A pub conversation that has probably been had by most engineering students at some point revolves around the application of golf ball-style dimples to the aerodynamic surfaces of an aeroplane or a car. Sometimes it is sparked by a rerun of a weak Australian TV movie featuring some plucky youths trying against the odds to race across the country using only the power of the sun. In it one of the youths suggests they cover the car’s surface with dimples, ‘just like a surfboard or a golf ball’. The car of course goes on to win the race by miles. But that’s all in the fictional land of TV. In the real world, the use of dimples has seemingly been restricted to the outer surface of golf balls almost exclusively.

In a spin

In golf ball manufacture, dimples have been accepted practice since the 1930s, when research showed how they could increase lift and reduce drag of a spherical object in flight. But what seems to have muddied the waters – at least as far as racecar engineering is concerned – is the fact that golfing is all about a spinning ball rather than simply reducing drag over a non-spinning body.

So could the same principle really be applied to racecars? It is rumoured that in recent years a Formula 1 team, thought to be Ferrari, experimented with dimpled surfaces but failed to make them work beyond the wind tunnel.

However, a chance encounter at PRI between editor CAW and oval track suppliers Fast Wings resulted in a picture of one of the US firm’s dimpled wings being published in VTEC. ‘The dimples seem to work. The car gripped much better with it on, the rim even turned inside the tyre’, explained a Fast Wings’ spokesman, yet the firm had no non-anecdotal data available on using dimples on an aerodynamic surface.

Nevertheless, the picture was noticed in Indianapolis, and Josh Poertner of Zipp Speed Weaponry, one of the world’s market leaders in racing bicycle wheels, contacted Racecar.

Poertner’s firm, Zipp, holds the world patent on dimpled disc wheel, and they seem to work, being chosen by a number of top teams including some Tour de France front runners. Zipp had spent time and money developing the dimples in the Texas A&M low-speed wind tunnel, where the dimpled wheels showed very good...
THE DIMPLED [BICYCLE] WHEELS SHOWED VERY GOOD REYNOLDS NUMBERS

In speed cycling, aerodynamic efficiency is critical and the advantage gained by dimpled wheels appears to be genuine. The shape that really trip the airflow and create the effect. As with anything else, the costs associated with testing the myriad options are extremely high, and then there is the perpetual battle between ideal engineering design and manufacturability on a production scale.

Shape of things...
The internal shape of a dimple is another area that is not yet fully understood. Zipp uses a meniscus-shaped dimple with a flat bottom that sweeps upwards near the edges. Apparently this shape is popular in current golf ball design, particularly with manufacturer Titleist.

The way the Zipp wheels, and most cycle wheels, are tested in a tunnel is different to the way cars are tested. The wheel is spun in the airflow and the amount of power taken to spin the wheel measured. This is then taken into account, along with the standard measurements of translational drag, lift and side force relative to the wheel axis. So in effect, the two measurements have to be balanced, as some gains in drag may show similar or even greater losses in terms of energy to spin. Zipp’s dimpled wheels showed much better figures compared to its non-dimpled designs in these tests, as did one other area Zipp has experimented with — rim shape.

The leading edge of a bicycle wheel is the tyne, which is essentially round in section, so we...
Dimples

have to design rim shapes that can re-capture the air separating off of the tyre. The idea behind our design is that these rim shapes can only take advantage of the airflow if the air is sticking to the surface of the rim. With a v-shaped rim or flat-sided rim, the airflow becomes separated from the leeward side of the rim as soon as the rim begins to face airflow more than one or two degrees off axis. Or in other words, as the wheel 'yaws into the wind,' explained a Zipp spokesman. The flow that has separated causes the formation of a vacuuum area behind the rim and, on a cycle wheel at least, that is the main source of drag on the wheel. Two years ago we tested dimples on one of our rims that had an essentially parabolic shape, and found that they did absolutely nothing. But the reality of that wheel was that the airflow was separating off the tyre, so the rim was not able to act as an aerodynamic element as it was not directly seeing any airflow.

It is quite possible similar scenarios have prevented dimples showing a gain when racecar manufacturers have experimented with them without a complete understanding of how they work. With a curved section, we were able to keep the airflow on the rim surface out to seven or eight degrees of yaw, but eventually the flow begins to separate or 'stall' on the backside. Using dimples in combination with these rim shapes, we forced the airflow into a higher energy state, forming a turbulent boundary layer near the surface of the rim which allows the air to remain attached to the rim even at higher angles. The trade-off with this is that we are creating a slightly higher skin friction drag on the rim, but since this is some 10 or more times lower than the pressure drag, we find a bulged rim to be remarkably analogous to a golf ball in that the pressure drag reduction is many, many times greater than the total skin friction drag. The result is a wheel that is not just faster in one condition, but faster through the range of conditions you will experience.

Whilst a racecar wheel is somewhat different in shape, the possibility of using dimpled hubcaps or sidewalls is certainly an interesting proposition, and one that needs further investigation.

Beyond the wheel

As well as its work with wheels, Zipp has also developed a dimpled hub for racing cycles, which suggests areas such as the driveshfts on a single-seater racecar could perhaps benefit similarly. An area such as this is constantly exposed to the sensitive rear airflow and, whilst shorter and under somewhat different demands, the principles could potentially be transferred. 'I think that our new dimpled hub is pretty analogous to a racecar driveshaft, and on the hub we are seeing 14-20% of drag reduction at low yaw angles in the wind tunnel (at 30mph) and this is only a very small part,' explains Poertner. 'At the high yaw angles the flanges (the Zipp hub is only 100mm end to end with flanges at each end) start to block the airflow over the centre of the hub so the effect goes away,' claims Poertner. This is less likely to be a problem with a racecar's driveshaft.

So what other areas could benefit from a dimpled surface? Perhaps a diffuser or even the entire underfloor: Could dimples make a wing more effective? It seems Lexus has recently dimpled the bottom of one of its road cars to 'reduce noise', which begs the question, is this reducing noise by reducing drag?

One of Zipp's engineers had previously been involved with the Chevrolet IRL wind-tunnel programme. One of the points he raised was that this is probably a non-existent issue in IRL or similar racing as the wing angles are so shallow and they never really saw separation issues in the tunnel on any of their designs, so they were tuning wing shapes in very much the same way you would an aircraft wing,' explained Poertner. 'In F1, at a place like Monaco, the low speed and transient effects on wings that are in a very high downforce set-up could be interesting. At some higher speed, you will likely see an adequate Reynolds number to keep the flow from separating in some areas of the track (such as under the nose or Massa's may be reduced by a factor of 10 or more,' he continued. Though Monaco is an extreme example in F1, the principle could apply to other types of cars on other street circuits like Spa, France or Houston, USA, as well as on some of the twistier road courses like the Hungaroring.

'I wonder if the dimples may only increase skin friction drag at high speed, but possibly increase downforce and reduce drag at low speed. Or at least lower the stall speed of the wing by some percentage, sort of like vortex generators on an aircraft wing which either increase stall angle or decrease stall speed,' Poertner concludes.

Of course, numerous other unanswered questions still exist, such as how big do dimples need to be? And how deep? In a control formula like AgP or GPz could putting a dimpled sticker on the underside of the cars' wings be an unfair and legal advantage? If every surface of the car were dimpled, would it have an even better effect? After all, sharks have rough skin over their entire body, which is said to allow them to pass through the water more efficiently. There are many misconceptions and unknowns relating to dimples in aerodynamic design, as one aerodynamicist told Racecar: 'It's something that comes up every now and again, but has never really got anywhere. At least not yet...'

"A TURBULENT BOUNDARY LAYER ALLOWS THE AIR TO REMAIN ATTACHED"