Science and bicycling meet in a new helmet design

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When we recently did an overview of the evolution of bicycling technology, helmets were barely mentioned. They've been made out of the same materials for decades, and the only improvement they've seen in that time is a more efficient venting layout. But the timing of that article turned out to be propitious because, a few months later, Trek got in touch to let me know it was introducing the first major change in helmet technology in years.

Normally, emails like that are little more than marketing, or failing that, everything's proprietary and can't be talked about. But in this case, Trek promised that there was peer-reviewed science behind the announcement and I'd get the chance to talk to the scientists themselves. A few weeks later, I got the chance to check out the helmets and meet the scientists (though I narrowly missed my chance to shake hands with cycling legend Jens Voigt).

What's a helmet actually do?

The obvious answer is that helmets are meant to protect your brain when your head experiences an impact. But the more detailed answer requires delving into a little bit of physics. On a simple level, an impact generates force that, if nothing

is protecting you, is translated directly to your skull. A helmet's job is to dissipate that force. If a helmet could be arbitrarily large or heavy, this would not be a problem. But cyclists are notoriously picky about their equipment's weight and aerodynamics, which means that a helmet has to do all its redirection of forces in as little space as possible, using light materials.

Given this constraint, helmet manufacturers have settled on expanded polystyrene foam (EPS), the same material that's used for disposable ice chests. EPS was described to me as a bunch of polystyrene bubbles encased in a more diffuse mesh. On impact, those bubbles can rupture, diffusing some of the force, and the mesh can allow the bubbles to slide past each other, diffusing a bit more of it. It's simple and effective for straightforward impacts.

According to April Beard, Trek's helmet product manager, research focusing on football helmets began to indicate that EPS wasn't enough. Studies there had shown that many impacts didn't generate the sort of linear forces that EPS worked well against; instead, there were lots of twisting and off-axis forces involved. While these wouldn't necessarily translate into damage to the skull, they could put strain on the underlying brain, as different parts were subjected to distinct forces. This could cause breaks in the axons that provide connections among nerve cells, interfering with memories and other cognitive functions. Dissipating these off-balance forces is a much larger challenge.

Beard said that one idea was to provide helmets with internal liners that would slide on impact and handle some of the off-axis force (a system called MIPS). But then an engineer at Trek found a paper by a company called WaveCel that seemed to provide an even better option.

Materials meet science

WaveCel is the product of orthopedic surgeon Steve Madey and a biomedical engineer named Michael Bottlang. The two had been working on a variety of ideas related to medical issues and protective gear, funded in part by federal grant money. When considering the idea of a lightweight material that could evenly distribute forces, Bottlang told Ars that they first focused on a honeycomb pattern. But they found that it was actually too robust—the honeycomb wouldn't collapse until a lot of force had been applied, and then it would fail suddenly.

The design they eventually developed has a shape that allows flexing almost immediately when force is applied. "It starts to glide right away," Bottlang said. The manufacturing technique creates a clear point of failure that allows more extensive flexing once a certain level of force is exceeded—part of the structure will fold over rather than experiencing a complete failure. Then, once folded, the polymer it's made of will allow neighboring cells to glide over each other. This provides some resistance even after the structure has collapsed.

(The one thing that Trek kept proprietary was the identity of the polymer material.)

For the helmet, a patch of this material is attached to the inside of a more traditional EPS helmet, which provides impact resistance. But the WaveCel mesh is allowed to float within the helmet and can absorb much of the force of off-axis impacts. The thin strips of soft material that cushion the helmet where it rests on the head (also found in more traditional helmets) are attached directly to the WaveCel mesh.

It looks more uncomfortable than it is. Madey, the orthopedic surgeon, said they've done tests that show that, even if

placed directly on the skin, the WaveCel mesh wouldn’t break the skin under most impact forces.

- The new helmet combines traditional foam and a retention system with the mesh inserted in between.
- From outside, you have to look closely to tell it’s not a traditional bike helmet.
- The difference is slightly more obvious when there’s a color contrast between the insert and helmet.
- The pads that rest on a rider’s head sit directly on the protective mesh.
- Without the rest of the helmet, the mesh insert wouldn’t help much.
- For a commuter helmet, where there’s not much air flow to begin with, the WaveCel insert probably won’t make much difference.

How does their new helmet work? According to a paper authored by Bottlang and Madey, helmets including the material reduced rotational acceleration from impacts by 73 percent compared to a normal helmet. A slip pad within a normal helmet (MIPS) only dropped acceleration by 22 percent, which seems like a substantial difference.

But how does it feel?

Trek, through its subsidiary Bontrager, is introducing helmets incorporating the proprietary material for casual road riders, commuters, mountain bikers, and serious road riders. We were given one of the road helmets to test and managed to get four short rides in with it. The arrival of spring provided conditions ranging from brisk, dry air to a warm, humid day; managing heat on rides is a major issue for me, so I was curious how the Trek helmet compared to a recently purchased one from a competitor.

Trek’s sales pitch is that the helmet is far safer without

representing a compromise compared to existing helmets. (Only time and detailed accident accounting will be able to tell us if this is true.) The new helmet does weigh slightly more than an all-foam helmet, but that wasn't at all noticeable during a ride.

Fit in a helmet is a matter of personal taste. Trek's offering provided the usual means of keeping things in place: a chin strap and an adjustable rear retainer that wraps under the base of the skull near the neck. Trek's version of the chin strap includes magnets to align it, which worked nicely once you got used to them, but snapping the chin strap in place has never been a major point of friction to me. Trek's rear adjustment works by pulling a thin cable, rather than the all-plastic strap system on my current helmet; I didn't notice much practical difference. The soft liners inside the helmet that rest on your head were comfortable, but the ones on the Trek helmet didn't seem as effective at wicking sweat away from my eyes.

Overall, the parts that were like a traditional helmet continued to act that way; the presence of the WaveCel insert didn't make any difference.

Air flow

Where things did seem to matter is the air flow. As noted above, EPS is used as an insulator and could easily cause you to overheat on hard rides or warm days. Most helmets manage that with vents that direct air through the helmet in contact with your head. The WaveCel insert provides a bit of a trade-off: it keeps the insulating material further away from your head, but can also keep air from flowing across it.

How does this trade-off work in practice? For the most part, it's OK. I found that I could orient my head so that I'd get a blast of cool air on it, though doing so required either riding fairly upright or staring down at my front tire. Beyond

that, the lack of air flow was notable, but it didn’t feel like the helmet defaulted to being quite as hot as my more traditional one. Whether I’d say the same after a ride in August will have to wait a few months.

Overall, the WaveCel announcement was a pleasant surprise. The number of areas of science it pulled together—materials science and engineering, neuroscience and epidemiology—was impressive, and it resulted in a product that may actually make a difference in people’s lives. How much a difference, if any, will have to wait until enough people are using the helmet and we get some accident statistics. But in the meantime, it’s been integrated into a solid product in a way that’s pretty unobtrusive.

This story was updated to clarify when I was discussing MIPS technology, since a remarkable number of readers are aware of it.

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