TOURING OREGON: BMW's R100/S

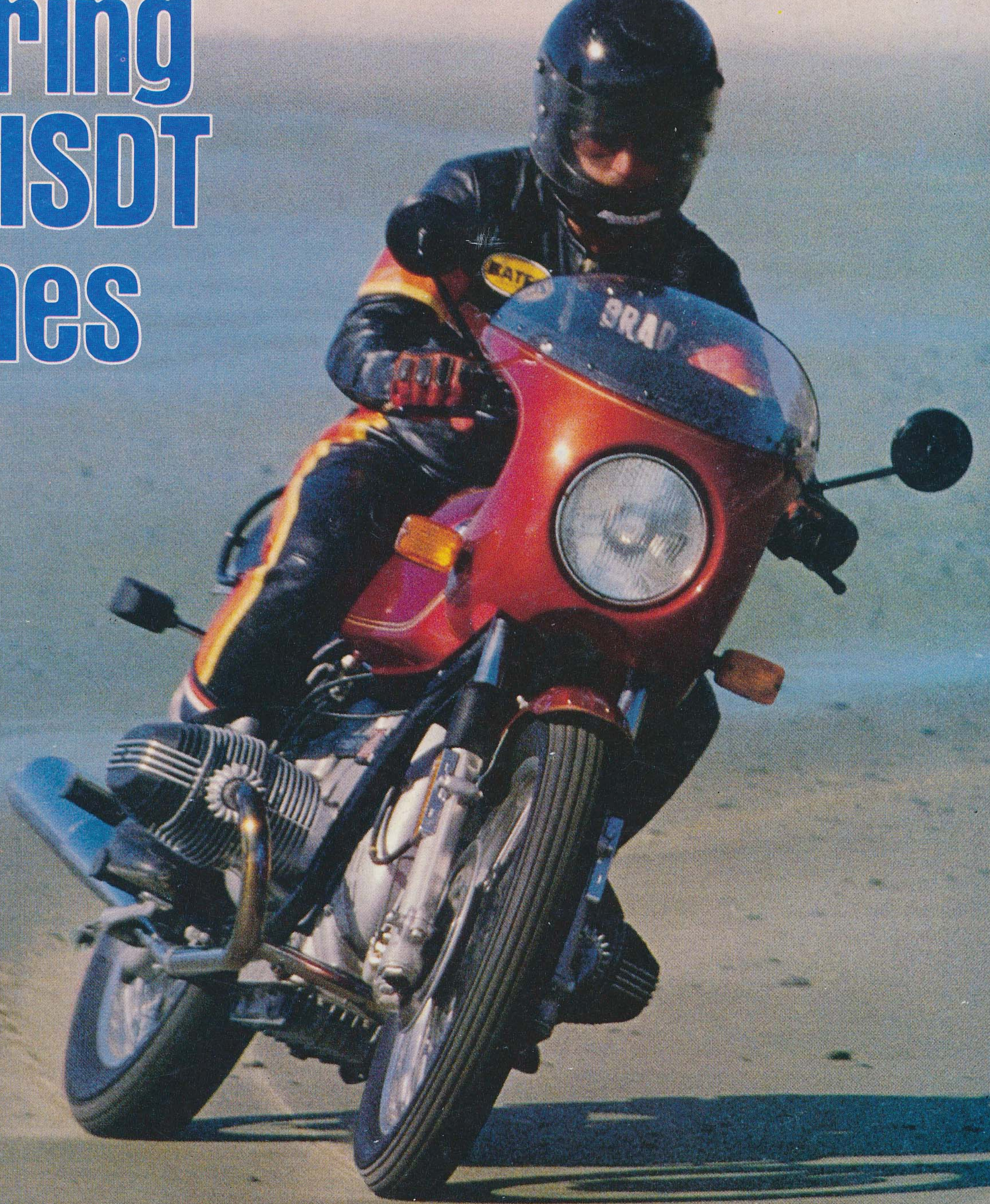
Motorcyclist

MOTORCYCLIST
02179
NOVEMBER
PETERSEN PUBLISHING COMPANY

Comparing 250cc ISDT Machines

Getting Started:
Enduro
Motocross
Road Racing
Touring

Husky's Shiftless 390MXer



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Motorcyclist Magazine

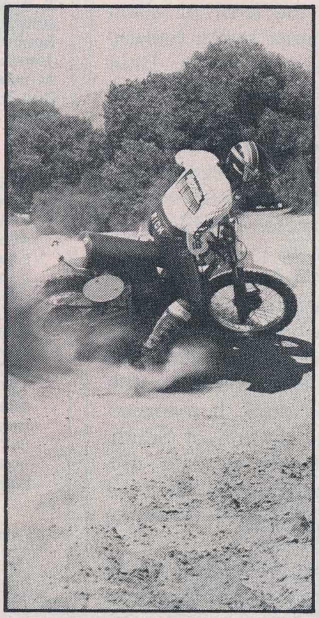
PUBLISHED
MONTHLY
NUMBER 965

NOVEMBER 1977

TESTS

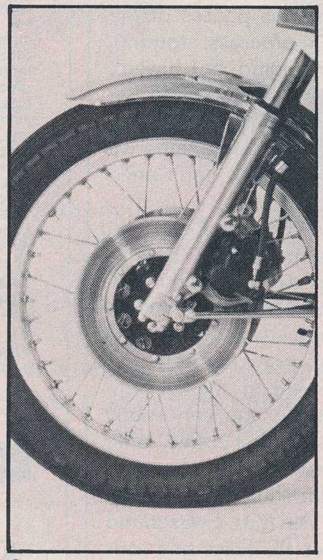
The Pacific Northwest scene from a seat of solid gold.

Some real, some pretenders, but in the end all are fine trail bikes.



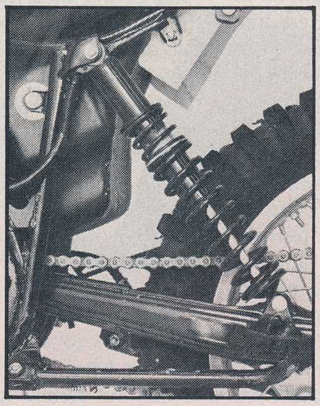
Husky's 360 playbike has become a full-blown 390 GP racer.

FEATURES



Softer front legs for the CB750 and GL1000.

A scientific approach to taking the plunge.



PART THREE: How Optimum Rear-End Geometry results in maximum efficiency and travel.

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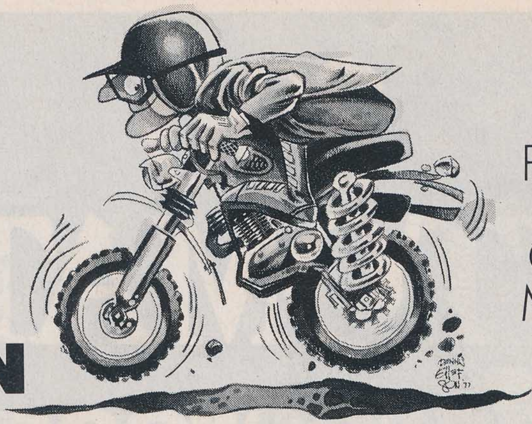
COVER

Feature Editor Brad Zimmerman gets the BMW a little sideways on Cannon Beach in Oregon. A complete log of his further antics is found in the BMW Tour Test. Photo by Action Oz.

THE LONG AND SHORT OF SUSPENSION



PART THREE: HOW OPTIMUM REAR-END GEOMETRY RESULTS IN MAXIMUM EFFICIENCY AND TRAVEL

By Bruce Burness

It's time to talk about some of the subtleties that make the difference between an adequate rear suspension and a superior one. This article will also be a do-it-yourself manual for more enterprising racers looking for a little extra edge in performance.

The last article in this series dealt with shock-mounting leverage ratios and calculations of wheel and spring rates. If you have not read that article, I urge you to do so before proceeding any farther. Determining the (leverage) ratio between the vertical wheel movement and the movement of the shock absorber is essential even if you plan to forego major structural changes and only adjust shocks and springs.

RISING AND DIMINISHING RATES

As hinted last month, an average leverage ratio taken for the complete wheel travel does not tell the whole story. In fact, in most cases, the leverage ratio will change a little bit with every inch you move the wheel. Some suspensions become stiffer the more you compress them *(rising rate);* others begin to get softer *(diminishing rate).*

In researching geometry for motocross and off-road use, you will find many conflicting opinions as to the superiority of a rising or a diminishing rate. Obviously the motorcycle manufacturers don't agree on what is optimum. I personally lean heavily in favor of rising rate geometry. But before getting into my reasons, let's take a look at the physical differences in various motorcycles that determine a rising or a diminishing rate.

Studying the rear shock mounts of today's motocrossers will reveal an array of angles for leaning the shocks forward. These angles determine whether a suspension system has a rising or a diminishing rate. As a rule of thumb, if a shock is leaned forward about 20 degrees from vertical it will have a rising rate. If the shock is laid down farther the rate will begin to stay constant throughout its travel; and if it is laid down still farther, a diminishing rate will result. Oddly enough, if you begin making the shock more vertical than 20 degrees, the rates change and deteriorate in exactly the same way they do when laying the shock down.

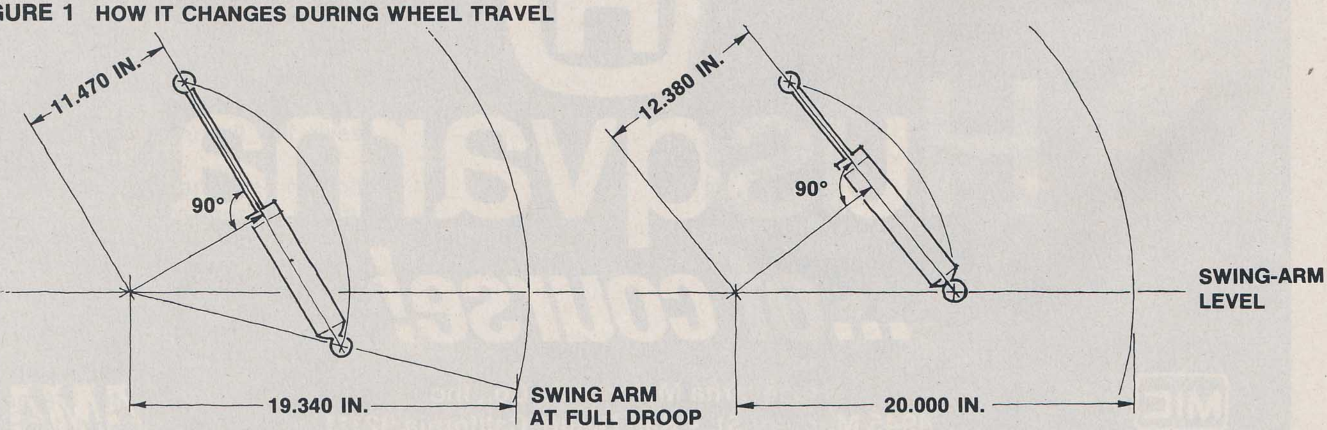
If you make changes to the shock angle by moving just one end of the shock, you not only change the rise characteristic, but also the basic leverage ratio. If that is done, the difference in rise characteristic will be overshadowed by the new leverage ratio and evaluation will be misguided. It *is* possible to retain a basic leverage ratio and to alter the rise characteristic independently.

I am sure that many of you have heard or read that it is beneficial to have a shock pointed at some magical angle, such as "more towards the center of gravity," or "at the steering head," or "in the direction the motorcycle is traveling," or "directly into the rider's body." I say baloney to all of those statements. It may be true that all of the motorcycles that received such treatment were improvements over their predecessors, but not for those reasons. The only thing the motorcycle knows and feels is how the rear tire interacts with the ground, and that is partially determined by the rate at which the wheel can move in relation to the chassis. I believe that you can ignore the direction your suspension unit is mounted, provided the leverage ratio is correct and you have designed in maximum amount of available rise in rate.

IN FAVOR OF RISING RATE

Why am I so in favor of rising rates? A quick look at the springs on most professional motocrossers gives the first clue. They are almost all of the double spring type—some even have triple springs. Even motorcycles with heavily laid-down shocks (or diminishing rates) use double springs. A double spring gives a very soft rate in the beginning and a significant increase in rate toward the

FIGURE 1 **MECHANICAL LEVERAGE AND HOW IT CHANGES DURING WHEEL TRAVEL**



LEVERAGE = $\frac{\text{SWING ARM}}{\text{SHOCK ARM}}$ **LEVERAGE = $\frac{19.340}{11.470}$** **LEVERAGE = 1.686 to one**

ILLUSTRATIONS: STEVE AMOS

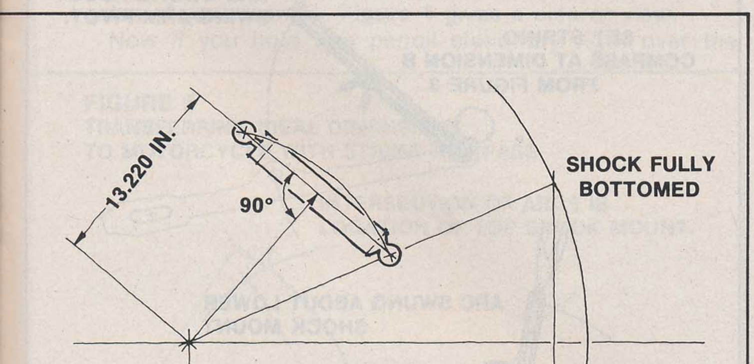
end of travel *(rate progression)*. This benefits the rider because the suspension can move easily over small and medium bumps, but rise up in rate enough not to bottom over larger bumps.

If double springs work so well why bother with geometry that changes the leverage ratio? There are two reasons. First, it is physically difficult to manufacture springs with enough rate spread to compensate for a diminishing rate geometry. Second, it is much more difficult to produce shock damping that is matched with a low spring rate at one end and a high rate at the other.

Rising rate geometry doesn't completely eliminate the need for double springs. At best the most change in leverage ratio that can be expected is about 20 percent. That may not sound like a lot, but if you have a 20 percent diminishing ratio to begin with, a 20 percent rise in ratio will help the shock problem by 40 percent. Also recall from the last article that leverage ratio must be squared in order to predict the rate at the wheel. If you square two ratios that are 20 percent different, you end up with a 44 percent difference at the wheel.

Proof that 20 percent improvement from the geometry is significant was dramatically demonstrated to me in a shock test conducted last year. The test bikes were a 450 Maico AW and a 400 KTM. Both motorcycles have the same wheel travel and use the same free-length shock absorber, suggesting they have the same average leverage ratios. However, the KTM shock absorbers are leaned forward considerably more than the Maico's, giving the KTM a diminishing rate. The test results were completely predictable. The spring combination that gave a nice soft ride yet did not bottom out on the Maico, was too stiff over small bumps and bottomed out on the KTM. The performance of still others confirms in my mind the need to take advantage of rising rate geometry. Late model Can-Am motocrossers suffer the same symptoms as the KTM. They are too easily bottomed and not all that smooth over the small stuff. Pre-1976 Husqvarna GPs are another example. In fact, on '76 models, Husky saw fit to move the shocks to a more upright attitude in order to rectify the problem. Kawasaki did the same on its works team bikes. Honda is still fighting the bottom/softness compromise. The shocks on the Suzuki RM-B are more upright than those on A models. Finally, the factory KTMs of Moissiev and Kavinov have shock mountings that are much more upright than those on the KTMs seen in the U.S. And reportedly, upright shocks will be standard on 1978 KTMs.

To learn how the rising rate phenomenon occurs, study **figure 1.** The three drawings show the same suspension in three different positions of travel. First note that the leverage ratio is computed by dividing the effective shock lever into the effective swing-arm lever. Note also that these dimensions are not the lengths of the actual parts but of a distance measured at 90 percent to the reaction point. The three drawings show how the effective lengths change during travel. The numbers are real and represent a typical amount of rise in rate even though the drawings are not to scale.

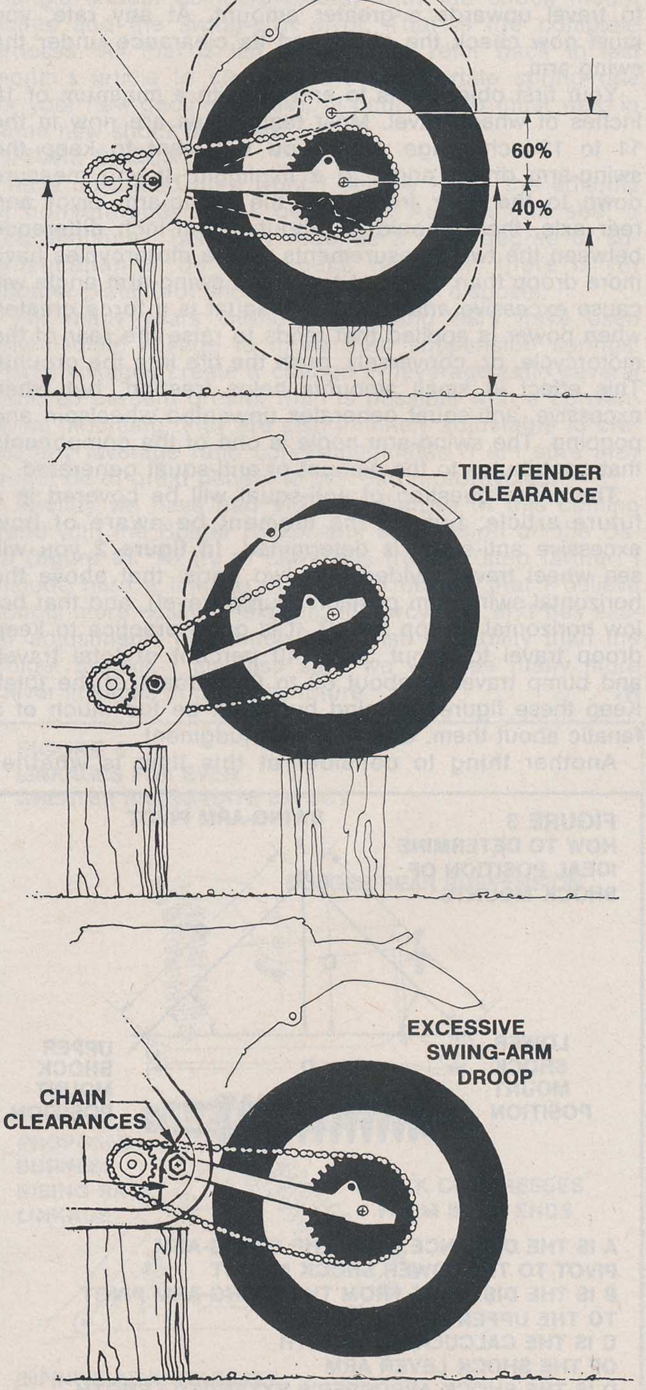


DESIGNING GEOMETRY

Now that we all agree that rising rate geometry is a desirable characteristic, let's begin designing a perfect geometry for your existing motorcycle. The highest priority is obtaining maximum wheel travel without sacrificing anything else. First you must make a survey of your own motorcycle to determine existing limitations.

Begin the survey by placing your motorcycle on a box

FIGURE 2
LIMITS TO REAR WHEEL TRAVEL



SUSPENSION BASICS

or stand and removing the shock absorbers. Now you can swing the rear suspension up and down manually and get a better look at the problems. Can you safely let the swing arm hang down farther without getting too much angle in it? Will the chain clear the top of the swing arm? If you let the swing arm droop farther it will raise the back of the motorcycle and the seat. Is that tolerable for your size and type of riding? If the back of the motorcycle is raised, steering angle (rake) will be reduced. Can you raise the front end enough to compensate? All of these things and more must be considered before you commence cutting and hacking. Maybe you don't have to droop out the swing arm. Maybe the fender and seat can be reconfigured to allow the wheel to travel upwards a greater amount. At any rate, you must now check the chain and its clearance under the swing arm.

Your first objective is to end up with a minimum of 10 inches of wheel travel. Most team bikes are now in the 11 to 12-inch range. Next, you will want to keep the swing-arm droop angle at a minimum. If you measure down to the floor from both the swing-arm pivot and rear axle, there should be about a four-inch difference between the two measurements. Some motorcycles have more droop than that, but too much swing-arm angle will cause excessive *anti-squat.* Anti-squat is a force created when power is applied that tends to raise the rear of the motorcycle, or, conversely, push the tire into the ground. This effect in small amounts helps traction, but when excessive, anti-squat generates unwanted wheelspin and pogoing. The swing-arm angle is one of the components that contributes to the amount of anti-squat generated.

The entire question of anti-squat will be covered in a future article, but for the moment be aware of how excessive anti-squat is determined. In **figure 2** you will see wheel travel divided into two parts: that above the horizontal swing-arm position (bump travel), and that below horizontal (droop travel). It is good practice to keep droop travel to about 35 to 40 percent of total travel, and bump travel to about 60 to 65 percent of the total. Keep these figures in mind but don't be too much of a fanatic about them. Use your own judgment.

Another thing to consider at this time is whether swing-arm length needs to be altered. Maybe the general handling is too responsive and a longer swing arm is in order. If it seems right for improved steering and weight transfer do it now as it will also help deliver more wheel travel without excessive swing-arm angle.

CHOOSING THE CORRECT SHOCK

The next step is to check shock manufacturers' catalogs for possible units (see Shock Buyer's Guide in October, 1977 *Motorcyclist).* The first thing to consider is travel. Try to choose a shock with a lot of travel so that you don't have to use too high a leverage ratio. The problem here is that shock manufacturers can't build in a lot of travel without increasing the overall extended length of the shock. In fact, the best a manufacturer can do is increase the shock travel only half the amount he adds to the extended length. Maybe the shock travel you want comes with such a long extended length that there is no way to fit the unit to your motorcycle. If that is the case, use a shorter shock and increase the leverage ratio. But if you use a high leverage ratio, make sure the shock is plenty rugged and the manufacturer has provided for increased damping. The best manufacturers will have shocks with damping abilities for several leverage ratios.

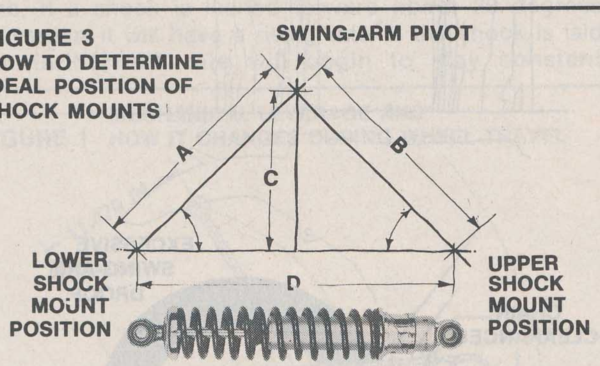
When you think you have decided on a particular shock, divide its travel into the travel you feel you can build into the rear wheel. This will give you the leverage ratio you must use for mounting. Check again to see if the damping is correct for that ratio.

CALCULATING CRITICAL DIMENSIONS

Before you go any farther a little math is in order. You know your leverage ratio and you can measure the swing arm to get the length of one of the two levers. In order to determine the length of the shock lever arm you must divide the leverage ratio into the swing-arm length.

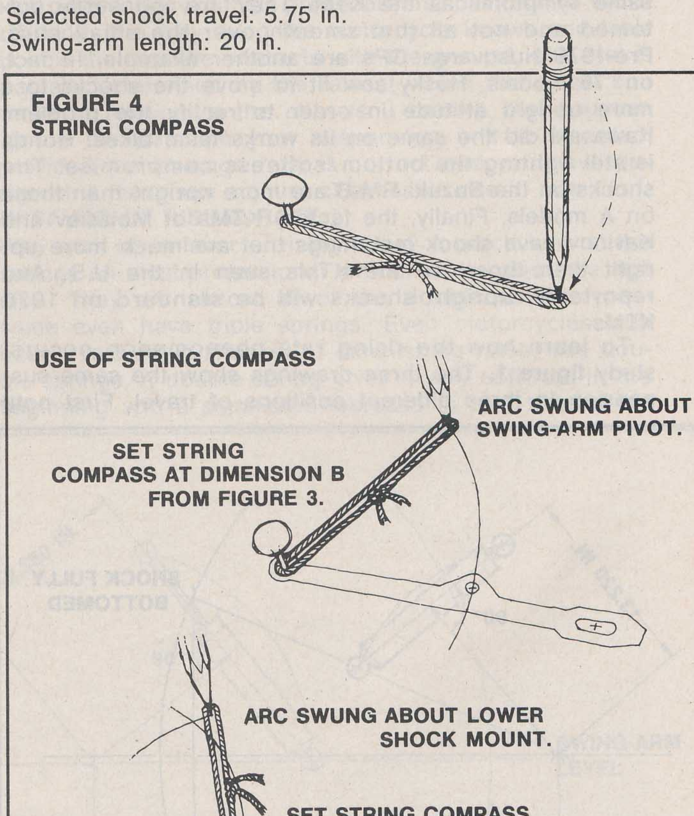
EXAMPLE
Planned wheel travel: 10 in.
Selected shock travel: 5.75 in.
Swing-arm length: 20 in.

FIGURE 3
HOW TO DETERMINE IDEAL POSITION OF SHOCK MOUNTS



A IS THE DISTANCE FROM THE SWING-ARM PIVOT TO THE LOWER SHOCK MOUNT
B IS THE DISTANCE FROM THE SWING-ARM PIVOT TO THE UPPER SHOCK MOUNT
C IS THE CALCULATED LENGTH OF THE SHOCK LEVER ARM
D IS THE SHOCK ABSORBER'S EXTENDED LENGTH

FIGURE 4
STRING COMPASS



$$\text{Leverage ratio} = \frac{\text{planned wheel travel}}{\text{selected shock travel}}$$

$$\text{Leverage ratio} = \frac{10 \text{ in.}}{5.75 \text{ in.}}$$

$$\text{Leverage ratio} = 1.74 \text{ in.}$$

$$\text{Shock lever arm} = \frac{\text{swing arm}}{\text{Leverage ratio}}$$

$$\text{Shock lever arm} = \frac{20 \text{ in.}}{1.74 \text{ in.}}$$

$$\text{Shock lever arm} = 11.49 \text{ or } 11\tfrac{1}{2} \text{ in.}$$

Once you have these figures you can make a diagram on a large piece of paper to determine where to mount the shock on the swing arm. Refer to **figure 3** to better visualize this procedure. The hypothetical shock we selected with 5.75 inches of travel will probably have an extended length of 15.5 inches. Whatever the extended length of your selection, make a straight horizontal line of that length on the paper. Now bisect (divide in two) that line to find the halfway point. From that halfway point project a line straight up (or perpendicular). The calculated length of your shock lever arm determines the length of this second line. Now, from the top of the second line draw two lines back down to the ends of the original horizontal line. You should now have a triangle divided by a line up the center.

This triangle represents the ideal shock mounting for maximum leverage ratio rise. Visualize the top of the triangle as the point for the swing-arm pivot. The lower left corner represents the lower shock mount and the lower right corner the top shock mount. If you tip the triangle on its left side it will make more sense.

If you constructed your triangle with accuracy both sides should be equal in length. These sides represent the distance from the swing-arm pivot to the lower shock mount *and* the distance from the swing-arm pivot to the upper shock mount. The important thing to remember is that maximum ratio rise will only occur when those two dimensions are equal.

The next step is to transfer these dimensions to the motorcycle in order to fabricate the mounts. To do this you need a device capable of drawing arcs with radii as long as those in your calculated dimensions. A string compass will be adequate for this purpose. To make a string compass tie the string into a loop and stretch it around two pencils. Retie the string until the distance between the pencils is the same as the length of the sides of your triangle. **Figure 4** gives a clearer view.

Now if you hold one pencil stationary right over the center of the swing-arm pivot you can swing the other pencil in a circle and draw two short arcs: one in the general area for the upper shock mount and the other across the swing arm, where the lower mount will be. Before drawing these arcs it might be useful to tape some cardboard over the two general areas on the motorcycle to help identify the lines. **Figure 5** illustrates the arcs to be made with the string compass.

Next reset the string compass so that its radium is the same as the extended length of the shock absorber you have chosen. Take a close look at the arc drawn on the swing arm and select the spot you want to be the center of the lower shock mount. For the next arc this spot will be the stationary end of the string compass. Swing an arc from this point across the upper arc already drawn. The point at which the two arcs cross is the correct location for the upper shock mount. To verify that you have done this procedure correctly, take your paper triangle and hold it up to the motorcycle. The tips of the triangle should coincide exactly with the shock mount points and the swing-arm pivot. That is the complete process. All that is left to do is to refer back to last month's article to compare the appropriate spring rate for your new geometry. And, of course, you must weld in some new shock brackets.

FUTURE SHOCK

I have described here what I believe to be the epitome of conventional shock geometry. As you can see, a "conventional" geometry requires a high degree of sophistication to be at its best. However, there is yet another plateau of shock linkage at our disposal.

For many years Grand Prix racing cars have used intermediate linkage to move their suspension springs. These linkages create a change in leverage ratio several hundred percent greater than is possible with a conventional mounting; they are also infinitely adjustable to create any leverage ratio curve imaginable. I am sure they would be of great benefit to off-road motorcycles.

Already we have had the first glimpse of this coming trend with the Bolger rocker-arm suspension on the Ossa **(figure 6).** To try to carry this trend a step farther, I include here a linkage of my own design that I believe adapts more easily to existing motorcycles, and has easier adjustments and much more rise capability than the Bolger system. I am also sure we will see many more clever linkages in the near future. M

FIGURE 5
TRANSFERRING IDEAL DIMENSIONS TO MOTORCYCLE WITH STRING COMPASS

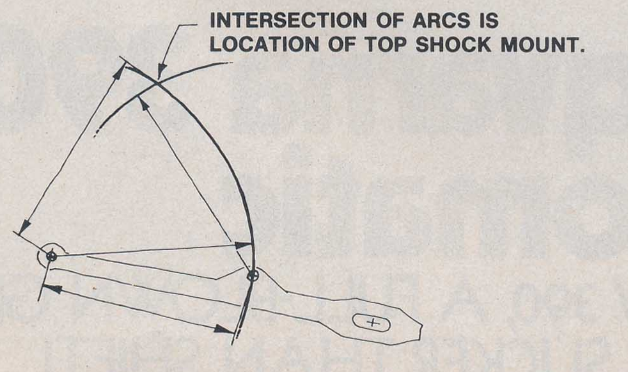


FIGURE 6
LINKAGES FOR EVEN GREATER RISING-RATE EFFECT