Supplement #4

Leaning Out and Leaning In

Leaning Out

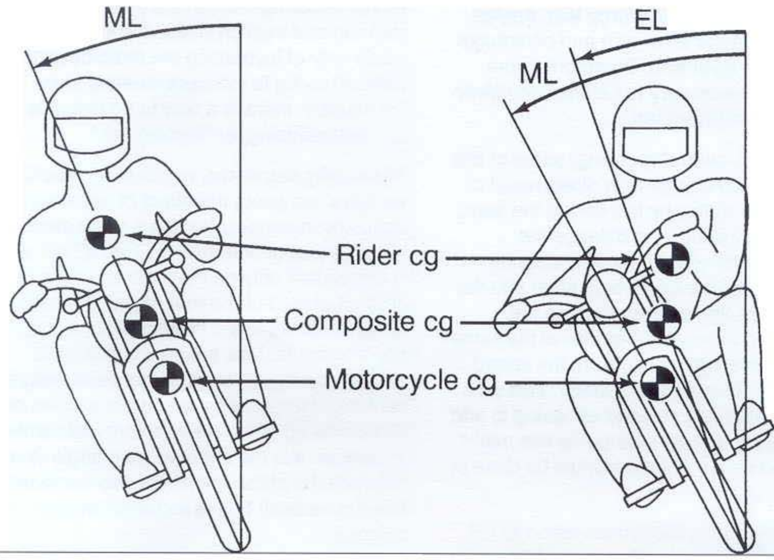
Since increasing the motorcycle's lean angle is a way of ensuring the tightest possible turn within steering and traction limits, it would be nice if there was a way of increasing the motorcycle lean angle without having to increase steering angle or speed. Fortunately, there is a way to do this. It is called counterbalancing, or "leaning out."

To see why this works, we must first realize that, as we have just seen, the effect of reducing turning radius by increasing lean at a given steering angle is a matter of geometry only. That is, the turn radius is dependent only on the steering angle and the amount of lean of the motorcycle's wheels. On the other hand, we recall from the "Cornering" supplement that the balance condition is determined by the struggle between weight and centrifugal force, each acting through the overall or composite cg of the rider-motorcycle combination. Therefore, it is the effective lean angle (the angle between the plane containing the composite cg and the vertical) that is important in determining balance.

When the rider leans with the motorcycle, the motorcycle lean angle and the effective lean angle are the same. "Leaning out" shifts the composite cg slightly to the outside, and the effective lean angle is reduced relative to the motorcycle lean angle. This is shown in **Diagram 2**, where ML stands for motorcycle lean, which is measured from vertical to the motorcycle centerline, and EL stands for effective lean, which is measured from vertical to the line through the composite cg.

What does this do for us? Since the effective lean angle is smaller, the weight has a shorter lever arm; so the need for centrifugal force to maintain balance is reduced. This means that the large lean angle necessary for a small turn radius can be maintained at a lower speed than if the rider were to lean with the motorcycle. There are two potential reasons for leaning out: (1) it permits cornering at a slightly lower speed in situations where traction might be lower than normal; and (2) the rider is not comfortable with either the speed required to maintain balance or with the perception of the lean angle required to make the turn while leaning with the machine.

Diagram 2: The Effect of Leaning Out



Note that the effectiveness of "leaning out" depends on how much the rider's weight is able to produce a significant shift in the composite cg. This is determined principally by the ratio between the rider's weight and the weight of the machine. A heavy rider on a light machine can produce a relatively large cg shift. A light rider on a heavy machine can't shift the composite cg very much. One conclusion from this is that on any given machine, the heavier rider has the potential to turn at a slower speed than the lighter rider. Nonetheless, every rider can gain some benefit from "leaning out" in a tight turn.

Highway-Speed Turns

The next topic is at the opposite end of the turn spectrum, turns at highway speeds. The most typical problem that arises with such turns is when the rider misjudges the radius and/or the slope of the turn and discovers, while in the turn, that the radius must be tightened. So long as the rider stays within available traction, stability, and control limits, then the principal concern is one of having enough ground clearance to increase lean angle.

At highway speeds, the centrifugal force can compress the suspension and reduce ground clearance significantly, so the option of increasing lean angle may be severely limited. What else can the rider do to decrease turn radius?

One option is to reduce speed. But as we have seen in the supplement on "Cornering," this can result in stability and control problems if not done carefully, and it can further aggravate the ground-clearance problem. Fortunately, so long as there is a traction reserve, there is another option.

As we have already covered, the turn radius is determined by the lean angle and the steering angle. So when ground clearance limits the motorcycle lean angle, the rider can turn sharper only by increasing steering angle. But if the rider increases the steering angle to reduce the turn radius, the centrifugal force increases accordingly. The problem then becomes how to keep this increased centrifugal force from acting to decrease the lean angle and increase the turn radius. "Leaning in" is a technique that can help in this situation.

Leaning In

Recall from the discussion on tight turns that the rider can shift the composite cg away from the centerline of the motorcycle by shifting weight to the side. This produces an effective lean angle that is different from the motorcycle lean angle. In this case the rider needs to increase the effectiveness of the weight to counteract more centrifugal force, so the effective lean angle must be greater than the motorcycle lean angle. This is achieved by "leaning in," by concentrating weight on the inside of the turn. This is shown in **Diagram 3**. Again, ML stands for motorcycle lean angle, which is measured from vertical to the centerline of the machine. And EL stands for effective lean angle, which is measured from vertical to the line through the composite cg. As with "leaning out," the effectiveness of "leaning in" depends on the weight of the rider relative to that of the machine. On a given machine, the heavier the rider, the greater the potential for benefit from the technique.

Summary

In summary, "leaning out" results in an effective lean angle that is less than the motorcycle lean angle and permits cornering at lower speeds at any given turn radius and steering angle. It is useful when making tight turns at low speeds when steering angle can't be increased or when speed must be minimized because traction is marginal. "Leaning in" results in an effective lean angle that is greater than the motorcycle lean angle. Provided that the steering angle can be increased, it permits sharper turns at any given speed when ground clearance limits motorcycle lean angle. It is useful in highway-speed turns and in decreasing-radius turns, provided that ground clearance, rather than traction, is the dominant problem.

It is important to understand that neither "leaning out" nor "leaning in" has any direct effect on the amount of traction available, because they affect neither the tire loading nor the coefficient of friction. Therefore, neither technique is some sort of "magic" that will allow the machine to corner at a speed greater than that limited by traction. These techniques are principally useful in overcoming limitations in steering angle, ground clearance, and/or rider comfort. They can also affect stability and control to some extent, because they tend to lower the composite cg, in addition to shifting it laterally. But such effects are generally quite small and usually not significant.

Diagram 3: The Effect of Leaning In