Air

I'D LOVED BICYCLES for 10 years when I bought my first motorcycle. By then, balancing, steering and braking were second nature, but some new sensations were so unexpected, they were startling. One was that wind resistance seemed to almost suddenly become a significant force against the bike and body at about 55 mph. Inside a car you'd never feel it, and we didn't have any hills in Maryland that were steep enough to get within 10 mph of that velocity on our bicycles.

My first top speed run for MCN's radar was aboard a CBR900RR, reaching a little over 154 mph. Through my visor, its terminal velocity had the look of a warp drive shift from the bridge of the Enterprise—a streaking landscape focused on a dot in the distance. The bike became a projectile, and its direction could only be changed slightly; evasive maneuvers were out of the question. As the radar setup flew by, I unwound the throttle and dared to lift my body from the tank. I was nearly blown off the back by the force of the wind! I couldn't imagine that wind resistance could be so powerful that a firm grip on the bars might be inadequate.

I learned that same day that I would never be the fastest rider in a straight line. I was physically too big. Another tester who was two-sizes smaller was nearly 2.5 mph faster with every run. It wasn't all bad news—I really didn't want the job anyway—but it made me permanently thankful for Danny Coe's help. And it clearly illustrated how frontal area is directly proportional to drag.

Significantly, drag also rises with the *square* of the velocity. The difference in drag between 55 and 60 mph is a noticeable 19%, the difference between 55 and 80 mph is 212% (not the 45% increase in speed). Between 55 and 100 it's 330% and between 55 and 150 mph, it rises 744%. To double your speed, you need four times the hp to push against the air.

Air resistance can be ignored at low speeds; air viscosity simply doesn't matter. But the higher the speed, the more critical it becomes. The cartoon "teardrop" shape that can part the airstream and move all the streamlines carefully back in line without losing laminar flow is the model of efficiency. The teardrop has a drag coefficient, or Cd, of just 0.04. Compare this number to that of a flat-plate perpendicular to the flow, which has a Cd of 1.1.

Of course, constant helmet testing this month for our big comparison has had me focused on the subject. Determined to quantify their frontal area, because it really matters and hasn't been done before, the technique took some thought. Tracing the outline of a helmet shell precisely required a truly parallel reference line around its circumference. At first, I hoped simply to use the sun's help for a truly parallel shadow, mounting the helmet so it could be aimed exactly face up. But light bends at edges, blurring the lines—not accurate enough.

The final plan: First each helmet was installed on our anatomical head form and a level line was applied with pinstriping tape to the side of the helmet. Large sheets of 20 lb. Bristol board were used for the tracings. Taped in the center of each sheet was a smaller square holding a bed of modeling clay. Each helmet was locked in the clay straight-up. A special tool supporting a straight edge at 90° to the table was used to trace the outline, marking every half-inch with extra attention to any detail changes in contour. A circumference line was then drawn to shape, connecting the dots, and the profile was cut out with an X-Acto knife. To determine the area of the profile, it was weighed with a laboratory grade gram scale and compared with a piece exactly 100 sq. in., the ratio providing the weight variation. By being very fussy with the details, the numbers should have an accuracy of plus or minus .5 sq. in. And the weighing was repeatable to an accuracy of .02g or less.

Still, like our eyeport measurements, which should be within 1° for repeatabilty, it's not NASA-grade data, but it provides a fair basis for comparison.

If one helmet is 20% larger than another (the range in our test), its drag will also be multiplied by that amount. Rollie Free rode his HRD Vincent Black Lightning to150.313 mph back in 1948 wearing nothing but a bathing cap and speedo, lying prone on a pad attached to the unsprung rear fender. Just the additional drag of a proper helmet would likely have held him below 150. "Brave" doesn't do it justice.

We were unable to find any data on the Cd of an actual motorcycle helmet. (If any reader can shed light on this subject, we're eager to share it.) However, judging by the drag coefficient of various geometric shapes, we can probably guess with some success. A sphere has a Cd of 0.45. this sounds pretty good until you learn that a solid hemisphere (half sphere) with the round end forward, is actually better, just 0.42. Behind the rounded backside of a helmet, air will tumble around to generate the turbulent flow that causes drag, and the big cutaway for the rider's entry creates a lot of noise as well as drag. We'd guess helmets have a Cd closer to .5.

It seems the best the helmet designer can hope for is to reduce lift, with a kind of high ducktail that encourages the air to wrap around the sides to form more vertical turbulence than horizontal. Full face and modular helmets can do this very effectively, but some open face and shorty helmets will try to pull your head off at freeway speeds. Incidentally, some of the most effective windshields we've tried also split the air to the sides, rather than pushing it primarily over the top. The big BMW GS is a good example. And slots that direct air up the backside of a windshield are often remarkably effective as well, as they serve to create laminar flow past the top of the windshield, reducinging turbulence. In fact, efficient windshields can significantly increase fuel efficiency compared with naked motorcycles.

Supercomputers are required to crunch complex computational fluid dynamics (CFD) problems. But despite their might, it's Adrian Newey's mastery of the black art of keeping air attached to vehicle shapes and how to set it free that keeps him the most highly paid engineer in Formula One. And some of the most beautiful forms are also the most aerodynamic, with shapes that seems to reveal Nature's divine plan. Gearhead rapture doesn't get any better than to behold a thing that's both very fast and very beautiful.

Dave Searle

—Dave Searle
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