Technical Response **EBB 9/9/2005**

Blowing the Lid Off, Motorcyclist Magazine June 2005

I have gotten a number of requests for a response to the technical issues raised in the helmet article in the June 2005 issue of Motorcyclist Magazine. Of course, there was more to that article than the purely technical but a close examination of the technical issues may suggest what weight to assign to the rest of the material presented.

The contention in the article is that Snell helmets are too hard and transmit too high a G loading to the head. The article presented side by side helmet testing to demonstrate that the G's transmitted through various helmet types in flat surface impacts varied with the helmet type and the helmet certification. On this basis, they ranked DOT-only helmets first, then ECE 22-05 helmets (European), then BSI 6658 (British spec before ECE 22-05) and last Snell.

What they did not show was whether these lower G's would lead to lower rates of serious injury. There was, instead, an appeal to reason: the suggestion is that if high G's are bad and zero G's are good then, for any two sets of G's, the lower G's must be better. But this may be misleading. Injury risk is not thought to be proportional to G's but, instead jumps from some low level to some very high level when the impact G's pass through some threshold level. If a crash helmet can attenuate impact shock so that it remains below this threshold level, the expected injury risks will be minimal. A second helmet configuration which attenuates the shock even further may not yield any real improvement in injury rates.

All the current crash helmet standards rely on this threshold model: that there are levels of G shock that healthy people can tolerate safely but at some threshold point above these levels the risk of injury begins to increase dramatically. And, in fact, all the helmets tested for the Motorcyclist article got G levels that would meet all the various motorcycle helmet impact criteria in play. If the article's contention that some of these helmets are substantially safer than others is true, then all the current standards, DOT and ECE 22-05 as well as Snell and BSI must be wrong.

An important consideration in this threshold model of impact injury is that experts disagree on what value of G should be selected. Snell and BSI limit peak shock to 300 G but a straightforward comparison of these two standards with either DOT of ECE 22-05 is complicated by differences in impact test procedures and apparatus as well as by other test criteria. However, it may well be that the impact criteria imposed by all four of these standards limit shock to levels that most healthy people can tolerate safely, at least for those crash impacts no more severe than the various standards demand. Helmet experts and experts in pediatric head and neck injuries attending a 2003 conference discussing helmets and helmet standards for children's motor sports concluded, among other things:

> "Keep the 300g acceleration limit in a pediatric motorsports helmet standard until more data suggest otherwise."[1]

No one contends that lower G's would, of themselves, lead to higher rates of serious injury. However, there are good reasons why a lower G helmet might be less protective in a given crash. Helmets can manage only so much impact and, all else being equal, the softer the helmet, the less severe the impact it can manage.

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[1] Review of Pediatric Head and Neck Injury: Implications for Helmet Standards, Arbogast KB, Margulies SS, Patlak M, Fenner H, Thomas DJ (eds), Children's Hospital of Philadelphia, Philadephia, PA, 2003

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Helmets control the shock to the head by crushing. In a helmeted impact, the part of the helmet shell that strikes the impact surface stops moving almost immediately but the head inside the helmet remains in motion crushing the thick EPS liner inside the helmet as it goes. As it is crushed, the EPS liner applies controlled braking forces to the head and slows it gently. As long as the liner can still give up some crush to the moving head, the head will continue to slow gently until all its impact velocity has been reduced to zero. The concern is whether the head slows to a full stop before the liner runs out of crush. Once the liner runs out of crush, it loses its ability to control the G's applied to the head. Instead the collapsed liner will transmit all the remaining shock practically instantaneously. The head G loading will suddenly skyrocket. What we see in our testing is that the G's jump well beyond 500 and up into the thousands. All the experts agree that these shocks are injurious. So it is critical that helmets be thick enough to allow the liner to continue crushing until the head slows completely from its initial impact velocity all the way down to zero. And the lower the level of G's the liner transmits to the head, the thicker that liner has to be to manage a given impact velocity.

Many would like to see softer liners <u>and</u> greater impact management capacity but that doesn't appear to be an option, at least with current technology. Helmets already are as thick as riders can reasonably be expected to wear. The choice, then, is softer liners <u>or</u> greater impact management capacity. And the question is whether softer helmets with lower impact management will reduce the rates of serious injury or make them worse.

The Motorcyclist study proposed that the impact management capacity of the softer helmets they studied was sufficient for most street riders. They supported this contention with some testing at fairly high levels of severity. However, their comparison looked mostly at impacts on flat asphalt. There are other impact surfaces that may overwhelm a helmet's impact management capability even at lower impact severities.

Snell, DOT and BSI all call out impacts against a hemispherical impact surface. Helmets tested against this hemi anvil in low severity impacts generally obtain lower peak G values than when they are tested against flat surfaces. However, the impact management capability of a helmet in hemi anvil impact is also much lower. If the severity of the test impacts is increased, the helmets will begin to fail catastrophically against the hemi in impacts they could handle easily against the flat. The reason for the lower G's in manageable impacts is that the helmet shell bends around the anvil so that a small area of the liner is subject to crushing. This smaller area of liner generates correspondingly lower levels of braking forces and G's. But, consequently, the crush will be deeper. Instead of a shallow amount of crush over a broad expanse of liner, hemi impact punches through the helmet causing a deeper amount of crush in a limited area. And if the helmet liner is not thick enough to allow this deeper crush, the lower levels of G seen at first in hemi impact may break suddenly to levels well beyond any lab's measurement capacity or any rider's tolerance.

The article questions just how frequently riders will encounter this sort of hemispherical impact surface. But, in fact, the hemisphere is in the standards as a companion to the flat anvil and to represent the opposite end of a range of impact surfaces. This range goes from load spreading surfaces represented by the flat anvil to aggressive, load concentrating surfaces represented by the hemi. There is a spectrum of potential impact surfaces stretching between these two but a helmet that stands up to both will likely be good for every surface in between. The question ought to be what sorts of impact surfaces do riders' heads and helmets strike and what's the outcome. The COST 327 study collected data from motorcycle crashes in various parts of Europe and came up with the following:

> "A round object was the most frequently struck, 79%, and the severity of injury was fairly evenly distributed. An edge object, for example a kerbstone was the least likely to be struck, 4%, but the most likely to cause a severe, AIS 5, injury. A flat object was struck in 9% of cases but was the least likely to cause an injury."[2]

There is some uncertainty here; "round object" could mean either cylinders or hemispheres or both and the radius of curvature could be short or quite long. However, the report definitely suggests a spectrum of impact surfaces from flat through "round" to edge surfaces like the kerbstone. Furthermore, the report indicates that the rates of serious injury increase as the impact surfaces moves from load spreading through to load concentrating. That is; helmets are more effective protecting against flat surfaces than they are against load concentrating surfaces. If this is truly the case, softer liners may not yield a significant reduction in injury in flat surface impacts but the loss in energy management may incur a terrible toll in impacts against load concentrating surfaces.

The flaws in the Motorcyclist study, to my mind, are that they did not pursue their study of flat surface impacts all the way to a consideration of expected injury reduction and they did not consider any increase in injury that might result from impacts against load concentrating surfaces. I have not questioned the data collected in the Motorcyclist study. Instead, I've questioned their experimental design and their conclusions. But, at bottom, there will always be the question of just how serious they were when they set about this effort. When I first heard of it, I urged them to take it to one of the scientific journals for publication. Of course, it would have gotten a rigorous screening from experts in the field before it was accepted for publication. And later, when they presented their findings, they could also count on questions and criticisms from the scientific community. But good science should always stand up well to screening and to questions and criticisms. In fact, good science is made better by this process. Had they taken this route and cleared these hurdles, they would have had the material for a much stronger Motorcyclist article afterward.

I believe that the process would also have lead them to substantially different conclusions and recommendations, perhaps, even to those same conclusions and recommendations we currently hold here, at the Foundation. But I am certain that we here would have followed, where ever the process lead.

I think, in spite of everything though, that we at the Foundation have given the ideas in their comparison fair consideration. We have rejected these ideas not because of the source or even the manner of their presentation. We have rejected them because they are unsound. I do not dismiss the possibility that someday a better, sounder study might convincingly demonstrate the same conclusions. But without a clear and convincing demonstration it would be irresponsible to proceed.

[2] COST 327 Motorcycle Safety Helmets Final Report of the Action, Chinn B (editor in chief), European Commission, Directorate General for Energy and Transport, Belgium, 2001