BRAIN WAVE

AN INNOVATIVE AUSTRALIAN HELMET DESIGN MEETS THE SAFETY NEEDS OF USERS, NOT JUST MANUFACTURING STANDARDS.

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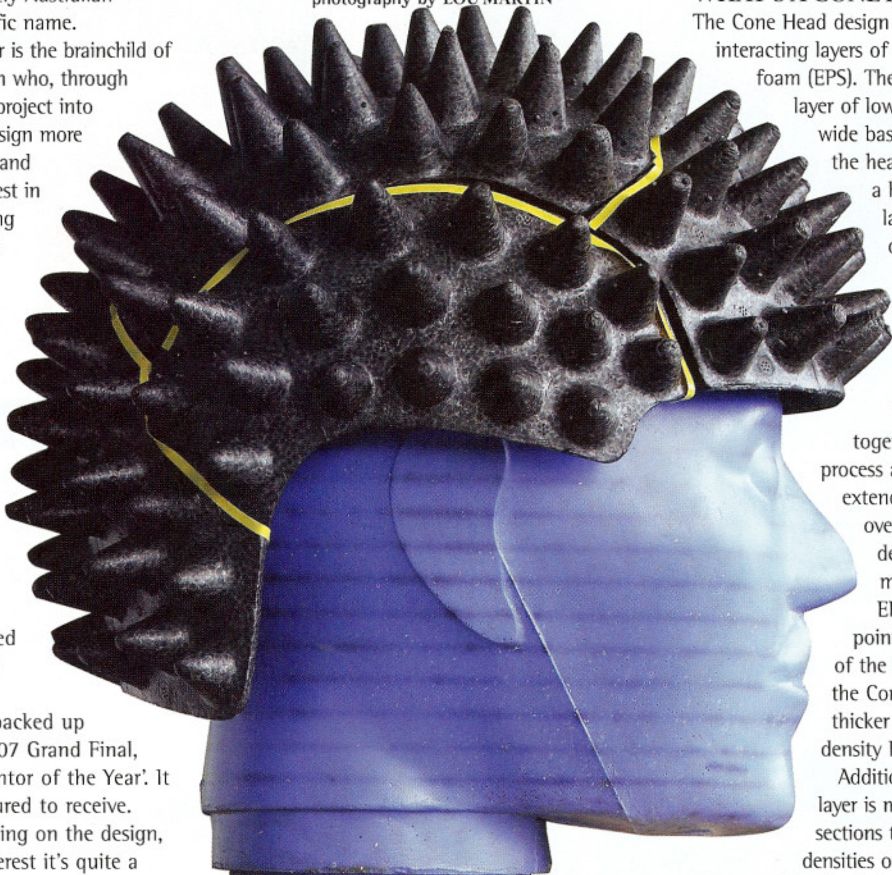

Imagine a motorcycle helmet that could significantly reduce the chances of head and brain injury in an accident. A helmet with an inner lining that acts like crumple zones in a car, progressively absorbing impact forces from head movement. A helmet whose lining offers specific impact absorption rates in different areas, to protect the weakest parts of the skull.

A helmet like this would represent an enormous advance in safety technology for motorcyclists. The good news is such a helmet exists. Even better, it's a purely Australian invention and it's got a terrific name.

The Cone Head helmet liner is the brainchild of Brisbane physicist Don Morgan who, through his involvement in a research project into the effectiveness of helmet design more than 20 years ago, developed and maintained a passionate interest in the area. Only now, after a long and often frustrating time, his vision is coming to fruition.

It will not be the ultimate expression of his design philosophy, as the production model must meet Australian and international design standards, many of which he considers inappropriate but, according to Don, it will be much safer than many current helmets.

Don's design is creating huge levels of interest spurred by his winning an award on the ABC TV show *The New Inventors*. That award was backed up with a win in the show's 2007 Grand Final, making him their 'New Inventor of the Year'. It is an award Don feels honoured to receive.

"After so many years working on the design, and no one showing any interest it's quite a change," he said.

Don was also one of 12 finalists in the 2007 Asian Innovation Awards, presented by *The Wall Street Journal Asia.*

The motivation for Don's novel design came from a research project in the mid-1980s sponsored by the then Federal Office of Road Safety. Working for the Queensland Institute of Technology, he was tasked with investigating the effectiveness of motorcycle and bicycle helmets. The project lasted about four years and included crash simulations as well as experiments with cadavers.

"It was quite obvious that the single-density liners in helmets were not doing their job properly, as the forces were being transferred through to the skull."

Part of the project included attending accidents and recovering the victims' helmets. It's something Don can't forget.

"We would correlate the injury or post-mortem reports with the damage to the helmets," he said. "This process showed that the liners weren't working properly as, while the accident victim suffered head injuries, there was often little or no evidence of damage to the liners."

The ineffectiveness of those helmet liners troubled Don ever since, and the Cone Head helmet liner design is the culmination of years of effort developing and testing his ideas.

"I was looking at different designs when the idea came to me in 1993. Initially I thought its got to be square-based pyramids, then moments later I thought cones would be even better. I always had at the back of my mind a tool that could be used to make it and the cones would be easier to make."

WHAT'S A CONE HEAD?

The Cone Head design consists of two interacting layers of expanded polystyrene foam (EPS). The cones emanate from a layer of low-density foam with the wide base of the cone next to the head. This is covered with a higher density outer layer, which Don calls the overlying layer, and it is this layer that gets the helmet through the regulatory standards, as they require the additional strength.

The layers are fused together in the manufacturing process and the softer cones extend right through the denser overlying layer. If the two densities of foam were made in different coloured EPS, you would see the points of the cones on the top of the outer layer. Importantly the Cone Head EPS liner is no thicker than a current single-density EPS helmet layer.

Additionally the Cone Head layer is made up of five different sections that can have specific densities of EPS foam depending on the area of the head they are designed to protect.

WHY IS A CONE HEAD BETTER?

When you pick up a helmet the first thing you notice the hard outer shell, usually made of a fibreglass composite or hard plastic. Its role is to protect against abrasion and penetration and, while it's often nicely painted, this outer shell is not the primary protective tool. That job falls to the layer of EPS beneath the outer shell, and it is in this EPS lining that Don's Cone Head design differs markedly from current helmet liners.

Describing the way a helmet works is a little more complex. In a simple flat drop scenario the helmet's outer shell is stopped instantly, while your head keeps moving inside the helmet at the same speed until it hits the EPS liner. The EPS liner's job is to crush at a controlled rate and so bring your head to a progressive stop. The rate at which your head stops is critical to your survival: the more progressive the deceleration, the less chance there is of damaging your brain and that gives you a better chance of survival.

Often we think that in an accident the helmet protects us from an outside impact, the force coming inwards, when in fact our head is also moving outwards in the opposite direction crushing the liner.

As Don deftly explained, "Well, it's Newton's Third Law, that there is always an equal and opposite force. The head in an accident wants to keep going, while the shell of the helmet is being forced inwards. The key is to produce gradual deceleration."

SHOCK THERAPY

Our brains are very soft and float in a sac filled with cerebral fluid. Rapid deceleration and rotational acceleration forces mean the brain moves inside the skull and can even strike it, causing damage. In a serious impact you can bruise the brain, tear blood vessels, split the corpus callosum (the nerves joining both sides of the brain) or rupture the sac in which your brain sits.

Like many contemporary researchers, Don believes that current single-density liners are just too dense or hard. Using high-density foam means that forces are transferred faster, with greater peak G-forces in impacts, and that means more injuries.

Don's design is special because the lower density cone layer improves the way that the EPS liner can absorb impacts, producing a safer helmet that also passes the current strict regulatory standards that demand firm liners.

The reason the Cone Head design can use softer foam is that when the cones are crushed they act like a controlled crumple zone in a car, progressively requiring more energy to crush without ever bottoming out. Don said some people have other ideas as to why the cones work so well, and that involves shock waves.

"I might be being a bit technical here, but if you imagine throwing two stones into a smooth pond and you watch the ripples extend outwards, when they meet the interaction can dissipate some of the energy," he explained. "So the idea is that each of the cones produces a shockwave and these multiple shockwaves are dissipating energy as they interact with each other."

According to Don, the orientation of the cones and the density of the foam used to form them are crucial to the design's effectiveness.

"Initially we had the broad part of the cones on the outer, but testing clearly showed we produced better results with the broad part of the cones against the head. So that's the way we continued.

"We also tested in various density configurations, with the cones being high-density and the outer layer being low-density. But the best result is the one we have ended up with."

The Cone Head design also has advantages when it comes to rotational acceleration because its low-density EPS liner weighs less. Rotational acceleration is the rotation moment created when a tangential force is applied to the helmet and can cause significant damage to the brain. The lighter the helmet, the less rotational acceleration is generated when the helmet is struck, making it safer.

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BUT DOES IT WORK?

In 2000 Don secured funding from the Australian Transport Safety Bureau to test his ideas, and in 2001 he wrote a report that compared his Cone Head designs with contemporary single-density EPS foam liners.

In that review he noted that some single-density helmets had foam densities as high as $90kg/m^3$, even though he determined that a human head was unable to deform foam with a density of more than $50kg/m^3$. These high-density liners would transfer the force of the impact directly to the head rather than absorb it, as the head wouldn't be able to deform the foam.

The testing undertaken comparing single-density liners with the Cone Head liner was performed by an independent laboratory in NZ, and showed that the Cone Head liner produced up to a 20 per cent improvement in the duration of an impact. This represents a significant improvement in impact absorption, even though in these early flat foam tests the cone heights were only half the thickness of the whole liner, and the magnesium head-form used for the testing impacted the flat liner over a smaller area than would occur with a curved liner. In a real helmet the pressure of impact would be spread over a larger curved area.

"This is indicative of a liner that is more effective in absorbing the impact," he said. "A hard foam single-density liner has a very short time duration... [while in the production version] with the cones extending throughout the whole thickness of foam [it] would mean an even longer time for crushing."

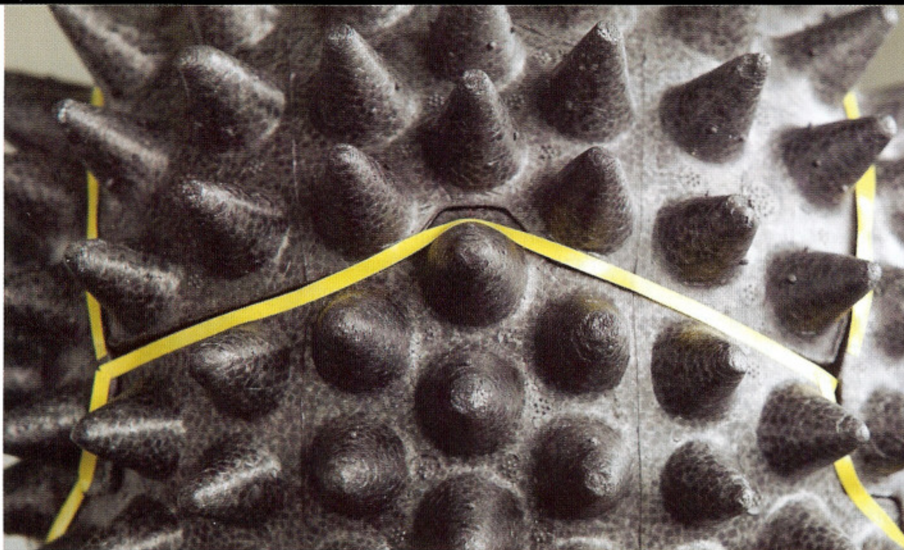
The greater time taken to absorb impacts also has other benefits.

"Together with this is a reduction in the peak force transferred. Hard single-density foams have a higher peak force transmitted whereas the Cone Head design, because it takes more time to absorb the impact, has a lower transferred peak force."

Significant improvements were also found in elliptical crushing and profile crushing tests.

"Think about the head form, it's like an ellipse," Don explained. "When a head-form is placed in a helmet and whacked against an anvil, such as in the Standards tests, it produces an elliptical shock wave, which then produces an elliptical depression in the liner.

"The Cone Head design produces a much greater depression in the foam in the outline of the ellipse than in single-density helmet liners.



So the shock wave is being spread out."

When it came to the profile crushing – that is the flat crushing of the Cone Head foam itself – there was 5 per cent improvement. Don said the results of this test don't reflect the true performance of his design as the measurements were not made immediately afterwards and there was some recovery in the foam's shape.

CUSTOM COVERAGE

Because the Cone Head design is made up of five separate sections, it can take into account the different weaknesses of the skull, and EPS foams of various densities can be used for specific areas of the head. Single-density EPS liner helmets can't provide optimal density around critical areas.

For example, the Cone Head liner in the temporal region [the temples] is softer, that is it's made of a lower density foam than that used the crown because the temporal region is the most fragile area of the skull, being about one-third the thickness of the rest.

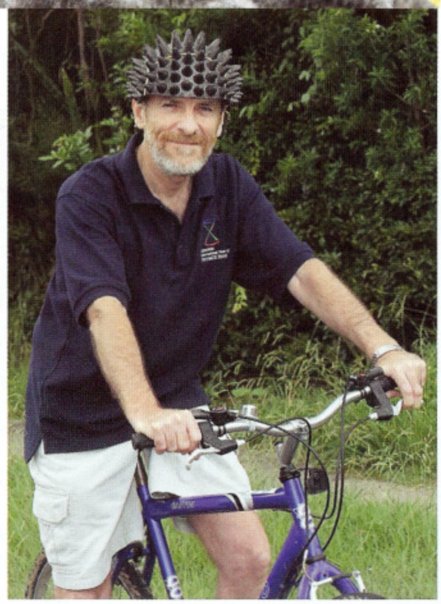
"I am amazed that no one has come up with this before. I would have thought that one of the larger helmet manufacturers would have done it. They have thought about dual density, but not providing different densities for different sections to protect the varying requirements of the skull."

Yet Don's Cone Head liner is still a compromise. He knew he would have to get the helmet through the various international standards, not to mention survive the general wear and tear everyday use brings.

"In essence you are building a helmet with two contradictory aims," he said. "The primary aim of providing safety and impact absorption is being compromised by the second aim, which is to pass the regulated design standards that don't reflect reality. It's like robbing Peter to pay Paul."

STANDARDS VERSUS SAFETY

Ironically, Don found the reason many helmets had such dense EPS liners was to get them through the Standards testing, where a solid magnesium head-form wearing the helmet is dropped on to an anvil. While this technique is easily repeatable, using such a dense metal



head-form to measure a helmet's effectiveness is now considered unrealistic, as it doesn't behave like a human head.

The current AS1698 Australian Standard for helmets prescribes, among other things, a maximum of 300Gs' force transmitted to the head-form and two successive strikes in the same location. This is similar to that required under the voluntary Snell standards that exist in America.

Until recently an impact with a 300G transferred force was considered to be survivable, but the mood is changing, and the science now suggests that impacts resulting in forces above 250G are often fatal, while those below 200G are survivable.

Recently the European Union's COST 327 report into helmet effectiveness reflected Don's own views on helmet liner density and regulated standards. The COST 327 case studies revealed that improving energy absorption levels by 24 per cent would save approximately 1000 European riders' lives annually, with a corresponding reduction in injury severity.

The Cone Head liner design has produced laboratory results that are consistent with the desired outcomes determined by the COST 327 report – that is, helmet liners that provide more absorption in impacts.

HOMEWORK

In addition to Don Morgan, the following resources were used in the authoring of this article:

EU COST 327 REPORT
<www.mhap.info/Reports%20for%20website/Abridged%20extract%20from%20COST327%20report.pdf>

STANDARDS AUSTRALIA AS1698
<www.standards.org.au>

SNELL FOUNDATION
<www.smf.org>

UN/ECE 22.05
<www.unece.org/trans/main/wp29/wp29regs/22rv4e.pdf>

ATSB HELMET LINER REPORT
<www.atsb.gov.au/publications/2001/helmet_liner.aspx>

Importantly, the COST 327 study identified the link between regulatory standards and helmet performance in the real world.

"Of vital importance in the efficacy of a helmet is the link between the measurements prescribed by standards and the tolerance of the human head to injury in an equivalent impact," the report stated.

THE STRUGGLE

It is a remarkable achievement for someone to have a novel safety idea turned into a production reality, and even better, that it is an Australian one. The shame is that no Australian company was interested in developing the concept.

"I approached several manufacturers, but no one wanted it in Australia," Don said. "So I signed a license agreement with an overseas manufacturer."

During the struggle to have his idea developed Don applied for various government grants, such as the Queensland Government Innovation Start-Up Scheme, but wasn't successful. His licensing partner, however, immediately saw significant opportunities.

"All this year [2007] we have been testing the helmets and doing things such as varying the EPS density and testing under different conditions. We are now in the certification stage and the next stage will be the production stage."

Don Morgan's New Inventor of the Year award is a major fillip, but the legacy of his effort is likely to be a much greater achievement, with reduced mortality rates and less severe head injuries for those involved in motorcycle accidents. In future it is likely that people may even owe their lives to this man's determination and effort over the past 22 years.

"There will still be horrific accidents in which people wearing a Cone Head helmet won't survive," Don said. "You can't make a helmet that will save you in every situation. I am concentrating on improving helmet performance so the threshold area between serious injury or death and recoverable injury or no injury is greater." **tw**

Cone Head helmet liner helmets will be available in Australia within the next year.