## Does changing down on approach to a bend reduces the risk of understeer?

A moving conventional vehicle experiences Engine Braking Force, which always opposes motion (I.E. it tries to slow the car!) On steering into a bend, the car begins to accelerate 'Centripetally', that is it accelerates towards the centre of the bend. (Centripetal literally mean 'centre facing').
This acceleration occurs even if the car's linear
 speed along the road surface remains constant, because Centripetal Acceleration results from the rate of change of the 'direction' element of car's Velocity and not the 'speed' element of Velocity; therefore, Centripetal Acceleration exists even if speed through the bend is constant, simply because the car's direction is constantly changing: which is contrary to the way most of us think of acceleration.

Acceleration is always caused by an associated net Force (Newton's Second Law). Both the Acceleration and the associated Force responsible for it are quantities that have size and direction: they are Vector quantities. It is a fact that the direction in which the Force acts and that of the resulting Acceleration are the same, as such, the


Centripetal Force associated with Centripetal Acceleration also acts towards the centre of the bend: in driving terms, we call this Centripetal Force, the Corner Force.

Every Force has an equal and opposite Reaction Force (Newton's Third Law) and the reaction force opposing the Corner Force is known as Inertia. Inertia therefore points away from the centre of the bend. (Note: Inertia is NOT Centrifugal Force!!)

Corner Force is a demand which must be met by real forces acting on the car, in this case the force of Friction between the tyres and the road surface. If the forces that contribute to the Corner Force equal the Inertia Force, the car will be stable in a bend; but if Inertia is greater than the forces that contribute to the Corner Force, the car will understeer and possibly leave the road!

When a car steers through a bend it continually tries to 'slip' sideways towards the outside of the bend, under the influence of its Inertia, the only thing stopping it sliding off the road is Friction between the tyres and the road surface. I.E. if cornering on ice, where Friction is low, Inertia is likely to be greater than the opposing Friction Force, causing the car to understeer and slip sideways off the road.


For convenience, Friction is shown as one Force in the diagram; however. it acts at all four tyre contact patches!

Friction opposes sideways 'slip', so it must therefore point towards the centre of the bend, as this is the opposite direction to the sideways motion; this is not surprising as it is this Friction Force that meets the demand of the Corner Force and to do that it must point in the same direction as the Corner Force!

We have also said that Engine Braking opposes motion. The diagram on the left below is looking down on one of the tyre contact patches, with the car in a straight line on approach to a bend. Note how the Engine Braking Force oppose forward Velocity.

The Diagram on the right shows the Velocities and Engine Braking Forces acting on the Contact Patch at the instant the driver steers to the right, in to the bend.


Plan view looking DOWN on tyre Contact patch before steering into a right bend.


Engine Braking
Component 2
Slip Angle $=\theta$

On steering into the bend to the right, the Contact Patch stays more or less pointing forward, but the tyre walls twist and deform, pointing into the bend.

In the Diagram above on the right, the Contact Patch tries to move to the right in the direction of the Peripheral Velocity (I.E. the direction the tyre points into the bend), whilst at the same time slipping to the left, as shown by the Drift Velocity. This sideways slip is controlled Understeer and every car does it. Front wheel drive; rear wheel drive or fourwheel drive: they all Understeer in a bend! The angle between the original Velocity and the Peripheral Velocity is known as the Angle of Slip: or simply, Slip.
Typically, if Slip exceeds about $20^{\circ}$, you would lose it in the bend!
It takes a lot of energy for the car to slip sideways like this and that energy comes from the cars initial motion energy, also known as its Kinetic Energy. If Kinetic Energy is reduced during Understeer as it is converted in to Work Done in pushing the car sideways, the car slows down in the bend, even if the gas pedal is kept constant throughout!

If you are mathematically inclined, you will note that Peripheral velocity is 'V $\operatorname{Cos} \theta^{\prime}$; with $\theta$ being somewhere between $0^{\circ}$ and $20^{\circ}$, ' $\operatorname{Cos} \theta^{\prime}$ is less than 1 ; therefore, ' $V \operatorname{Cos} \theta^{\prime}$ is less than V : which also confirms that the car slows down on steering into the bend!

On slowing down in the bend, weight shifts to the front of the car, which upsets the ideal stability. To redress the weight shift, regain stability and put back the energy lost to this sideways slip, the driver must gently squeeze on the gas, as the steering wheel is eased into the bend; hence the term: Ease and Squeeze! In short, every bend in the world should be taken under light acceleration for this reason.

You will also see from the Diagram above on the right, that Friction opposes the Drift Velocity. If the car was cornering on ice, this Friction would be very small, and the car is far more likely to Understeer out of control and slip off the road to the left in a right bend; or slip towards oncoming traffic in a left bend!

## The Friction Force can be seen to act towards the centre of the bend and it is this Friction that is mainly responsible for meeting the demand of the Corner Force!

Engine Braking opposes motion and it can be seen from the diagram above that there is a component of the Engine Braking Force, shown by the green arrow, that opposes the Peripheral Velocity; whilst another component of the Engine Braking Force, shown by the red arrow, opposes the Drift velocity.

This component of the Engine Braking Force acts in the same direction as the Friction Force; this is very significant, because Friction plus this component of Engine Braking are the real forces that meet the demand of the Corner Force.

To put it another way, if Friction plus this component of Engine Braking can add together and cancel out the effect of the Inertia Force, the car remains stable with a controlled amount of understeer and this is what normally happens when we drive through a bend under control.

However, the maximum Friction Force available is finite and when driving normally, there is always Friction in reserve; you don't use all the available Friction in any given bend unless you are pushing the car to the limit!

With an Engine Braking Component helping to meet the demand of the Corner Force, less of the maximum Friction Force is needed to meet this demand, leaving more Friction in reserve to cope with unintentional Understeer, usually because of inappropriate speed into the bend.

Lets just show how these Forces look on the simple Force diagrams shown below:


In the diagram on the left, the Corner Force demand exceeds the sum of Friction plus Engine Braking Force in $6^{\text {th }}$ gear and the car experiences uncontrolled Understeer!


In the diagram on the right, the Corner Force demand is met by Friction plus the bigger Engine Braking Force in $4^{\text {th }}$ gear and the car does not experience uncontrolled Understeer: it remains stable!

Experience tells us that the Engine Braking Force increases, if a lower gear is selected at speed: for example, dropping from $6^{\text {th }}$ to $4^{\text {th }}$. This because in the lower gear, the pistons experience more gas resistance as they try and move up and down in their cylinders with increased RPM: this resistance is the main cause of Engine Braking!

The argument developed above shows that there is a component of Engine Braking acting in the same direction as the Friction Force between the tyre contact patches and the road; this component of
 Engine Braking therefore helps meet the demand of Corner Force. You could equally say that this component of Engine Braking plus the Friction Force add up to oppose the Inertia Force, which is trying to make the car Understeer: its simply another way of looking at the same issue.

In the lower gear, the Engine Braking component increases, therefore making it more likely to meet the Corner Force demand and conversely, less likely that the car will experience uncontrolled Understeer.

This agrees perfectly with our driving experience, as most drivers will know that taking a sharp bend in a high gear, is likely to result in uncontrolled Understeer with the car running dangerously wide in the bend; whereas changing down to a lower gear fractionally before entering the bend, lets the car hold its line beautifully with a controlled (I.E. a normal) amount of Understeer that feels perfectly stable in the bend: it does not run wide.

## It is wrong to say that changing to a lower gear for a bend gives more grip: it cannot!

What we can say is that changing to a lower gear for a bend reduces the demand for grip, as some of the Corner Force demand is met by an increased Engine Braking component provided by the lower gear. This lower demand for grip is effectively the same as having increased grip, as there is more grip in reserve if the car inadvertently tries to increase Understeer, usually because of too much speed into the bend.

To summarise, the lower gear does not increase grip, it simply reduces the demand for grip: which amounts to the same thing, hence why we change down on approach to a bend, as it reduces the demand for grip, making the car feel more stable; less prone to understeer and more able to deal with understeer as there is more Friction Force in reserve!

George A Cairns
CWCAM Chief Observer

