Electric on Exmoor

An electric bike race over Exmoor

Nick Long

I was in the restaurant when the second wave of ridicule broke over me. I had just been roundly abused on the internet, but I thought I was safer here, among friends and family. You expect them to be a little more understanding than the harsh anonymous critics online.

Maybe it wasn't the best time and place to announce that I was going to enter an electric bike race. Not in front of this group anyway. What I had to endure for the rest of the evening was a series of jokes about how the prizes should really go to the motor instead of the rider, about how the batteries should be lined up on the podium, about how it was all so pointless. "I couldn't have done it without my batteries", was the suggestion from Trevor, another engineer, for the winner's tearful thank you speech.

Hub motor

Electric bikes, or more accurately, electric assist bicycles are a rapidly growing phenomenon, and like all such things there is a shift going on, both in the bikes themselves and in people's attitude to them. Once they would have been barely more than a gimmick or a toy, something that was just not capable of being put to any serious use, or if they did actually work, would be dismissed as only for the old and feeble.

E-bike design has progressed. You can still buy an underpowered and overweight machine that handles badly from a dealer you will never see again. But equally there are sporty looking models, with quality components, that will give you 30 miles range. These ride like a decent bike, with the simple difference that you can go up a hill as if it isn't there. The better ones are well over £1000 new, and it's not geriatrics who are riding them. There are people getting rid of their cars and commuting to work on e-bikes. And there are people who are riding them just for fun. Cycling sounds like a solitary activity, but e-bikers tend to be active internet users too. Inevitably then, as soon as there were two e-bikes in the country, there was an internet forum to talk about them. Now we were talking about a race over Exmoor.

4 batteries and a bicycle

There is a standard conversation that e-bikers have. Someone will say, "Wow, that's a smart looking bike". E-biker will then mention some distant place he has just come from. "Wow, that's really impressive, you've ridden all that way?" The e-biker is then out of modesty compelled to point out the motor and the battery. The member of the public has spotted them of course, but not really connected them up; they don't necessarily look the part and he is wondering if they are fancy modern bicycle accessories. The next line in the conversation is always "Oh, that's cheating." We get a wry smile out of it every time, because the person accusing us of cheating has just got out of a motor car. Think about it – which one of us is really using an artificial aid to replace leg power?

The mockers do have a point about e-bike racing, however, and it lies in that switch between leg power and artificial power. An e-bike is not an electric motorcycle - it is an electric assist pedal cycle. To get the best out of it requires rider effort too. In normal leisurely e-biking, the focus may have switched nicely from the rider's leg power to the electrical system. But e-bike racing switches it straight back to the muscles. And for someone like me, who is in his fifties but knows a lot about electric motors, that is very bad news indeed.

Handlebar controls

There is a name for the people with bulging thighs who flash around on racing bikes. We call them lycras. The return joke is that we are Japanese grandmothers, a reference to the perceived market for e-bikes and the fact that the power limits in Japan are lower than anywhere else. But the sad fact is that a lycra on an unpowered road bike is usually faster than a non-lycra on an e-bike.

The EU law on e-bikes is that they must weigh less than 40 kg and the motor must stop delivering power at 25 kph (15 mph). Below these limits it is officially a bicycle; above them it's a motorised vehicle and needs registration, insurance, tax and licensing. There is also a 250 Watt limit on motor power; but electric motors are not like petrol engines, the power of an electric motor is set not by the motor, but by how much electricity you give it, so no-one knows how that limit is defined, let alone how it could ever be enforced. Clearly, that bit of the legislation was not written by a wise and mature individual with a deep knowledge of electric motors.

40 kg (88 lbs) is a heavy bike, heavier than it is pleasant to ride. The manufacturers have struggled to get the weight down and any e-bike nowadays that weighs in at more than 25 kg, including batteries, is old fashioned.

That leaves the 15 mph limit as the one important bit of the rules for being street legal. The law doesn't say the bike can't go above 15 mph, just that the motor must stop delivering power there. Above 15 mph, its an ordinary bike, running on pedal power alone. For normal, going down to the shops sort of riding, which most people do at 10 mph or less, that is fine. But a lycra is doing at least 20; the ones with the stretchiest, shiniest clothing are doing over 30. Actually, I think some lycras even walk faster than 15 mph.


Nick, Andy, Wai Won & Conal

That's the problem with racing an electric bike; if its street legal then almost anyone could outpedal it. But even if it's not street legal, there's a good chance a lycra could outpedal it. Most North American states set the limits higher, at 750 Watts and 20 mph, but that's still not clear of lycra territory.

There is an annual event, the Tour de Presteigne in Wales, which is a sort of festival for e-bikers and what started as a light hearted endurance run to see how far bikes could go in an hour is now seen as the benchmark competition in the UK. The Presteigne "race" is run on closed roads so the 15 mph cut off limit doesn't apply.

The bike that won the first Tour de Presteigne was an eZee Torq. The eZee bike company is one of the main manufacturers of e-bikes, and it can be credited with kicking

off the current interest in sporty rather than plain models. The first Torq was almost the exact opposite of utilitarian. With 28 inch wheels and an extended wheelbase it was a monster compared to the average shopping bike. What's more it was built for speed; both the motor and the pedals were so high geared that it actually became difficult to ride at less than 15 mph. Naturally, it did come with a 15 mph limiter built into the control electronics, but equally naturally, websites began to spring up explaining how anyone, even without an extensive knowledge of electric motors, could get underneath with a pair of wire cutters and disconnect it.

The Torq became famous. You had to put some effort in, but it was far and away the fastest commercial e-bike. This was hardly the Japanese grandmother market. This was something that would beat the train to work or to ride just for the fun of it. Did I mention that my bike is one of these early model Torqs?

There was a downside though; optimising for speed meant weaknesses elsewhere. It was uncomfortable; a lot of road vibration got transmitted to the rider, and it didn't climb hills very well. Comfort and hill climbing are exactly the reasons some people will purchase e-bikes, so the Torq was getting a reputation.

Torq Mk 2

Fast forward only two years to the 2008 Tour de Presteigne and things have changed. In response to customer feedback, eZee Bikes have added front suspension to the Torq and changed the gearing. The company has also come out with a public statement about the importance of complying with the law; the new Torq has a bigger motor but the bike is set up less for speed and more for hill climbing. The restrictor circuit is also a little smarter and not so easy to disable.

The other thing that has happened is a needle match developed between eZee and another manufacturer: Kalkhoff from Germany. They had come into the market with a revival of an old scheme – the electric motor driving the chain rather than the wheels. That means the motor can get the benefit of the bicycle gears and, in theory, can climb any mountain. As it was, the eZee Torq won again, but there was a feeling abroad that, this time, it wasn't so much a contest between the bikes as between the lycras that the rival manufacturers had bribed or cajoled to ride them.

It should have been no surprise after that to find the internet, and especially Pedelecs, the UK forum for e-bikers, alive with comments that the whole thing was meaningless. If the rules had been different, a different bike would have won, the armchair experts pronounced. Somehow you can't argue with logic like that.

As a long time racer in another field of motorsport, I was trying to pick my way through this minefield and work out just how an electric bike competition could be made to work. I had just started to formulate some ideas when I was thoroughly trumped.

Wai Won Ching, the owner of eZee Bikes, posted a challenge. He didn't accept the reports in the magazines that the Kalkhoffs were better than the eZees at hill climbing, that they would go further and faster than anything before, cure world hunger and prevent climate change.

Ching's challenge was simple. The Tour of Britain cycle race, successor to the old Milk Race and similar to the more famous Tour de France, runs every September. Stage 3 goes through the West Country; it is 115 miles long and has some of the nastiest hill climbs, including a long slog to the top of Exmoor. Ching proposed to take his bike round the course and challenged the Kalkhoffs and any other manufacturer to join him.

The challenge was posted on Pedelecs. Ching had done the calculations, he said; his bikes could carry the four batteries necessary to do the 115 miles and the hill climbs, the

others couldn't. He even offered a deal on batteries to other eZee riders who wanted to come along. It was time for the talk to stop; the others could put up or shut up.

That was when the first wave of ridicule washed over us all. Predictably enough, much was made of the point that the lycras would be doing the course without electric assistance, so what was proved by doing it with? One manufacturer said he thought the whole thing was pointless so he saw no reason to be involved. A more bizarre response came from the Kalkhoff distributor. They could do the course on three batteries, so there was no point entering a competition that allowed four. Well, do it on three, then, and hold the fourth aloft at the finish, some of us replied, but I think they were really looking for excuses.

Ching's challenge had a specific target. David Henshaw, the editor of AtoB magazine, and previously a Torq fan – it was he who rode one to victory in the first Tour de Presteigne – had published one of the reviews saying the new Kalkhoffs were better. They went up hills better and they could go further on a charge. The Tour of Britain ride was what should have suited them exactly – steep hills and long distance. Right down to the ground and up their street. Not only that, but David lives in Dorset, so it was almost on his doorstep. Just ride along with me, we'll have a good day out and see which bike is best, was the invitation.

David signed up, and so did half a dozen of us. The electronic mockery continued of course. Mostly it was along the lines of what does it prove, which I dismissed as coming from people who just do not understand racing. The purpose is not to engender proof beyond scientific or legal doubt; the purpose is simply to do it, and do it better than the next man. Tony, aka Flecc, is the Pedelecs guru and author of one of the websites on de-restricting the Torq. He posted a comment, apparently in all seriousness, that with all these riders in their fifties, when it came to packing essentials, an ambulance, defibrillator and oxygen were probably more important than spanners and a puncture repair outfit.

Andy Grayland

There was talk of elaborate rules, with one person keen to specify the number of spare spokes we could carry, and a complicated points scoring system, until Ching wrote in again: There is only one rule. We are all gentlemen, we will ride round the course and see if we can do it. The online chatter slowly turned away from laughing at us and into dissecting the details of the ride itself.

So who is this gentleman who makes bicycles in Shanghai, writes perfect English in his emails and can put his finger on the British character more accurately than the average internet nerd? The conundrum was answered when I finally met him on the day before the ride. Wai Won Ching was born in Singapore and started life as a British citizen. He went to China as an investor when it started to open up, found himself involved with a bike factory and thought – I can do better than this.

I had less than two months to prepare both the bike and myself. As I worked deeper into the details, it became clear just how neatly phrased the challenge was. Yes, there is the futility, the comic aspect even, of doing something with electric assist straight after it's been roundly demonstrated that it can be done without. But looked at from the point of view of electric vehicle engineering there were some very serious technical challenges. First, there was the distance itself; just getting enough batteries onto a bike was not

trivial. Second was the nature of the course. One idea I had been working on for an e-bike race that solved the lycra problem was to alternate uphill and downhill segments. On the uphill, provided it was steep enough, the electric power would always be more important than the muscle power. Downhill, it would be neither muscles nor electricity that mattered, but things like bike handling, rolling resistance, brakes and sheer nerve. As someone on Pedelecs put it; it's not legs of iron you need, but balls of steel.

The Tour of Britain Stage 3 route fitted right into this scheme. The guys on the forum were gleefully analysing the route and posting statistics showing it was really 120 miles and there was over 10,000 feet of climb, and another 10,000 of descent. Ten thousand feet is two miles. The average guy our age has enough trouble doing two miles horizontally, let alone vertically.

Then there were the individual hills themselves. I was going to cycle up some of the steepest hills in the country, and I was going to do it on a bike that was famous for not going up hills. By this time I was gaining a lot of respect for the lycras, and wondering just how prophetic Flecc's post about the defibrillator and oxygen might turn out to be.

To grasp the difficulty here, and understand the essential difference between the two designs of e-bike, requires some understanding of electric motors. Unlike combustion engines, an electric motor can provide drive right from zero rotation speed and can operate over a wide range of speeds. But the efficiency depends crucially on the speed; once up to its top speed the conversion of electrical energy to motion can be almost 100%, but at slow speeds it drops towards zero and the energy ends up as wasted heat.

Wai Won Ching & David Henshaw

There are two commonly accepted ways to design an e-bike. One is to put the motor in the crank area, by the pedals and have it drive through the gears. This is more complex, but it does mean that as the hill gets steeper, a lower gear can be selected and the motor continues to work. The other method is to build the motor into the hub of one of the wheels and have fixed gearing. Hill climbing then involves a combination of motor and rider effort – the rider's task is to put enough effort in to keep the bicycle moving above a minimum speed. The steeper the hill, the more effort is required, until eventually both rider and motor grind to a halt. A fit cyclist can take a hub motor e-bike up common or garden hills, but there is always a limit.

On the face of it then, there was no contest; some of the hills on the route were prototype mountains and the drive through gear system should be the only game in town. But the more I went into it the more I realised Wai Won Ching had done his sums. The Kalkhoffs could go fast, they could climb steep hills and they could go long distance, but they would not be able to do all three together. In the long run, the hub motor was going to win. The trouble was, he had done his sums on the Torq2, not on my Torq1.

There is a sweet spot on a hub motor bike, keep the speed above that and everything is wonderful. Fall below it, and the performance drops off and it starts really eating the battery power. The Torq2 puts that sweet spot around 7 or 8 mph. On the Torq1 it is reckoned to be 12. If I fall below 10 on a climb I need to worry because once it starts to go it falls apart very rapidly. The demand from the motor causes the battery voltage to sag, which in turn drops the power available, and the bike slows further. At the same time the rider is running out of gears to change down to, so the power from him drops too. It's a vicious cycle and sooner or later its better to get off and push. Of course, the drive through gears rider never has to get off and push, but then if he is only doing walking pace, is he really any better off?

This called for the standard race preparation programme, consisting of a little training for me and a series of modifications to the vehicle. Over the next few weeks, I experimented with different gearing. That sounds simple, but what I really did, with the help of emails back and forth to Shanghai and the guys on Pedelecs, was to completely rebuild the whole derailleur system on the bike. We got it so that the delivery of rider power could be managed smoothly and efficiently all the way down to 7 mph, a big improvement on before, but while still leaving the top end in place for the downhill sections. You would have seen me around this time in August, patrolling the hills of Somerset with a spirit level strapped to the bike. I needed to test the man/machine combination against the steepest hills in my area and work out exactly what gradient I could climb.

Tweaking the electric drive is not so easy. The mechanical side of the system is fixed, but there are things an electronic engineer can do to the electrical side. I built a step up booster circuit, that would take the power from a set of batteries, convert it to a higher voltage, and then deliver it to the motor. This would solve the problem of voltage sag under load as well as slightly increase the power that could be delivered. There would be a little switch just behind the seat; when the going got tough I could reach round and switch in the turbo. The effect would not be great, maybe just an mph or two on a steep hill, but it could make all the difference. The downside was that it would drain the batteries like an open tap, and I also knew I was running a real risk of overheating the motor if I ran it too long.

Route checking - Pete Mustill on left

And finally I solved the road vibration problem. I opened out the mudguard clearance and squeezed in a special front tyre of German design. The 2 inch wide Schwalbe Marathon Supreme is supposed to be proof against punctures, have exceptionally low rolling resistance and take the place of suspension. It also costs about as much as a car tyre, despite being tiny enough to roll up and put in your pocket. On the other hand it does actually do all these things it claims – I've got one on another bike. I was thinking of asking if they had a super expensive, higher-technology version that would go up hills on its own.

There is another feature of the standard race preparation programme - it never quite finishes. So when Conal arrived to collect me and the bike on a Tuesday afternoon in September, I was still wiring the batteries in. Battery technology is really what controls the development of electric vehicles. Gone are the days when lead-acid was the only choice and I was building a veritable showcase of technologies. In the frame was a stack of Nickel Metal Hydride cells; the panniers on the rear had connectors to take the Lithium Ion batteries I would be borrowing from Ching, and finally a special box behind the seat held some of the latest Lithium Iron Phosphate cells I had had flown over from China. The battery market is a complex mix of weight, cost, power density, and the number of charging cycles until the cells start dying. LiFePo, as Lithium Iron Phosphate is called, is the new hot bet, but mainstream vehicle manufacturers are holding back until it is better proven, leaving it for now to the experimenters and first adopters. LiFePo is also supposed to be slightly safer; just about every battery type ever invented has been known to explode under some conditions, though usually only when over-charged.

Preparation - never finishes

Stage 3 of the Tour of Britain was on Tuesday the 9th. The route starts in Chard in Somerset at about 300 ft above sea level, goes west into Devon via the most up and down route possible, up over Exmoor and down to the northern coast of the South West peninsular. From there it works its way east and north

to Burnham on Sea, but with a minor excruciating detour to go over the Quantock hills instead of round them. Frenchman Emilien Berges won the stage with a time of 4 hours and 49 minutes. 23 of the 91 riders came in under the five hours and no-one took more than five and a half.

Initially the plan was to ride the route just after or just before the main race, but we had settled on doing it the following day. We were booked into a small hotel in Chard for the Tuesday night. Conal O'Rourke drove down from London, picking me and my bike up on the way. Conal works in local government and uses his e-bike for the daily commute into work in North London. By the time we arrived the others had already taken over a corner of the restaurant and got into training. As well as Wai Won Ching, there was Pete Mustill and Andy Grayland, two of the organisers of the Presteigne rally, with their support driver Phil. Rhys Mortimer and Fiona from Cyclepoint, the UK eZee distributor, were there with a van full of bicycles and batteries. Rhys had a knee injury so wasn't riding, but one of the bikes in the van was for David Henshaw, the sixth rider, who would be coming in the morning. For some reason Kalkhoff had declined to lend him a bike, so he was borrowing a Torq2. It wasn't how it was planned but it was going to be an all eZee affair.

We did not get away early in the morning. Officially this was blamed on having to wait for David, but the reality was that we were just not organised enough. We were still fitting batteries and handing out maps long after David arrived, a lack of preparation that would come back to haunt us at the end of the day. Pete, though, had set off early; his plan was to take it gently and expect us to catch him up half way round. The rest of us set off together, though at some stage we knew David was likely to make a break; he was a strong cyclist and would probably want to set his own pace. The remaining four of us had planned a series of regrouping points to avoid us getting too strung out, and so that help was never too far away if it were needed.

Top of a training hill

For the first stage I was flying in formation with David, not so I could slipstream him the way the racing cyclists do but simply because its easier to set the right pace if you ride with someone else. On my own on the flat I tended to let the speed of the Torq1 run away with me and I would end up cruising too fast for the batteries to last the course.

Not so on the hills, though. That first leg of ours ended with the climb up Staple Hill and I was having trouble keeping up with David on the Torq2. I had to operate the turbo button and take myself down to the very bottom gear, but I made it. This was looking good, but it was only the first hill.

David was on a roll and carried on at his own pace. I hung back to regroup with the others and over the next two stages we tackled several more training hills before pausing at South Molton ahead of the big climb to the top of Exmoor. The difference between the Torq1 and all the other models on steep hills was clearly showing; coming up the long

drag out of Tiverton I was having to work but they looked as if they were cruising along. I tried to comfort myself with the thought that they were probably just acting.

There was no sign of the route from the day before and we were following segments of maps - I had mine taped to the handlebars - but even so, each one of us took a wrong turn at some stage of the journey. The other thing I was doing was monitoring the battery depletion. I had on board instruments that counted miles run and battery current used. The consumption looked good so far, but it depended on where I did the calculations. If I worked it out at the top of a hill after caning the batteries it looked bad, as if I couldn't make the full distance, but down at the bottom, after clocking up more miles for practically zero power usage, it always looked better.

The calculation is essentially simple, but the boost circuit complicated matters and involved a correction. As if riding an electric bicycle over Exmoor wasn't eccentric enough, I was supposed to do advanced feats of navigation and mental arithmetic at the same time.

Conal fixing a puncture

The South Molton stop is halfway round the route. Here we learned that Pete was only 15 minutes ahead and that David had just passed him. What faced us next was the big climb and we made an executive decision to delay lunch until we'd conquered it. Apart from anything else it made sense to let the support vehicle carry the weight of the sandwiches.

For some reason, the road to the top of Exmoor is called Mile Hill; in fact it's a long straight climb of more like five miles. But here is the good bit: although the altitude gain is enormous - some one thousand feet - because it is strung out over all those miles, the actual gradient is not too bad. The energy expenditure to get to the top is still eye-watering and there is a "King of the Mountain" award in the Tour of Britain race for it, but it's not actually that steep. For someone with a turbo button and a knowledge of electric motors that is good news.

In fact the tables were turned on the newer Torqs; they were past their sweet spot and running out of steam. The science bit is that the combination of back voltage from the motor and voltage sag from the battery meant the electric power they could deliver was limited. For me it was different; with a combination of the boost circuit and leg power, I could hold the old Torq right on the sweet spot for mile after mile. Both legs and batteries were taking a punishment but I was slowly drawing away from the rest of them.

Or at least I was until about three hundred yards from the top, when it all stopped on me. A minute later it started again, and ran perfectly, then stopped again. During our triumphant picnic I assessed the situation. 67 miles covered, well over half the battery energy gone, and an intermittent problem with the motor. On the other hand, it was mostly downhill from here and it had all the symptoms of an overheating problem so would no doubt fix itself if left alone.

Conal, Nick, Wai Won & Andy on top of Exmoor

I was wrong on both counts. Before the big descent to the coast, we had to hop from peak to peak, traversing a series of valleys, and one of those included the most vicious climb of all, the one in

five gradient out of Withypool. Secondly, the intermittent problem got worse and worse and I found myself nursing the bike along; at the slightest sign of strain – a hill, for instance – it would start to misbehave. The Withypool hill was the scene of a major refusal and I had to push it up there. The others managed to ride, but not much faster than I was walking.

Downhill

The descent, though, when I eventually got there, was brilliant. With an aero tuck position and the fancy German tyres I could catch up and zoom past everyone else, and this time with no complaints from the motor.

Down on the flat, on the main road from Minehead to Bridgwater, we caught up with Pete. He had run out of batteries and was issued with a new one so he could carry on. David was still ahead somewhere but other problems were developing. We were now on main roads at rush hour, it had started to rain and there was limited daylight left – we really should have ignored the five hour times of the athletes and started earlier. A decision was made to cut the detour over the Quantock Hills and head straight for the finish.

We now had a group of five and we slogged on in worsening conditions. My motor problem was getting worse all the time and eventually I gave up and surrendered to the rescue vehicle. The rest carried on into Bridgwater and called it a day. In the rain and the failing light it just wasn't safe to continue. We found the first big restaurant and holed up there. We phoned up for Rhys and Fiona to join us, they had been waiting with the van at the official finish, some ten miles further on, and reviewed the day.

So what had we achieved? I had clocked up 98 miles, which meant I had dragged another 30 miles out of a stricken bike. The others had done distances of 105 to 112 miles, according to how lost they had got at various stages. Wai Won, Andy and I all had some battery capacity left, and when we crunched the numbers the following day, it would have been enough to do the full distance. David did not make the finish either. He ran out at 96 miles and pedalled the bike to the nearest railway station, but he had done it at a decent average speed and admitted to being very impressed with the bike's performance.

Treat the Earth well

And what had we proved? The question of whether it takes three, four or five batteries to get round the course is of course overshadowed by the glaring fact that a large group of people had gone round the day before on none. But they are young athletes and we are not. The number of batteries is also meaningless unless you know how big each one is. With the eZee bikes the four battery limit was not arbitrary. Four batteries on board leaves the bike under the 40 kg weight limit; with five you would have to start stripping off the mudguards and lights and fitting special German tyres. What we had shown was that a street legal e-bike with a grey haired rider could make a serious impression on one of the most challenging endurance courses around.

Back in my workshop I worked out what had gone wrong with my bike. Modern electric motors do not use brushes and commutators to switch the current around; they do it electronically. Buried deep in the motor are tiny sensors that detect the position and one of

these was misbehaving. I may not have burned the motor out on Mile Hill, but I had certainly overcooked it and caused some damage.

I had also made progress on my side project: if not to build a better e-bike, to build a better e-bike race. Our Tour of Britain ride was not a race as such, but it had proved, at least to me, that an uphill and downhill course was the answer to the problem of running an electric bike race without the lycras taking over. With the right collection of gradients you could sort the electric men from the boys and not end up with a handful of skimpy clothing.

The other thing we were all agreed on was that we wanted to do it again. In fact, we realised that we had the foundation here of a decent annual competition. The plan is to run an e-bike over Exmoor race in September 2009. This time we hope that all the manufacturers will join in.

Nick Long
©2008
nick.long@re-voltage.eu

All photos by Terry Donovan
terry@ikonstudios.com

Further information

Tour de Presteigne

Pedelecs

eZee Bikes

Cyclepoint

Flecc's Torq site

Endless-Sphere forum

A to B Magazine

Re-Voltage

Ikon Studios