

WORLDFOOTWEAR

Comfort in footwear

Comfort in footwear is an old conundrum. How do you define it? Well, it basically falls into two main areas: mechanical comfort involving cushioning, compression-set resistance, resiliency and shock absorption, and sensory comfort, which concerns temperature and moisture management.

Upper-foot comfort relies on the materials used in the upper as well as the essential factor of fit. Under-foot comfort depends more on the insole or the foam foot bed materials that are combined with it. Modulus or softness in this area affects both immediate (perceptive) and long-term (performance) comfort. End use determines the required modulus so dress shoes tend to use soft foam and sports shoes a much firmer foam. A wide range of foam modules is therefore essential.

Overall sensory comfort involves making the internal shoe environment more comfortable through moisture control. Moisture is caused through perspiration by the foot, which is a mixture of water and water vapour resulting from both physical and psychological stress. The aim of moisture management must therefore be to absorb liquid moisture and transport water vapour away from the foot in order to keep it dry. It is therefore essential to release this moisture while the shoe is not in use.

Problems

Hydrophilic foams can absorb over 1000% moisture by weight. However, their intrinsic hydrophilicity prevents them from releasing that amount of moisture, so the shoe never dries out. This can cause discomfort, microbial growth and unpleasant odour, which the wearer may become all too aware of when it is too late. As the comfort factor has become an increasing marketing strategy in recent years, so answers have been sought.

The cell structure is all-important and uniformity of cell formation is a key factor. If it collapses under compression and temperature, compression-set resistance and impact attenuation can be greatly reduced. Furthermore, a non-uniform cell structure can also lead to inconsistent moisture management.

A closed cell structure combined to a hydrophobic polymer base may therefore offer poor moisture control. In addition, closed cell materials derive a significant portion of their modulus from compressing the gas inside each cell. This pressurised gas diffuses out over time, reducing load retention and causing compression set.

The mechanics of comfort

Modulus or softness is a critical factor affecting both immediate and long-term comfort. It can be very different

depending on end use, so it is important to offer a range of moduli for different applications. Another key factor is change in softness or modulus of the foam with extent of compression.

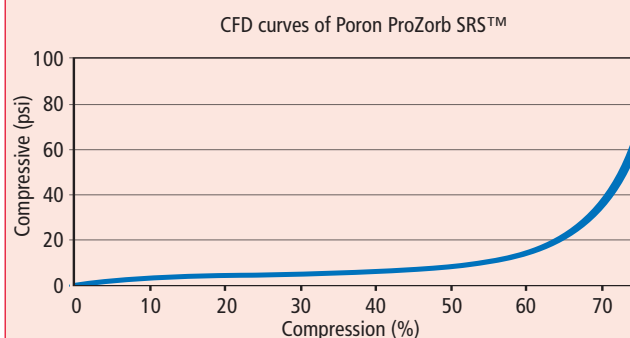
Compression Force Deflection (CFD) relates to compression (Figure 1). Although foam suppliers provide CFD at 25% compression as a measure of softness, the weight of the person or the dynamic nature of the application (walking or jogging) will apply varying amounts of compression. This can produce a modulus or hardness value higher or lower than that at 25% compression even though this is the design parameter. It is important that a material's CFD curve remains flat over a significant range of compression to ensure the same modulus and comfort across a wide range of physical activities. Therefore, the CFD curve should be used as a measure of the softness of the material as much as the 25% CFD value.

Long-term or 'performance' comfort is measured by the compression set resistance of the foam. Compression set is defined as the loss in thickness when compressed for a period of time at a specific temperature. Typically, for footwear materials, foams are compressed to 50% of original thickness and held at room temperature or 70°C for 22 hours (ASTM 3574 Test D). Physical activities such as walking, jogging or running involve varying degrees of shock or impact on the feet, which may be transmitted to the rest of the body. Shock or impact is one of the leading causes of fatigue and injury in sports. Impact attenuation is a very effective technique of managing that energy.

The two critical components of sensory comfort are temperature and moisture build-up in the shoe environment while in use. Humidity or moisture typically builds up due to body perspiration of the lower and upper part of the foot.

The frequently used water droplet test (where a drop of water is poured on the surface of the foam and the speed at which it is wicked away used as a measure of water absorption) is

Figure 1: Compression Force Deflection Curve of Poron ProZorb-SRS foam



misleading. While it indicates that the foam has a high absorption rate, it does not evaluate its ability to give up that moisture and dry quickly. If the absorption rate is very low, then the foam may not be able to effectively manage foot perspiration. A significant amount of foot perspiration is in the form of water vapour. The foam must allow for its movement away from the foot and through its bulk while in use and its removal when not in use.

For an insole-foam to contribute to the total comfort of the wearer, both mechanical and sensory comfort features need to be provided by the material. Slow recovery foams allow for a combination of very low hardnesses, which provide perceptive comfort to the wearer, while offering impact attenuation or shock absorption due to the nature of the polymer. Rogers Corporation, a manufacturer of speciality materials, believes that its ProZorb foams are the only ones that combine this desirable combination of slow recovery with good moisture management and excellent mechanical comfort.

Solutions

Rogers Corporation began life as the Rogers Paper Manufacturing Company in 1832 at Manchester, Connecticut, in the USA. Founded by a Dutch immigrant, the company supplied paperboard to the textile industry for the next 70 years. In around 1900 and with a decline in this market, insulating board for the growing electrical power transformer industry was introduced. This in turn led to a further variety of paperboard products ranging from artificial leather to rail joints, as this willingness to innovate saw the company through the Great Depression.

In the early 1940s, Rogers entered the footwear field by adapting its cellulose based insulation board into shank board for insoles. It continued this business until the late '50s when it

began to coat a Texon insole board with a PVC/plasticised dry blend called Poron material. This was one of the first man-made poromeric breathable materials to be substituted for leather board and linings.

This was also combined to cotton and non wovens for use in quarter linings and insole covers, but, at this stage there were no cushioning properties whatsoever.

The big breakthrough came in the mid '70s with the development of Poron Urethane cushioning foam products. Instead of applying another material such as sponge rubber under linings to provide cushioning power, Rogers now had both lining and cushioning in one high performance component. And, of course, urethanes proved to be both environmentally safer and offer better performance than PVCs.

What are Poron Urethanes?

These products are flexible polyurethane foams made from chemical reactions between isocyanates and polyols. This mixture of component chemicals is mechanically frothed and spread on to a substrate to produce the foam in sheet form. To accelerate the chemical reaction, the liquid mixture is then heated. Once the chemical reaction is completed, the liquid mixture turns into a cured-foam.

In 2002, ProZorb moisture managing materials appeared. These combine moisture management and cushioning for footwear, apparel and consumer applications. These are designed to provide effective moisture management by the use of patented open cell technology. They are made from specially formulated polymers to minimise permanent deformation under high temperature, pressure and dynamic loading. The combination of formulation and uniform open cell structure can be tailored to provide high performance in all types of footwear.

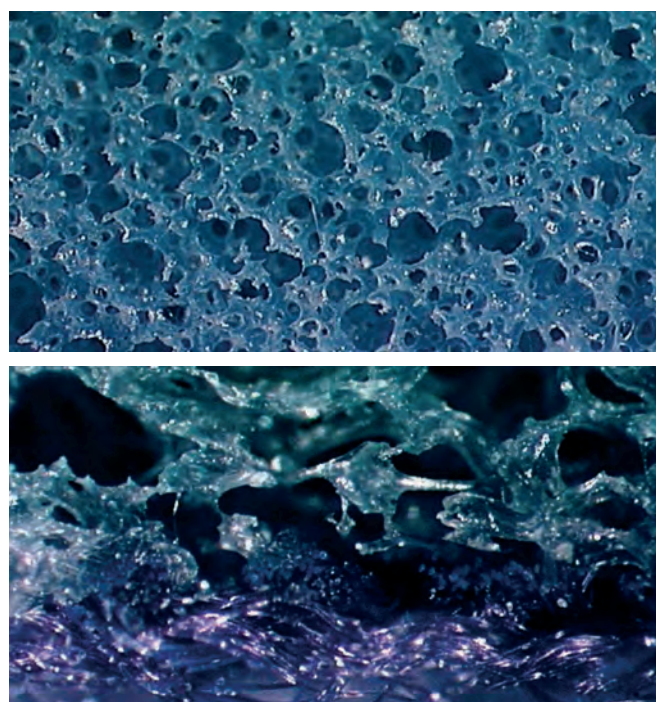
Typical cell diameters are 100-150 microns and the gaps between the cells are only 20 microns. It is this open cell structure that makes the material breathable and improves compression-set resistance and long load retention for longer lasting performance in wear. Each cell acts like a tiny 'spring' and, since the cell is open, this 'spring' has a wide compression range that provides much of the high shock absorption properties. The uniformity of cell structure also provides consistent mechanical and moisture transportation properties.

To accommodate the wide diversity of footwear types and applications, there are now over a dozen unique grades and formulations, which are available in a range of densities within each grade and in over 80 standard colours. In addition, special colours to suit customers' requirements can also be produced on request.

Other applications

Poron materials have also found their way into many other industries. Recently developed ultra-soft and thin foams are used to seal and protect liquid crystal displays, cameras, and microphones in cell phones and other portable electronic devices. The company also produces high performance silicone and polyolefin materials for communications, computer, transportation and many other industrial consumer applications. The simple concept of a foam pad for added comfort inside a shoe has come a very long way. 

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These optical micrographs demonstrate the uniform structure of Poron ProZorb (left) open cell foams compared to closed cell foams (right) (50X magnification).