Highlights 2007

A look back on a special year

Delft University of Technology

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Challenge the future

Mathematical model explains bicycle stability

Why are bicycles so inherently stable? For more than a hundred years scientists have racked their brains trying to answer this question. After lengthy analysis, Dr Arend Schwab of the TU Delft faculty of Mechanical, Maritime and Materials Engineering has derived a mathematical model which is able to predict the stability of a bicycle: 'It's a combination of factors.'

'You need a lot of stamina, and working with others keeps you enthusiastic.'

What is so mysterious about how an ordinary bicycle works?

'Everyone knows how a bike is made, but no-one knows exactly how it works. It is rather strange; if a bike is immobile and you let it go, it falls over, but give the same bike a decent push and it stays up. Even if you give this coasting, riderless bike a sideways push, it doesn't fall over; it corrects itself and goes on. How does it do that? Why are bicycles so inherently stable?'

Has an explanation for this never been found before?

'For more than a hundred years scientists have racked their brains for an answer. Many came up with mathematical models for predicting the stability of a bicycle. They got a long way, but none of these models was completely watertight. We compared fifty of these models, all produced by noted scientists, and every one came up with different predictions. There were little mistakes all over the place. Even bicycle manufacturers have never really understood how a bike works; they just improved their products by trial and error.'

So, what's the secret of bicycle stability?

'It's a combination of factors. Our model comprises 25 parameters: the wheelbase, the wheel mass, the front fork angle, the centre of gravity, and so on. All these factors combine to determine the bike's stability. They are all related to two bicycle movements: leaning and steering.

We also tested whether our model's predictions worked in practice, and they did. So now we can predict the stability of a bike right from the blueprint. We can tell whether a particular design is going to produce a stable or a nervous bike. For instance, the flatter the angle of the front forks, the more stable the bike, but the harder it is to make turns.'

Bicycle manufacturers must be pleased to hear it.

'They do stand to benefit, yes. Using our computer model, improving a bike's characteristics is no longer like groping round in the dark. You can modify the design in precise ways. For instance, you could make a bike more stable for old people, perhaps with an engine near the handlebars. That would be innovative. And you could use our model to further develop the design of exotic bike types, such as the reclining bicycle, the folding bicycle, or bikes made especially for the disabled. Or you could give all bikes a hallmark indicating their degree of stability.'

So now we want to do more research into cyclist behaviour. Only when we can look at the interaction of bike and rider will we have a full picture. But that's when you could, in principle, make a custom-built bike for anyone.'

What's next in line for the bicycle project?

'We now know everything about the 'hardware', the bike itself, but we know nothing about the rider. What does a cyclist actually do? How does he behave on a bicycle? Much of this behaviour is routine, unconscious. Take a right turn for yourself, for instance; if you look carefully, you'll see that you steer a little to the left first. All cyclists make these counter-steering movements entirely automatically and unconsciously.

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How did you come to carry out this research?

'I had a sabbatical and I wanted to do something enjoyable. It transpired that Cornell University in the USA had some bicycle research that needed 'tidying up'. I had the software with me and I knew how to develop the models. And I was also in touch with a colleague at the University of Nottingham in England, who was working on motorbike dynamics. We talked and worked together for hours on Skype. I would never have got this far without their collaboration. You need a lot of stamina, and working with others keeps you enthusiastic. You keep on coming up with ideas, and you check each other's work. That's the best way of making progress.'

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