Initiating a turn

The basics

How do we actually initiate the turn, we have already seen that a moving motorcycle has an automatic tendency to stay upright? Do we lean first or steer first? If we were to turn the handlebar in the direction we want to go, both centrifugal force and gyroscopic precession of the front wheel would cause the bike to topple outward. Therefore, if we momentarily try to turn the bar in the opposite direction, then the centrifugal and gyroscopic forces will cause the machine to bank to the correct side. There are four main effects to be observed.

A steering action to the *right*, will cause the machine to start turning *right,* and just as in a car, centrifugal force will cause a lean to the *left*. This is the major banking influence.

This steering action as we have seen, will also produce a small precessional tendency to lean the machine to the *left.* This is a small effect when the wheels are on the ground.

- Gravity will then initially augment the banking effect, but this will become less important as the centrifugal force away from the turn centre builds up and balances the gravitational moment completely, when the bike reaches the steady state lean angle.
- The velocity of banking or roll rate will give rise to gyroscopic torques which oppose the rider's counter-steering input helping to steer the front wheel into the curve. This gyroscopic torque is in opposition to the rider applied steering torque, and in fact balances most of his input and hence works against rapid steering. However, without this "negative feedback" the bike would be rather unstable and very hard to control.

These forces will also act on the rear wheel which, because it is rigidly attached to the bulk of the machine, will tend to make the machine yaw into the curve. However, this reinforcing effect is secondary to that of the front wheel. (Steering rake and front-wheel trail, i.e. castor, also help steer the machine into the curve, as we shall see later.) When we have established our correct lean angle, the processes for maintaining balance, as described above, will come into effect and help keep the bike on our chosen path.

We have seen, then, that a turn can be initiated by steering momentarily in the "wrong" direction. Termed "counter-steering", for most riders this action is accomplished subconsciously. In racing, riders often make use of deliberate counter-steering to achieve the high roll rates necessary under those extreme conditions. Briefly, it is the combination of gyroscopic moments and centripetal force that requires this counter-steering action, we don't have a choice in the matter. There are those that would have us believe that counter-steering wasn't known about until the 1970s. or '80s.. This is nonsense, it is well documented that around the start of the 20th century the Wright Bros. were well aware that this was the mechanism for turning a bicycle. In the early 1950s., whilst chief engineer at the Royal Enfield motorcycle factory, Wilson-Jones did a series of tests with real motorcycles to investigate this further. The results of these and some of his other experiments into steering geometry were published in engineering journals.

However, counter-steering doesn't explain how we can corner 'no-hands'. Although, whilst it is possible to do this, it is accomplished only with a lot more difficulty. So let us consider what happens if we try to lean first. As there is nothing solid for us to push against, the only way we can apply bank is to push against the machine with the inertia of our own body. To lean the bike to the left, we must therefore initially move our body weight to the right. The left leaning bike will now generate camber forces from the tyres tending to lean both rider and machine over to the right, the roll rate will again cause a gyroscopic steering torque which helps ensure correct balance. The initial bike lean to the left might well be considered as a ‘counter-lean’, analogous to the ‘counter-steer’ of hands-on turning. Anyone that has tried changing direction ‘no-hands’ will know that we have far less control over the machine with just body movement available. The mechanisms involved with counter-steering produce much greater response and more finesse of control.

So, we now have two possible methods of initiating a turn and it is interesting to note that in both of them (banking and counter-steering) our physical effort is in the opposite sense to that which might be thought natural. When learning we adapt quickly and the required action becomes automatic. It is these reverse actions that require us to learn to ride in the first place. The required responses are clearly counter intuitive. When learning most of us wobble about out of control until our brain latches on to the fact that counter-steering and counter-leaning is the way to do it. Once the brain has switched into reverse gear, it becomes instinctive and is usually with us for life, and we can return to riding after a long layoff with no need to re-learn the art of balancing or steering.

In practice, we subconsciously combine both methods, with some steering and some body motion. The relative proportions in which we combine the two methods depend partly on riding style but also on speed and machine characteristics. For example, a heavy machine with light wheels at low speeds demands a different technique from that appropriate to a light machine with heavy wheels at high speeds and hence a different feel. However, humans adapt quickly and the correct technique soon becomes second nature.

More detail

Having considered the basis of initiating a turn in fairly general terms, let’s now look at this very important aspect in more detail.

Consider a racing bike approaching a corner and the rider needs to heel over as fast as possible. He strongly applies counter-steer and the machine starts to lean over rapidly, but getting a quick roll acceleration also means we need a quick roll deceleration. We start off upright with no roll velocity and we end up at 45-50 degrees lean, again with no roll velocity. In the process the roll velocity must have increased up to a maximum value somewhere around about half of the final roll angle, and then decelerated back down to zero roll velocity at the final lean angle. So the whole lean-in process is not just as simple as a bit of counter-steering followed by straightening out at the end. Basically, we use counter-steer to lean the bike in, at about half way through the roll we have to remove it and possibly give it some "pro-steering" to cause the roll deceleration.

For a long time those that read various motorcycle magazines may have been somewhat confused by the rather conflicting “explanations” often given for this process. There would appear to be two conflicting theories and the adherents of one seem to deny completely any possibility of validity in the other. We might term these two theories

- **Gyroscopic or precessional theory**. Where it’s taken as read, that at least the majority of the lean-in torque comes from gyroscopic reactions.
- **Steering out from under theory.** Which basically assumes that as the front tyre steers out from under the CoG., gravity will then continue the lean as the steering straightens up.

I imagine that most open-minded people interested in this subject would be inclined to the view that there are probably some truths and untruths in both points of view with reality lying somewhere in a combination of both. We shall see that this is indeed the actual situation, but we shall also see that the physical mechanisms from either theory alone is capable of explaining the motorcycle lean-in. However, neither theory alone properly explains all the observed phenomenon. Both theories however, require that we use “counter-steering” i.e. the initial rider’s input is counter to that necessary for a very slow speed turn.

The whole process of establishing a stable cornering attitude is extremely complex and to understand it properly needs a mathematical explanation outside of the scope of this book, but the following is a detailed description of the process using graphical rather than mathematical results from computer dynamic simulations. In order to fully understand what’s happening some of the simulations represent impossible situations, but are never-the-less useful. For example, in the first simulation we consider the case in which the tyres produce no lateral force, thus leaving us with only gyroscopic reactions to lean the machine. Another simulation is done with no gyroscopic effects, this approach allows us to clearly see the individual forces and is useful to test the two theories above. The simulations allow us to investigate the effects of parameter combinations that just aren’t possible with a real machine, and this can provide valuable insights to the detailed behaviour. All the simulations are for a bike travelling at 100 kph, and the rider is aiming for a lean angle of 44 degrees. The bike data is not for any specific bike but, except where noted, are typical of an average large capacity machine. Before tackling the following, the reader is advised to read the appendix describing the mechanisms of gyroscopic effects. The following text is quite detailed and possibly tedious to read, but is included for those that want to better understand the detailed mechanisms of the lean-in process.

Gyroscopic effects only

In this simulation the tyre parameters are set to produce no lateral tyre forces. This is a situation that is difficult to achieve in practice, the closest we might manage would be to ride on an ice-rink with slick tyres. However, this simulation is very useful to test the “gyroscopic only” proposition above.

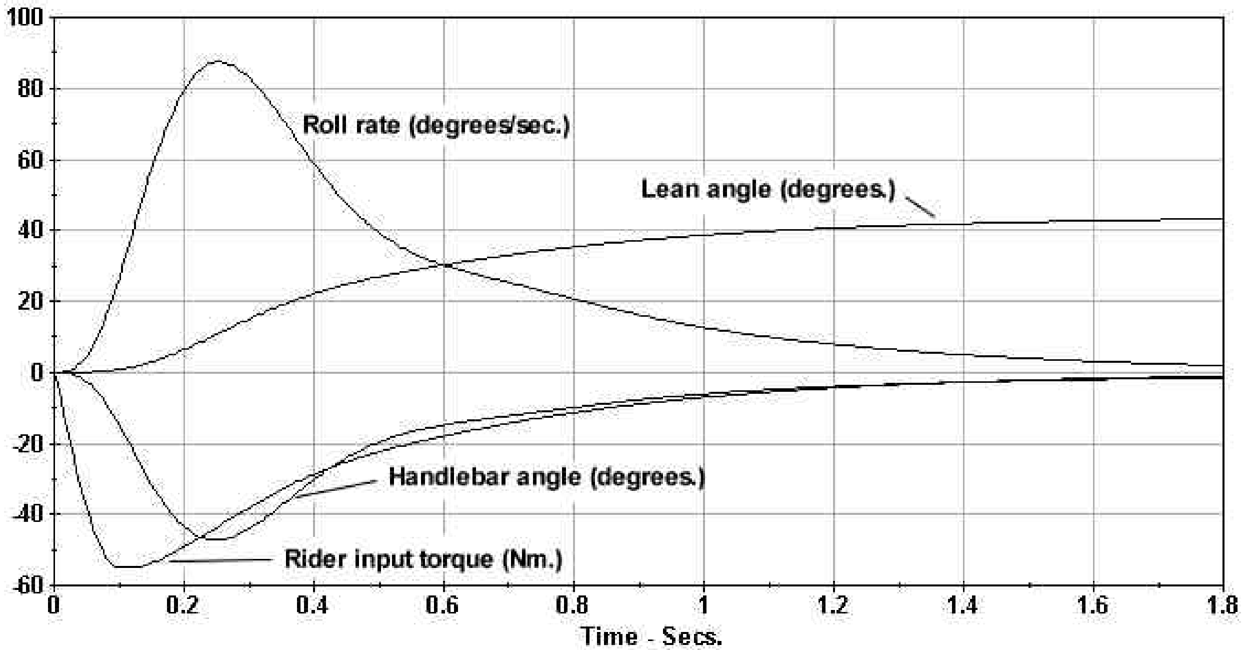

Fig. 4.6 **Lean-in performance with no lateral tyre forces. Note how the leaning velocity or roll rate builds up to a**

maximum and then decreases to zero as the final lean angle is reached. Note also that the steering angle does not follow the shape of the input torque.