a designer to create a very plush – yet durable – seat which minimizes dimension changes and loss of firmness during use. So, understanding the design capabilities of polyurethane foam can play a big role in the ultimate styling of the finished furniture piece.

Considerations in Furniture Design

Before understanding how foam selection affects furniture design, several basic design considerations must be understood. Furniture design falls into two basic categories: visual and functional. Foam can affect both.

The visual aspects of design are virtually unlimited, and foams can be fabricated or molded to meet any of a variety of requirements. (See IN•TOUCH Volume 1, Number 5: "Foam Fabrication")

Functional design should take into account a number of factors, all of which may work with each other, assisting in providing the correct degree of seating comfort. Fabric type, spring type/design/construction, seat/back geometry, basic frame design, physical events during actual sitting/leaning, seating foam type, construction of the back, and firmness ratio between seat and back are major design factors to be considered in seating and comfort design.

One of the most vivid examples of the interdependency of all components in the sitting-comfort system is fabric selection. One can design a piece of upholstery with every part of the sitting-comfort system absolutely correct and perfect, including the fabric, but if the piece is ordered and manufactured with a cover material that is significantly different than the original design fabric, the fabric may override everything else in the system and the piece could sit poorly. Everything within the sitting-comfort system must be considered carefully.

Some of the more important factors in seating design are:

- Seat height
- Seat depth
- Total Vertical Motion (TVM) or "Ride," which is the deflection of the seating system during sitting
- Cradling, or the way the body weight is distributed on the cushion surfaces
- Back Pitch Angle, the angle between the seat and back
- Seat Pitch Angle, or the angle of the seat relative to the plane of the floor
- Ratio of firmness of seat to firmness of back

Foam suppliers can provide valuable input on furniture design and how to specify foam to achieve certain design objectives. You also may wish to review other IN•TOUCH issues for more information on specific foam properties that relate to furniture design functions.

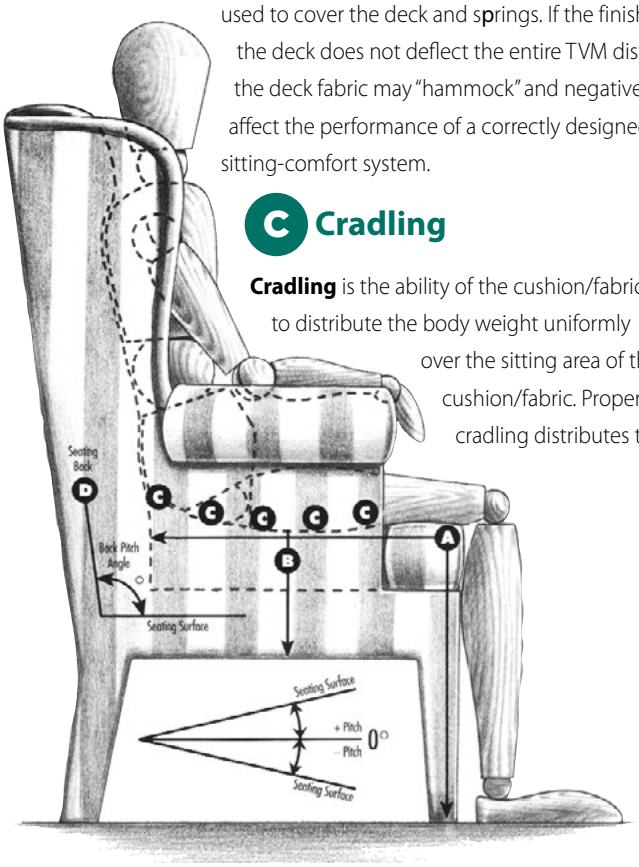
Visit the literature section at www.pfa.org for a complete, downloadable library of IN•TOUCH Bulletins.

A Seat Height and Seat Depth

Seat height will vary depending on the function of the piece. With a well-designed piece of residential/contract fully upholstered furniture, the seat depth and seat height should add to about 39 inches. For example, if the seat height above the floor of an upholstered piece is 17 inches, the seat depth should be about 22 inches. Significant variation from the 39 inch rule will result in poor comfort regardless of the selection of materials and other construction. A 28 inch seat depth in furniture with typical seat height will force most people to sit - if they lean against the back - with the front of the cushion ahead of the knee joint. Even worse, if the person sitting doesn't lean against the back, he or she may be forced to sit without any back cradling or support - a very uncomfortable situation.

B Total Vertical Motion (TVM)

Total Vertical Motion (TVM), sometimes called "**ride,**" is related to many factors. The major factors are fabric selection, seat cushion thickness, decking materials, deck cover, deck construction, spring type, and spring installation construction. Enough TVM is necessary to provide an initial "illusion" of comfort, but excessive TVM almost always causes "bottoming" or allowing one to feel the springs and/or deck construction at the bottom of the maximum TVM. Foam durability can definitely affect the TVM of any sitting- comfort system. Another factor that can significantly affect the whole sitting- comfort system is the deck covering material and the method used to cover the deck and springs. If the finish of the deck does not deflect the entire TVM distance, the deck fabric may "hammock" and negatively affect the performance of a correctly designed sitting-comfort system.



C Cradling

Cradling is the ability of the cushion/fabric to distribute the body weight uniformly over the sitting area of the cushion/fabric. Proper cradling distributes the body weight so that there are virtually no areas of body contact where the weight/load is concentrated. Proper cradling creates an interfacial pressure between the cushion/fabric and the body which is uniformly distributed on the parts of the anatomy in contact with the cushion.

Excessive interfacial pressure can restrict blood flow and cause a seated person to shift frequently to redistribute the pressure. Excessive interfacial pressure may contribute to the formation of decubitus ulcers or bed sores in people confined to wheelchairs or hospital beds.

Cradling varies widely depending on the use of the upholstered piece. Dining chair cushions, for example, usually are very thin, and only minor amounts of cradling can be effectively designed into the sitting-comfort system. However, cradling may not be very important because dining room chairs are not intended for long term sitting. Conversely, recliners are typically designed for maximum cradling because of intended long-term seating requirements.

D Angle, Pitch, and Ratio

As the angle between the seat and back (**Back Pitch Angle**) changes from 90 degrees to greater than 90 degrees, the back construction begins to carry more of the load and must be designed to have proper cradling and durability. However, too much Back Pitch Angle can decrease sitting comfort unless other considerations are made, i.e., raising and supporting the legs as in a recliner.

The Back Pitch Angle is very design dependent and sometimes, if more pitch is required for comfort, the front of the frame can be raised in relation to the back of the frame (**Seat Pitch Angle**), so that acceptable comfort levels can be attained.

The Seat Pitch concept is one reason why rocking mechanisms add so much to the comfort of upholstered (and non-upholstered) pieces. In a rocker, a person can continually adjust the pitch of the body in the system, continually redistributing the seating load. This is why people can sit comfortably over a long duration in non-padded, wooden rocking chairs.

The Ratio is the relationship of the seat firmness to back firmness. The firmness of the seat must be matched properly to the firmness of the back cushion. There is no set "formula" for this, but a good rule of thumb is that the more weight a person places on the back cushion, the closer the ratio of firmness between the back and seat cushion. In a chair where a person sits upright, the back cushion can be much softer than the seat cushion.

With back pitch angles greater than 90°, if the seat cushion construction is firm and the back cushion construction is soft, the comfort of the system will be negatively affected. With greater angles, the firmness of the seat construction should be matched to the firmness of the back construction.

Specifying Foam for Upholstery Applications

A number of foam properties will affect design considerations:

- Density
- Firmness (IFD)
- Compression Modulus (Support Factor)
- Flex Fatigue
- Resilience

Each of these foam properties is important in developing upholstery that provides proper comfort. (See IN•TOUCH Volume 1, Number 1: *Flexible Polyurethane Foam: A Primer* for more information on these properties.)

DENSITY: Affects the foam's ability to provide support, comfort and durability. Generally, as foam density increases, durability also increases. Some of the factors related to durability are loss of firmness (flex fatigue), breakdown in the sitting area of the cushion (dishing), and fabric bagging caused by loss of foam dimensions (compression set).

IFD: A measure of foam firmness that is independent of density. Even high density foams can be soft. For upholstery, 25 percent IFD can range from five pounds to 50 pounds. Softer foams may be laminated to firmer foams to provide surface softness. Firmness can affect the "ride" of a cushion. Firm foams are often used to create certain "feels" as in thin-profile applications such as in arms or backs. Firm foams may also be used to create or hold certain shapes.

COMPRESSION MODULUS (SUPPORT FACTOR): Compression modulus is primarily a function of the type of foam. Conventional foams have compression modulus in the range of 1.9 to 2.1; filled foams 2.1 to 2.4; and high resilience grades 2.2 to 3.0. Within a foam grade, the modulus is typically a function of the foam density. In most cases, the higher the density the greater the compression modulus. Laminating hard and soft foams together can also increase compression modulus for the composite cushion structure. However, the firmness of the laminated foams cannot be too far apart or the cushion may seem to "bottom out" on the firmer portion.

Compression modulus affects cradling. For greatest comfort, the compression modulus should be selected to maximize cradling. When cushions are thick, lower compression modulus foams may be used to improve cradling and to achieve more even distribution of body weight. If cushions are thin, not too much TVM can be expected. Interfacial pressures of these designs will definitely decrease the comfort of thin cushion seating systems. Higher compression modulus foams may be used in thin cushion applications to prevent system "bottoming" and/or "hammocking" of the seating area.

FLEX FATIGUE: This important measurement of durability is an indicator of a cushion's long term ability to provide the proper cradling and TVM. Foams that have good flex fatigue values will tend to retain their original firmness and support levels, which means that the cushion can retain more of its original characteristics.

RESILIENCE: The surface resilience of a foam also affects comfort and design. Foams with high resilience feel springy and provide a good "hand" for cushioning. Conversely, low resilience, or a "dead" feel, typical of many viscoelastic (memory) foams, may be desirable in some pillow and padding applications.

Summary

Like design aesthetics, functional designs can vary tremendously, and designers can create comfortable seating by varying design considerations. Ultimately, the intended use for the furniture must dictate much of the design. Here are some key considerations:

- The ability to achieve long term sitting-comfort decreases markedly as the cushion thickness and system thickness decrease.
- I n some thin seats, long term sitting-comfort is virtually impossible without some sort of pitch adjustment such as a rocker mechanism.
- Since no two people are alike, a designer has to consider whether or not upholstery will be used by a range of people with different weights and shapes. A cushion that provides enough support for a person of a higher weight must also be soft enough to provide comfort for a lighter weight individual.
- Furniture functions vary and should be considered by designers. For example, a waiting-room chair may not be used long by a single individual, but it will see a continual use by a number of people. For this type of furniture, durability is key.

Other factors can affect furniture design. However, by considering the elements described in this bulletin, a furniture manufacturer can better understand product function, and the role flexible polyurethane foam plays in providing seating comfort.

This information is provided as a service of the Polyurethane Foam Association to improve the understanding of key issues that affect flexible polyurethane foam cushioning. To learn more about specific foams, contact your foam supplier.

A complete library of PFA IN•TOUCH issues can be found at www.pfa.org.

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