8$$

$$\text{Shock travel} = B - b \text{ or } 13.5 - 9.5 = 4$$

$$\text{Leverage ratio} = \frac{\text{wheel travel}}{\text{shock travel}} = \frac{8}{4} = 2 \text{ in.}$$

This may seem like a roundabout method, but if the procedures are performed with care, it is the only method that takes all angles and shock lengths and swing arm arcs into account.

With the leverage ratio and your estimated wheel rate you now have enough data to compute spring rates using the following formula:

$$\text{Spring rate} = \frac{(\text{leverage ratio})^2 \times \text{estimated wheel rate}}{\text{number of springs in suspension system}}$$

EXAMPLE
Collected data:
leverage ratio = 2
estimated wheel rate = 65 lb./in.
number of springs = 2 (monoshocks have only one spring)

$$\text{Spring rate} = \frac{(2)^2 \times 65 \text{ lb./in.}}{2} = \frac{2x2 \times 65 \text{ lb./in.}}{2} =$$

$$\frac{4 \times 65 \text{ lb./in.}}{2} = \frac{260 \text{ lb./in.}}{2} = 130 \text{ lb./.in.}$$

Thus, 130 lb./in. is the correct spring rate to give a wheel rate of 65 lb./in. If, when field testing, you find that your best wheel rate is far out of the range suggested earlier you probably have other parts of your suspension set up incorrectly. Wheel rate is fundamental and should not be deviated from very much. Adjust other parts of the suspension to suit the correct wheel rate. We will analyze all of the other aspects of rear suspension in future articles.

If you want to solve for wheel rate rather than spring rate, use the following formula:

$$\text{Wheel rate} = \frac{\text{spring rate} \times \text{number of springs in system}}{(\text{leverage ratio})^2}$$

In summary, we have learned that spring rate is outdated as a measure of rear suspension performance. The advent of suspensions that multiply movement have changed this concept. The real figure you are interested in is the wheel rate. This is a more realistic concept in that it measures the actual force at the axle. By computing the leverage ratio of your machine, and then converting it to wheel rate, you have a basis for fine-tuning your suspension.

Next month we will show you how rear suspension is designed, and the desirability of actually varying the wheel rate as the suspension moves. *M*

GLOSSARY

LEVERAGE RATIO The ratio between rear axle (or wheel) movement and shock absorber movement due to the linkage between them.

WHEEL RATE The amount of force necessary to move the wheel straight up one inch. Conversely, if you push down on the seat right over the rear axle the wheel rate is the number of pounds needed to move the chassis one inch.

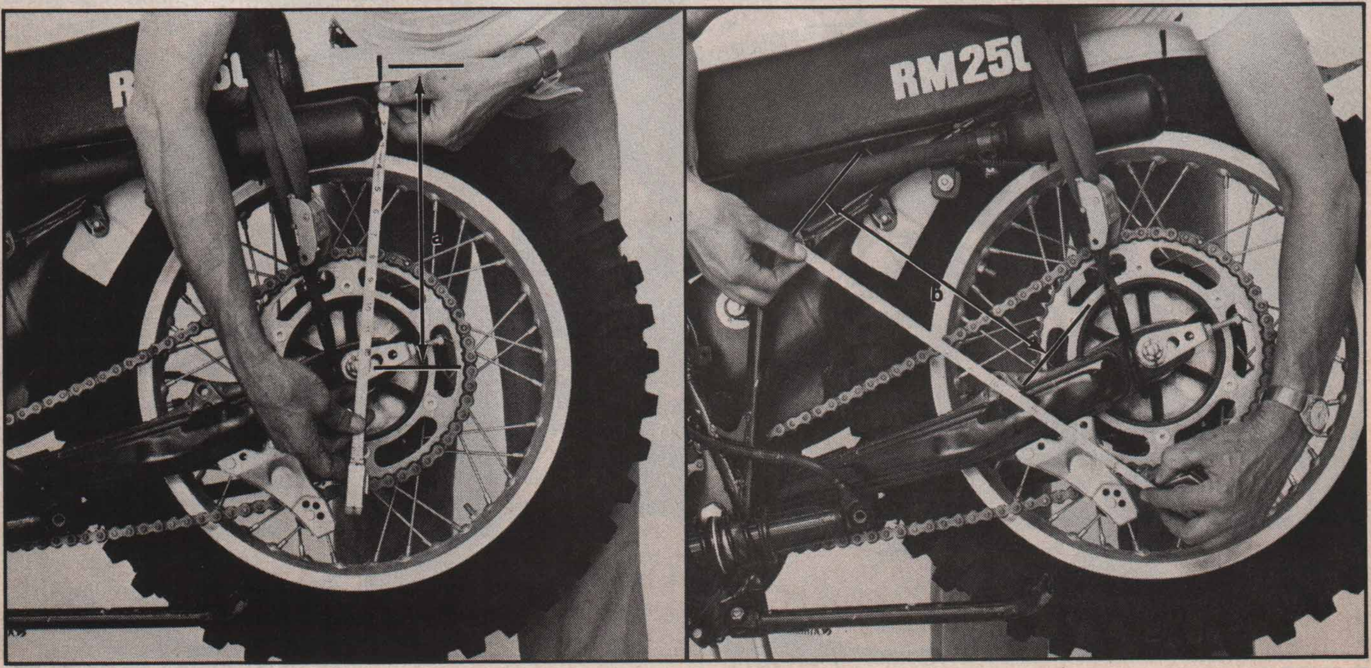


FIGURE 4