Cornering Supplement #3- Cornering

CORNERING

For many riders, cornering is what enjoying motorcycles is all about. For others, it is a necessary evil that is endured only as a means of getting to the next straight section of highway. Regardless of which end of the spectrum a rider places himself, the ability to corner smoothly and safely is a necessary skill. This supplement presents the basics of cornering in more detail than most riders need or care to know about. It is intended, as are all of the technical supplements, to provide you with background information.

SLOW, LOOK, LEAN, and ROLL! That's what we recommend as the procedure for cornering. We will look at each of these in some detail, but before we do that, let's take a minute to put this procedure into the context of riding.

In this course, we discuss the mental activity of riding in terms of SEARCH, PREDICT, and ACT. Our cornering procedure should be thought of as only one example of applying our basic strategy to a specific riding situation. No corner exists independently. The rider has to SEARCH, PREDICT, and ACT his or her way both to the corner and away from it, as well as through the corner itself. So let's begin with the approach to the turn to establish a context for our cornering procedure.

Line of Sight and Speed

> As the rider approaches a turn he or she must decide on two things concerning the corner: an acceptable line and an appropriate speed.

To make these judgments, the rider must first determine what sort of corner it is. Is it a sharp corner or a wide "sweeper"? Is it a single corner or one of a series? Is it of constant radius or does the radius change? Is the road banked properly or is it "off camber"? Are there any surface defects or hazards? Is there conflicting traffic? Can the rider see completely through the corner, or is the line of sight restricted?

That's a lot to find out in a short period of time, and a mistake in any one of them could mean trouble. To gather such information about a corner, the rider must be able to see as much of the corner as possible. Remember what we say in the Riding Strategies discussions about maintaining an aggressive search with a 12-second visual lead. Well, that applies to more than just urban situations. Granted, it may not be possible to always maintain a 12-second line of sight, but the principle remains a valid one. The rider must consciously work to maximize the line of sight.

Notice that there is a subtle difference between the visual activity associated with the SEARCH that occurs as we approach the corner and the LOOK that occurs as part of the cornering procedure. They are certainly related and, in fact, overlap as the transition from the approach to the corner takes place. However, some riders could become confused and think that they should not do any "looking" until they have slowed for the turn.

There is one general rule concerning line of sight in corners: the exit is where you want to go, so the exit is what you need to see. Until you can see the exit, you really have no idea what sort of corner it is and what is going to happen immediately after it. Therefore, if you can't see all the way through the corner to its exit and beyond, then you should "stay wide" and limit your speed until you can. "Staying wide" means keeping as close to the outside as is practical, consistent with roadway and traffic conditions. But what does "limit your speed" mean?

Well, it's sort of like not "overriding your headlight" at night. It means maintaining a speed that will provide time and space to successfully react to situations as they first appear in your field of view. There's more to the subject of speed in turns than this, and we'll get to that shortly.

But for now let's continue on the subject of selecting a path of travel.

One of the principles of traction management is that the rider should try to maximize the amount of traction reserve to ensure that there is traction available to make changes in speed and/or direction should that become necessary. One of the ways to do this is to minimize the amount of side force the tires must generate in a turn. If you'll recall from the Traction Pie Supplement, the cornering force necessary in a turn depends on two variables: speed and turn radius. For any given speed, the greater the turning radius, the smaller the side force and the greater the traction reserve. This means that the rider should choose a line through the corner that tends to maximize the turning radius, again consistent with roadway and traffic conditions.

Apex

And there is one more factor that we need to consider when selecting a path—where to place the apex.

> The apex is the point along the path through the corner that is closest to the inside boundary of the turn. Where it occurs in relation to the geometry of the turn can be very important to the efficiency and smoothness of the line.

To see what the options are regarding the apex, let's begin by considering a simple, constant-radius turn with no obstructions to line of sight. Our traction-management principle of selecting a path with the greatest practical radius tells us that we should begin the turn as far toward the outside as we can, then follow a smooth path that takes us near the inside edge of the turn at its midpoint, then exit the turn as far to the outside as practical. This puts the apex at the center of the turn. We can use this as the reference point for the rest of the discussion.

Apex — Increasing Radius

Next, consider a turn with an increasing radius. This is not a particularly challenging sort of turn for most riders, but they can be set up poorly if an inappropriate apex is chosen. To arrive at the greatest practical radius for this type of turn, you must place the apex prior to the midpoint of the turn; that is, an early apex. A normal or center apex for this type of turn results in an overly sharp initial radius and makes poor use of the extra room available during the last part of the turn.

Apex — Decreasing Radius

The opposite end of the turn spectrum is the decreasing-radius turn. This type of turn is difficult because the tendency is to select a path that produces an apex too early in the turn and requires an adjustment in line and/or speed to prevent running wide at the exit. The greatest practical radius is achieved by using a path that results in an apex which is beyond the center of the turn, a late/delayed apex.

Since the most difficult of these three types of turn is the decreasing radius, it is the prudent prediction that a rider should make when approaching a blind turn. If the rider sets up for a decreasing radius and a late/delayed apex and then discovers a constant or increasing radius as the exit comes into view, this is a pleasant surprise. The late/delayed apex almost always results in greater reserves and more options for the rider to adjust to surprises that are not pleasant. So, in that sense, it is potentially the safest option for any turn.

Apex — Multiple Turns

All of the foregoing discussion concerning apex selection was based on the assumption that there was a single turn to contend with. When one turn leads to another, then the selection of path and apex becomes more complex, and the simple rules discussed above might not result in the best line through the series of corners. Consider, for example, a series of two turns where the first is a constant radius and the second is a decreasing radius. If the rider selects a normal or center apex for the constant-radius section, he winds up in the wrong place to enter the decreasing-radius section. If, instead, the rider sets up a late/delayed apex for the constant-radius section, the rider is in a good place to enter a path with a late/delayed apex for the decreasing radius. This is but one example of the need for the rider to SEARCH well ahead and to PREDICT what is going to happen next before ACTING when it comes to selecting a path and an apex for any turn or series of turns.

Apex — Summary

To summarize, when approaching a turn, the rider should select the path that tends to maximize line of sight until the exit becomes visible and then follow the path that results in the maximum effective turn radius through the exit of the turn. In many cases, the "ideal" path and apex must be modified because roadway and/or traffic conditions preclude using the path with the best line of sight or the maximum turn radius. With this in mind, we can get on to the subject of speed.

3 Speeds for Cornering

It is useful to think in terms of three speeds associated with any corner. The first is the **approach speed**, which is simply the speed of travel when the corner is first perceived by the rider. It can be any speed consistent with the conditions and the rider's skill and preference. The second is known as the **entry speed**, which is the speed as the rider makes the steering input to begin the lean. We'll deal with this one in detail in a moment. The third is the **exit speed**, which is the speed as the bike leaves the turn and enters the ensuing straight section or another turn.

Of these three speeds, the entry speed is the most critical, because it determines how safely and smoothly the turn can be made.

Approach / Slow

The approach speed is reduced to entry speed prior to the turn. This is the SLOW part of our basic procedure and involves rolling off the throttle, using both brakes, and downshifting as appropriate. The point where this begins and the strength of the brake application is determined by the amount of speed to be lost, the distance available, the braking ability of the machine under existing conditions, and the braking skill of the rider.

Selecting an entry speed is a very complex decision. It depends on the rider's perception of the turn radius, surface condition, and slope; limitations on the line of sight; the speed, position, and direction of other traffic; and the presence of fixed hazards. It also depends on the rider's ability and willingness to use the motorcycle's available cornering performance and, most important from a safety perspective, the ability to respond to the worst-case scenario PREDICTED during the approach.

The need to select a clearly conservative entry speed when the exit is not visible has already been mentioned. Here the need to be able to respond to our worst-case prediction dominates our decision. When this is not the case, then we are free to choose an entry speed that is consistent with the other factors. We'll get into it in greater detail when we discuss the ROLL part of our recommended procedure, but at this point we should define the **upper limit** on entry speed. It is the speed that will permit a gradual roll on of the throttle from the entry point (or the point where the exit becomes visible) through to the exit. Entry speed may be lower than this, but it should never be higher.

Cornering Sequence

With the establishment of the entry speed, the SLOW portion of the cornering procedure ends. LOOK is next; although, as we pointed out earlier, it is really just a continuation of the SEARCH aspect of our overall riding strategy. However, there are some specific aspects of the LOOK that deserve special attention.

Look

The first is that it should involve not just a movement of the eyes but a turn of the head so as to "face" the exit and the intended path after the turn. For gradual turns, this is a minor turn of the head; for sharp turns, it is an exaggerated head turn; and for U-turns, it means turning the head as far as it will turn. The reasoning behind this technique is that it not only allows the rider to SEARCH more effectively, but it also provides what we call "visual directional control." This means that the mind tends to "automatically" make the control inputs necessary to make the motorcycle go where the rider is looking. It also tends to discourage looking down, which causes balance problems. And it prevents wobbling by permitting the rider to perceive the turn as a single, coordinated maneuver rather than as a series of short arcs.

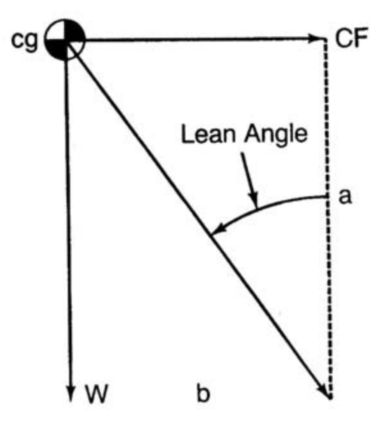
One final aspect of the head turn associated with the LOOK is that the eyes should be kept level with the horizon. The reason for this recommendation is that some individuals tend to become disoriented if their head is tilted while in a turn. Not all people are affected in this way, but keeping the eyes level is a good idea. Those who are prone to this reaction will be spared the problem, and it doesn't hurt anything for those who don't have the problem.

Lean

This brings us to the LEAN in our procedure. There are two ideas to get across here: (1) the motorcycle must lean to turn and (2) lean angle is most quickly, effectively, and precisely controlled through the use of pressures on the handgrips. For detail on the second topic look at the supplement on "Countersteering." For now, let's look at why leaning is required.

A motorcycle needs to lean to turn for two reasons: First, by leaning, the tires produce much of the cornering force necessary is to make the bike turn. But the principal reason why a motorcycle needs to lean in a turn is to maintain balance. When a motorcycle turns,

Diagram 1: Basic Balance Condition



centrifugal force, acting through the center of gravity (cg), tries to cause the motorcycle to lean toward the outside of the turn. To maintain balance, the cg must be moved toward the inside of the turn (that is, the motorcycle must be leaned) so that the weight, which also acts through the cg, can counteract the centrifugal force by trying to cause the motorcycle to lean farther into the turn. What we have is really a "balance" between two opposing torques, like in arm wrestling. **Diagram 1** illustrates this situation.

This diagram is similar to one we saw in the "Traction" supplement. Here, think of the bike as being like one leaf of a door hinge. The axis of the hinge is the line between the contact patches on the ground. The diagram shows that the centrifugal force (CF) acting with the lever arm "a" (the height of the cg above the ground) generates a torque about the axis that tends to lean the bike to the right. The weight (W) acting with lever arm "b" (the lateral or sideways displacement of the cg) generates a torque about the same axis that tends to lean the bike to the left. The magnitude of these torques is simply the product or the force (CF or W) multiplied times its respective lever arm (a or b). When these two torques are equal (CF x a = W x b), the bike is balanced and the lean angle remains constant. If the two torques are not equal, then the lean angle will change in the direction of the stronger torque.

Notice that if the bike is vertical, the weight has no lever arm and can produce no torque to affect the lean. On the other hand, at zero lean angle, the centrifugal force has its maximum lever arm and, therefore, the maximum potential for affecting lean angle. *This is the principal reason why steering input is the most effective way of initiating a lean.* It is also why attempting to use weight shift for this purpose is so ineffective. The rider's weight is too small relative to that of the motorcycle to produce a lateral cg shift big enough to result in a significant lever arm for the weight.

However, as the lean angle increases from zero, the lever arm for the weight gets larger, and the lever arm for the centrifugal force gets smaller.

This means that the effectiveness of the weight in producing an effect on lean angle increases, while the effectiveness of the centrifugal force decreases. Therefore, as lean angle increases, weight shifts become relatively more important, and they can be used to good advantage to make fine adjustments to lean angle while in a turn. Consider, for example "dropping" the inside knee off the tank to initiate a slight increase in lean angle. Some riders use this and similar techniques, and they should not be discouraged from using them. Two ideas that should be discouraged are (1) shifting body weight is the best way to initiate a turn and (2) counter steering is for obstacle avoidance only.

Roll

This leads us to the final step in the recommended cornering procedure, ROLL on the throttle. This part of the technique is based on the need to stabilize the machine on its suspension and to prevent any sudden changes in the distribution of traction between the two tires.

Recall from the supplement on "Traction" that the accelerations that produce changes in speed result in a shift in the relative loading of the tires. They also result in extension or compression of the suspension components. What do these things mean to the rider when the motorcycle is in a turn?

In the "Traction Pie" supplement, we noted that in a corner a significant portion of the available traction is being used for the side forces necessary to make the bike turn, plus the steering forces and driving forces necessary to maintain speed and control. Any excess traction is the reserve for making changes or responding to surprises. We also know that the total cornering force is divided between the two tires based on the relative speed of the wheels.

For large-radius turns, the two wheels are tracking along nearly equal arcs, so each is subjected to approximately the same demand for cornering force. In tight turns, the front wheel is tracking an arc of significantly greater radius than the rear wheel. Therefore, it is traveling faster and has a greater demand for traction.

The distribution of available traction between the tires is determined by the cg location, the angle of incline (if any), the speed (aerodynamic forces), and any accelerations and/or torque-reaction forces that occur from moment to moment. So long as nothing changes abruptly, the traction distribution remains fairly stable. But if the rider introduces changes through the abrupt use of the throttle, there is a rapid shift in available traction from one tire to the other. This could be enough to leave one tire without enough traction to handle its need.

Traction Shifts — Abrupt Deceleration

Suppose, for example, that the throttle is abruptly rolled completely off when the bike is at a large lean angle (or even a small lean angle on an off-camber surface). The deceleration would cause a shift in available traction away from the rear. If the engine braking were strong enough, this could be enough to produce a skid of the rear tire. If not, there still could be a problem at the front.

While the deceleration would make more traction available at the front, it would also have a component (because of the lean angle) that would add to the demand for side force. Therefore, it is possible under certain conditions to produce a skid of the front tire by rolling off the throttle in the turn.

Traction Shifts — Abrupt Acceleration

Similar problems at the rear could be the result of rolling the throttle on abruptly or excessively. The traction available at the rear would go up as a result of the acceleration, but the increased demand for traction—due to high Driving Force and increased Cornering Force as the speed builds—could exceed what is available.

Abrupt Speed Change — Other Difficulties

Other difficulties arise from abrupt increases or decreases in speed in a turn. As such changes occur, the suspension extends or retracts. This will change the ground clearance and steering geometry and can introduce oscillations in the suspension. Reduced ground clearance limits lean angle and can result in loss of traction if parts of the motorcycle start to drag. The steering and suspension changes can result in directional stability and control problems.

Solution to Roll

The solution to all of these problems is to avoid abrupt speed changes in a turn. And since greater ground clearance and extension of the front suspension tend to add to overall stability and control, a gradual ROLL on of the throttle to produce a steady speed or a gentle acceleration is preferable to a deceleration. But we should emphasize that what is called for is a gentle, gradual roll-on only; too much acceleration or speed can drive the demand for traction beyond what is available, and a skid would occur.