

Tank slappers and the way to avoid them

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A potentially fatal phenomenon that has been haunting motor-cyclists for decades could soon become history. Steve Farrar reports.

Although he was just 30 seconds into the race, Paul Orritt's Honda Fireblade was touching 150mph as it crested Bray Hill. A highly experienced rider, Orritt was looking forward to almost two hours of trouble-free, high-speed racing in the 1999 Manx Grand Prix. But as he guided his bike smoothly around the gentle bend that led down into the hill, his plans came to a violent end.

Without warning, the front wheel started to thrash from side to side and Orritt found himself battling just to stay on. Bikers call it a "tank slapper" because the handlebars suddenly seem intent on battering the fuel tank into submission.

Orritt had faced such episodes before. But this time it was different. "It just wouldn't come out of the tank slapper," he recalls. "I was no longer in control." The bike fishtailed down the hill, eventually throwing Orritt into the road. He flew for another 100m before smashing into a fence. When he awoke in hospital, he had six broken ribs, two smashed shoulder blades and a mangled right hand that no longer had an index finger. That he survived at all was surprising.

Orritt has his own theory as to what triggered the catastrophe - he remembers that the trouble began immediately after he ran over a couple of bumps in the freshly laid road surface. Yet no other competitors reported suffering similar problems. Orritt's experience is, however, by no means unique. It is impossible to know just how many motorcyclists have fallen victim to a bike that abruptly takes on a life of its own, but there have been a few high-profile cases. In 1993, two police motorcyclists on a high-speed training exercise came off their bikes as they negotiated a sweeping bend on the A3 north of Guildford. One died. In 1996, Suzuki recalled a new model after several people were killed in similar circumstances. Statements were subsequently issued in both cases noting that uncontrollable oscillations set in after the bike hit bumps in the road while taking a corner at speed. But exactly what was happening and why most riders seemed to get away with it remained a mystery - until now.

Engineers at Imperial College, London, believe they have found the solution. The answer they have come up with shows how a host of seemingly unconnected elements can sometimes combine to devastating effect. David Limebeer, professor of control engineering at Imperial, has worked on the project with colleague Robin Sharpe, professor of automotive product engineering at Cranfield University, for nearly five years. He is very happy with the new analysis. "It shows these accidents are not acts of God," he says. "There is real science going on; stuff we can explain and hopefully sort out."

Limebeer has studied video footage of Orritt's last few moments in the race and noted the distinctive features of the bike's behaviour that led to the crash. But the engineers' action has been largely confined to the latest computer-modelling techniques. Vast quantities of simultaneous calculations are needed to unravel the complex interactions of the forces

and geometry of bike, rider and road. A powerful multibody modelling programme called Autosim, devised by scientists at the University of Michigan in the United States, has enabled Limebeer and his colleagues to recreate the circumstances that lead to the tank slapper in unprecedented detail.

All the important features of this type of accident can be replicated and tested without putting anyone at risk. The problem has been known to science since it was described as "speedman's wobble" in a journal paper of 1922. Yet it has proved remarkably resistant to the attention of engineers. Unravelling its many elements was impossible without powerful modern computing techniques. In fact, there are two linked forms of motorcycle instability: wobble, which occurs at low speed and causes the front wheel to rapidly flip back and forth like that of an unruly shopping trolley; and weave, the fish-tailing effect that happens at high speed and that caused Orritt to crash. Both, potentially fatal, share many general characteristics.

It is clear that an outside influence is needed to spark the phenomena. Subtle undulations accidentally introduced into a road surface during its construction can be enough. These need be no more than a centimetre in height and stretch over just a few metres, so long as they have precisely the right wavelength between peaks to "tune in" to the wobble or weave dynamics of the bike and its rider - values determined by intrinsic mechanical properties.

Other factors need to be present too. The bike has to be travelling at just the right speed. It must also be taking a corner, with the bike leaning at a particular angle. Together, these elements enable the vertical oscillations caused by the bumps in the road to become amplified and transmitted to the bike's steering - like a tuning fork applied to a guitar string. The magic combination sets loose the unseen forces behind the tank slapper.

Engineers have experimented with ways to influence the extent of the problem. They have found that heavier riders are less susceptible to the problem than lighter ones. More significantly, hazards inherent in tinkering with the bike's settings have emerged. While increasing the steering damping reduces the risk of wobble, it increases the chance of weave. "It needs a holistic approach," Limebeer says.

The results have been sent to motorbike manufacturer Triumph as well as to the Metropolitan and Thames Valley police forces. Aspects have been published and discussed at major conferences, while an overarching paper has recently been submitted to a leading journal.

The next task is to look at how an understanding of the science behind weave and wobble can be used to construct a motorbike that is less susceptible to the problem. Limebeer admits that designing them out is a delicious prospect. When he experienced the problem soon after he started riding motorbikes some eight years ago, he was lucky enough to be able to ride through the weave. But he is acutely aware that many, including Orritt, have not been so fortunate.