STABILITY

by Ken Condon

MOTORCYCLES FALL OVER easily. The moment you straighten the bike and raise the sidestand, you must assume control for the balance of the machine as gravity constantly tries to pull the bike to Earth. Motorcycles become more balanced once underway, but they are still notoriously unstable when ridden at very slow speeds.

None of this is news, of course. From the moment you first swung a leg over a motorcycle, you learned the importance of balance. To help you gain better control of your bike in slow speed maneuvers, let's take a closer look at the dynamics that affect motorcycle stability.

The Nature of Balance

Gravity pulls on all the parts of the bike, but to best understand how balance works let's imagine that gravity is pulling at a single point, which is called the "Center of Gravity" (CoG). A motorcycle is balanced when the CoG is vertically inline with the tire contact patches. If the CoG shifts to either side of the contact patches, then gravity pulls more on that side. That's the "weight" you feel when you lean the bike over onto the sidestand.

With the motorcycle moving forward, we control balance by continually "steering" the front wheel contact patch to keep it located directly under the CoG. Imagine balancing a baseball bat vertically on the palm of your hand. To keep the bat balanced, you must constantly move the bottom of the baseball bat side-to-side and forward-to-back around its CoG to control the "lean" and keep it from falling over. A similar thing happens when you turn your bike's handlebar; turning the bars to the right keeps the bike from falling to the right. (Figure 1)

Unlike the baseball bat, a motorcycle has two contact points, one for each tire. This means that balancing a motorcycle requires only side-to-side motion (lean angle). This movement in space that relates to lean angle is referred to as "roll." Lean angle and roll are controlled mostly by steering the contact patch to one side or the other, which shifts the motorcycle's mass around its CoG. (Figure 1) It's possible to balance a bike just by moving your body weight around, but steering the contact patch is much more effective and efficient.

One reason why balancing a motorcycle at very slow speeds is so difficult is that the front wheel's contact patch doesn't track sideways very quickly. It takes quick action on the part of the rider to arrest unwanted roll. This is usually done with handlebar movements.

Inertia

Balance gets easier as the bike increases speed, when forward motion and gyroscopic forces assist with balance. Newton's First Law of Motion states "Every body continues in its state of rest, or of uniform motion in a straight line, except when it is compelled to change that state by forces impressed upon it." This tendency for objects to stay at rest or stay in motion is called inertia. A motorcycle rolling down the highway at 60 mph wants to continue rolling along at 60 mph, however wind resistance and friction forces from tires, brakes, and bearings eat up some of the forward energy so we need engine power to maintain a steady speed.

Not only does inertia resist changes in speed, it also resists changes in direction. This resistance to directional change contributes to stability by pulling the motorcycle straight ahead; the faster you go, the greater the forward energy, and the more resistance the bike has to changing direction. (Figure 2)

Gyroscopic Force

At speed, the spinning motorcycle wheels contribute to stability through gyroscopic forces. Stability increases with speed, because gyroscopes maintain their relative position in space and serve to keep the motorcycle upright. The faster the wheels spin, the stronger the gyroscopic force. A small increase in speed makes an otherwise wobbly motorcycle more stable.

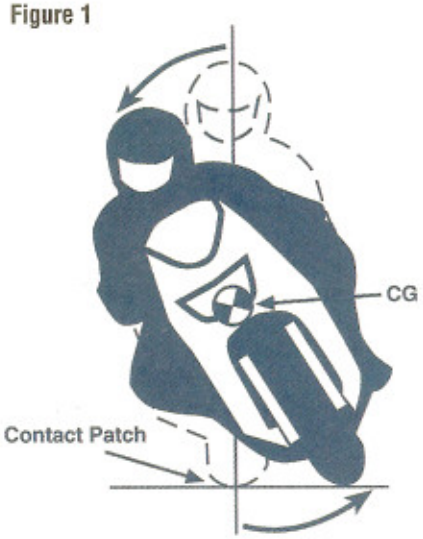
To turn a motorcycle we must overcome the stabilizing effect of the spinning wheels. The way to initiate lean is to introduce handlebar force, also known as countersteering. The best way to understand how gyroscopic force works with direction change is to hold a spinning bicycle wheel by the axle ends. Gyroscopic forces keep the wheel spinning straight and upright. If you turn the wheel to the right, gyroscopic effect causes the top of the wheel to lay over to the left in reaction to the twisting force (torque). This effect is called gyroscopic precession. The strength of gyroscopic precessional forces are determined by gyro weight, rotational speed, and the angular movement of the axles (steering).

But wait. Before you think that gyroscopic precession is the primary force that causes a motorcycle to lean, understand that there are many more factors that come into play; one being the friction between the tires and the road. Unlike the handheld spinning bicycle wheel, a motorcycle's tires are in contact with the ground, which means that tire friction becomes a big factor. And the friction of the tire on the pavement is much more powerful than the gyroscopic forces. The wheels do serve as gyros that stabilize the bike, but gyroscopic precession has relatively little to do with initiating lean. Initiating lean is done by countersteering, which works mostly by unbalancing the bike, by "steering" the front tire out from underneath the Center of Gravity and causing it to fall over.

Slow Speed Maneuvering

The stability offered by gyroscopic effects is minimal when riding at slow speeds, which often means that steering is twitchy. It also means that gyroscopic precession is almost non-existent, so steering resistance is minimal. This is one reason why it takes only a minute amount of countersteering pressure to initiate lean at very slow speeds; often so slight that riders fail to recognize that they are counter-

Figure 1



Leaning rotates the motorcycle's mass around its Center of Gravity (CoG).

steering at all.

To prove that countersteering is indeed used when riding at slow speeds, try to steer to the left when riding slowly. You'll quickly discover that your intended left turn suddenly becomes a right turn. Pay close attention and you'll recognize that an almost imperceptible amount of countersteering is required to get the turn started in the proper direction—press lightly on the left handlebar to lean left. Once the machine begins to lean, then you turn the handlebars to direct and balance the motorcycle—but it still takes countersteering to initiate the turn.

Keeping It Balanced

A significant factor that contributes to motorcycle balance is the geometry of the motorcycle's front end. Take a look at your motorcycle from the side. You'll notice that the forks are inclined back from vertical. This angle is called "rake." Rake usually varies between 24° for sport bikes to 32° for cruisers. A steep rake offers quicker steering, but less stability. A more laid-back rake offers stability but slower steering.

Take another look at your motorcycle and you'll notice that the forks are typically offset ahead of the steering pivot or axis. Now look at where the tire meets the ground (contact patch) which is located vertically below the front axle, and notice that the contact patch is located behind where the steering axis meets the ground. This invisible line invariably makes contact with the ground ahead of the front tire contact patch.

This distance between the steering axis and the contact patch is called "trail" and typically measures from 3.5" to 6". Trail acts as a righting force, not unlike the caster wheels on a shopping cart. This caster effect self-centers the wheel and helps maintain straight-line balance. (Figure 3)

Rake and trail also influence balance and stability by affecting motorcycle attitude. If you sit on a stationary motorcycle and turn the handlebars you'll see that while the contact patch stays put, the steering head moves off-center in the direction you turn the handlebars and rises and falls when the handlebars are turned from side-to-side. This causes the CoG to become offset from the contact patch in the direction of the turn and allows gravity to pull the bike over.

The point of describing this is for you to understand that turning the handlebars will shift the CoG/contact patch relationship and can be used to help you stay in balance when riding at slow speeds. If you are coming to a stop at a stoplight and feel the bike falling to the right, simply turn the handlebars to the right to drop the steering head to the left. Try it.

Body Position

Many riders manage instability by dragging their feet or duckwalking when maneuvering around parking places, turning within tight confines or negotiating stop-and-go traffic. Some think that they can somehow balance the bike better or catch it if it falls when their feet are dragging. However, keeping your feet firmly planted on the foot pegs and your knees against the tank contributes to stability by anchoring your lower body to the motorcycle. Stabilizing your body is important because abrupt shifts in bodyweight can upset the combined motorcycle/rider mass, especially at slow speeds. This is why it's important to instruct passengers to remain still, especially when moving at slow speeds.

Slight changes in body positioning can help keep the combined CoG of rider and motorcycle properly balanced when riding at slow speeds. Weighting your footpegs or shifting your shoulders from side-to-side can fine-tune direction control and balance. When turning, it's helpful to lean the bike independently of your body by supporting your weight on the footpegs and relaxing your upper body. This allows you to shift your weight freely and turn the handlebars fluidly.

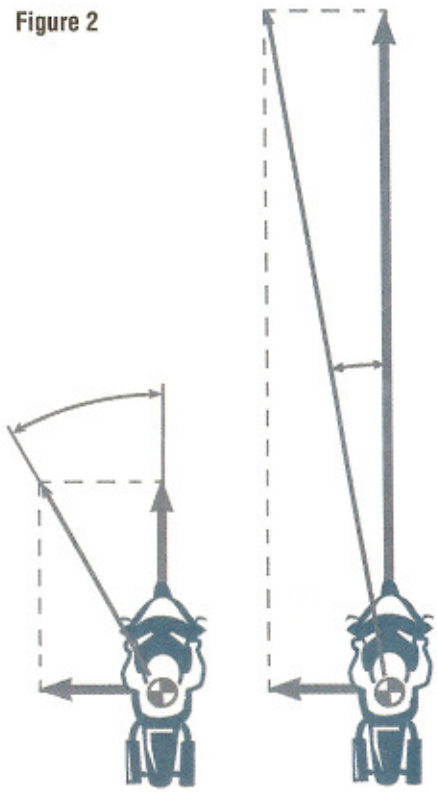
Counterweighting is a technique where you keep your body upright as you lean the bike into a turn beneath you. Counterweighting can help maintain balance at slow speeds, because if you were to lean your body in line with the bike (as you do when riding at faster speeds) then you and your motorcycle will likely topple over. The counterweighting technique involves weighting the outside footpeg (the right peg for left turns) and letting the motorcycle lean beneath you while your body remains more or less upright. For the tightest turns, shift your butt to the outside edge of the seat. The more lean angle you can get from the motorcycle, the tighter the turn you can make, but remember to keep your body upright.

Eyes Up!

One of the most useful things you can do to maintain balance and help direct your motorcycle is to keep your eyes up. This means looking well ahead when riding slowly in a straight line and turning your head to look where you want your motorcycle to go when making a turn.

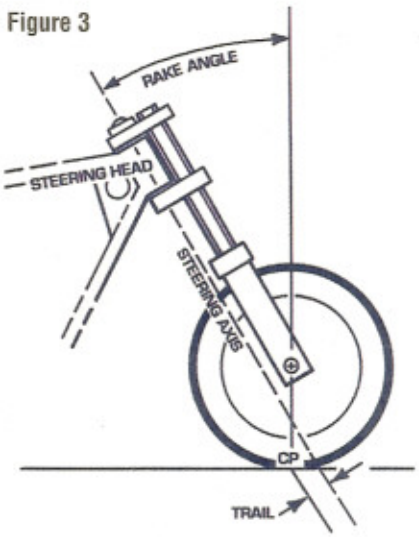
It's natural for most people to keep their eyes up when riding at speed, but many riders abandon this good habit when riding slowly. Unfortunately, looking down can contribute to instability and a lack of

Figure 2



Increased speed (shown here by the vertical force vector) provides greater inertial stability and more resistance to changing direction.

Figure 3



Two factors that dictate a bike's stability are rake and trail.

confidence. You are better able to maintain equilibrium if your eyes are up and oriented well ahead, not on the ground.

Keeping your eyes pointed ahead also allows you to gather information about where you'll be in the next few seconds. This is critical for avoiding a patch of oil, a pedestrian or a driver who is vying for the same parking space. Keep your eyes up to get an early look at these hazards and to avoid any sudden, and possibly abrupt, use of the brakes.

Visual direction control is the term used to describe how your eyes can help direct your motorcycle through turns: you go where you look. Of course, good visual technique isn't a cure-all for making turns, but it does contribute to direction control and should be a significant part of your slow riding technique.

When making anxiety-provoking slow speed maneuvers, it's easy to get caught in the "target fixation" trap. Target fixation is when your eyes and attention latch onto a scary hazard. Because your eyes have a role in guiding your motorcycle toward where you look, staring at any hazard is a problem. A common scenario is when a rider attempts a slow speed U-turn across the width of a road. As the rider gets close to the opposite edge, he or she panics, fearing that the motorcycle will run wide. The rider instinctively looks down at what he or she so desperately wants to avoid and the bike drifts toward the outside edge of the road as if by magic.

Master slow speed maneuvers with proper technique.

Minimize Instability

Because stability diminishes at low speeds, it's beneficial to minimize the amount of time you're riding slowly. If you are in stop and go traffic, keep plenty of space between you and vehicles ahead to allow yourself to maintain a stable speed. If you must stop, delay braking to allow the least amount of time at unstable speeds. You can also minimize slow speed riding when starting from a stop by getting up to a stable speed as quickly as possible. This may require waiting a moment for the person in front of you to move ahead before easing out your clutch.

Speed Control

When riding slowly, it's best to avoid using the front brake, because front brakes are often rather touchy and can easily cause a slow-moving motorcycle to lurch to an abrupt stop and tip over. The solution is to rely on the less powerful and more controllable rear brake. Of course, you can only do this if your feet are on the footpegs.

The rear brake is also useful in maintaining stability and balance. Dragging your rear brake (while keeping your throttle steady) is a good way to adjust speed as you make a tight, slow speed turn. However, some motorcycles have integrated brake systems that don't allow rear-brake-only application.

Slow speed control depends a lot on steady forward drive. You will not be able to skillfully negotiate a tight turn if your motorcycle is lurching abruptly due to rough throttle application. Unfortunately, many motorcycle throttle mechanisms are rather sensitive, which can make slow speed maneuvers a greater challenge.

To adjust speed, you may be tempted to roll off the throttle, but this often results in choppy throttle inputs and abrupt deceleration. Instead, it's better to keep the throttle steady and adjust speed by using techniques that don't involve significant throttle adjustments, such as slipping the clutch and dragging the rear brake.

Of course, either of these techniques still require good throttle control. A helpful trick that maintains steady throttle is to keep your right wrist in a low position below your knuckles. This "locks" the wrist and minimizes throttle movement. You can also "anchor" your thumb or forefinger on the control pod for further control.

Tight Turn Technique

Let's put all of these slow riding tips together to perform a low-speed, tight U-turn. The first thing you need to do as you approach your tight turn is determine an appropriate entry speed. You may already be rolling at a slow crawl, so braking may not be necessary. But if braking is required, do so smoothly and favor your rear brake to minimize abrupt speed adjustments. Also, delay your braking to minimize the amount of time that your motorcycle is unstable and squeeze your clutch to prevent stalling.

Once the motorcycle is slowed, position your weight on the outside footpeg and lean the motorcycle beneath you as you release the brakes, ease out the clutch into the engagement zone, roll on the throttle slightly and turn your head to look through the turn. Use your clutch to feed power smoothly. Minimize throttle movement by keeping your wrist down and anchoring your thumb or index finger against the control pod. Slip the clutch and lightly drag the rear brake for speed control and stability. You may have to lean quite a bit to make a very tight turn, but that's okay as long as you match the amount of steady forward momentum with the lean angle.

Slow speed maneuvers cause anxiety even with veteran riders. But, with some practice you can increase confidence and decrease the likelihood of a slow speed tip-over.

The Author

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