PROFICIENT MOTORCYCLING— Balancing And Steering

by DAVID L. HOUGH

We've harped on "push-steering" enough by now that *everyone* ought to know about it. If you're new to *Road Rider* and haven't yet encountered the term, push-steering is the phenomenon of pushing on the handlebar grip in the direction you want to go. In other words, push on the *right* grip to turn right. Push on the *left* grip to turn left. If you haven't tried this technique yet, motor your favorite roadburner down the street and give it a try. Then come on back and join us while we dig a little deeper into the mysteries of how motorcycle front-ends work.

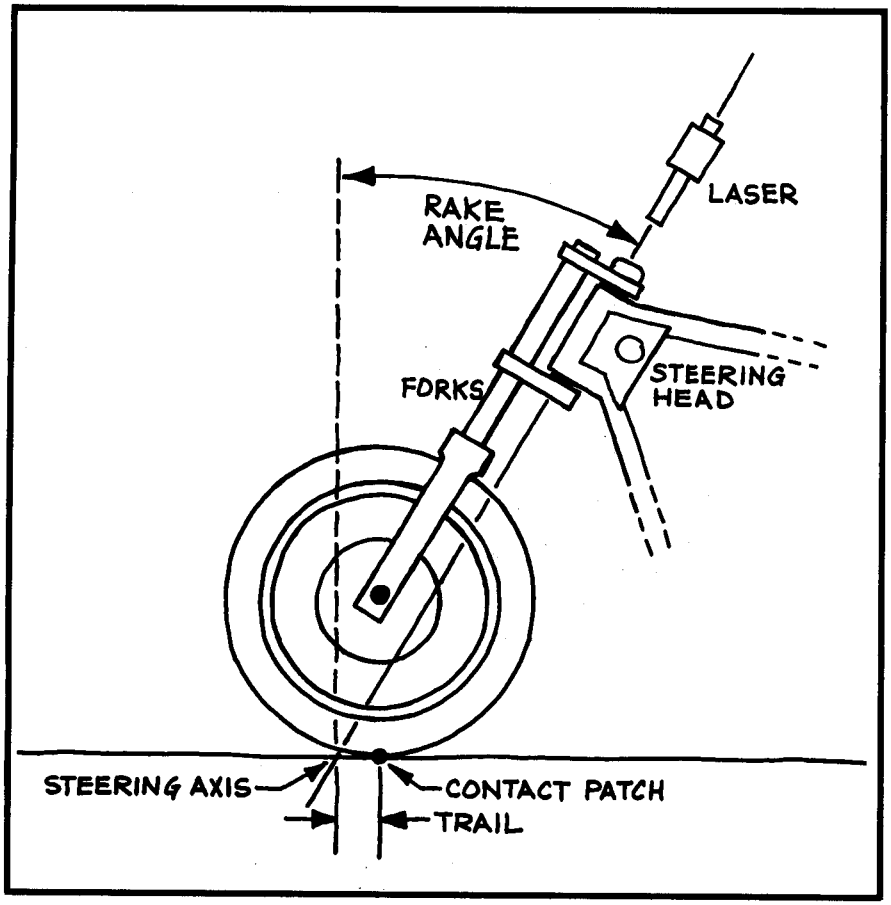

Figure 1: rake and trail

Balancing and Steering

Just to make sure we're all on the same wavelength, let's briefly review how a two-wheeler balances and steers. Balancing a motorcycle requires a bit of body English, of course, but what really does the trick is steering the front wheel back and forth to keep the tire contact patch under the mass of bike and rider. For example, if the machine starts to topple over to the right, we steer the front wheel more to the right until everything is rebalanced. We do the same thing with our feet while walking. This balancing act is continuous as we ride along. If I were to run my BMW through a puddle of white paint, you'd see that the track of the front tire makes a snaky line as it steers left-right, keeping the machine in balance.

Steering is the same thing as balancing, except that we intentionally steer to *un*balance the bike, so that it begins to fall over slightly to one side. As gravity overcomes inertia and the bike leans over, we steer to maintain balance, and the front tire forces the front end into an arc. Even during a turn, we steer the left-right snake path to keep the bike balanced and heading in the direction we want to go. The little left-right swerves are usually so slight that you'd swear the handlebars don't turn at all, but they do. If the grease in the steering head were suddenly to become epoxy glue and harden, we'd be unable to balance for more than a few feet.

Now, I've called this balancing-and-steering business push-steering just to keep it simple, but we really need to make it a little more complex. Pushing on the right grip is the same as turning the handlebars to the left, isn't it? Turning the bars to the left to make a right turn means the bars are turned counter to the direction you want the bike to steer. Sure enough, the techno-wizards call push-steering "countersteering." We'll find the term countersteering helpful later on.

Front-End Geometry

Motorcycle front ends *look* simple enough, but the geometry is really a fascinating bit of complexity. The front end not only has to steer the bike, it has to balance it, soak up road bumps, and do most of the braking. Lots of motorcycle engineers have gotten wrinkled brows and gray hairs trying to design the "perfect" front end. Don't worry—we'll keep it simple and not get into *all* the little details just yet.

The most noticeable oddity about motorcycle front ends is that the forks lean back at the top, and the axle is pushed out front. If you poke around under the handlebars, you'll see that the bearing around which the whole front end pivots—the steering head—is also leaned back, or raked at an angle (Figure 1). Pretend for a moment that we could shoot a bright-red laser beam straight through the steering-head bearings, and down through the tire until it hit the ground. If we were to measure the angle of this red beam, we'd find that it rakes back about 28 degrees. We would also discover that the beam doesn't pass through either the axle or the spot where the front tire sits on the ground. Our imaginary laser beam is really the center around which the front end steers. It would, in fact, strike the ground several inches *ahead* of the tire contact patch. There must be some reason for this, you may suspect. You're right. With the front tire rolling along the ground *behind* the steering axis, the front wheel wants to stay centered. The distance between the steering axis and contact patch is called "trail." If trail is too short, steering gets light and fidgety. If trail is too long, steering is heavy and solid, and the bike doesn't want to turn. Most contemporary road bikes have a trail of about five inches.

The Contact Patch

Since the way the front wheel wants to point is determined by the position of the front-tire contact patch in relation to the steering axis, it would be nice to have the contact patch stay put—but it doesn't. The patch not only changes shape, it changes location. When we load up a motorcycle, the tire bulges slightly on the bottom. If the tire is over-inflated, the contact patch shrinks in size. If the tire is under-inflated, the contact patch grows obese.

The contact patch moves forward or back as the tire rolls over a bump (Figure 2). As the tire first hits the bump, the contact patch suddenly leaps forward, and trail shrinks. When the tire rolls over the bump, the contact patch stays with it for an instant, and trail increases, perhaps doubling. This explains why the front end wants to waggle when crossing a set of ruts or an edge trap, such as a curb.

The contact patch also moves off-center to the left and to the right. When the bike leans over in a turn, the contact patch moves over toward the sidewall and gets way off center from that red laser beam we imagined earlier (Figure 3). That's okay, because the off-center drag on the tire can be used to help keep the machine balanced and stable during a turn. If the engineers are very clever, they can come up with exactly the right

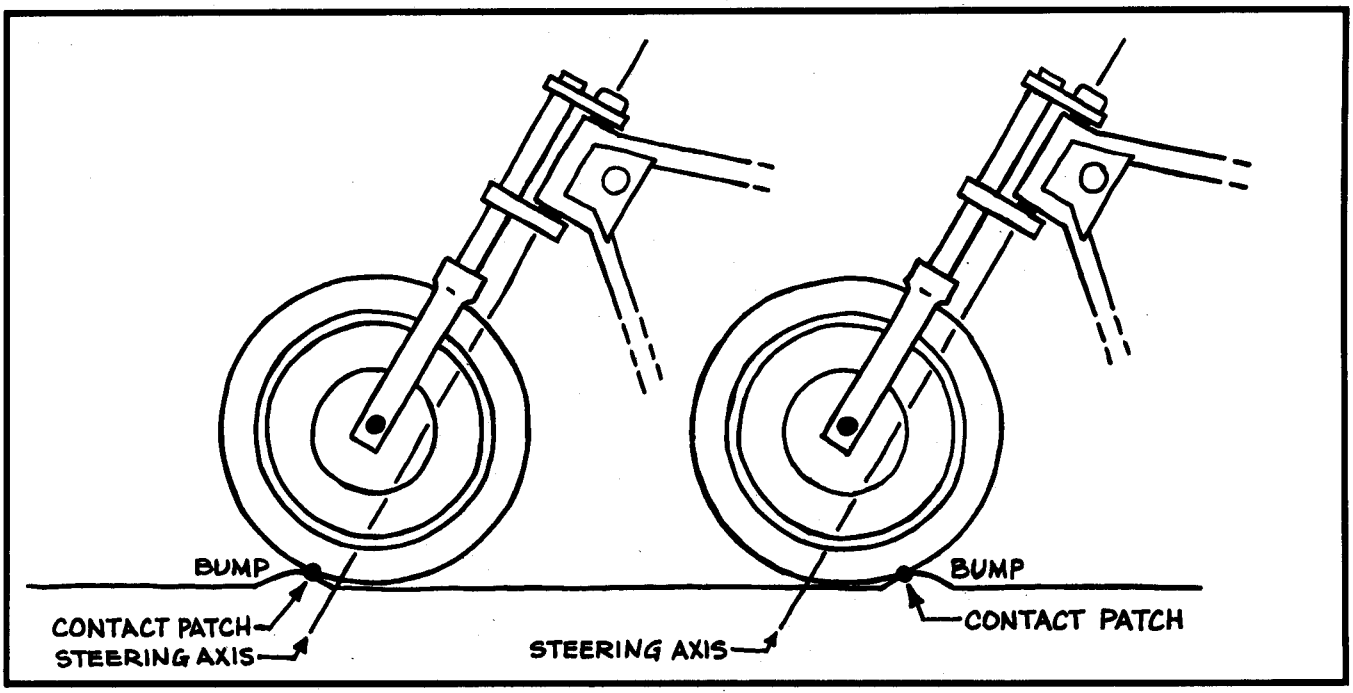

Figure 2: rolling over a bump

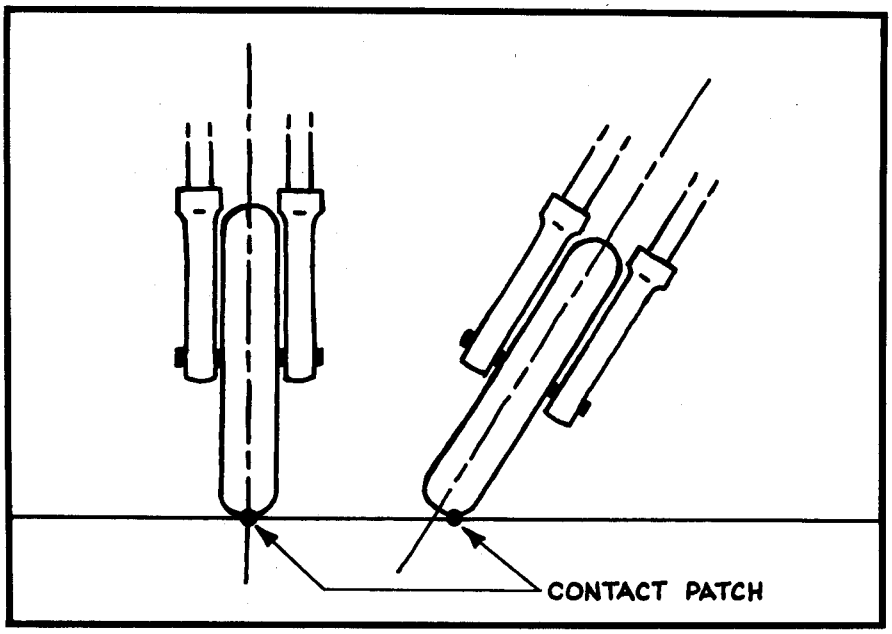

Figure 3: leaning over

combination of rake, trail, tire shape, and tire diameter to provide neutral steering while the bike is leaned over.

In the real world, however, the engineers don't always get the front-end geometry just right, and steering can be less than ideal. With excessive trail, the machine will resist leaning over, and the rider must continue to push on the low handlebar to keep it leaned over in the turn. Such a machine—for example, the popular "cruiser" class—will feel very stable in a straight line, but will require more muscle to bank through the twisties.

If trail is too short, the motorcycle will continue to lean over farther and farther during a turn—unless the rider begins to *pull* on the low grip to keep if from wallowing over. Such a machine will feel top heavy. The top-heavy feeling may not be so much a matter of weight distribution or center of gravity as it is poor steering geometry. What is spooky about a top-heavy machine is that steering pressure reverts from push-steering while upright to pull-steering when leaned over. The rider is actually countersteering to maintain lean angle and direction, but it certainly doesn't *feel* like push-steering.

So What?

You're probably wondering, "So what does all this stuff about rake and trail have to do with being a better rider?" The answer is that accurate balancing and steering require more than just knowing how to push-steer. If you can figure out what your particular motorcycle likes to do, you'll have a better idea of how to control it, and why it feels the way it does.

If the front-end geometry gets out of whack, the bike will become more difficult to control. Here are some common sources of rubbery steering:

Tires. Remember that under-inflated or over-inflated tires have an effect on steering as well as load-carrying. Keep those rubber donuts pumped up just right to keep the contact patch the right size. When you're looking around for new tires, pay special attention to the shape and overall diameter of a replacement, and try not to stray too far from the originals. Tires with a wide-oval shape may have more rubber on the road, but the contact patch may not move to the correct position when leaned over. A rear tire may be the same rim diameter, but the actual outside diameter can be an inch larger or smaller from brand to brand. A larger-than-stock rear tire will decrease rake and trail. Larger tires on both ends will increase trail. Even a larger front tire alone will increase trail ever-so-slightly. If in doubt, stay with the brands and models of tires recommended by the manufacturer of your bike.

Bearings. Steering input is transmitted from the handlebars down the fork tubes to the axle, then to the wheel and tire via the wheel bearings. Any slop in the chassis bearings can contribute to a rubbery feel, especially at low speeds. Steering-head bearings must be periodically cleaned and adjusted. If the front end wants to steer in little fits and jerks, it may be time to replace the steering-head bearings. Don't forget to inspect the swingarm bearings, too. They can cause spooky steering.

Nuts And Bolts. Loose bolts here and there in the chassis can contribute to some strange feelings in the front end. A loose nut on top of the upper triple clamp can cause some forward-and-backward play in the front end. If the triple-clamp-to-fork-tube bolts are loose, the forks can work out of alignment so that the wheel is pointed in a different direction from the handlebars. Don't forget to check the axle pinch bolts, as well as the fender-brace and fork-brace attachments.

Sidecar Steering

We've been talking mostly about two-wheelers up until now, but let's not forget about sidecar outfits. Sidecar rigs steer backward from two-wheelers. To steer an outfit into a right turn, *pull* on the right grip. Three-wheelers don't lean over in turns, so countersteering doesn't work at all. With all the drag of a sidecar pulling on one side, plus the bike not leaning into turns, the bike's two-wheeler steering geometry makes for very heavy steering. Sidecar outfits steer much better with about half as much trail as a solo bike—two to three inches, instead of the typical five inches of trail. While it is *possible* to re-engineer the geometry of the front end, it is very tricky and potentially hazardous to your body. If you're serious about long-distance sidecar piloting, consider changing the whole front end to one of the leading-link designs now available at major sidecar shops.

Your Next Bike

If your motorcycle handles like a dream, keep it that way. But if you now realize that your bike has a permanent case of ill-handling—even after you've pumped up the tires, greased the bearings, and torqued the bolts—we won't blame you for looking at new machines. You may be a lot more critical about how your next machine handles in the corners. Of course, there is one big drawback to buying a better-handling bike: if you *still* wobble through the twisties, you can't blame it on the motorcycle.