Slip Angles - Beyond Countersteering

By James R. Davis

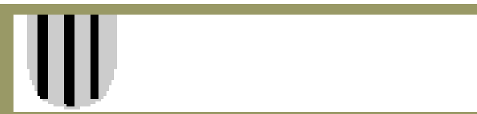
In the discussion on counter-steering you learned a great deal about camber thrust and how it helps convert the lean of a wheel into a turn of that wheel. We will now look at the tires more closely and see that though camber thrust helps change the direction of travel of the wheel, the fact that the tires are flexible results in phenomena that tends to fight changing direction. Specifically, we will look at one kind of tire deformation (torsional) that accounts for under- and over-steering.

Tires can deform in four ways:

- **Radially - (from side to side) - like the bulging in the sidewall above the contact patch.**
- **Circumferentially - like the way the sidewalls wrinkle in soft drag tires when accelerating.**
- **Axially - a deflection that tries to pull the tire off its wheel or rim.**
- **Torsionally - this is a difference in axial deflection from the front to the back of the contact patch. Think of a turn to the right. If the rim of the wheel towards the front leads the contact patch and the rim of the wheel towards the back trails the contact patch then it is clear that the rim has twisted to the right more than has the contact patch. (See the second diagram below.)**

To the right you see a representation of a tire as seen from the top. The green area is what the contact patch would look like if you had x-ray vision. This representation is of a tire that is moving in the direction it is pointed.

The lower the air pressure within the tire is, the greater will be the *radial deformity* of the tire. That is, the larger the bulging will be around the contact

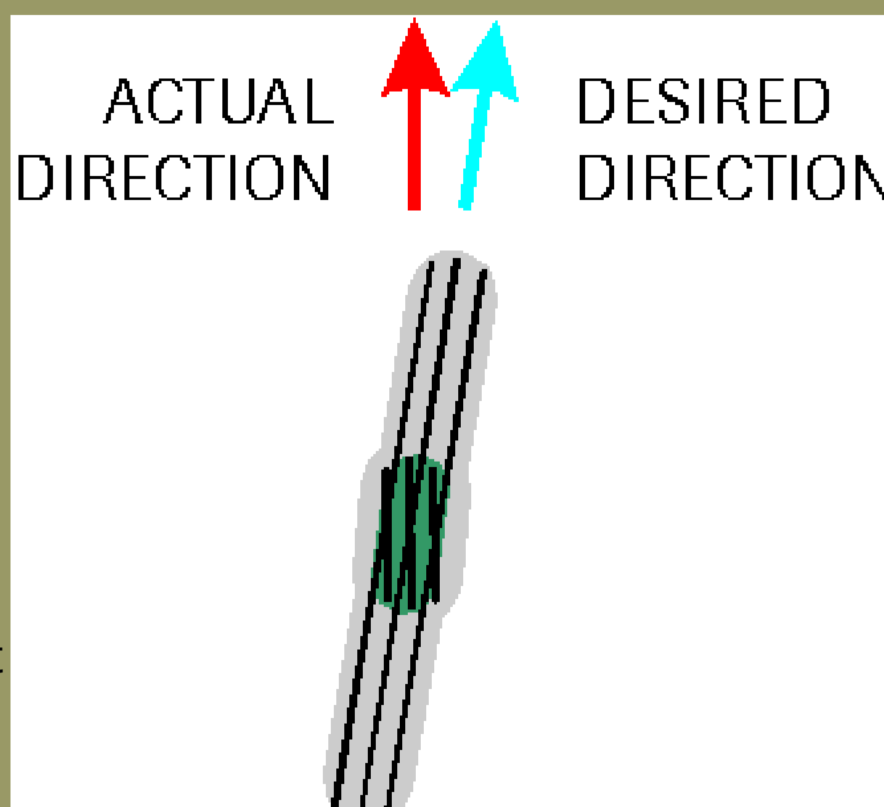


patch and the larger the contact patch itself will be.

The bulging demonstrates that the sidewalls of a tire have great flexibility. Because the flexing of rubber generates heat, but is a poor conductor of that heat, if your tire pressure is too low you can damage the sidewalls by riding on underinflated tires - a catastrophic failure can result.

Te get a feeling for what *torsional deformity* is, sit on your motorcycle at a dead stop and turn the handlebars 20 degrees in either direction. When you let go of the handlebars the front wheel will be pointed something between 15 and 18 degrees from where it was before you turned it - not 20 degrees. Indeed, if you paid attention you noticed the handlebars 'spring' back part way when you let go of them. How can you account for this phenomena?

Obviously, the contact patch did not turn as far as you thought it would when you turned the handlebars. Why? Because the contact patch has traction with the road surface and the tire's sidewalls flexed (torsionally deformed). The fact that there was a springing back of part of the movement of the handlebars is merely the result of the torsional deformity 'unwinding' when force was removed.



Torsional deformity happens whenever you are moving in other than a straight line. The diagram to the right shows a tire (from the top - ignoring lean angle) on a bike that is making a right turn. You will note that the direction the wheel actually travels is determined by which way the contact patch is pointed, NOT the wheel itself. Further, the diagram is illustrative of what happens to BOTH the front and rear tires. Indeed, because of the greater camber thrust of the front tire, the discussion so far is more apt of what happens with the rear tire than of the front one.

The angular difference between the direction the contact is pointing and that of the wheel itself is called its *slip angle*. It should be apparent that if the slip angles for the front and rear tires are the same, the bike will steer essentially as if there was no slip angle at all. But, at least for a motorcycle, you will find that the tire in the rear generates a larger slip angle than does the tire in the front.

If the rear slip angle is larger than the front one you have a condition known as *over-steer* while if the front slip angle is larger, the condition known as *under-steer* results.

You will recall that a slip angle results from a combination of the facts that the tire's sidewalls are flexible AND that the tire has traction. Note that if there is no traction (riding on ice, for example) then the slip angle will become essentially zero. On the other hand, if a wheel travels in a direction other than the one its contact patch is pointing, then you have a SLIDE angle rather than a slip angle. Slide angles and slip angles are VERY DIFFERENT.

Let me make this very clear. Inertia determines the direction a bike will travel if it slides. If you lose traction you will slide in the direction you were traveling at the time the slide starts. So long as you have traction you will travel in the direction the contact patch points, not the tire. Slide angle is the angular difference between the direction inertia sends you and the direction your tires are pointing while slip angle is the angular difference between the direction your contact patch is pointed (thus, the direction the tire moves) and the direction the tire is pointed.

Decreased traction reduces slip angles and increases slide angles!

What else affects slip angles? Acceleration and braking, tire profile size, belt wrap direction, and tire camber.

- **Acceleration and braking affect traction primarily because of weight transfer.**

- **A 'low profile' tire has sidewalls that do not flex as much as normal tires - hence, less torsional deformity (i.e., less slip angles.)**
- **Radial tires are belted with the belt threads running radially while standard tires are biased at an angle or circumferentially. In addition, radial tire sidewalls are constructed to strongly resist *axial deformation*. In other words, radial tires produce smaller slip angles than do the others. (This means that it is critically important that you NEVER have one tire be a radial and the other be standard construction. Corner handling will be almost unpredictable!)**
- **Compared to the rear tire, since the front tire of a motorcycle is narrower and has greater camber, its camber thrust is greater. Camber thrust attempts to turn your wheel into a turn. Thus, greater camber thrust yields smaller slip angles.**

For these reasons you should expect that your rear tire is almost always operating with a greater slip angle than your front tire. (i.e., your motorcycle tends to over-steer.)

What changes a slip angle into a slide angle? Excessive slip angles!!! That is, a slip angle is so called because the part of the contact patch that is to the outside of your turn is moving faster than the wheel itself is in the direction it (the contact patch) is pointing while the part on the inside is moving more slowly. (Exactly like camber thrust.) Since the outside part is moving faster than the tire it must be slipping. The inside part is gripping better than it would if moving in a straight line. For this reason the contact patch 'walks' itself into the turn.

The greater the slip angle, the larger portion of the contact patch that is slipping. At some point there is so little part of the contact patch that is not slipping that traction is lost and the tire begins to slide. Until shortly before a slide traction increases. Note, however, that traction is generally not lost all at once. Rather than an abrupt loss of traction, it tends to be lost gradually. (Thankfully!!!)

So now you know how it is that over-steer means that the rear tire has a greater slip angle than does the front one, thus it probably has more traction, yet despite that greater traction, it is the first tire to slide while in a curve.

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