Using Specialty Engineered Foams in Seating Design

By Manuel Sanchez
Senior Applications Engineer
E-A-R Specialty Composites
Indianapolis, Indiana

USING SPECIALTY ENGINEERED FOAMS IN SEATING DESIGN

The term *ergonomics* commonly is used today to refer to everything from workstation design in both factory and office environments to handle grips for hand tools.

Ergonomic principles consider how people safely and effectively interact with the tools, equipment and environment around them. When the study of ergonomics developed more a decade ago, interest was focused mainly on the workplace. Ergonomic theory held that if the interaction between the worker and his equipment could be improved, employees would be able to work more efficiently and safely.

As ergonomic study advanced, consumer markets began to implement the principles as well. Product designs were now developed around the end-user, rather than viewing the end-user as an external element that must conform to the product. Soon consumers increased demand for products that were *user-friendly*—comfortable, quiet, and generally easy to use.

Today in some markets, claims of an *ergonomic* design are so common that they're almost meaningless. Yet for other products, ergonomic concepts remain critically important. This is particularly true in seating design for the healthcare and transportation markets. Seats must be comfortable, reduce fatigue and, in some cases, protect the occupant from injury.

New Ergonomic Problems

As ergonomic problems are addressed, it often becomes apparent that traditional engineering approaches are not sufficient to satisfy the ergonomic needs. Engineers are forced to develop new methods to solve these problems, to "think outside of the box." Among other challenges, design engineers have also had to develop methods to evaluate seemingly subjective criteria, like comfort.

Traditionally, seating comfort has been achieved by using a combination of physical shape, mechanical articulation and some form of cushioning padding. Very often this padding consists of a highly resilient urethane foam. The comfort these foams provide is mainly subjective. For example, one person may find a stiff seat comfortable, while another may prefer a softer cushion.

Discomfort is generally caused by the way that the body interacts with the high-resilience (HR) foams. These foams act like a spring, returning a force that is directly proportional to the amount that is deflected. This causes an uneven distribution of the seat occupant's weight, subjecting some parts of the body to higher pressure than others. These pressure points can cause localized blood flow restriction. Short-term effects of this include soreness and fatigue that force the occupant to shift weight to relieve the restriction and restore blood flow (similar to tossing and turning in bed). Long-term effects can be more serious, including skin inflammations and decubitus ulcers (bed sores).

To further complicate matters, these subjective comfort evaluations are usually made over a very short time duration. What is comfortable at first may not be comfortable later. We have all experienced this during long trips in a car or an airplane. In nursing homes and other long-term medical care facilities, where patients may be confined to bed or wheelchairs, the long-term response to a cushion is of extreme importance.

It is also necessary for some seats to protect occupants from impact. In the airline industry, for example, regulations call for a seat that can protect a passenger from a specified shock input. Traditionally, a thick foam cushion on the seat pan would be used to absorb the shock. Theoretically, the additional sway space would be enough to absorb the shock.

Testing has proved this to be inadequate, however. In fact, the cushion can actually cause amplification of the shock input. *Bottoming out* — compression of the foam to a maximum — results in rebound of the HR foam, which can amplify the shock. (Ironically, most aircraft seat designs could easily pass federal regulations for shock absorption if the passenger would be willing to sit on the bare seat pan.)

Other problems facing seating designers include trying to design a seat for a wide range of occupant sizes and shapes. These all must be achieved while meeting the economic criteria of cost and weight.

High Tech Solutions

One means that has been developed to objectively evaluate the comfort of cushions is pressure mapping. This system uses a series of pressure sensors to measure pressure variances across a surface, in this case the cushion on which the occupant is seated. The result is a graphical display of the pressure distribution across the seat.

Advances in foam-making technology may provide an alternative to the traditional HR foams. Rate responsive foams can provide a simple cost effective means to solve ergonomic problems. CONFOR® foam, manufactured by E-A-R Specialty Composites is the leading rate-responsive foam for ergonomic applications.

CONFOR foams were originally developed for NASA for impact protection for aircraft passengers. They are medium density, highly damped, semi-reticulated (semi-open celled) urethane foams.

BEHAVIOR OF RATE-RESPONSIVE FOAMS

As the name implies, *rate-responsive* foams have different properties under different rates of strain. In other words, the foam collapses and seems to be “soft” when pressure is applied relatively slowly. Upon impact, however, the foam is firm. Moreover, these foams do not respond to deflection with a proportional force, i.e., they do not act like a spring. They *relax* under load. This allows an even distribution of pressure across the body, reducing pressure points. This material behavior is a direct result of the amount of *damping* within the foam.

Damping is defined as the ability of a system (or material) to dissipate energy. CONFOR foam achieves this through hysteretic loss, directly converting mechanical energy into low-grade heat. This ability arises from the chemical makeup of the material, a unique polyurethane polymer structure that gives the material its rate responsiveness.

All materials used by design engineers have some amount of inherent damping, even structural materials such as steel and aluminum. The level of damping in steel and aluminum, however, is extremely low, and the rate responsiveness is not observable under normal operating conditions. CONFOR foam, however, contains a significant amount of internal hysteretic damping, which gives rise to its *energy-absorption* and *thermal-forming* properties.

CONFOR foam responds to temperatures. When it is placed against a warm body, the foam begins to mold around the body. This molding action contributes to the equal distribution of applied loads to the body. Equal distribution of applied loads eliminates pressure points, thus eliminating vascular restriction and improving comfort, particularly after long-term use. The thermal-forming behavior enhances the pressure-reduction capabilities of CONFOR foam, making it an excellent choice for ergonomic applications.

CONFOR foam's energy-dissipation properties have provided designers with an improved method of dealing with high-energy impacts.

Traditionally, shock inputs have been reduced by using a thick, soft cushion that can disperse the kinetic energy input over time. Large, high energy impacts require a large amount of *sway space*. The more energy in an impact, the more sway space that is required. In today's smaller, compact designs, such space is often not available in a product design. Rate-responsive materials, however, use the internal damping as well as the mechanical deflection of the foam to dissipate the impact energy. This allows CONFOR to dissipate more energy with less sway space.

A matter of physics

As the amount of hysteretic damping in a material increases, the more temperature- and rate-responsive it becomes. There is no way to reduce the temperature and rate response without decreasing the energy-absorption characteristics of the material. The hysteretic damping provides CONFOR foam with its unique abilities to conform to the body when placed in direct contact and to dissipate large amounts of energy input.

ERGONOMIC SEAT DESIGN USING CONFOR FOAM

CONFOR foams have been used in a wide range of applications, including first-class and crew seating for aircraft, wheelchair cushions, infant incubator pads, therapeutic mattresses and pillows—ergonomic applications where comfort, pressure management, and impact protection made CONFOR the ideal choice. Using the following design principles, these applications demonstrate how CONFOR foam can

Type	Texture	Application
CF-NT	Extra Soft	Seats for infants, cover for stiffer material, bedding applications
CF-40	Very Soft	Seats for children, cover for stiffer material
CF-42	Soft	Seats for 115 lb. person 3"-4" seat pad
CF-45	Firm	Seats for 170 lb. person 3"-4" seat pad
CF-47	Very Firm	Seats for 200+ lb. person, or seat in hot-humid environment for 170 lb. person.

* This table should be used only for reference and does not represent all applications possible. For more detailed material information, refer to E-A-R's Technical Data Sheet TDS-13 or contact the Applications Engineering Department.

Figure 1

minimize often conflicting design criteria that can impede ergonomic design.

Consider the environment of use. Within the CONFOR family of foams, there are five standard stiffness grades that are designed to have optimum damping performance in temperatures ranging between 50°F to 90°F. It is the foam's thermal-forming capability that defines the service temperature range. Even the very firm grade becomes rather soft at 80°F, and the soft grades will be firm at 32°F.

It is important to remember that even at lower temperatures, surfaces exposed to body warmth in time will respond normally, softening and conforming, improving the pressure reduction performance. Outer surfaces will remain stiff and supportive.

Specifying a stiffness grade depends to a great extent on the temperature of the environment of use. Generally, designers working on a seat for a warm environment must select a foam at least one grade stiffer than normally would be selected. The inverse would be true for a cold environment. To design for a range of temperatures, multiple layers of varying stiffness can be used. But other parameters—size, thickness, load, design life, cost and comfort—can affect the choice as well.

Consider the intended occupant's weight. Another key design element is the average weight of the intended occupant. The chart in *Figure 1* gives some rules of thumb about stiffness selection and weight.

One way to accommodate a wide weight range is to incorporate a composite of multiple stiffnesses. For example, for occupants ranging in weight from 80 pounds to 200 pounds, a seat designer could layer CF-42 and CF-45, using the softer foam on top. This composite could provide optimal support and conformability for a wide range of possible occupants. Again, if hot environments play a factor, CF-45 and CF-47 could be used.

Combine CONFOR foam with traditional seating urethane. CONFOR foams are denser and therefore heavier than most traditional seating foams. To meet weight restraints and cost restrictions, designers often will combine common urethanes with strategically placed CONFOR foam to create a lighter, more cost-effective seat without accepting a major reduction in ergonomic performance.

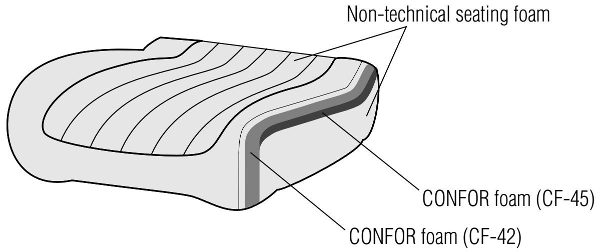

Figure 2: Example of Composite Ergonomic Cushion

One common construction sandwiches a layer each of formulations CF-42 and CF-45 between a base core and thin top layer of traditional seating foam. (See *Figure 2*.)

The base significantly reduces the overall weight, while the top layer gives an initial feel of "softness" and protects the CONFOR foam from frictional shear stresses. The thin top layer does not inhibit the CONFOR foam's thermal-forming behavior or balanced support, however. This composite construction currently is used in aircraft seats, vehicle armrests and wheelchair cushions.

Designers also frequently use CONFOR foam shapes, rather than sheets, placing them strategically to support such areas as the lumbar or cervical regions, or the thighs and shoulders. (See *Figure 3*.) This provides more options for support, comfort and pressure reduction.

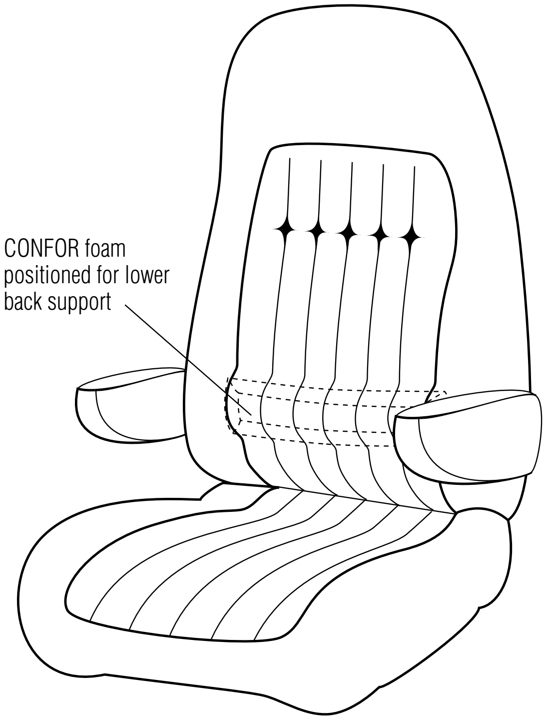

Figure 3: Aircraft Seat with Lumbar Support

CONFOR FOAM'S SHOCK-ABSORPTION CAPABILITIES

Trainers in numerous professional, high school, college and professional sports have discovered that CONFOR foam's unique properties give players added impact protection that can not be achieved with any other material. Hockey, soccer, gymnastics and football teams employ the material as padding during routine play as well as for existing-injury protection.

Several National Football League teams use CONFOR foam in "flak jackets" designed to protect players from injury or re-injury of their ribs.

For several years, CONFOR foam has been used in military fighter jets, to improve comfort and protect the pilot upon ejection. Testing has shown that the material significantly reduces the amount of energy transmitted to the pilot's body during ejection. Tests by Boeing Aircraft and Wichita State University found that CONFOR foam can help the aircraft industry meet federal regulations for crash-worthiness.

FAA Regulation 23.562 requires aircraft cabin crew seats to allow the occupant's lumbar region to be subjected to no more than 1500 pounds of loading during an impact of 19g. There are several options available to engineers to meet this regulation.

One design option involves expensive and complex mechanical actuators to reduce shock. Another is to increase cushion stiffness and thickness to absorb the impact energy through *crush* (kinetic energy). The resulting rebound and amplification of energy, however, presents a whole new set of design problems.

CONFOR supplies virtually the only *material* solution for this problem, due to its shock-absorption behavior (See *Figure 4.*)

CONFOR foam's high internal damping properties can be compared to the fluid in a mechanical shock absorber. CONFOR foam's damping converts mechanical energy into heat, allowing absorption of energy by two different mechanisms—deflection and heat dissipation. Thus it exhibits high energy absorption with minimal sway space required.

The graph in *Figure 5* demonstrates the advantages CONFOR foam brings to high-impact-absorption applications. It compares the deceleration response of one-inch-thick pieces of traditional seating urethane and CONFOR foam when a 16.9-pound weight is dropped onto 25-square-inch foam samples from a height of 24 inches.

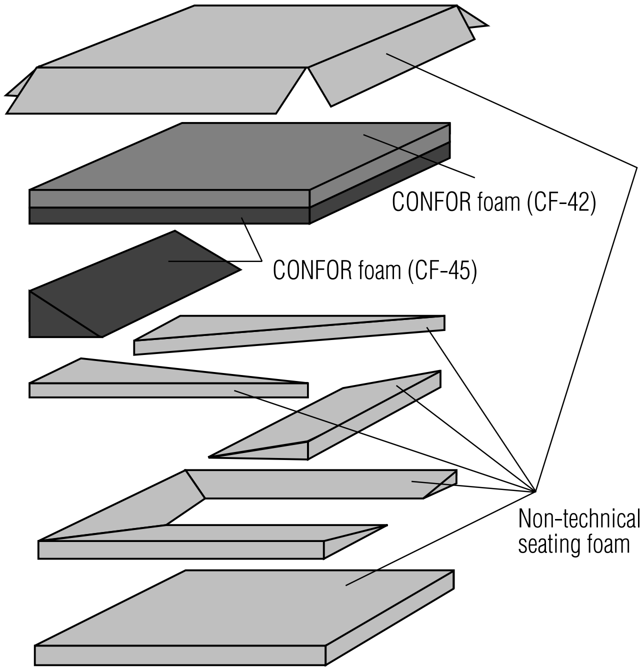

Figure 4: Airline Crew Seat Cushion

CONFOR foam provides a peak acceleration response less than half that of the undamped urethane and spreads decelerations over time. The response of the CONFOR material is much closer to an ideal, square wave impact response. In contrast, the sharp *accelerate-decelerate* peak of the usual seating urethane can have harmful effects on the human body, i.e., head, neck and back injuries.

A True *Ergonomic* Material

Design engineers must remember that a shock event is complex, with no simple solutions. However, CONFOR foam's rate-responsiveness provides for an improved method of dissipating energy, not only for seating applications, but for small electronics and other impact protection applications as well.

With each anticipated event, engineers must consider the entire environment. This includes optimizing the system stiffness and damping to produce the most favorable response.

CONFOR foam provides designers with a powerful alternative to traditional cushioning materials, and in many cases, it provides the definitive solution for comfort management, pressure management and shock protection applications. Sometimes, it may be the only solution that does not result in a new set of problems to solve.

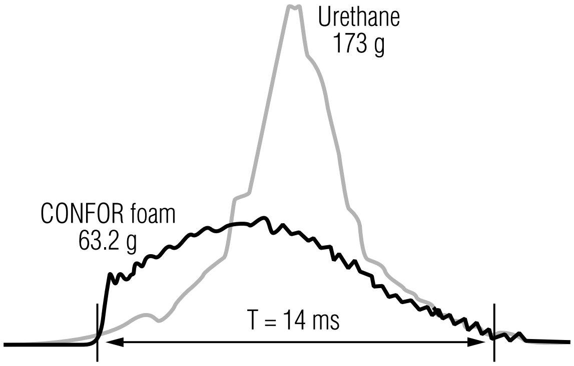

Figure 5: Acceleration Response of CONFOR Foam vs. Common Urethane

Additional information, material samples and design assistance are available from E-A-R's Customer Service Department by phoning (317) 692-3000 or by faxing (317) 692-3111.

Aearo E·A·R Specialty Composites™

Aearo Company
7911 Zionsville Road
Indianapolis, IN 46268
Toll-free (877) EAR-IDEA
(327-4332)
Fax (317) 692-3111
Website: www.earsc.com
E-mail: solutions@earsc.com

Printed 10.00