Gyroscopic Effects

EVERY MOTORCYCLIST WHO really wants to understand how gyroscopic forces influence handling should spend a few minutes holding a spinning wheel's axle in his or her hands to experience firsthand the phenomenon of gyroscopic precession. Bicycle wheels are often suggested for this, but an even better experiment would be to compare actual motorcycle wheels of various sizes to feel how the gyro force changes with different wheel diameters, weights and widths.

I suspect most of us have owned a toy gyroscope, and of all the tricks it could perform, my favorite was how, when spinning very rapidly, its cage could be supported horizontally at one end, so it hung in space in apparent defiance of gravity. Gyro force can be that significant. And just think, at 60 mph, the average motorcycle wheel will be spinning between 760—885 rpm, will weigh between 23 and 45 lbs. and will have a diameter between 25"–29", making our wheels excellent big gyroscopes.

The basic science is that the bits of matter that make up a spinning wheel travel faster and farther per revolution the further they are from the center, by a factor of the radius squared—reducing the importance of weight at the hub and giving the material at the tire/rim the greatest influence. Thus, if you had two discs of the same weight turning the same rpm, one twice the diameter of the other, the larger disc will have four times the angular momentum. Of course, real wheels and tires are not simple flat discs of material, so we need to measure their individual Moments of Inertia to make precise calculations. Although rpm and weight will multiply the momentum, diameter is exponential, making it the more important factor. And what we call gyro force happens when we disturb this angular momentum.

Rather than getting bogged down in math, let's try handling actual spinning wheel/tire combinations. Because experimenting with wheel sizes has been part of my long-running DR650SE project, three wire wheels were handy for comparison purposes. To support the wheels, I used a Marc Parnes wheel balancer, a beautifully crafted setup that uses adjustable cones on a 1/2" axle to engage the wheel bearings. With this, it was a simple matter to rest one end of the axle on a stool, hold the other end, and use my 12" buffing wheel against the tread to spin each to the same "road" speed for testing.

What I noticed immediately with the first wheel/tire, a supermoto 17" x 3.50" front rim with 120/70 tire, was how the gyro force instantly deflects all your steering inputs like a Tai-Chi master changing the direction of your action. With the wheel spinning in the forward direction, a steering movement to the right (like countersteering for a left turn) is immediately twisted into a movement 90° from your desired direction—tilting the wheel's top to the left, just the way a motorcycle would bank into a left turn. The more forceful the steering, the more forceful this reaction, which will attempt to lever the front fork in the same direction, contributing to turn-in.

Tested next was a 21" x 2.15" wheel with a 90/90 TKC80 dual-sport tire. Slightly lighter (22.5 lbs. vs. 23.0) and 3.65" larger in diameter (27.25" vs. 23.6"), its sensation was remarkably different. Unlike the 17" wheel, which was quite easy to steer, the larger diameter displayed much greater resistance. And it was not the axle's resistance that was most apparent, but rather the spinning gyro force—like an invisible disc of inertial energy that seemed to grow with rpm. It is also interesting that this disc-like energy sensation is very distinct with a narrow tire, suggesting that a very true wheel (in terms of balance and runout) would also provide a very stable field of inertial energy.

The third wheel was an 18" x 2.50" fitted with a 150/80 TKC80 tire, 4.5 lbs heavier (27.5 lbs.) and 2.65" larger diameter than the 17". This wheel gave another unusual sensation. Of course, its greater size and weight gave it strong gyro inertia, but it didn't display the distinctive disc-like force field of the 21" wheel. Rather, it seemed as if the width of the wheel's spinning mass gave it a broader base on the axle, much like a spinning cylinder would behave differently from a flat disc. In addition to its greater size and weight, this lateral inertia also made it more resistant to quick changes of direction.

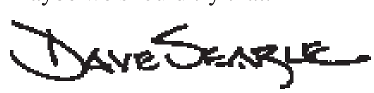
It almost seemed as if we should give special names to the states of rotational inertia. At low rpm, often noted as road speeds below about 12 mph, there is no effective gyro stability present in our wheels—call this *insignificant* rpm. But beyond this point the gyro force seems to grow geometrically—*significant* rpm, until it finally reaches the mind-boggling ability to defy gravity altogether (as in our toy gyroscope) which perhaps we should call its *cosmic* rpm.

Even such simple experiments clearly indicate that a larger diameter wheel will reach significant gyro inertia at a lower rpm than a smaller diameter, which makes sense as dirt bikes will utilize a 21" front wheel to give stability in rough terrain at relatively low speeds. It also confirms that the advantage of a 17" front wheel (as on a sportbike) will be most appreciated at very high speeds, when a much taller tire might be too difficult to steer quickly, while at the more modest speeds encountered on the street, it may lack the same reassuring stability of a 19" or 21" wheel.

Gyro inertia is very important. It's what allows our motorcycles to automatically stabilize their forward direction, even without rider input. If a speeding bike were to begin a slight fall to the right, gyro precession will cause the tire to steer to the right, and trail in the steering geometry will then cause the front of the bike to follow in this direction. And when the front tire's contact patch overshoots the vertical plane of the CofG, this cycle of self-correction will reverse. Seen from above, you can actually see a motorcycle's front tire follow a subtle weaving path while maintaining an overall straight ahead direction.

The bottom line: Gyro stability is something you really feel when you ride, and the taller the wheel, the more you'll have and the sooner you'll have it. Likewise heavier wheels and higher rpm also magnify gyro force. But to give it a precise value, you must measure the Moment of Inertia of the wheel/tire combination.

Maybe we should try that.



—Dave Searle
Editor