Winter 2001
ISSUE 2

WSA APPLIED TECHNOLOGY



Special Supplement:

covering design and technology in the hardware sector

Climbing Helmets:

a look at current research findings

Driven to distraction:

golf clubs and systems for 2002

climbing helmets

current research findings

by M.Taylor & D. Brook
Performance Clothing Research Group
School of Textiles and Design
University of Leeds



Edelrid technical advisor, Hans Kammerlander
Photo: Fengler

To most non-climbers the consequences of falling off or of being struck by falling rock or ice are obvious. These people would probably be surprised, if they visited a UK climbing venue, how few climbers were wearing helmets.

The first helmets specifically designed for use by climbers and mountaineers became universally available in the 1960's. Their usage probably peaked late in the 1970's, and since then has declined here in the UK. Few UK based climbers would consider climbing in the Alps without suitable head protection due to the risk of stone fall, but consider the risks of a head injury to be much lower at home and so rarely wear a helmet.

This is a rather misguided assessment of the risks. In 1986, Reid et al [1] published their findings from a five-year study into mountaineering accident fatalities in Scotland. They performed autopsies on 42 of the 121 people who died. Of these 42, it was found that head injury was a major fatality factor in 21 cases. The researchers concluded that over 25% of those who died could have been saved if they had been wearing a helmet. It is interesting to note that of these 42 people, only five were wearing a helmet. Of these one fell 400 feet and suffered a skull fracture as well as severe chest injuries and a torn aorta. One bled to death through a fractured pelvis after falling 20 feet and had slight brain swelling as the only sign of head injury. The three others, who each fell a considerable distance, had no head injuries.

In an American study [2] of fatalities in Yosemite National Park during a three and a half year period, 9 out of 13 fatalities were caused by head injuries.

Articles in the climbing press by Kirkpatrick [3] , Musgrove [4] and Shepherd [5] have tried to educate the modern climber about modern lightweight climbing helmets, the consequences of not wearing one and the need to seriously consider their use. As Kirkpatrick says, the severity of a climb is not a good gauge of whether a helmet is needed, as a Moderate route with its large ledges and easy angle is possibly more dangerous than an overhanging E7 if you happen to fall off (to a climber Moderate is an easy climb and an E7 one of the most difficult).

The Test Criteria

Modern testing criteria for climbing helmets were cooperatively developed at Leeds and Stuttgart Universities, for the UIAA (International Union of Alpinist Associations), in the 1970's and were based on the old British Standard for industrial head protection (BS 5240:1975). The harmonisation of standards across Europe has resulted in the new EN 12492:2000 for mountaineering helmets, which came into force last year, that is very loosely based on the UIAA standard. Aside from a few detail changes there was an increase in drop weight diameter of 10mm from 90 to 100mm, to bring the mountaineering helmet standard into line with other helmet standards, this has resulted in a situation where helmets that met the previous version of the EN may fail if they were resubmitted now (this is particularly true for helmets which rely mainly on foams for energy absorption – see later). In this new standard, there are seven tests. Peak impact, where the crown of the helmet is subjected to a 98-Joule impact. Front, side and rear impacts – where the helmet is subjected to 24.5 Joule impacts. The other criteria are a penetration test, and a test of chinstrap strength and its effectiveness. [6]

To meet the requirements of the new BS EN the transmitted force must not exceed 10kN during any of the impact tests (this is reduced to 8kN in the UIAA standard).

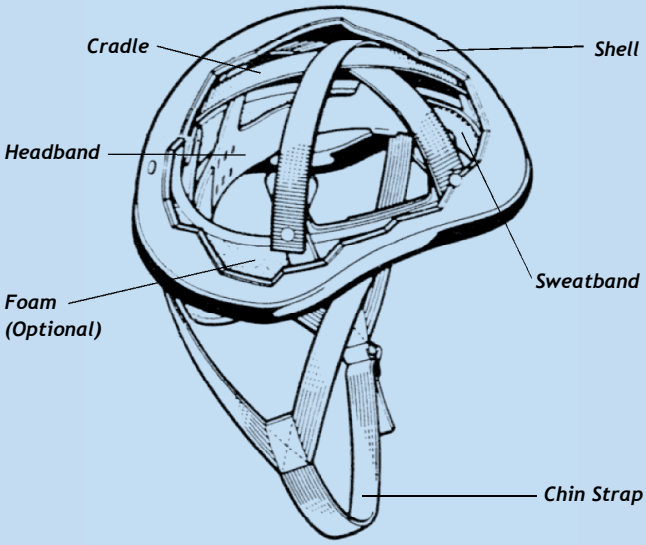
Overview of Helmet Types and Performance Mechanisms

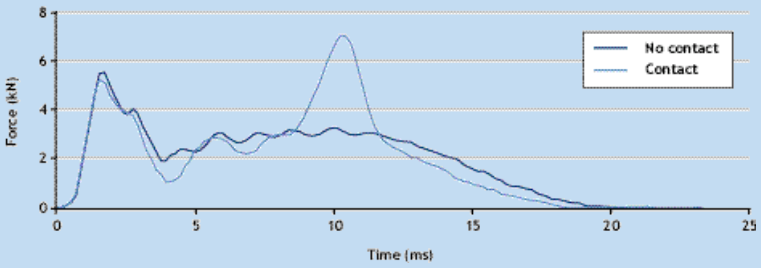
All mountaineering helmets consist of a shell and a means of absorbing energy within the shell - usually a cradle, a foam liner or a combination of these. A recent trend has developed for lighter weight helmets, and so we classify helmets as traditional or modern lightweight in construction.

Traditional

Traditional style mountaineering helmets have a hard outer shell and a textile cradle to secure it on the head. The shell can be an injection moulded or vacuum formed polymer, or a resin/ fibre composite. The clearance between the shell and the cradle plays a vital role in the performance of the helmet. The components of a traditional climbing helmet are shown in figure 1.

During a major impact, the first energy absorbing mechanism is in the attachment points between shell and cradle. These are loaded and stretched. After this, the different shell materials behave in different ways. The polymeric shells distort by localized stretching and inversion, whilst the textiles in the cradle stretch. The shell then recovers, and in the case of injection moulded ones there may be no signs of it having suffered a major impact. The cradle however will have suffered irreversible extension, so reducing the shell/ cradle spacing. If, due to excessive stretch in the cradle or excessive distortion of the shell, the shell and cradle touch during the impact then the peak impact force will be greatly increased (figure 2), as there is a direct material path between falling weight and skull. Since polymeric shells stretch so much they need a large shell/ cradle clearance or a layer of energy absorbent expanded polymer foam built in, to reduce peak impact forces. This also allows smaller shell/ cradle clearances as the foam prevents the shell touching the cradle by absorbing some of the impact energy. One problem with this construction is that after the impact the shell may show no signs of damage, but the foam will be permanently deformed and can no longer absorb much energy [7].





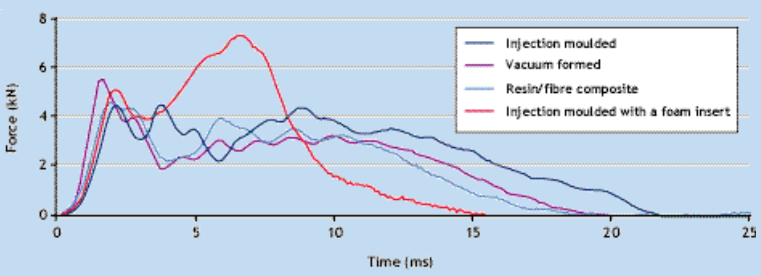
Top: Figure 1 - a traditional climbing helmet.

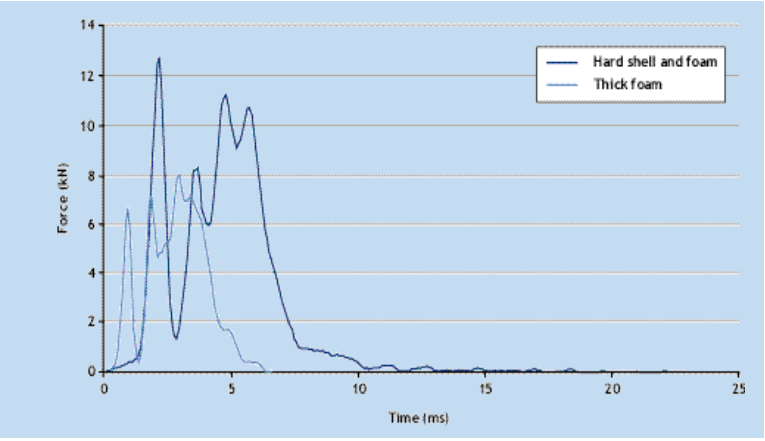
Above: Figure 2 - EN 12492 crown impact force/ time curves for the same helmet, one showing a large peak at approximately 10ms due to contact between the helmet shell and the headform, whilst the other shows no such contact.

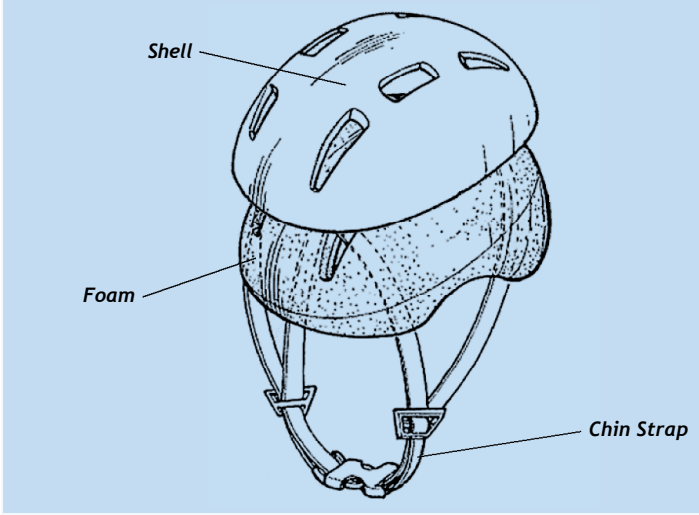
Below: Figure 3 - Force time curves for EN 12492:2000 crown impacts on traditional style helmets.

Typical force time curves for traditional style helmets in the crown impact test of EN 12492:2000 are shown in figure 3.

To save weight with traditional helmets is difficult and with polymeric shells it is almost impossible, as the shell has to be thick enough to resist buckling and penetration. With composites weight can be saved at the expense of performance by using less material.







Above right: Figure 4 - A lightweight climbing helmet.
Above: Figure 5 - Force time curves for EN 12492:2000 crown impacts on lightweight helmets.
Right: Table 1 - Typical helmet weights.

Helmet Type	Typical Weight (g)
Injection moulded	470
Vacuum formed	380 - 400
Resin/fibre composite	500 - 600
Injection moulded with foam insert	380 - 420
Hard shell and foam	400 - 450
Thick foam	250 - 350
Carbon/Dyneema	305

Modern Lightweight

In the late 1990's Petzl introduced a new type of helmet to the world of climbing, the Meteor. This heralded an influx of new lightweight designs mostly based on cycling helmet technology. These come in two main styles, those that consist of a tough outer shell with expanded polymer foam liner, and those manufactured solely from foam with no hard outer shell. The two styles work in different ways. Figure 4 shows the main components of a lightweight helmet.

To absorb energy, thick foam helmets with no hard shell deform. The shell compresses from both sides, with the impacting mass penetrating deep into the shell. The sharper the profile of the penetrating mass, or the narrower its diameter, the deeper the penetration, the more the energy absorbed but the greater the risk of contact between the striker and the head (see Taylor and MacNae [8] for more detail on this).

Those helmets with a hard outer shell are pushed onto the head at which point the foam begins to compress. The shell also deforms compressing the foam from the other side. The shell can never touch the head but the foam can compress so much that it can no longer absorb energy and higher forces are transmitted to the head.

Generic force/time curves for these helmets are illustrated in figure 5.

Traditional vs. Lightweight

As Figures 3 and 5 clearly show, the impact event for a traditional helmet lasts more than twice that of a lightweight helmet. As the area under these curves has to be the same (it represents the impact energy of the system), the longer the time of the impact the lower the peak transmitted force. As the figures plainly show, helmets that utilise a textile cradle and a hard, relatively inflexible shell transmit almost half the peak force of the best helmets that relies on foam for its impact resistance.

Recent Developments

For several years the manufacturers of fibre/ resin composite helmets experimented with high performance fibrous polymers such as carbon and aramid. These produce helmets that work, but they tend to be heavier than helmets made from the traditional glass fibre, and show little or no improvement in performance.

Then, recently, carbon fibres were combined with Dyneema, a gel-spun highly drawn polyethylene fibre from DSM, to produce a helmet traditional in style, with corresponding performance (a peak transmitted force of 4.2kN in tests), but which only weighs 305 grammes (see table 1 for typical helmet weights). Table 1 also clearly shows that some of the 'modern lightweight' helmets are just as heavy as the 'traditional' ones. This carbon/ Dyneema composite technology is very similar to that used in some modern military battlefield helmets.

Now that the energy absorption mechanisms are better understood it is possible to identify the contribution of the various components of a given helmet to its overall performance. Measurements are now being made on individual components to construct an analytical model to predict helmet performance.

References

1. Reid, W A, Doyle, D, Richmond, H G and Galbraith, S L 'Necropsy study of mountaineering accidents in Scotland', Journal of Clinical Pathology, Vol 39 (1986) pp 1217-1220
2. Bowie, W S, Hunt, T K and Allen, H A Jr 'Rock-climbing injuries in Yosemite National Park', Western Journal of Medicine, Vol 149 No 2 (1988) pp 172-177
3. Kirkpatrick, A 'Bouldering mats for the head', Climber, July 2000 pp 61-63
4. Musgrove, D 'Yorkshire', Climber, April 2000 p 18
5. Shepherd, N 'Helmets', On The Edge, No 89 (1999) pp 64-69
6. Mountaineering equipment - Helmets for mountaineers - Safety requirements and test methods. BS EN 12492:2000
7. Brook, D B 'Energy absorption on new and used mountaineering helmets', Proc. The 1 st Int. Conf. On Science and Technology in Climbing and Mountaineering, University of Leeds, UK (7-9 April 1999) ISBN 0736031065
8. Taylor, M and MacNae, A, 'Heads up pt. 2', Summit, No 20 (2000) pp 30-35