17 Feel

Prior to reading this chapter is important to be familiar with the content of chapters 2, 4 and 14, particularly pages 4-2/3 and 14-9.

We hear so much about the word "feel" in connection with riding motorcycles, but what is it, does it even actually exist, can we measure or calculate it? It is so often taken for granted and rarely questioned. Some people are supposed to possess better feel than others and bikes vary in their feel. Is feel an intrinsic property of both man and machine, or just a product of our imagination? There is braking feel, steering feel, cornering feel and sometimes we talk about feelings of stability or even instability. Is feel actually beneficial, if it is then should we try and enhance it and how can we do that?

The purpose of feel is to provide some form of feedback relating our control actions to the response of the bike/rider combination. Without this feedback it would be very hard to ride, we would not know how hard to pull on the brake lever nor how hard or how far to turn the handlebars. The absence of feel would take away the rider's ability to balance at low speed. Control and feel are closely connected.

Control

Control can be either one of two main types:

- Open loop.
- Closed loop.

Open loop would be for example; riding along "no-hands" and then giving the handle-bars a nudge. The bike would react according to its internal dynamics but the rider would then have no further control over the response. Feel in this case is irrelevant.

Fig. 17.1 **Diagrammatic representation of open loop bike control.**

On the other hand, a closed loop system allows the rider to make continual control corrections according to the feed-back or feel that he gets from the motorcycle. It therefore follows that the rider's control inputs will depend on his ability to feel what the bike is doing. We all know that any two riders will react differently to the same control situation.

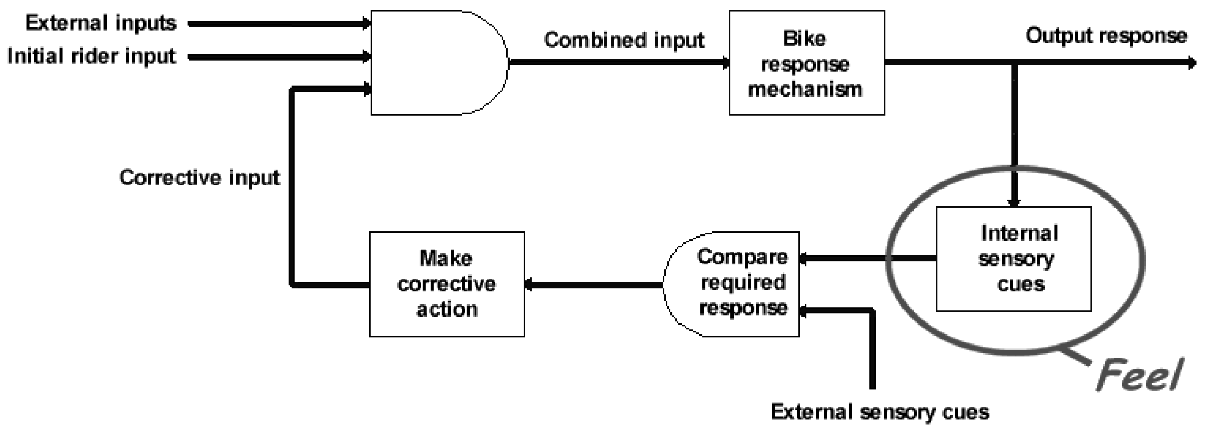


Fig. 17.2 **Basic closed loop motorcycle control. The external inputs are from road bumps and wind etc. The output response is some change in the dynamic state of the bike, such as braking deceleration or steering. The sensory cues can be external, for example, visual cues relating to lean angle or position on the road. The cues which relate to the feel or feed-back between rider and machine, such as inertial forces are referred to here as internal.**

Fig. 17.2. shows the basis of a real motorcycle control system. There are three principal inputs and one output. The output is simply the reaction of the motorcycle, linear acceleration or steering for example. The inputs consist of:

- External forces acting on the machine, such as road and wind disturbances. The output response to these influences may be determined by the inbuilt stability characteristics of the bike or they may need some corrective action from the rider.
- External sensory cues. Probably visual in the main, for such tasks as following a desired track and/or indication of lean angle. Other cues may be audio or tactile, for example the feel that some riders get from dragging a foot or knee when cornering.
- Initial rider control input designed to achieve some dynamic response from the motorcycle.

There is another input “internal” to the closed loop system, which is of great importance. That is the rider generated corrective input. After the initial rider input the bike will give some response, but it is unlikely to be exactly that which the rider requires. Hopefully, there will be some feedback or feel that helps the rider decide on a corrective action. For example, internal cues such as arm force will help him sense the braking force and combined with the external visual cues such as closing speed and distance, a continuous comparison can be made with the required degree of braking to decide whether it is high enough or not. The rider will then make an appropriate corrective input by pulling more or less on the brake lever.

It is the examination of some of the internal sensory cues or FEEL which is the principal theme of this chapter. Feel exists on various levels, and these can be viewed in two distinct groups. Which may be called: “proportional feel” (or “non-limit feel”) and “limit feel”. In almost all cases, it is the ultimate ability of the tyres to provide horizontal grip that is the limiting factor in any manoeuvre. Thus we must look to the tyre characteristics to provide us with a mechanism of the feel for impending disaster, if indeed such a mechanism exists. In the non-limit situation we have reserves of tyre grip and so we have different feel needs which must be met in other ways.

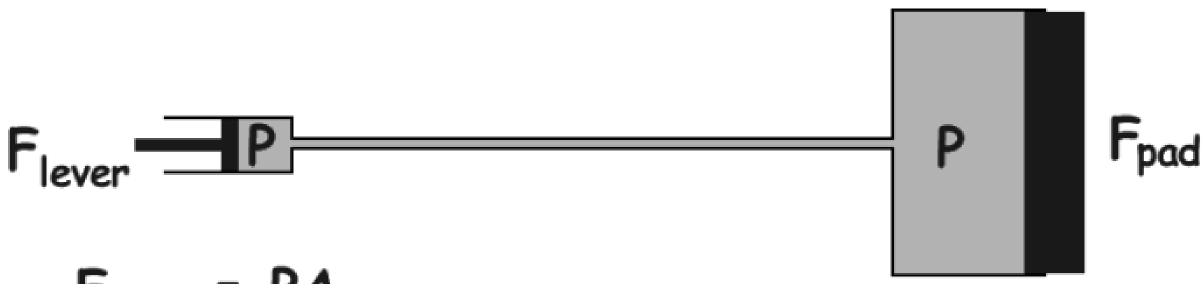
Braking

Let us initially look at braking to understand feel better. We pull harder on the brake lever and we feel the bike slow more, this happens on all bikes, but all brake controls have a different feel, some are hard yet others are soft. Most people don't like a really hard lever and claim that it has no feel. Yet if the lever is too soft it detracts from our confidence that the brakes will actually stop us, and we worry that we'll run out of lever movement under hard braking.

From a mechanical point of view there are many factors which control this feel of hardness, which is the relationship between the applied lever force and the lever movement. Mechanical flexibility and air in the hydraulic liquid are the principal sources of "give" at the lever. Flexibility exists to some extent in all parts of the braking system.

Starting at the wheel end we have:

- Disc. Unless the disc is perfectly flat the force of the pads will try and flatten it at the point of application, thus allowing more movement of the pads. Even discs that are flat when new may become warped slightly with use and/or high temperatures.
- Pads and calipers. Calipers will tend to separate because the piston forces push the inner and outer sections in opposite directions.
- Caliper mounting. Less of a problem with modern bikes, but in the early days of disc brakes some manufacturers didn't pay enough attention to this.
- Hoses. Inferior hydraulic hoses expand excessively under high pressure. Just a small expansion requires a significant extra amount of fluid to be pumped in and hence more lever movement. The use of stainless steel braided hose is a good option here.
- Master cylinder. Extra flex can be present here due to inadequate handlebar clamping and lever pivots etc.



$$F_{lever} = PA_{mc}$$
$$F_{pad} = PA_{caliper}$$
$$F_{pad} = F_{lever}\frac{A_{caliper}}{A_{mc}}$$

Fig, 17.3 **The force on the brake pad is purely dependent on the total piston area multiplied by the line pressure. The line pressure, in turn, is only dependent of the force on the master cylinder piston and its area. Line expansion and other flex does not change this relationship but will alter the feel.**

An interesting and generally misunderstood aspect of flexibility in the braking system, is that it makes no difference to the force that we need to apply to achieve a given degree of braking. A set braking torque requires a specific force on the pads, this is determined by the piston diameter and the hydraulic pressure. The piston diameter is fixed and so the braking force is dependent on fluid pressure. This in turn is dependent on the hand-lever force. Therefore, for a given braking force the lever force remains the same, but the ***movement*** of the lever depends on the flexibility in the system.

Proportional feel

If we accept that feel is required to give some feedback of the effectiveness of our efforts then such a mechanism clearly exists. Neglecting such factors as variation in pad co-efficient of friction with time and temperature, we have seen that braking deceleration is directly related to lever-force. As riders we sense the amount of deceleration through our bodies. Forces in our arms, wrists, knee grip forces on the tank and even the loads of head and helmet on our neck muscles all act together to give us a feel for the amount of braking and of course our fingers tell us how hard we are pulling on the lever.

If this feel mechanism is sufficient then why do many riders claim that a hard lever lacks feel, and are much happier with some give but not too much? How can the introduction of some give help us control braking better? The answer is because we are human and not computers. We take in information in many different subtle ways and in this case, lever force is just one way and lever movement is another, the combination of the two can be more valuable than either individually. Being human, we all differ from one another and so some riders like a hard lever, and others prefer various degrees of give. In some cases it is not only a matter of an improved feedback of information but a question of control finesse. If we want to make a small control adjustment we generally find that easier when some movement is involved as well as a force change.

To have confidence in the brakes the ratio of lever force to stopping deceleration must be within a certain range. If we have to pull really hard we get a feel that the bike won't stop well enough, on the other hand if the lever is too effective, then the brake control will tend to feel like a switch. Either ON or OFF. We have trouble modulating our hand force if that force is too low.

Proportional braking feel, relates rider effort to braking but it cannot help us determine how hard we can brake before exceeding the maximum grip of our tyres. This is obvious when we consider that so many of the external factors, that affect the maximum grip at any moment, do not change the proportional feel. Maximum tyre grip is affected by road type and condition, wet or dry, surface dust, temperature, tyre wear and many other things. So the lever force (and give) required to achieve maximum braking is not fixed but can vary very quickly, and it is not surprising that some get it wrong from time to time and that can hurt. We'll see when we look at "limit feel" that there is another mechanism available to help here, although very few riders have the ability to really use it effectively.

Limit feel

The proportional feel that relates rider input to machine output is very useful and it would be hard to ride even moderately well without it. However, of more importance when racing or otherwise riding close to the limit, would be a form of feel which gives us some warning as we approach that limit. The limiting factor for most if not all bike manoeuvres is the limiting grip of the tyres. We need a feedback mechanism to tell us what is happening at the tyre/road interface. So it is to the tyre characteristics that we must look if we wish to find help.

We have seen that tyres have to slip in relation to the road in order to generate significant horizontal force. When braking, the tyre surface rotates slower than the corresponding road speed, conversely under acceleration the wheel has to spin slightly faster than the equivalent road speed. Up to the point of maximum tyre grip, an increase in longitudinal force results in increased slip, maximum grip occurs around 10 to 15% slip. Fig. 17.4 shows some example tyre characteristics for both braking and acceleration, maximum grip is at the points marked “C” which in this case is around 11% slip. This means that if we can apply enough driving torque to the wheel at 100 km/h. road speed, then the maximum tyre driving force will occur when the peripheral tyre velocity is just over 110 km/h.

Each section of the characteristics is divided into four main areas, marked “A” to “D”. The initial area “A”, up to around three quarters of maximum force and slip up to 4 percent, is basically linear. That is, any increase in braking force is accompanied by an approximately proportional increase in slip. At higher braking forces we enter into the “B” area, this is quite different from “A” because just small increases in braking force result in increasingly disproportionate high degrees of slip up to the maximum level of grip force at “C”. As we approach the maximum possible braking capability the slip increases rapidly. Unfortunately, we can’t detect this increased slip directly, even if we could see the tyre it would not help.

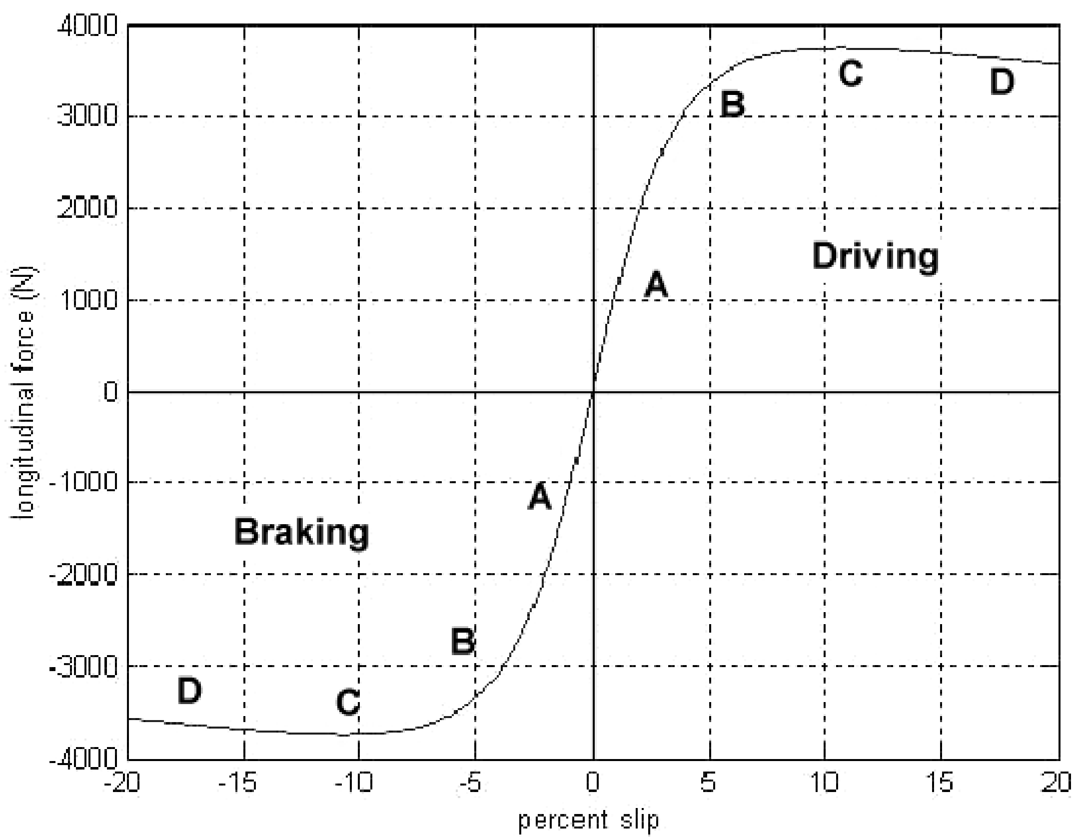


Fig. 17.4 **This graph shows the relationship between tyre force and the percentage longitudinal slip needed to produce that force, for both driving and braking. The actual values vary between tyre types and also vertical load, so this graph should only be considered as a general guide to typical characteristics.**

The generation of steering force also requires some slip, that is we have to steer in more than the direction of travel, this is called a slip-angle. Tyres are called upon to provide forces in different directions at the same time. An example is braking and cornering together. The tyre has to simultaneously generate a force inline with the wheel to give a braking force and another force at right angles to the wheel to give the cornering force. However, there are strict limitations on how far we can push this. Medium braking and medium cornering is OK. but I think that we all know that the harder we brake the gentler we have to be with the cornering. The reverse is also true, hard cornering can only be successful with gentle braking. A friction ellipse is often used to illustrate this point. *(These topics are discussed at length in Chapter 2.)*

As we brake hard and the longitudinal slip increases the slip angle required to generate a given turning force increases also, fig. 7. In other words, we have to steer more, when braking, to get the same turning effect. The tyre becomes less effective at steering whilst we are braking. In other words the steering stiffness has been reduced. The rider feels this as a lightening of the steering action. The steering stiffness is equal to the slope of the curves shown in figs. 17.4 & 17.5.

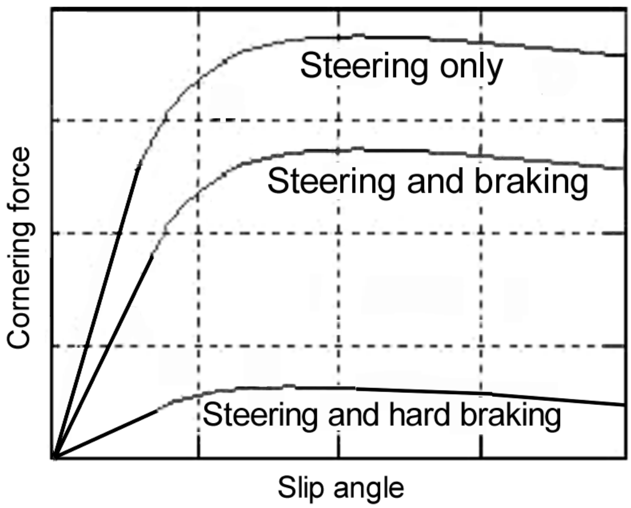


Fig. 17.5 **General representation of the cornering or lateral force tyre characteristics under conditions of steering only and steering with braking.**

It is unusual to need large slip angles when braking and so it is the initial portion of the curves that mainly interests us. The slope of the line is the steering stiffness and we can see how this is greatly reduced under hard braking.

Riders with sufficient feel use this change in steering stiffness to help judge their near limit braking.

A motorcycle never balances in a perfectly straight line, it is continually executing a series of balance correcting weaves, these are so small at normal speeds that we don't notice them directly, but they indirectly give us a feel for the steering stiffness, which is how we can sense or feel the reduced road grip when riding on a slippery road. The lateral tyre forces necessary to maintain balance will be similar regardless of the surface condition, but the steering stiffness will be reduced on a wet road which means that the balance maintaining steering displacements have to be greater. These greater movements, accompanied by lower steering torques, will be felt (often subconsciously) by the rider, at least those will sufficient feel, indicating a slippery surface. (See chapter 2.)

Returning to the braking situation. Braking forces from the front cause a directionally destabilizing moment, which can only be partially compensated for by the stabilizing moment from a rear braking force (see p. 14-9). It is up to the rider to provide any steering correction to maintain directional stability.

We have seen that as the longitudinal slip increases, the steering stiffness reduces and so through the balance and stability maintaining steering movements a rider feels the steering get lighter, just as on a slippery road. This then is the feel mechanism that gives a skilled rider the feedback for when he is approaching the braking limit. The steering feels increasingly loose the closer he gets to disaster.

Anyone unfortunate enough to have fallen due to locking the front wheel knows just how sudden this can be. An examination of fig. 17.4 shows why wheel locking occurs so quickly. As we increase our braking force up to point “C”, the maximum force that the tyre can produce, the slip starts to increase rapidly, now if we increase the applied braking torque to the wheel, just a tiny bit more than the maximum that the tyre can produce, this excess force goes to decelerate the wheel, which increases the slip taking us into area “D” in which the braking force of the tyre is reducing, thus leaving more excess force for wheel deceleration. This is known as positive feedback and is an accumulative process, the wheel deceleration increases rapidly, which results in a rapid locking of the wheel. Once past the tyre’s maximum capability at point “C” the resulting process is so rapid that it is very hard to prevent completely locking the wheel. There is another factor that makes the situation even worst. As the wheel locks and the braking force decreases, the forward load transfer decreases also, relieving the vertical load on the front tyre and so reducing further the force that the tyre can generate.

The dynamic lock-up performance varies between tyres and is dependent on the detail of the tyre characteristics. Consider fig.8. which shows two fictitious tyre characteristics. These are extreme examples just to illustrate the point. Tyre “X” reaches maximum grip with little change in it’s characteristics but once past the peak the braking force from the tyre falls off rapidly as the tyre slows (more slip) and so the subsequent lock-up would occur rapidly. On the other hand, with tyre “Y” the lock up occurs slower giving more chance of recovery.

The above has only considered the mechanism of limit feel as it applies to front wheel braking. The situation for the rear wheel is a little different and there are two cases to consider.

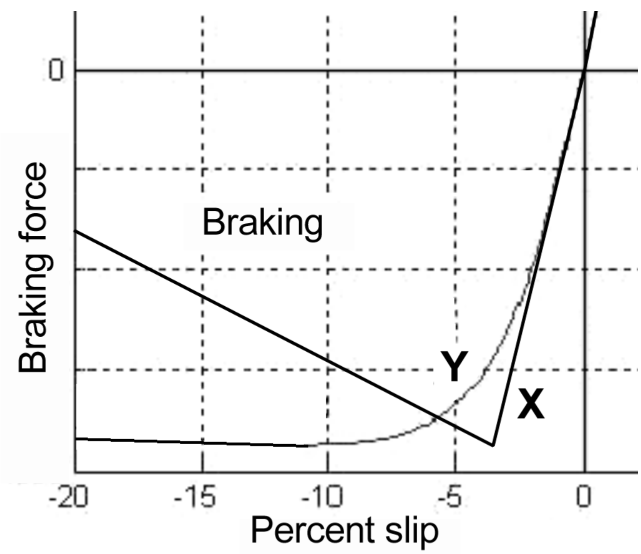


Fig. 17.6 **This is the braking only section of fig. 17.4. Showing two fictitious tyre characteristics. These are extreme examples just to illustrate the point. Tyre “X” reaches maximum grip with little change in it’s characteristics and so would give little warning, additionally once past the peak the braking force from the tyre falls off rapidly as the tyre slows (more slip) and so the subsequent lock-up would occur rapidly. On the other hand, tyre “Y” gives more warning and the lock up occurs slower giving more chance of recovery.**

Front and rear braking together

Assume that the front is braking more than the rear, which is the normal situation due to load transfer. As we have seen, fig. 14.7, strong braking at the front causes the bike to be directionally unstable, the back-end wants to overtake the front in simple terms. This is prevented by steering actions from the rider who tries to keep the two ends in alignment. When also braking with the rear brake this applies a stabilizing effect which eases the burden on the rider. As we increase the rear braking we increase the slip and enter area “B” and, as with the reduced front steering stiffness explained above, the rear slip angle increases as we increase the braking force and we feel the back-end get looser. This is a signal to those with enough sensitivity that the back brake is near the limit. In the opposite fashion to that described for the front wheel, as the rear brake locks and loses some braking force there is a reduced frontal load transfer and more vertical load returns to the rear, thereby increasing the tyre braking force, slowing down or preventing a complete lock up.

As humans our internal computers are not very good at multi-tasking, although women are said to be better than men in this regard. Unfortunately, this means that we generally find it hard to “limit feel” both front and rear brakes together and many, including otherwise highly skilled racers, opt to use only the front brake for serious stopping, using the rear only for its stabilizing effect. For heavy braking on dry surfaces we lose little by this, because under these conditions there is little, if any, vertical load on the rear to support much braking.

Rear braking only

Unlike the previous cases, this gives inherent directional stability. The rear is always tending to pull the bike back into line after any disturbance. Whilst this is a generally desirable feature it doesn’t help us feel when the tyre is close to locking. Up to the braking limit we still have the “proportional feel”, that is, we press harder on the pedal and feel increased deceleration, but there is very little in the way of “limit feel” to warn us when to ease off. Hence it is very difficult to judge a lock-up coming, with rear only braking. Fortunately when riding in a straight line it does not require a high level of skill to maintain balance with a locked rear wheel. There will still be some braking force from the rear which will maintain directional stability and balance stability is mainly achieved through the front. A more serious problem occurs when using rear braking whilst lent over, even mildly. Then, when the wheel locks without much warning the backend may slide out very quickly. It is unskilled riders who use rear only braking and these are the least capable of handling this situation, and so a crash is almost inevitable. In many cases it is the dreaded high-side, especially if the rider follows his natural reaction to shut the throttle.

We must strongly resist grand-daddy’s advice to *“leave the front brake alone son, or you’ll fly over the handlebars*”. It is difficult to over estimate the damage that such well-meant but ill-informed advice has caused.

Cornering

We have had a good look at braking feel, but although there are similarities there are several differences when compared to cornering feel. Motorcycle steering is an unusual control problem. As we have seen, braking is a quite straight forward operation – we pull the lever gently and we get gentle braking, we pull harder and we stop quicker. Steering a car is also simple and intuitive – we turn the steering wheel by say 5 degrees and hold it there and the car turns slowly, we turn the wheel some more to 20 degrees and hold it there and the car steers much sharper.

Motorcycles don't steer like that, the process is much more complex and has two distinct phases and a transition between the two. There is a short duration transient phase (counter-steering) which initializes the process followed by a relatively steady phase to maintain the turn. If we just turned and held it like car steering we would end up on the ground very quickly. Instead, we have to apply a short burst of counter-steering to get the bike leaning and then when the turn is established we apply a relatively small steering torque and steering angle to maintain it. Between the counter-steering and steady state conditions there is a transition phase during which a whole complex series of dynamics occur. Any desired change in the cornering state must be accompanied by these same actions, whether it is exiting a turn or changing line in the middle of one.

As the physical turn process is so complex it should come as no surprise that the question of cornering feel is also complex. It is also largely a learned characteristic rather than a natural property. I think that steering a car can be termed "natural" or very close to it. Once told that a clockwise turn on the wheel produces a right hand turn and vice versa, almost anyone can steer a car with no learning. Obviously, with experience we get better, but on a basic level it is a pretty natural response to turn the wheel more when we want to steer tighter. The balance and steering of a bike is so different from any natural idea of control that we must learn to do it. There is a very strict level of learning that is required to be successful, it is like a switch. Below this level we just can't balance and ride, but once above that level, experience lets us get better and it begins to feel more natural. If we learn to ride young enough and do it often enough then it does become just as natural as steering a car. On the other hand for some riders it never becomes natural and they always have to stop and think about which way to steer. There are many tragic cases of collision avoidance situations where low mileage riders got it wrong, often with fatal consequences. That doesn't occur with car driving. A car driver may make the wrong decision about which way to head but he never steers in the opposite direction to that decision.

The idea of "proportional feel" hardly applies here. We don't have a situation where just steering some more directly results in more turning. It is the external cues such as the visual path following that tell us whether we need to turn more or less. In place of "proportional feel" let us use the term "Non-limit feel".

Non-limit feel

This aspect has more to do with the ease or otherwise of turning. We all know that different bikes have a different steering feel. Some seem to steer quickly and with little effort. Some feel like we have to hold them down to stay in a turn, others feel like they have to be held up and so on. There are many levels of different feel.

It is generally during the counter-steering phase that we get a feel for how easy and fast that a bike turns in. There are many bike design parameters that affect this but the two main ones are trail and the rotational inertia of the wheel assembly. More trail produces a greater torque about the steering axis that opposes any attempt to turn the steering, therefore it reduces the effective part of the effort that the rider puts in and so the bike turns in slower. We can also say that for a given rate of turn-in the rider has to increase his effort to compensate for more trail. The steering feels heavier. The torque due to trail is also affected by the steering stiffness of the tyre.

More rotational inertia increases the gyroscopic effects. As the bike builds up roll velocity the gyroscopic effect is to require a torque about the steering axis, just as with the trail torque, this torque also acts in opposition to that supplied by the rider, making the steering feel heavier and/or slower.

Counter-steering is an essential part of any steering action, it might be entering a turn in which case we start by steering out of the turn, it might be exiting a turn in which case we have to initially steer into the turn. Even the continual small adjustments to our line require some counter-steering action. As a consequence we are constantly being made aware of the steering weight feel as affected by trail, steering stiffness and wheel inertia.

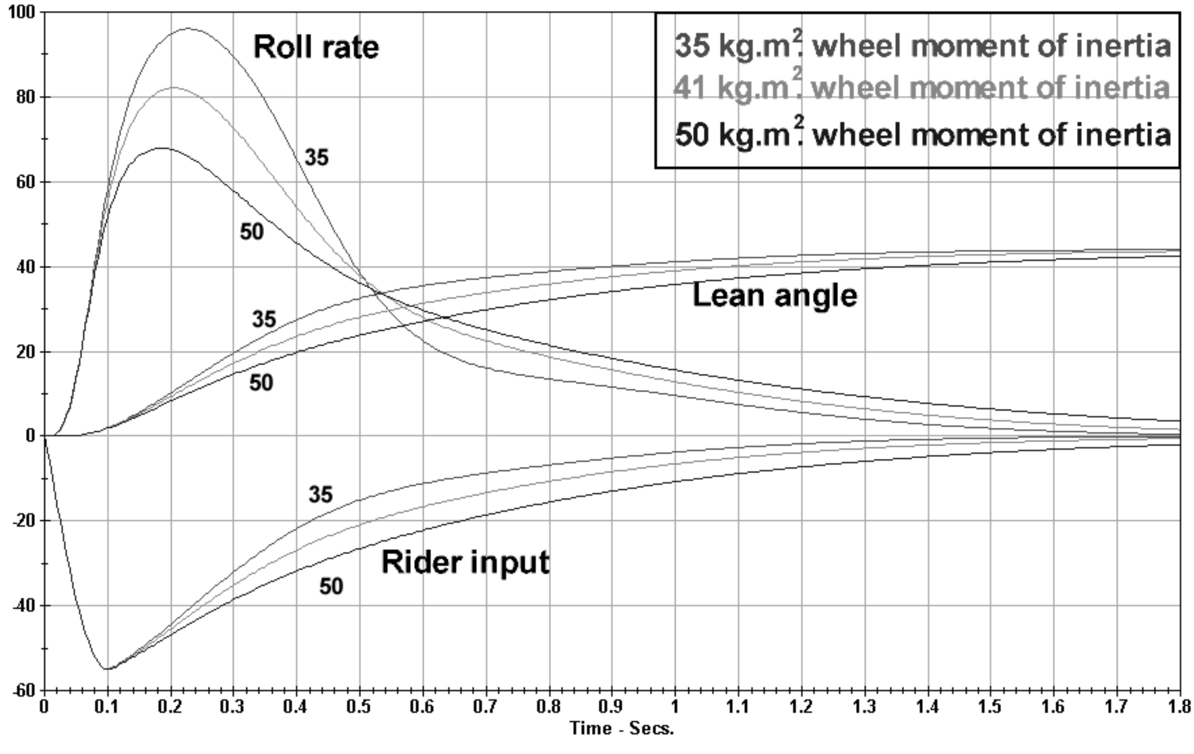


Fig. 17.7 **A simulation of the lean-in performance with different values for the front wheel moment of inertia. The initial rider input was the same but note how the peak value of the roll rate is enhanced with the lighter wheel, leading to a quicker build up of lean angle and a more responsive feel.** ***(See chapter 4 for a detailed explanation)***

Once the turn is established, tyre width has a major influence on feel. If we had zero width tyres, like riding on a knife edge, then as long as our body was inline with the centre plane of the bike there would be no residual steering torque and we could take our hands off the handlebars and the bike would continue on the same radius turn without any further rider input. This fictitious case also assumes no external disturbances like road irregularities etc. Real world tyres have real width which has been increasing with time. This width causes the tyre contact patch to move around to the inside edge of the tyre, this means that the lean angle of the bike has to be a bit greater with wide tyres than for narrow ones, and the forces at the tyres become offset from the centre plane. These effects all result in the various steering torques not balancing out, and we are left with a residual torque which must be balanced by the rider. In other words if we removed our hands from the bars half way around a corner at a reasonable lean angle, then it would not continue as before. The point to remember is that the steady state cornering feel of a bike varies with tyre width.

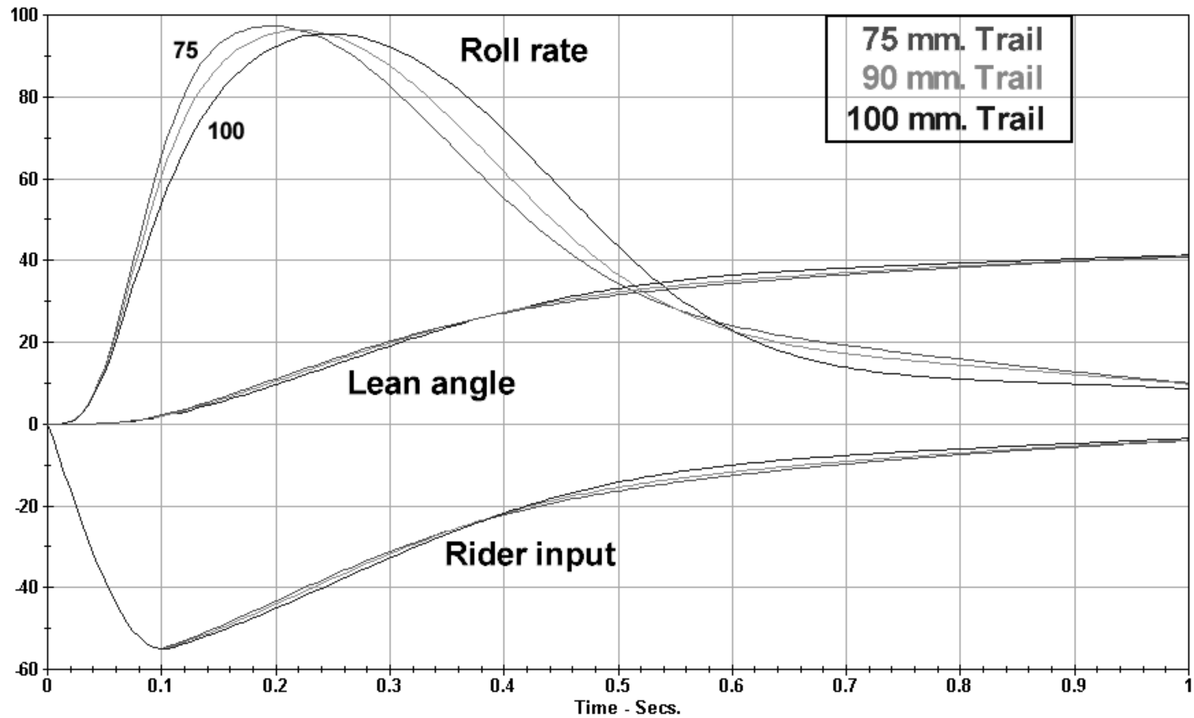


Fig. 17.8 **In this case the simulation considered different trail values. Note that the roll rate initially builds up quicker giving a more responsive feel.**

Limit feel

It is very hard to recover from exceeding the cornering limit of the tyres, especially at the front. For those who wish to corner near or at the limit, like racers, it is vital to have a feel for just how close we are. It is rare to get a second chance to get it right.

Although very different it might be useful to look at some aspects of cornering limit feel for cars, before considering the more complex issues facing motorcycle riders.

Cars

Referring to fig. 17.9, and using the same lettering significance as in fig. 17.4, we can see that in the linear part of the curve, denoted “A” a given increase in slip angle results in a proportional increase in cornering force. Driving harder around a bend brings the tyres into the non-proportional area “B”, in this case to achieve a given increase in cornering force, the slip angle needs to be increased at a higher rate. In simplistic terms, we can say that the steering wheel must be turned through greater angles, when approaching the limit, to achieve a given increase in cornering force. Thus providing the driver a mechanism for limit feel. Probably a more important feel indicator, dependent on steering geometry, is the change in steering torque required to produce changes in cornering force. These parameters can be measured for any particular car and values assigned, thus giving numbers to feel characteristics.

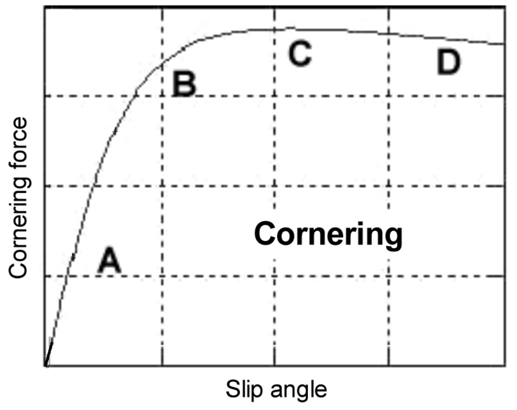


Fig.17.9 **Similar to the curves for braking and driving in Fig. 17.4, we rely on a slip to produce cornering force. Instead of a percentage slip we relate the force to the slip angle. This the angle between the direction of the tyres centre plane (projected onto the ground) and the direction of actual travel. Just as with the braking case, the detail shape of these curves determine the degree of limit feel.**

Motorcycles

Motorcycles are very different to cars and their tyres generate their cornering forces through two separate mechanisms.

- Camber thrust. This is the name given to the lateral force generated at the tyre/road contact patch which is a result of a camber or lean angle.
- Slip angle. This is the source of the lateral tyre force created whenever the tyre is not aligned with the direction of travel. This is the principal mechanism of cornering force production in a car because there is little lean angle of the tyres, however, when considering motorcycles we only have to apply slip angle to produce enough force to make up the deficit force when there is insufficient camber thrust. Which is certainly the case at high cornering speeds.

Figs.2.24/25 show some typical cornering characteristics to be expected of motorcycle tyres in general. Just as the steering stiffness reduced under hard braking, so it does under hard cornering. For example, a slip angle between 0 and 1 degree will handle cornering needs up to about 35 degrees of lean. The difference between 5 and 6 degrees is barely noticeable, at a lean angle around 45 degrees. Therefore, as we approach the cornering limit of the tyres any steering motion becomes less effective, giving warning to those able to feel it.

As we might expect the mechanisms of limit feel are different front to rear and we will consider them separately.

Front

Under given conditions we can plot a graph similar to fig. 17.4 but including the effects of lean angle, as in fig. 2.24 which gives an idea of how the cornering force from steering is related to the slip angle (the detail of such curves varies with different lean angles). Just as with the limit braking case, as we approach the limit the steering stiffness decreases. That is, to achieve the same response, the change in lateral force, we must move the handlebars more and this effect gets more pronounced as we approach the limit. Often sub-consciously, but this is the feel that racers use to stay on two wheels.

Rear

The idea of a slip angle at the rear might seem rather harder to understand as we cannot steer the rear directly in the manner of the front. However, tyre characteristics demand that we need increasing slip angles as we increase cornering acceleration. In order to produce rear slip angles, the whole part of the bike, except for the front steered part, must adopt an angle to the direction of travel. The rear end must hang out to varying degrees, and this attitude angle is a form of feedback or feel. When turning we cannot separate the front and rear, both are going around the same corner at the same speed and so if we were cornering in a coasting mode we wouldn't be able to control which end would break away first. In fact in such a mode with equal quality tyres at each end it is more likely to be the front, because that is where we apply the steering and the variation in slip angle would occur quicker.

In reality, we know that often the rear will slide out first, but that usually occurs when we are applying power not coasting. As we increase power the tyre is called upon to give both longitudinal and lateral force, just like when braking. The more driving force we apply the greater the slip angle needed and so as we open the throttle the bike will get looser quicker as we approach the limit. So the limit feel at the rear can be the relationship between throttle and the rear steering stiffness. Riders with enough skill can maintain a sliding action through this feel. This is essential in speedway and dirt track riding and current road racing bikes have enough power to enable its use also. The use of this drifting technique can be useful on several levels. It allows a large degree of steering adjustment to be done through the throttle which actually increases this type of feel and so it is more controllable when riding on the limit.

An explanation of the physics of drifting was given in chapter 2.

So where is the benefit in drifting? --- In racing, feel and control over what the tyre is doing can be enhanced by skilled use of this technique. When cornering in the classic style it is hard to feel the limit of adhesion and there are minimal control options left to deal with the situation when that limit is exceeded. On the other hand when the bike has been setup with significant drift the rider has more control over the total tyre force through the throttle. Therefore when he feels that he is about to lose it, he can just close the throttle a little to restore adhesion somewhat. Feel is enhanced because the yaw attitude is very much under the control of the rider.

Racers often drift their machines for additional reasons. With a lot of power available the classic large radius line through a corner is not always the best and it is often beneficial to turn as sharply as possible at the bend entrance, and leave the straightest possible exit path to get the maximum acceleration out of the bend. Drifting the bike into the bend can sometimes help get the machine better lined up for this quick exit. Control over the yaw attitude is also useful to setup the exit angle from a corner, for example if the bike is steering outward too much, it can be made to turn inward by throttle application.

Summary

We have seen that feel exists on many different levels. Some aspects are purely subjective, whereas others have a scientific basis and could even be assigned numerical values if we had enough tyre and other data. The characteristics of tyres are largely responsible for giving various mechanisms for us to develop a feel for the approach to the limit of adhesion, in braking, driving and cornering. The principal tyre parameter for providing this feel is the steering stiffness, or more correctly it is the reduction in steering stiffness as the tyre is pushed toward its limit. The ability to sense this feel varies widely between riders, and this is what often differentiates between top racers. The concept of steering stiffness is important and is the core parameter for providing limit feel as well as a feel for the surface conditions. We have implicitly considered the tyre characteristics as being relatively steady. In practice, road disturbances are continually changing the ability of the tyres to generate grip, which leads to limit feel being less than ideal.

We've looked at feel as a form of feedback, relating the bike response to a rider initiated control action, but there are other non-response orientated factors which determine the overall feel of a bike. The "hardness" feel of the brake lever was considered, but this can be as elementary as: Does the bike suit us ergonomically? Does it feel comfortable? There are other, more psychological factors at work. Do the controls work in a way that matches our intuitive or learned expectations? We have seen that counter-steering is, by its very nature, a counter-intuitive feature and must be learned, whether consciously or not.

Drifting a bike like this, without the direct feel between throttle and rear tyre slip, would be impossible. Of course it also requires riders of exceptional ability, like Randy Mamola shown here..