



No. 12-122898- -00020-0000

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Señor D.

Superintendencia de Industria y Comercio

E.

S.

D.

No. 12-122898- -00020-0000

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Referencia: Solicitud Patente de Modelo de Utilidad
Título: Asiento deformable con un espesor reducido para uso en vehículos de transporte de pasajeros
Solicitante: Marcopolo S.A.
Exp. No: 12-122.898
Asunto: Recurso de Reposición contra la Resolución No. 204 del 6 de enero de 2015

MF

Yo JESÚS M. MÉNDEZ BERMÚDEZ, identificado con cédula de ciudadanía No. 13.491.525 de Cúcuta y con Tarjeta Profesional de Abogado No. 99.678 del Consejo Superior de la Judicatura, en mi calidad de apoderado de la sociedad **Marcopolo S.A.**, y estando dentro del término legal, respetuosamente manifiesto a este Despacho que interpongo recurso de reposición contra la Resolución No. 204 de 6 de enero de 2015, por medio de la cual se deniega la patente de Modelo de Utilidad a la solicitud de la referencia.

HECHOS

PRIMERO: Mediante escrito radicado ante la Superintendencia de Industria y Comercio el día 23 de julio de 2012, se presentó la solicitud de patente de Modelo de Utilidad bajo el título de **“Asiento deformable con un espesor reducido para uso en vehículos de transporte de pasajeros”**. Dicha solicitud se radicó con el propósito de que se diera inicio a la fase nacional de la solicitud PCT/BR2011/000014.

SEGUNDO: De conformidad con lo dispuesto en el Tratado de Cooperación en Materia de Patentes (PCT), el reglamento, lo previsto en el artículo 39 de la Decisión 486 de la Comisión de la Comunidad Andina, y la Circular Única de la Superintendencia de Industria y Comercio, se ordenó publicar el extracto sin que se hubieran presentado oposiciones por parte de terceros.

TERCERO: De conformidad con lo dispuesto en el artículo 45 de la decisión 486 se realizó el examen de patentabilidad y se requirió a la solicitante mediante el oficio 3968, notificado el 08 de abril de 2014 para que se pronunciara sobre las objeciones efectuadas a la solicitud en cuanto a la carencia de novedad y materia no aceptable para Modelo de Utilidad.

CUARTO: Atendiendo dicho requerimiento y dentro del término oportuno para hacerlo, di respuesta al mencionado oficio mediante escrito radicado ante la Superintendencia de Industria y Comercio el 16 de junio de 2014. Se presentaron nuevas reivindicaciones para dar mayor claridad y atendiendo a algunas objeciones de forma. Además se dieron las explicaciones necesarias de porqué si hay novedad en la invención.

QUINTO: No obstante lo anterior, la Superintendencia de Industria Comercio, mediante Resolución No. 204 del 6 de enero de 2015, resuelve negar la

patente a la presente solicitud con base en la falta de novedad y de que la materia no es patentable mediante Modelo de Utilidad.

SEXTO: La resolución No. 204 del 6 de enero de 2015, mediante la cual se niega la patente a la invención de la presente solicitud, fue notificada por edicto el día 13 de febrero de 2015.

RAZONES DE INCONFORMIDAD CON EL ACTO RECURRIDO

A pesar de los argumentos aportados en mi memorial de respuesta al Oficio 3968, su Despacho considera que persiste la situación de falta de novedad y además agrega que la materia reivindicada no está cobijada por la modalidad de Modelo de Utilidad. Los argumentos que, sin embargo, plantea su Despacho carecen de fundamento tanto técnico como jurídico como se demuestra enseguida.

Su Despacho argumenta que la presente solicitud reclama un material y, por esta razón, no puede ser aceptada como una patente de modelo de utilidad, con base en el artículo 81 de la Decisión 486.

La solicitante entiende y está en total acuerdo de que los materiales no pueden ser aceptados como patente de modelo de utilidad. Por favor note, sin embargo, que la presente solicitud de modelo de utilidad **no reclama el material per se**, esta reivindica **un asiento que comprende regiones hechas de materiales con propiedades viscoelásticas**, de modo que cualquier material viscoelástico puede ser utilizado para poder lograr el objeto de la invención.

Adicionalmente, debe notarse que ninguna de las reivindicaciones últimas presentadas se relaciona con especificaciones del material, su composición química o sus propiedades físicas, por esta razón las reivindicaciones de la presente solicitud de patente de modelo de utilidad no deben ser entendidas como reclamando el material *per se*, como parece entenderlo su Despacho.

CON RELACIÓN AL ARTÍCULO 81 DE LA DECISIÓN 486

Haciendo referencia al Artículo 81 de la Decisión 486, note enseguida las partes resaltadas:

“Art. 81. Se considera modelo de utilidad, a toda nueva forma, configuración o disposición de elementos, de algún artefacto, herramienta, instrumento, mecanismo u otro objeto o de alguna parte del mismo, que permita un mejor o diferente funcionamiento, utilización o fabricación del objeto que le incorpore o que le proporcione alguna utilidad, ventaja o efecto técnico que antes no tenía.”

Considere solamente la partes resaltadas arriba, tenemos:

“Art. 81. Se considera modelo de utilidad, a toda nueva [...] disposición de elementos, de algún [...] objeto o de alguna parte del mismo, [...] que le proporcione alguna [...] ventaja o efecto técnico que antes no tenía.”

Por lo anterior, la solicitante entiende que el asiento de la presente invención comprende:

- i. Una nueva disposición de elementos de un objeto (*asiento para vehículos de transporte de pasajeros*);
- ii. Y partes para esta (*áreas de interacción con el usuario*);
- iii. Con suministro de ventaja o efecto técnico que no tenía previamente (*al menos parte de su área de interacción con el usuario hecha de material(es)*)

deformable(s) – materiales viscoelásticos – con espesor reducido y capaz de retornar a su forma original y volumen y sin tener el problema de deformación persistente dentro de un periodo corto de uso).

Como se expuso antes, la solicitante entiende que el objeto de la presente solicitud de modelo de utilidad cumple con los requerimientos para Modelos de Utilidad impuestos por el Artículo 81 de la Decisión 486, ya que **la presente solicitud reivindica un objeto** (asiento para vehículos de transporte de pasajeros), que **comprende partes** (áreas de interacción con el usuario) que suministra ventajas y efectos técnicos (*espesor reducido capaz de retornar a su forma original y volumen y sin tener el problema de deformación persistente dentro de un periodo corto de uso*) lo que no es logrado por el estado de la técnica.

En vista de estas ventajas, la solicitante considera que la presente solicitud alcanza y cumple el requisito para modelo de utilidad, según lo establece el Art. 81 de la Decisión 486.

2. Con relación a la novedad – Artículo 30 de la Decisión 486 y Art 22 del PCT

Documento D1 (FR 2885091)

Respetuosamente, la solicitante manifiesta su desacuerdo con la opinión de su Despacho y considera que la presente solicitud es novedosa sobre D1 con base en los siguientes hechos:

Su Despacho afirma que “...espuma viscoelástica, es un término general, que incluye espuma de poliuretano que es un término particular que afecta, por esta razón, al material reivindicado ...”, y también afirma que “... dicho material es ampliamente conocido en el estado de la técnica como una espuma de poliuretano ...” sin embargo debe notarse que:

- I. La solicitud no menciona el uso de “espumas viscoelásticas”, en vez de eso propone la invención el uso de “materiales viscoelásticos **combinados** con espuma”, como puede verse a lo largo de la descripción y también en la reivindicación principal 1, como sigue:

“

1. Un asiento para vehículos de transporte de pasajeros, **caracterizado** en que comprende, en al menos partes de sus áreas de interacción con un usuario, material(es) deformable(s) con espesor reducido, en que:

- **dichos material(es) deformable(s) con espesor reducido es un material viscoelástico ó un material viscoelástico COMBINADO con espuma; y**

dichas áreas de deformables con espesor reducido, en donde ocurre la interacción con un usuario, comprende al menos uno de: un soporte de espalda (10, 20, 30); una porción superior del soporte de espalda (11, 21, 31); una porción inferior del soporte del espalda (12, 22, 32); y un asiento (13).”

- II. Las propiedades viscoelásticas no son comunes a todas las espumas de poliuretano, y tampoco son exclusivas de los materiales de espuma. Un ejemplo bien conocido es el Sorbothane®, el cual define en su sitio de red la diferencia entre un material elástico y un material viscoelástico, como sigue:

“Qué es viscoelástico?”

La viscoelasticidad es la propiedad de los materiales que exhiben características tanto viscosas como elásticas cuando sufren una deformación. Los polímeros sintéticos, madera y tejido humano, al igual que los metales a altas temperaturas, despliegan efectos viscoelásticos significativos. En algunas aplicaciones, aún una pequeña respuesta viscoelástica puede ser significativo.

Comportamiento elástico frente a comportamiento viscoelástico

La diferencia entre materiales elásticos y materiales viscoelásticos es que los materiales viscoelásticos tienen un factor de viscosidad y los elásticos no lo tienen. Debido a que los materiales viscoelásticos tienen el factor de viscosidad, estos tienen una rara de tensión dependiente del tiempo. Los materiales puramente elásticos no disipan energía (calor) cuando se aplica una carga, luego de remueve; sin embargo, una sustancia viscoelástica si lo hace.”

Fuente: <http://www.sorbothane.com/blog/the-difference-between-elastic-materials-and-viscoelastic-materials/#sthash.NijRSg9b.dpuf>

Adicionalmente, su Despacho afirma que la espuma de poliuretano mencionada en D1 revela una solución al problema de espesor reducido en asientos de vehículos por su definición en la descripción detallada, como sigue:

cual en el documento D1 se menciona de la siguiente forma: “...el cojín siendo hecho de espuma de poliuretano y que tiene sustancialmente entre 35 mm y 50 mm de espesor y que está dispuesto de manera que una bola de metal con un diámetro de 16 mm y una masa de sustancialmente entre 16 g y 17 g, se somete, cuando se deja caer sobre un cojín de espuma sustancialmente igual a 46 cm de altura, obteniendo una altura de rebote sustancialmente entre 11,5 cm y 16,1 cm. Por lo tanto, el espesor de la almohadilla de espuma se reduce sustancialmente. Sin embargo, la comodidad del asiento se mantiene por las propiedades elásticas de la banda textil y de amortiguación cojín de espuma.” demostrando que el documento D1 divulga la solución al problema de espesor en los asientos de vehículos utilizando una espuma de poliuretano.

El ensayo mencionado en D1 se conoce como “ensayo de rebote de la bola” y se ha estandarizado por la norma ASTM 3574 H, puntos 68 a 75. La literatura, IN TOUCH¹ - Vol. 11 n°1 (2003), revela una comparación entre espuma viscoelástica y poliuretano común, como sigue:

“Otras características incluyen la habilidad de la espuma viscoelástica de amortiguar la vibración así como absorber el impacto. Esta última característica de comportamiento se confirma en el laboratorio usando los ensayos de rebote de bola. Un rebote de la bola de menos del 20% (comparado con 50% - 60% con otras variedades de FPF [espuma flexible de poliuretano]) soporta la descripción de la espuma viscoelástica de poliuretano como espuma “muerta” o “de baja resiliencia”, porque carece la superficie de

¹ IN•TOUCH® is a regular publication of the Polyurethane Foam Association (PFA). It covers topics of interest to users of flexible polyurethane foam and is designed as a quick reference for background information on key issues. To get more detailed information about a particular topic, consult a PFA member.

“resortabilidad” de otros productos FPF. De hecho, ciertos productos de espuma viscoelástica reclaman absorber hasta 90% del impacto.”

Blair, G.R. y Horn, R.J.³² (1993) muestra ensayos comparativos entre tipos de espumas de poliuretano usadas en asientos para vehículos, que incluyen el ensayo de rebote de la bola. Las muestras ensayadas presentaron resultados variados entre 38 a 53%.

De los valores presentados en la descripción de D1 (el rebote estuvo entre 11,5 cm y 16,1 cm, para una caída de 46 cm), los resultados de dicho ensayo, de acuerdo con el ASTM 3574 H fueron 25 y 35%, respectivamente, mucho más inferior a los resultados esperados para un material viscoelástico.

Si una espuma de poliuretano común fuera equivalente a una espuma de poliuretano viscoelástica, como lo afirma su Despacho, el resultado en un ensayo de rebote de bola mostrado en D1 debería estar cerca al obtenido mediante comparar los valores obtenidos por Rajan et al³² (2011), el cual presenta una espuma viscoelástica de poliuretano que logra 3% de resiliencia en los resultados de los ensayos de rebote de bola (menor que las muestras Blissco, usadas como medios comparativos, las cuales lograron 5% de resiliencia del rebote).

Finalmente, debería notarse que el simple hecho que D1 muestre un asiento para vehículo hecho de espuma de poliuretano común no anticipa la solución presentada por la presente solicitud, ya que el uso de espuma de poliuretano en asientos para vehículos es ampliamente conocido en el estado de la técnica, como puede verse en IN TOUCH³ – Vol. 6 n°1 (1997), que afirma que la espuma de poliuretano flexible fue introducida en la industria del transporte a principios de los años 50 y Blair, G.R. y Horn, R.J. (1996) menciona que la espuma de poliuretano de alta resiliencia ha sido usada en asientos automotrices desde comienzos de los años 70. En este punto la solicitante hace recordar que la solución ofrecida por la presente solicitud no se basa en el uso de espuma de poliuretano, sino en el uso de materiales viscoelásticos combinados, o no, con espuma, distribuidos sobre el área de interacción con el usuario.

En la presente Resolución 204, la presente reivindicación 1 no fue considerada completamente por su Despacho durante el análisis de comparación entre la presente solicitud y D1, en la tabla 1 de la Resolución 204. Más específicamente, su Despacho no tuvo en cuenta el primer tópico de la reivindicación 1, como se presenta enseguida:

² Preparation of Molded Viscoelastic Polyurethane Foam for Pillow Applications – Rajan, K. P.; Dhilipraj, D. B.; Manikandan, R and Veena, N.R., 2011

³ Fleet Durability Testing of Moulded Polyurethane Foam and Competitive Automotive Cushions – Blair, G.R. and Horn, R.J.³ (1996), Utech '96: The international Polyurethane Industry Conference and Exhibition, Netherlands, 1996.

Available on “Conference Book of Papers” – iSmithers Rapra Publishing, 1996 – ISBN 1859570666, 9781859570661

Link to consult:

https://books.google.com.br/books?id=VFQr7AkH7KgC&lpg=PA5&ots=eY6gfjYnm_&dq=%22ball%20rebound%22%20%22polyurethane%20foam%22&lr&hl=pt-BR&pg=PA5#v=onepage&q=%22ball%20rebound%22%20%22polyurethane%20foam%22&f=false

“- dicho material deformable con espesor reducido es(son) un material viscoelástico y/o un material viscoelástico combinado con espuma; y”

Dicha característica, si no se suprime, representa claramente que la presente solicitud cumple con el requisito de novedad con base en los argumentos ya presentados y por el hecho de que D1 no menciona ni sugiere el uso del material viscoelástico, ni su combinación con espuma, sobre la superficie del asiento que está en contacto con el pasajero.

Adicionalmente, D1 no suministra una solución al problema de cambio de espesor del material de espuma, la solución de este documento está basada en el material elástico que tiene la lámina textil, en donde el material elástico de la lámina textil puede suministrar una mejor comodidad, y en consecuencia el espesor de la espuma del asiento puede disminuir.

Por lo tanto, la solicitante, respetuosamente, entiende que:

- D1 no anticipa la materia u objeto de la presente solicitud; y
- La presente solicitud de modelo de utilidad está en completo acuerdo con la Decisión 486.

Por las razones expuestas antes, la solicitante solicita, de manera respetuosa, que se conceda la patente de modelo de utilidad a la presente solicitud 12-122898.

PETICIÓN

Por lo anteriormente expuesto, respetuosamente solicito a la administración que revoque el acto administrativo por el cual se niega la patente a la solicitud de la referencia y, como consecuencia, se otorgue la patente.

ANEXOS

IN TOUCH Vol. 6 – no.1

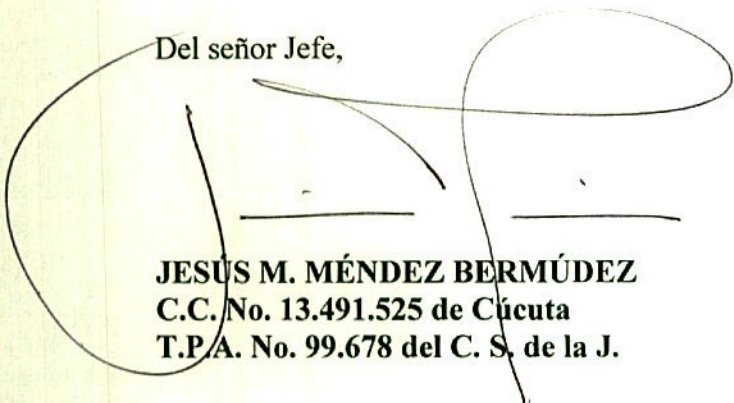
IN TOUCH Vol. 11 – no.1

Rejan et al (2011)

NOTIFICACIONES

Recibiré notificaciones en la Secretaria de este Despacho y en mi oficina, ubicada en la Calle 83ª No. 23-90 de esta ciudad.

Del señor Jefe,



JESÚS M. MÉNDEZ BERMÚDEZ
C.C. No. 13.491.525 de Cúcuta
T.P.A. No. 99.678 del C. S. de la J.

IN•TOUCH®

INFORMATION ON FLEXIBLE POLYURETHANE FOAM

IN•TOUCH® is a regular publication of the Polyurethane Foam Association (PFA). It covers topics of interest to users of flexible polyurethane foam and is designed as a quick reference for background information on key issues. To get more detailed information about a particular topic, consult a PFA member.

Flexible Polyurethane Foam in the Transportation Industry

Comfort, durability, safety and economy of operation are requirements of every modern mode of transportation. Manufacturers of private and commercial vehicles meet these prerequisites by using flexible polyurethane foam (FPF) in seating systems and other components.

This issue of IN•TOUCH® discusses how FPF can be produced in an almost unlimited variety of formulations to meet specifications for automobiles, trucks, buses, aircraft and boats. It is one of the most versatile manufacturing materials today, with proven reliability and flexibility. Polyurethane foam can be formulated to dampen the vibration that causes discomfort for the operator of an over-the-road tractor/trailer rig as effectively as providing a smooth ride for the driver of a luxury sedan.

FPF can be combustion modified to meet safety requirements for various types of seating from auto to aircraft, while providing long-term comfort and performance.

Marine applications are compatible with FPF's natural resistance to mold and mildew attack. The addition of antibacterial chemicals boosts FPF performance in this arena. Consistent physical performance in a constantly moist atmosphere and an ability to support and cradle the body in comfort make FPF the logical choice for boat berths, trim, and seating. Improvements and refinements to the "miracle material" introduced in the early 1950's continue to expand FPF use and add valuable benefits within the transportation industry.

Protecting the environment by recycling vehicle seats to keep them out of landfills is of paramount importance. Elimination of springs in vehicular seating has helped cut the cost of recovery for recycling by about two-thirds. However, the move to deep, all-foam seating brings challenges as well as progress. New research focuses on FPF varieties that dampen the vibration created by the dynamics of the vehicle and irregularities of the roadbed.

Some designers specify that a seat should be highly resilient. Others are much more concerned about vibrational-dampening qualities of the seat. The two specifications appear to be in opposition, but methods have been developed to control vibration and provide resiliency.



More than 40 years of research and product refinements have made polyurethane the material of choice for the transportation industry. Rigorous testing spearheads a search for new technologies leading to foam formulations to meet the changing needs and demands of the future.

Springless seats in vehicles are relatively recent developments. However, springs are rarely used in boats where plywood platforms are often the base for seats and bunks. High resilience (HR) foam, that provides essential support and cradles the body in surface softness, multiplies the comfort quotient in boats.

A new approach in aircraft seating is the introduction of graphite impregnated foam (GIF) which can be produced to meet aviation combustion requirements, while providing lasting comfort for passengers.

Comfort and Safety Come First in Automotive Seating

Manufacturers of automobiles, trucks, and recreational vehicles must practice both ergonomics and aesthetics in designing and engineering seating. This highly visible component, the main interface of the driver and his machine, is the second costliest in a motor vehicle. The engine is number one.

Overall comfort and performance of the seating system, consisting of frame, foam, covers and mechanisms is a key factor in the decision to buy a vehicle.

Increasingly, major auto companies outsource their seating requirements in efforts to improve quality and control costs. Design and engineering often are jobbed out.

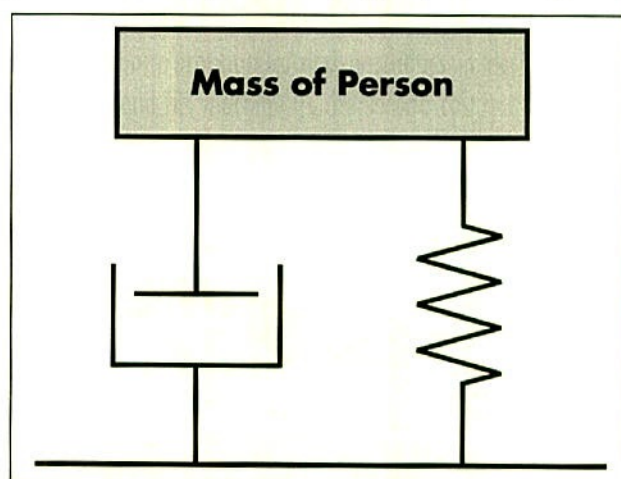
Companies that specialize in the dynamics of seating systems may produce the necessary parts themselves or purchase materials from other companies. As a result, many suppliers may become involved in producing seats for a single vehicle. Auto makers and their several tiers of suppliers explore new technologies and materials testing at every level to control costs and maximize comfort and ease of driving.

For many years auto makers have relied on FPF as a cost effective, durable cushioning material with the versatility required for complex designs. Now FPF has become an even more important element in automotive seating.

Emerging from technological advances is the replacement of combination spring/foam seating in favor of components made entirely of polyurethane foam. Until recently, automotive seat engineers and designers depended on tuning the springs (SEE DIAGRAM) to control **transmissivity**. Transmissivity is the transportation industry's term for the amount of vibration transmitted through the seating platform to the driver by the motion of the auto. In systems that incorporate springs, foam is used mainly as an easily applied, economical padding material.

Currently, almost half of all Japanese automobiles and a significant and growing portion of American cars are equipped with deep foam seating. These systems are lighter in weight, high performance and easier to recycle than spring/foam combinations. Manufacture of all-foam seats also is less labor intensive, a major cost-control benefit. Now, in a single molding process, seats can be manufactured to provide a soft, comfortable center section combined with firm perimeters for effective lateral support.

The move away from springs places much greater emphasis on the performance characteristics of the foam. Designers and manufacturers of all types of seating, including residential and commercial furniture, are concerned with the comfort factor. For the transportation industry, achieving a satisfactory level of comfort becomes much more complex.



Spring and dash pot models are used to predict foam cushioning behavior.

For example, sofas and chairs are static. Automobiles are dynamic. Designers and engineers must deal with the mechanical forces that produce the vehicle's motion.

It is imperative to specify foams that will eliminate most of the vibration transmitted through the floor pan by the dynamism of the vehicle and variables in the road bed.

Vehicle seats must perform another vital function. They must establish and maintain the driver in a position that allows ergonomic access to all controls and allows safe operation with unimpaired vision.

If the foam seat of a sofa or chair becomes compressed or stiff over an extended period of use, the consumer-owner may be unhappy. For the automobile driver, degradation of seating can reduce visibility and safety also becomes a factor.

H-Point is the term used by the industry to identify the height at which the driver has adequate visibility for safety. The H-Point is influenced by several situations that may develop in the foam with extended use. The primary influence is creep (settling or compression); which, in turn, is influenced by the amount of "work" put into the foam as measured by dynamic modulus (a measuring of the dynamic firmness), and dynamic hysteresis (a measuring of the change in dynamic firmness, providing information about the foam's ability to maintain original dampening properties).

Intensive Testing Spurs New Technologies

As consumer demands change and auto makers refine seating requirements to meet customer expectations, flexible polyurethane foam has emerged as the material of choice. Intensive testing of materials and components by auto manufacturers and their suppliers spurs innovations such as deep foam seating. This technologically advanced seating system reduces weight, boosts production rates and provides the comfort consumers seek. Research continues to enhance the reliability, flexibility and versatility that allows automotive designers and engineers to achieve their performance goals.

At the same time, the public benefits from seating that is comfortable, pleasing to hand and eye, enhances fuel economy and contributes to overall safety.

A primary target of this on-going research and testing is durability. Durability in vehicles is defined as the consistency of foam characteristics during prolonged use, such as a long trip and as over the life of the car, van, truck or bus. Seating foam is regularly subjected to harsh conditions such as excessive heat, cold and high humidity which can significantly affect performance. Significant advances have been made to improve foam durability.

Field tests as well as laboratory tests measure durability. In one test, for example, urban police cruisers were used as the test vehicles. Results of the study were reported at the

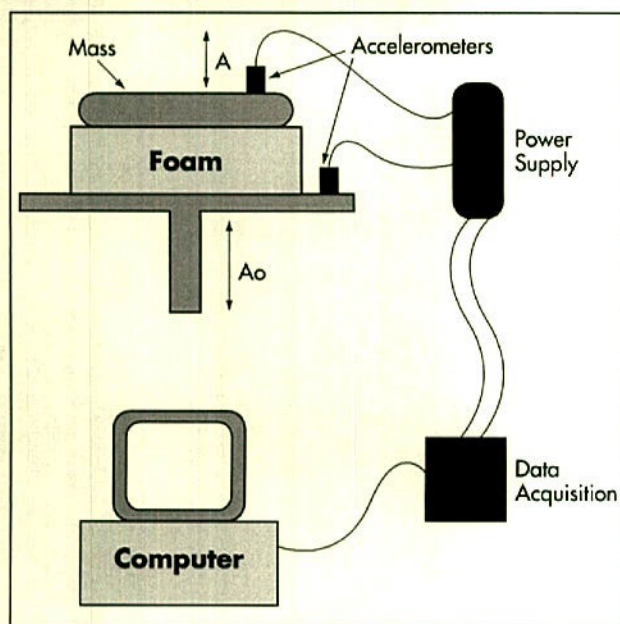
EA Foam Increases Vehicle Safety

Flammability and injuries from impact also are safety concerns that are addressed by advanced foam technology. Foam can be produced to meet the combustion requirements of federal Motor Vehicle Safety Standard 302 without the addition of flame retardant chemicals.

Energy-absorbing (EA) polyurethane foam increases protection for the occupant during impact. EA foam can be slabstock fabricated to required dimensions or molded to dashboard and interior trim specifications and can be formulated to slowly return to shape after impact or to crush completely for maximum energy absorption with minimum displacement.

Manufacturers and suppliers are continually experimenting and testing designs and components that increase safety and reduce vibration and the resulting discomfort.

Adding to the complexity of designing, engineering and making the "perfect" seat is each consumer's perception of comfort. Age, sex, height, weight and body type influence each person's comfort level. These individual, subjective factors represent about 50 percent of the comfort quotient. The other half comprises objective elements such as dampening vibration, establishing proper firmness, equitable distribution of body pressure, initial feel and durability. Continued research brings the transportation industry closer to a precise definition of comfort and to the techniques to achieve and measure total driving satisfaction.



ACDF testing uses accelerometers to gather vibrational wave data from the source as well as through different foams to document transmissivity rates over real time.

In a significant stride to solving the problem of vibration, a laboratory scale model has been developed to measure foam transmissivity. It has been proven effective in comparing the vibration dampening performance of different foam systems.

The transmissivity test is used along with others, including the ASTM Constant Force Pounding (CFP) test, ball rebound to measure resiliency (ASTM D3574 Test H) BMW durability tests, IFD tests and others to determine specifications that individual manufacturers or suppliers may require.

There are essentially three polyurethane molded foam technologies currently used worldwide in the manufacture of automotive seating. These are generally known as TDI HR; MDI HR; and TDI hot cure.

The transmissivity study used to create the model examined these three foaming technologies with specific emphasis on the vibrational characteristic responses over a frequency range of 1 to 16 Hz.

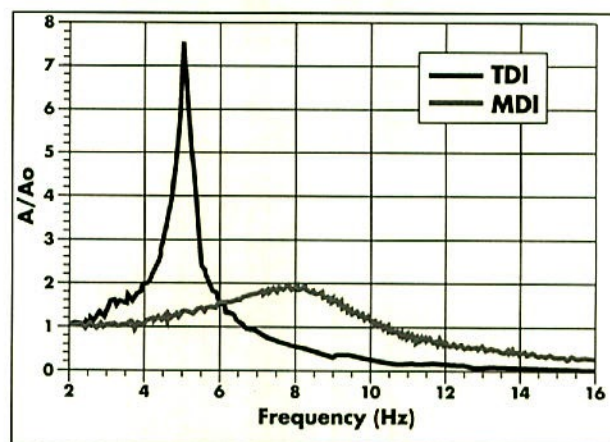
Generally, TDI chemistry provided the desired lower natural frequency response and was the least sensitive to processing variables.

Recycling: A Responsible and Profitable Option

Expense of recovering foam has been the major deterrent to re-use, but new techniques and technologies are sharply lowering costs and spurring efforts to recycle automotive seating. Even when fabric is adhered directly to the foam, it is relatively easy to separate the two materials.

Polyurethane cushions in these high-use vehicles were subjected to the equivalent of one vehicle lifetime (160,000km). After more than 2000 hours of ride evaluation, the cushions were evaluated in the laboratory and their physical properties compared with virgin foam. Over the period of testing, properties were virtually unchanged. Evaluations were made of several different grades of foam, and foam containing about 20 percent of recycled polyol content. All performed well and were considered to offer a good degree of support and comfort. Cushions manufactured from other fibrous materials, both natural and synthetic, failed in the field. These cushions were removed from the test fleet because of unacceptable performance before completion of one vehicle lifetime. Field test conclusion: FPF cushioning has proved to be the most durable seating material even in exceptionally high-use vehicles.

With the trend toward deep-foam seating in automobiles, controlling transmissivity has taken on new importance. Key to controlling transmissivity is to lower the foam resonance to a frequency below the critical human discomfort level while avoiding the natural frequencies of the vehicle.



An ARCO Chemical study presented at SAE (February 1996) indicates that TDI foam is effective at dampening vibration waves at typical highway speeds.

Studies show that the cost of recovery is reduced when seats are designed of molded foam without springs, fasteners and encapsulating frames. Cost of recovering a molded foam seat is currently about one-third the cost of recovering materials from combination seating.

A major thrust of the FPF industry is to develop an infrastructure to remove foam from scrapped vehicles before they are shredded. Another objective is to explore applications and test how recovered foam can be used in new seating. In fact, there are new vehicles on the market today that contain recycled foam.

In a major breakthrough in methods of recovery, polyurethane foam can be separated after shredding. The proprietary process removes the foam from the automotive shredder residue and cleans it to remove contaminants, oils, dirt and metal. After cleaning, the foam is dried and baled. The process produces small foam chunks that meet requirements of the rebond (bonded foam) carpet cushion market.

There are several options for recycling polyurethane foam. The floor covering industry is a ready market for recycled foam for use as carpet padding. Scrap foam is shredded into small pieces and placed in a processing unit with a chemical adhesive to produce rebond carpet cushion.

Another possibility is to shred the used foam components and introduce them back into the automotive seats as filler material or other components. For example, one of today's popular auto models contains a carpet padding/insulator component made from recycled foam.

It also is possible to return the foam back into its original raw materials by using appropriate chemical solvents.

A final option is energy recovery, burning the used foam as fuel to satisfy industry's energy needs. Energy recovery is widely used in other parts of the world but seldom in the U.S. where burning scrap materials is not generally considered recycling.

The American Plastics Council is currently working on the issue of energy recovery as an acceptable method of recycling.

Economies of recovery allow companies to create new profit centers while protecting the environment, a strong incentive to recycling. Also, industry will likely place greater emphasis on reuse of foam from vehicular seating as the United States moves to be in step with environmental concerns and requirements of the European community.

Safety Sets Criteria for Aircraft Seating

Flame resistance is the first consideration in specifications for aircraft seating. While weight of components that impact fuel efficiency is a concern for the airlines and comfort is a criteria for passengers, standards and regulations for the use of flexible polyurethane foam in aircraft seating are determined by the Federal Aviation Administration. Safety comes first. Federal Aviation Regulation (FAR) 25.853 sets the specifications for aircraft seating.

Commercial airlines are stewards of the regulations, or FARs, and exercise significant influence over the manufacture of airline seating.

Three basic techniques are used to meet composite and stand-alone flammability standards:

1. Using flexible polyurethane foam in combination with a fireblock.

In this process foam is wrapped with a special cover fabric that resists fire. The reinforced fabric serves as a shield, making the foam more difficult to ignite or to burn less rapidly.

2. Creating firehard foam with the addition of special additives.

Combustion modifying additives such as chlorinated phosphate esters or melamine are added during the foaming process to produce a product that is more resistant to ignition.

3. Graphite Impregnated Foam (GIF).

This relatively new technology produces a foam that can meet FAR 25.853 with minimal fire-blocking. By eliminating the fireblock fabric GIF modified foams can be priced competitively.

For corporate and general aviation aircraft GIF seating is becoming an important method for controlling flammability. Manufacturers of this type of aircraft are typically smaller and are able to respond more quickly to new technology. They readily recognize the merits of investing in a product that provides long-lasting comfort as well as meeting required safety. GIF technology also allows the design and fabrication of complex, comfortable and aesthetically pleasing seating for private aircraft.



While GIF foam seating promises the possibility of eliminating the need for fireblock fabrics, there are tradeoffs. When the fireblock is removed, comprehensive composite flammability testing will be required on each new seat design. Total fabricated seat weight may also change.

Seat design issues with commercial airlines become very complex. In addition to safety and comfort concerns, total seat weight can affect bottom line economics. For a commercial aircraft that contains hundreds of seats, a difference of a few pounds per seat can make a long term impact on fuel economy and operating costs. As commercial carriers restructure to minimize expenses, seat manufacturing costs are also under scrutiny. Since how seating comfort relates to airline profits has yet to be measured, seat production costs are often weighed against the benefits of fuel economy and seat durability. FPF that is light in weight, meets stringent safety requirements, in addition to providing lasting

comfort, will become increasingly important as the aircraft industry strives for value and profitability in the 21st century.

Marine Applications Mandate Durability and Comfort

Among both manufacturers and end-users, durability is a major concern. Materials must give long service and still allow designers to create the fashionable interiors that boat purchasers demand. Higher density and high performance foam formulations allow design versatility in cushioned surfaces that stand up to rugged wear and ever-present moisture.

Although FPF is inherently resistant to mold and mildew, antimicrobial compounds are added to ensure long service in the moist atmosphere of marine applications.

HR foams fulfill the requirements of boat manufacturers for comfortable, durable seats and berths. HR foams, with their high support factor and greater surface resilience, provide proper support and cradle the body even when installed over a solid decking.

Index to More Information

For in-depth information discussed briefly in "Flexible Polyurethane Foam in the Transportation Industry," see these issues:

"Support," "Comfort" and "Durability" and "Properties That Affect Foam Performance" — **Volume 1, Number 1**

Types of Fabrication (slabstock and molded) — **Volume 1, Number 5**

Foam Recycling and Bonded Carpet Cushion — **Volume 4, Number 1**

NOTE: The contents of this issue have been digested from a paper entitled, "Flexible Polyurethane Foam: Applications in the Transportation Industry." You may request a copy of the complete paper from PFA offices.

Transportation Industry Terminology

You may want to copy this section and save it for future reference by attaching it to the inside back cover of your PFA Flexible Polyurethane Foam Glossary. You can obtain a free copy of the PFA Glossary by writing the Polyurethane Foam Association, PO Box 1459, Wayne, NJ 07474-1459, or calling 201/633-9044.

Creep: The amount of settling or compression that occurs in foam over an extended period of use, such as a long auto trip.

Dynamic Modulus: The "felt" firmness of polyurethane foam during small amplitude vibration such as experienced in a moving vehicle.

Dynamic Hysteresis: The in-use measurement of the dampening properties of foam for small amplitude vibration. Measured by indenting foam samples and evaluating recovery of firmness.

H-Point: Safety measurement for adequate visibility in transportation driver side seating. Measurement of driver height influenced by creep, modulus and hysteresis.

GIF: A recent technological development widely used in private aircraft Graphite Impregnated Foam resists combustion and retards fire without compromising performance of the cushioning.

Transmissivity: In private and commercial transportation seating systems, the amount of vibration transferred through the seating platform to the driver or passengers.



Summary

Flexible polyurethane foam (FPF) can be produced in an almost unlimited variety of formulations to meet requirements of the transportation industry. Polyurethane foam is the material of choice for seating in private and commercial vehicles because of its durability, comfort and design versatility. Use of polyurethane foam allows manufacturers to achieve aesthetic and ergonomic objectives while practicing cost-effective production methods. Following are some of the current developments and benefits of flexible polyurethane foam in vehicular seating.

- ▶ 1. New methods make it possible to combine high resiliency for safety and comfort with characteristics to control transmissivity.
- ▶ 2. Trend to deep-foam eliminates spring components, reduces weight and cuts production time.
- ▶ 3. Springless seating makes recovery process for recycling quicker, easier and much less costly.
- ▶ 4. Absence of springs places greater emphasis on foam to dampen vibration produced by dynamics of the vehicle and irregularities of the roadbed.
- ▶ 5. A laboratory scale model has been developed to evaluate foam technologies and their ability to control transmissivity, dynamic modulus and dynamic hysteresis.
- ▶ 6. HR foam provides lasting support and comfort in springless seating and in applications over hard decking, such as in boats.

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.

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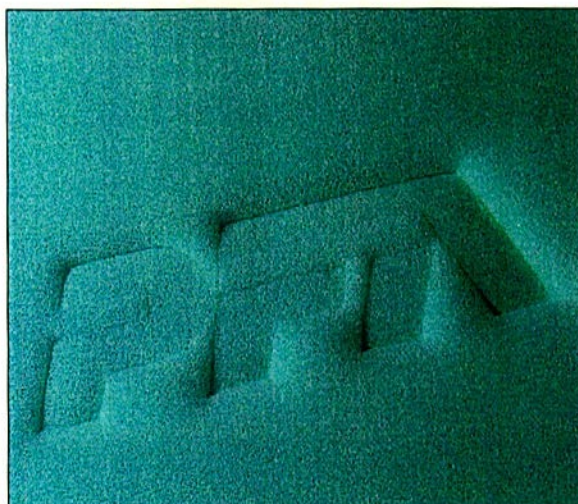
INFORMATION ON FLEXIBLE POLYURETHANE FOAM

IN•TOUCH® is a regular publication of the Polyurethane Foam Association (PFA). It covers topics of interest to users of flexible polyurethane foam and is designed as a quick reference for background information on key issues. To get more detailed information about a particular topic, consult a PFA member.

Examining viscoelastic flexible polyurethane foam

Viscoelastic foam, also known as memory or temper foam, was first commercialized during the mid 60's as a result of NASA's AMES Research technology transfer program. This open-cell variety of flexible polyurethane foam (FPF) was distinguished by properties allowing it to redistribute the G-Force suffered by astronauts during take-off and re-entry, and providing commercial pilots a more comfortable seating surface during long flights.

Although viscoelastic foam production technology has been available for more than 35 years, commercial products have only recently been made widely available to consumers. Viscoelastic pressure distribution performance represents one of the most significant comfort innovations from the FPF industry.



Viscoelastic foam is characterized by slow recovery after compression. Its ability to closely contour to shapes allows surface pressure to be distributed over a wide area.

Characteristics

Viscoelastic foam is typified by its slow recovery after compression. When a weighted object (for example, the human body) is positioned on viscoelastic foam, the foam progressively conforms to the shape of the object, and after the weight is removed, the foam slowly reassumes its initial shape. Due to this gradual recovery, viscoelastic foam also can be described as "slow recovery" foam.

Other characteristics include viscoelastic foam's ability to dampen vibration as well as absorb shock. This latter performance characteristic is confirmed in the laboratory using ball rebound tests. Ball rebound of less than 20% (compared to 50% – 60% with other varieties of FPF) supports the description of viscoelastic polyurethane foam as "dead" or "low-resilience" foam, in that it lacks the surface "springiness" of other FPF products. In fact, certain viscoelastic foam products claim to absorb up to 90% of impact. While lack of resilience may appear to be a disadvantage, as discussed later, a "dead" foam can be highly desirable in some applications.

In addition to these key advantages, many viscoelastic products also react to body temperature and ambient temperatures, softening with heat and more easily adjusting to body contours.



Moldable viscoelastic ear plugs are examples of how viscoelastic foam provides high-value performance with attractive economics.

Benefits & Applications

Viscoelastic foam's unique physical characteristics have led to its popularity in the bedding and medical industries. Due to its conforming aspect, viscoelastic material makes for a comfortable yet supportive mattress or mattress pad, and its low resilience works well in bed pillows. People with impaired mobility, confined to wheelchairs or hospital beds (especially burn victims) can benefit from the foam's capacity to redistribute weight and surface pressure, potentially reducing decubitus ulcers (bed sores) caused by aggravated pressure between the skin and bony areas of the body such as beneath heels, hips, elbows and the back of the head. If pressure is not relieved through body movement or technology, such as a viscoelastic foam surface, blood vessels may compress, inhibiting circulation and possibly irritating the skin tissue.

Aside from bedding and medical purposes, viscoelastic material can be used in standard household furniture (stationary or motion), office furniture, and in

some vehicle seating applications. It can cushion sports equipment, power tools, and footwear. Viscoelastic foam has also found utility in ergonomic applications such as neck, back and leg pads, as well as in arm and wrist rests for computers.

It can act as shock protection within electronics equipment and has been used in specialty packaging, military and commercial aircraft seating, and weaponry (for recoil suppression).

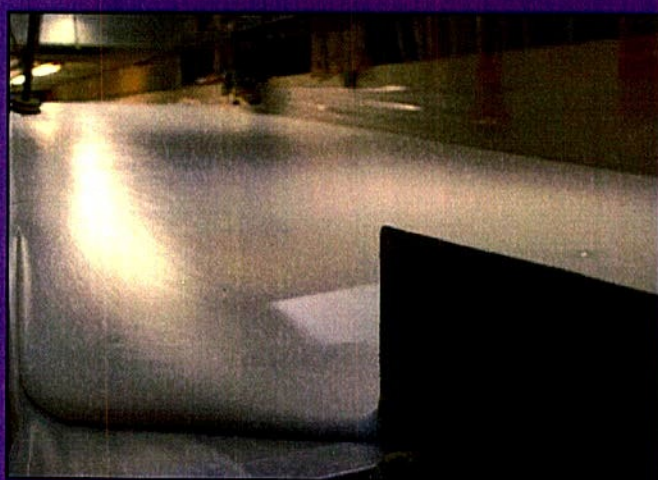
Why isn't viscoelastic foam used in more cushioning applications

With such valuable attributes, it would seem that viscoelastic foam products should be found in many more comfort cushioning applications. Unfortunately, production economics often restrict end-use applications. Unlike traditional foam processing, viscoelastic formulation flexibility is more restrictive. Raw materials must be carefully altered to generate foam with varying properties. Cutting, profiling and other fabrication techniques may also require more care due to the slow recovery aspect of the foam. These considerations certainly affect product economics.

Production

Formulating and Processing

While formulating and processing can be challenging, foam manufacturers and chemical suppliers have worked together to develop a range of successful viscoelastic products. For instance, certain formulations can alter the foam's recovery, elasticity, and firmness, giving it the ability to meet a diverse set of end-use needs. Because viscoelastic foam is hypersensitive to formulation, the challenge focuses on maintaining product performance consistency. This requires a close working relationship between FPF manufacturers and their raw materials suppliers. With careful attention to quality control procedures, end products can meet or exceed application performance requirements.



Viscoelastic foam can be manufactured using conventional flexible polyurethane foam slabstock and molding processing equipment.

Fabricating Considerations

Commercial slitters and saws can be used to fabricate viscoelastic foam. However, in most cases viscoelastic foam must be cut at a much slower rate than conventional foam due to its slow recovery characteristic. Cutting machines are capable of processing conventional FPF products at up to 150 feet per minute, but with viscoelastic foam, table speeds are commonly slowed to as low as three to seven feet per minute, depending on the softness of the material. Of course, slower fabrication reduces output and can affect product economics.

Fabrication of viscoelastic products mostly relies on horizontal and vertical cutting. Slow recovery products also can be convoluted and profiled, but there are limitations. Viscoelastic foam usually does not recover before it hits the blade; therefore the "dimples" are not as pronounced as with conventional convoluted or profiled FPF products.



Although fabrication speed for viscoelastic foam may be slower than with conventional FPF, a wide range of product designs can be produced.

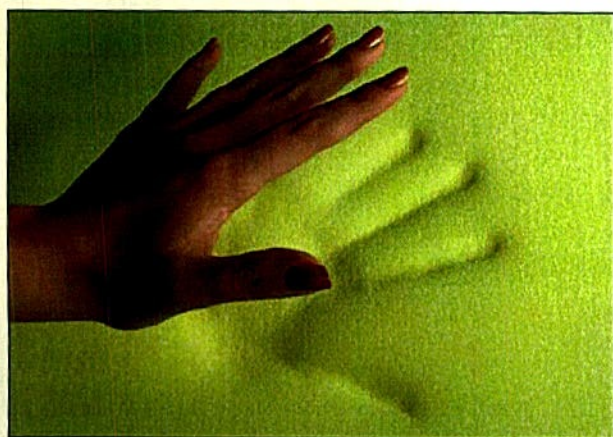
Physical Properties

Density

As with all FPF, the density for viscoelastic foam is the weight of one cubic foot of material measured in pounds. With conventional FPF formulations, a higher foam density generally equates to increased foam durability (retention of performance properties). The same is true of viscoelastic products. Density enhances durability and the ability of viscoelastic foam to maintain its physical performance. Viscoelastic foam found in most household and healthcare product applications typically ranges in density from 2 to 6 pounds per cubic foot (pcf).

Firmness

Normally, firmnesses of viscoelastic foams can range from supersoft (less than 10 lbs. @ 25% IFD) to semi-rigid (as high as 120 lbs. @ 25% IFD). The potential for surface pressure reduction is closely associated with firmness, and can vary based on the formulation. Viscoelastic products with a



The potential for surface pressure reduction is affected by foam firmness and recovery speed.

lower IFD tend to exhibit increased conformance and can distribute body weight more efficiently to alleviate pressure. However, if the IFD is very low, and there is not sufficient foam density or thickness to provide support, the product may "bottom out," negating the benefits of pressure reduction. When performing IFD tests, firmness measurements of viscoelastic products can be significantly affected by some of the foam's key characteristics: rate sensitivity (the foam's rate of recovery after compression), sensitivity to temperature, and sensitivity to humidity. Sample conditioning prior to testing is extremely important.

Rate Sensitivity

Viscoelastic foam rate sensitivity, observed as the speed that a foam sample recovers after compression, affects the way firmness (IFD) can be determined in laboratory tests. Because of rate sensitivity, when testing viscoelastic foam under load, as in IFD measurement, the speed at which the weight force is applied can alter firmness readings. In other words, if the indentation plate used in the test descends quickly, the foam may respond with stiffness, whereas slower speeds may result in different IFD measurements. With viscoelastic products, IFD tests should show notation of the process speed (rate of deflection) being used so that valid and fair comparisons among foam grades and between laboratories can be consistently made.

Sensitivity to Temperature

The physical properties of viscoelastic foam can be greatly influenced by temperature. Even slight changes in room temperature can affect measured firmness and recovery rates. Recovery rate has been positively correlated to heat, so that as the foam increases in temperature, pliability and compression and recovery rates increase. In colder conditions, viscoelastic products tend to become firmer or even stiff. Depending on the formulation, some viscoelastic products can maintain their "memory" feature at as low as 30° F, but the optimum range for best "memory" action is typically between 55° F and 85° F. Research is ongoing to find ways to moderate pliability and allow viscoelastic products to perform within a broader spectrum of temperatures, especially below freezing. This is especially important in vehicle seating and other applications where ambient temperature cannot be controlled in use.

In testing viscoelastic foam performance characteristics, it is also important to make notation of the ambient temperature and be certain that all comparison testing be performed under like conditions. Sample must be conditioned prior to testing.

Heat (even body heat) can soften viscoelastic materials and, in extreme situations, affect the foam's ability to provide support. This process is known as a phase change or relaxation. Rather than broadening the temperature range at which viscoelastic foam retains its slow recovery, foam formulation can be adjusted to narrow the temperature span at which phase change occurs, anticipating the influence of room temperature combined with body temperature. In other words, if the phase change occurs at lower temperatures, its reaction to added body heat could lessen its firmness to the point where support is lost. On the other hand, if the phase relaxation were to happen in warmer conditions, added body heat would not be enough to soften the foam, and the resulting foam rigidity would reduce the potential for pressure relief. Hence, careful control of the phase change characteristics is crucial for the foam to serve its pressure reduction purpose and to provide predictable support.

Sensitivity to Humidity

Not only does viscoelastic foam react to temperature but also to humidity. Viscoelastic products tend to soften in more humid conditions. For example, very pliant foam may feel slick or "buttery" as opposed to coarse, depending on the humidity. Surface feel is generally not a critical factor in end-use applications, because in almost all cases, the foam is enclosed inside a covering material that provides its own surface feel.

Firmness that changes with ambient conditions can make accurate calculation of physical properties difficult.

Performance Testing

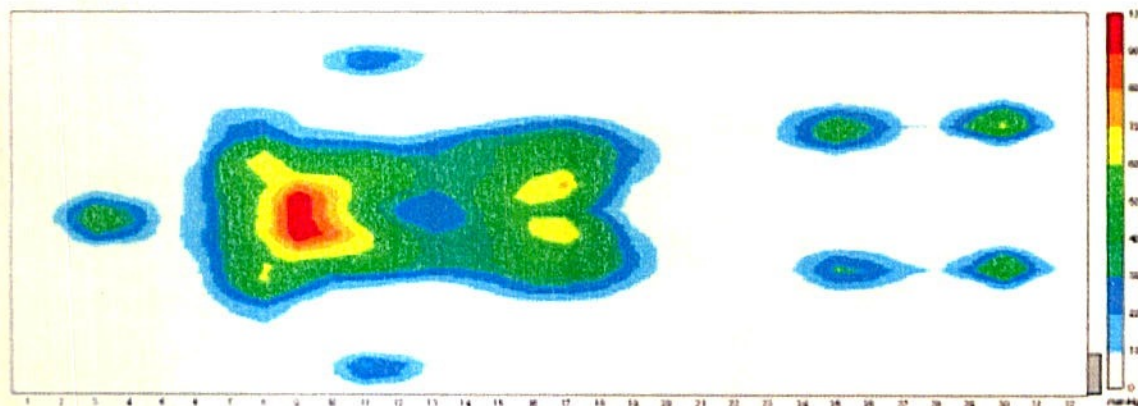
Pressure Reduction and Pressure Relief

Because viscoelastic foam can closely conform to the shape of the human body, it can efficiently distribute pressure over the whole surface. Pressure-mapping equipment is often used to calculate the degree of weight distribution. During the mapping procedure, computer programs monitor pressure. The body's impression is graphed to show which areas endure the most pressure (namely the shoulder blades, posterior region, head, heels, calves, and elbows).

Some viscoelastic foam producers perform these tests as an indication of how well the foam might act to minimize pressure. In the healthcare area, to be labeled as providing "pressure relief," readings must be at 32mmHg or lower, whereas "pressure reduction" performance is agreed to occur between 32mmHg and 50mmHg. The adjacent charts help illustrate the process and show some typical pressure readings for viscoelastic foam. When readings made on viscoelastic products are compared to those of conventional foam and other common cushioning surfaces, the pressure differences are notable.

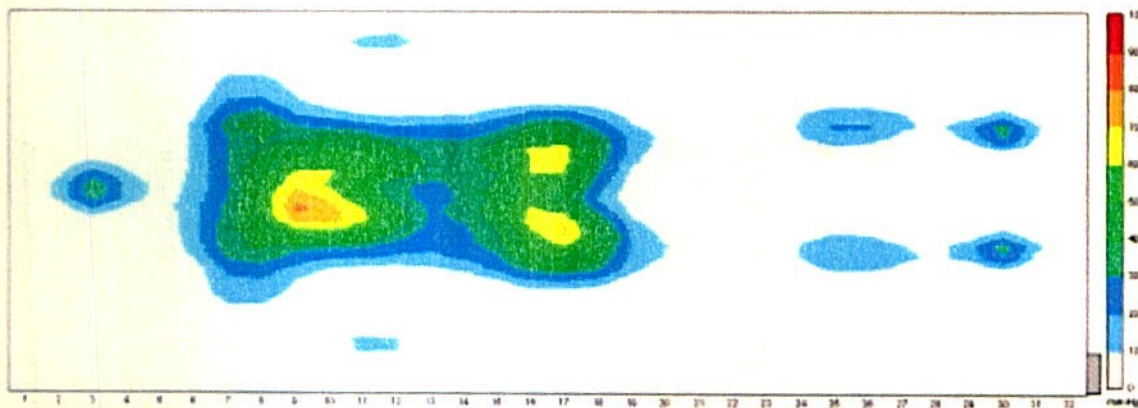
1.8 pcf Density
20 pcf IFD

Conventional Flexible
Polyurethane Foam



3 pcf Density

Viscoelastic
Polyurethane Foam



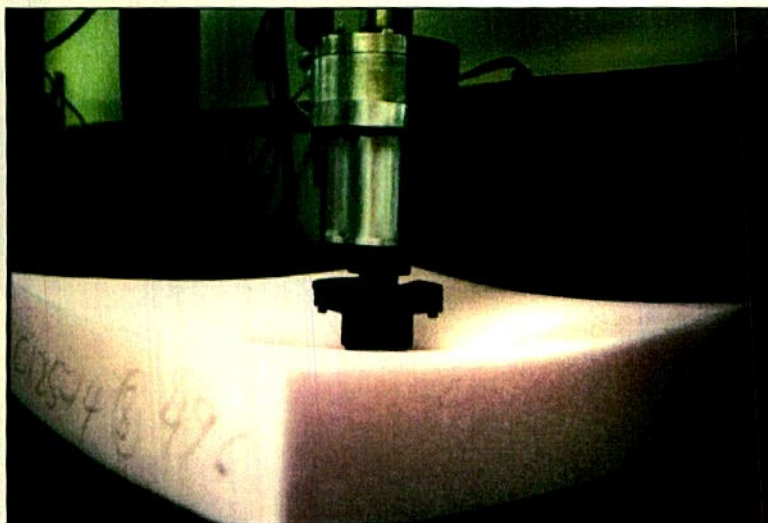
Pressure map comparison using 2" thick foam samples mounted on top of a rigid board covered with a 3" thick layer of 1.6 lbs density conventional foam with 40 IFD as a standard test foundation.

Test Samples: 2" thick slab of 1.8 pcf density conventional flexible polyurethane foam
2" thick slab of 3 pcf density viscoelastic polyurethane foam

Test subject: Male 67" height 195 lbs weight

Resolving Testing Procedures

With the unique nature of viscoelastic foam performance, some traditional FPF test methods do not produce consistent results. For example, measuring durability with the use of a Dynamic Pounding Fatigue Test procedure can be problematic. Due to the foam's slow recovery characteristic, pounding fatigue data loses validity because the foam has not fully recovered in between each cycle. Compression set testing may provide a better measurement of viscoelastic foam durability.



Work is underway to revise some of the standard testing procedures to accommodate viscoelastic slow recovery characteristics.

The foam industry uses IFD measurements to quantify FPF firmness. Unfortunately, IFD testing may not accurately evaluate viscoelastic foam firmness because the foam relaxes during the one-minute hold period before taking the IFD reading. Due to rate sensitivity and other factors, standard IFD testing procedures used throughout the industry are not completely understood and may not accurately measure the firmness characteristics of viscoelastic products.

Recognizing both the demand for consistent measurement of viscoelastic product performance properties and the importance of resolving standardized testing concerns, Polyurethane Foam Association members formed a technical task group to consider these issues. Problematic testing issues have been identified, and, through experimental testing and group testing verification, new test standards may be developed for use with viscoelastic products.

Environmental Considerations

As with any product, off-gassing naturally occurs. The formulation technologies used to produce viscoelastic foam products sometimes create the potential for more noticeable aromatic emissions than typically found in conventionally manufactured foam products. While not harmful, residual odor may be bothersome to some consumers. Therefore, it is advisable to thoroughly ventilate viscoelastic foam products prior to final product assembly.

In terms of environmental manufacturing objectives and recyclability, the production of viscoelastic foam is a friendly addition to a very environmentally conscious industry.

Flammability Considerations

Viscoelastic foam can be manufactured to perform with varying degrees of ignition and combustion resistance. Typically, with the addition of flame retardants, viscoelastic products can be produced to satisfy small open flame tests such as Calif. TB117 and FMVSS 302 and can be combined with barrier materials in mattresses designed to comply with other composite-type flammability specifications. As is the case with all flexible polyurethane foams, great care should be taken to avoid contacting a viscoelastic product with an ignition source such as a lit match or candle, heating element, sparks, exposed electrical wires, an exposed light bulb or smoking materials. Once ignited, all flexible polyurethane foams have the potential to burn vigorously, emitting great heat and dense smoke.

Summary

Viscoelastic foam technology represents new and exciting developments for the FPF industry. It is taking hold in a variety of markets (from medical to bedding to technical applications and more) and offers a unique cushioning alternative to conventional and HR flexible polyurethane foams. Its performance in specialized end-use applications has been well received by consumers. Ongoing industry and individual efforts are focused on improving the control of viscoelastic foam's performance, so that more successful applications can be developed for this unique cushioning, pressure distribution and shock absorbing material.

- ▶ 1. Viscoelastic foam is a type of open cell, flexible polyurethane foam.
- ▶ 2. Surface comfort and pressure distribution are closely related to the foam's ability to conform to body shape.
- ▶ 3. Slow recovery adds comfort characteristics, but also complicates the testing of viscoelastic products.
- ▶ 4. Viscoelastic foam firmness, support and height recovery rate are often affected by temperature and humidity.
- ▶ 5. Comparative laboratory testing must match ambient testing conditions for accurate comparisons and replicability of test results.
- ▶ 6. Some standardized FPF performance testing procedures may require special considerations to accommodate viscoelastic's slow recovery rate.
- ▶ 7. Viscoelastic products should be thoroughly ventilated after production and during fabrication to reduce the possibility of bothersome aromatic emissions.
- ▶ 8. Viscoelastic performance is a matter of taste. Some like it fast and some like it slow.

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 viscoelastic products, contact a member of the Polyurethane Foam Association.

Manufacturing Members of the Polyurethane Foam Association include:

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Flex Foam	Phoenix, AZ	Products Division	Fort Worth, TX	Vita, Inc.	High Point, NC
Foamex International, Inc.	Linwood, PA	North Carolina Foam Industries, Inc.	Mount Airy, NC	Wm. T. Burnett, Inc.	Jessup, MD
Future Foam, Inc.	Council Bluffs, IA	Plastomer Corporation	Livonia, MI	Woodbridge Foam Corporation	Mississauga, Ont.

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Preparation of Molded Viscoelastic Polyurethane Foam for Pillow Applications

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Received: 18 May 2010, Accepted: 2 March 2011

SUMMARY

There is a growing interest in developing and commercializing viscoelastic polyurethane foam suitable for pillow and mattress applications. In the present investigation, a novel combination of polyols with different molecular weights and hydroxyl values along with other ingredients were used for the preparation of viscoelastic polyurethane foam. The optimum polyol:isocyanate ratio was found to be 100:45 to yield a good quality foam. The physico-mechanical properties of the foam were measured as per standard procedures and compared with those of a commercially available viscoelastic foam sample. It was observed that the properties of the foam from this investigation were almost similar and in some aspects better than the properties of commercially available pillow foam. The foam can be further developed to make it suitable for hospital pillows and mattress applications.

Keywords: Viscoelastic foam, physico-mechanical properties, ball rebound resilience

INTRODUCTION

Polyurethane foams find wide uses in many engineering applications because of the degree of comfort and protection which are not achievable with many

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competitor materials [1]. Viscoelastic foams are a special type of flexible polyurethane foams which exhibit low resilience (LR) and slow recovery (SR) after compression. When a weight is applied on viscoelastic foam, the foam progressively conforms to the shape of the object, and after the weight is removed, the foam slowly reassumes its initial shape. Because of this gradual recovery, viscoelastic foams are described as "SR" foams. Other characteristics include its ability to damp vibration as well as to absorb shock. In addition to these key advantages, many viscoelastic products also react to body temperature and ambient temperature, softening with heat and more easily adjusting to body contours [2]. Viscoelastic foam was first invented for NASA's space programs in the mid 1960s, in order to reduce pressure points experienced by astronauts [3]. Pillows and mattresses made of viscoelastic foam have a unique characteristic of keeping the neck and head level with the spine and help patients who suffer from constant neck pain or headaches to get rid of the pain. Defloor et al. [4] studied the effective use of viscoelastic mattress to reduce the number of pressure ulcer lesions in different patient groups. Today, viscoelastic foams are widely used in comfort cushioning, packaging, bumper pads, sport and medical equipment, mattresses, helmet liners, pilot seats, earplugs, and for various noise and vibration dampening applications [5].

Several different chemical approaches were adopted by various researchers for the manufacture of viscoelastic foams. Kageoka et al. [6] has developed novel polyols for viscoelastic foams with reduced temperature sensitivity. The viscoelasticity of the polyurethane foams can be controlled by controlling the molecular weight distributions and functionalities of the reacting polyols and isocyanates [7]. The other routes for achieving viscoelastic polyurethane foam include use of the following, either singly or in combination: low molecular weight crosslinkers, blends of high and low molecular weight polyols, mixtures of polyols with different ethylene oxide content, use of alkoxylated alcohols, variation of the isocyanate index, introduction of plasticisers, building interpenetrating polymer networks (IPNs) and blending polyurethanes with other polymers [8]. In the present investigation, a novel mixture of low and high molecular weight polyols with different functionalities was used to achieve low resilient, slow recovering viscoelastic foam suitable for pillow applications.

EXPERIMENTAL

The materials and methods used in the present study are summarized below:

Materials

Polyols

A combination of diol and triol initiated polyether polyols with different molecular weights and OH numbers was used in the present investigation. Grafted copolymer polyol containing polystyrene and poly acrylonitrile (CS 540) supplied by Kumho Petrochemicals, Korea, was also used in the present study to impart the required hardness and load bearing properties. The polyols used in the present investigation are summarized in **Table 1**.

Table 1. Polyols used in the formulation

Polyol	Initiator	Functionality	OH Value (mg KOH/g)	Molecular weight Mw(g/mol)
Polyol -1	Glycerine	3	35	4750
Polyol -2	Glycerine, Dipropylene glycol	2.5	568	1450
Polyol -3	Dipropylene glycol	2	28	4050
Polyol -4	Dipropylene glycol	2	112	1002
CS 540	-----	-----	22.5	-----

Surfactants

Silicone surfactants are used in polyol formulations to increase the miscibility of the additives, to stabilize the foam and to control the cell morphology. The surfactant used in the present study is a mixture of L660 and L618 (Momenive Performance Materials, USA).

Catalyst Package

The catalyst package consists of DABCO 33 LV (Air Products Inc.), NIAX A-1 (Momenive Performance Materials, USA) and MP 602 (Air Products Inc.).

Crosslinker

The crosslinker used was Niox processing additive DP 1022 (GE advanced Materials, USA).

Isocyanate

Wannate 8102, a mixture of polyol-modified diphenylmethane diisocyanate and polyphenylmethane polyisocyanate supplied by Yantai Wanhua Polyurethanes

Co. Ltd., China was used in the present investigation. The NCO content of the isocyanate was 27%, hence its equivalent weight was 155 g/eq.

Blowing Procedure

Hand Mixing

The polyols, catalysts, water and other chemicals were measured into a 500 ml plastic cup and mixed at $25 \pm 1^\circ\text{C}$ using a bench mixer (Mars, USA) at 4500 rpm for 10 minutes. The required amount of isocyanate, maintained at $25 \pm 1^\circ\text{C}$, was then added to the blended polyol, and the mixture was thoroughly stirred for 5 seconds. This mixture was then immediately poured into a 2 liter plastic cup. Cream time, string-gel time, rise time and free rise density (FRD) were noted. Test blocks of dimension 375 x 375 x 100 mm were then molded using a MS mould kept at 50°C . The foam pieces were de-molded after 4 minutes of curing and were used for testing of various physico-mechanical properties of the foam.

Machine Mixing

The polyol blend was prepared in a 100 kg drum by adding the required quantity of polyols and other ingredients. The blend was mixed thoroughly for 60 minutes using a heavy-duty stirrer (RQ 134 S/D, Remi Motors) with a speed of 4000 rpm. The polyol and the isocyanate were then loaded into a high-pressure foaming machine (A 20, Cannon, Italy). The foam was poured using a 2000-3500 psi injection pressure at a throughput of 200-300 g/s into an aluminum pillow mold (80 x 41 x 17 cm) heated at 50°C . The pillow was demolded after 5 minutes and kept at 22°C for cooling.

Mechanical Property Measurement

The physico-mechanical properties of the foam such as density, indentation force deflection (IFD) behavior, tensile strength, tear resistance and resilience (ball rebound) were measured as per the methods described in ASTM D 3574 - 05. These properties were compared with the properties of commercially available viscoelastic pillow foam sample Blissco™ [supplied by Sreeram Foams Ltd., Chennai, India].

RESULTS AND DISCUSSION

Optimization of the Polyol Formulation

Various trial and error based experiments were carried out in order to optimize the formulation of the polyol system, which can produce a low resilient, slow recovery viscoelastic foam. The optimized formulation is given in **Table 2**. Patent application is currently in progress [9]. The amount of isocyanate required to react with the polyol and any other reactive additives in the formulation, plays an important role in deciding the viscoelasticity of the resulting foam. In the present investigation, the parts by weight (pbw) of the isocyanate required for 100 pbw of polyol mixture was calculated using the following equation:

Pbw of MDI required =

$$\left(\frac{\text{pbw polyol A}}{\text{eq.wt. polyol A}} + \frac{\text{pbw polyol B}}{\text{eq.wt. polyol B}} + \dots + \frac{\text{pbw polyol N}}{\text{eq.wt. polyol N}} + \frac{\text{pbw H}_2\text{O}}{\text{eq.wt. H}_2\text{O}} \right) (\text{MDI eq.wt}) \quad (1)$$

The pbw of isocyanate required as per the above equation was 89 and was taken as 100 index. The reactivity profile of the polyol at 100 index was determined using the cup test and it was observed that the reaction was very fast with cream time of 3 seconds and free rise density (FRD) of 120 Kg/m³. In order to slow down the reaction and to reduce the FRD, the index was varied from 50 to 100 and the bench properties of the polyol at these indices were determined and summarized in **Table 3**. As expected, the

Table 2. Optimized formulation of polyol blend

Ingredients	Parts by weight (pbw)
Polyol -1	10-30
Polyol -2	20-40
Polyol -3	10-20
Polyol -4	20-40
CS 540	5-15
Surfactants	1.0-2.5
Catalyst Package	1.5-3.0
Crosslinker	1.0-3.0
Water	1.0-3.0

reaction time was found to increase and FRD was found to decrease with decrease in isocyanate index. The variation of various bench properties with isocyanate index is graphically shown in **Figure 1** and **Figure 2**. It was found that 50 index, or in other words, a polyol:isocyanate ratio of 100:45 gave an optimum set of bench properties and a foam with very good viscoelastic characteristics.

Table 3. Reactivity profile (bench properties) of the polyol system

Bench Properties	50 Index (100:45*)	60 Index (100:54*)	100 Index (100:89*)
Cream time (seconds)	8	6	3
Gel time (seconds)	62	45	32
Rise time (seconds)	70	50	41
Free rise density (Kg/m ³)	65	98	120
*(Polyol:Isocyanate)			

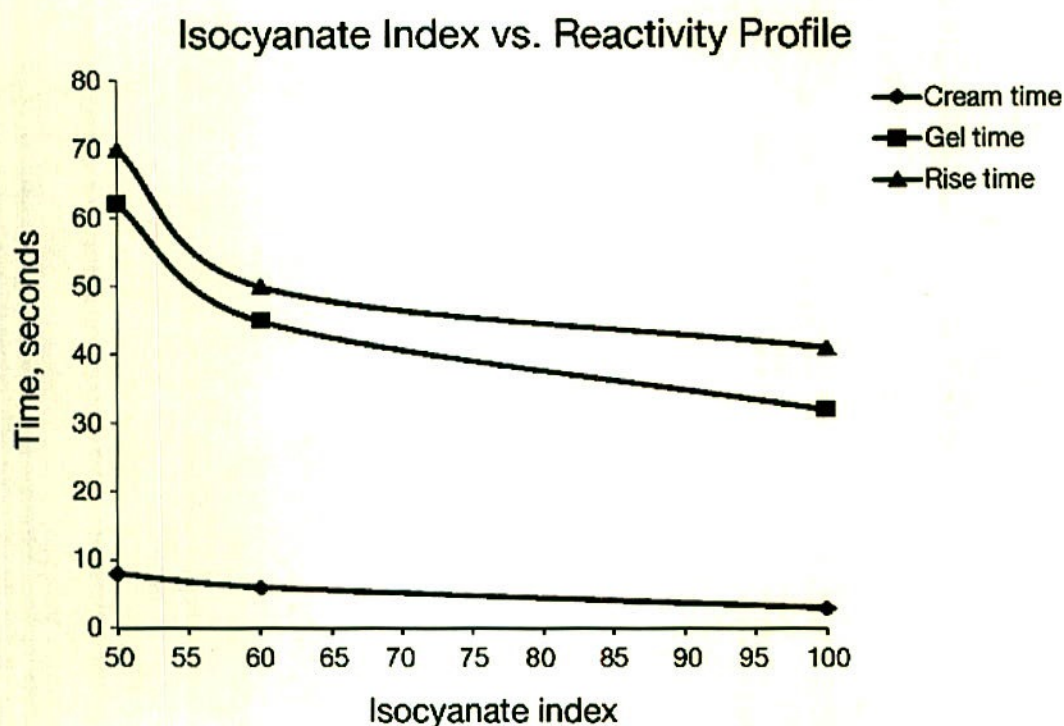


Figure 1. Effect of isocyanate index on reactivity profile of polyol

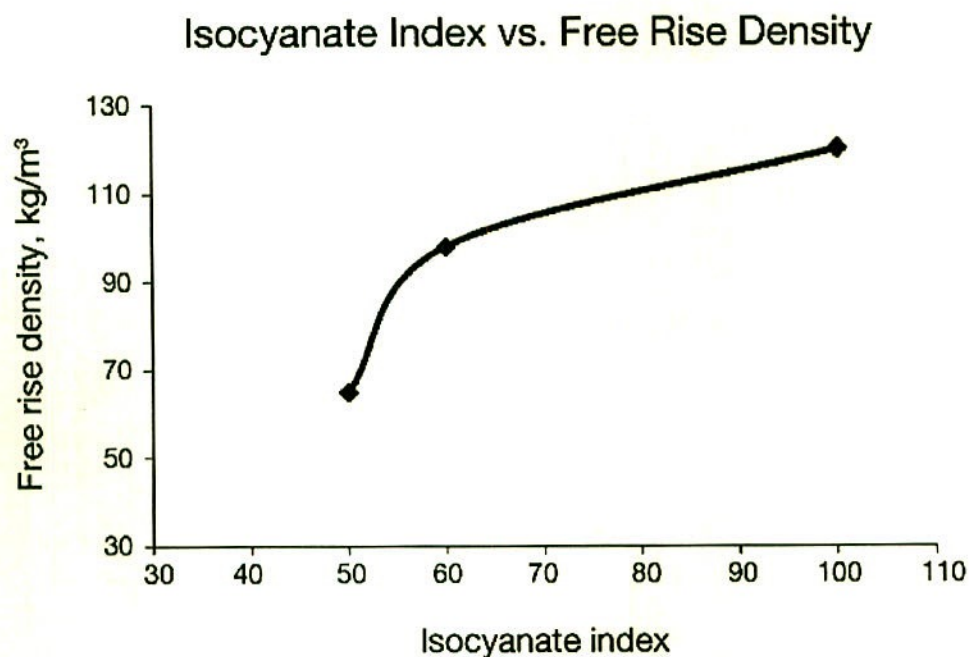


Figure 2. Variation of free rise density with isocyanate index

Mechanical Properties

The density of the molded foam was varied from 65 kg/m³ to 70 kg/m³. Viscoelastic foam mattresses and pillows are usually denser than other types of flexible foam available in the market. This makes it more supportive to the body contours, especially neck and shoulders. The density and other mechanical properties of commercially available viscoelastic foam pillow sample were measured and compared with the foam in the present investigation. The results are summarized in **Table 4**. Tensile strength, tear strength and elongation values were almost similar for both foams. Firmness or the comfort of the memory foam is measured by IFD rating. The cushioning quality is determined by measuring the sag factor (ratio of 65% IFD to 25% IFD). A value more than 2 indicates resistance to bottoming out. The degree of viscoelasticity and the energy dissipation characteristics are estimated by the ball rebound (BR) resilience values. The lower the BR value, the higher the degree of viscoelasticity in the foam [10]. The foam samples from the present investigation showed a rebound resilience value of 3%, whereas the value for the commercially available sample was 5%. The time taken by the foam to return to 95% of its original height after being compressed for one minute to 25% of its initial height was used to indicate the memory character of the specimens [11]. In this aspect also the foam developed in the present study was found to be better than its commercially available counterpart.

Table 4. Physico-mechanical properties of the viscoelastic foam

Properties	Samples from the present study	Samples from Blissco™
Density (Kg/m ³)	65-70	65
Tensile strength (Kg/cm ²)	1.13	1.20
Elongation (%)	124	128
Tear Strength (Kg/cm ²)	0.68	0.62
IFD at 25% (Kgf)	3.25	3.42
IFD at 40% (Kgf)	4.51	4.62
IFD at 65% (Kgf)	8.73	8.68
Sag Factor	2.69	2.54
Rebound resilience (%)	3	5
Time to return 95% height	14	10

CONCLUSIONS

A novel viscoelastic polyol blend consisting of different types of polyols and other additives was developed.

The optimum polyol:isocyanate ratio was found to be 100:45 to get a low resilient and slow recovery viscoelastic foams suitable for pillow applications. Foams were prepared both by hand mixing and by using a high-pressure PU dispensing machine.

The physico-mechanical properties of the foam were measured as per ASTM standards and compared with a commercially available viscoelastic pillow sample. Rebound resilience and time to return 95% of original height values were found to be better for the foam developed in the present investigation while all other properties were almost similar.

The foam can be developed further for applications such as hospital pillows and mattresses.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to the management of Manali Petrochemical Ltd., Chennai, India, for their support for the successful completion of this investigation. The authors would also like to thank Mr. M Sivaswamy, Consultant (R&D) and Mr. R Meenakshisundaram, Head (AT/QA), Manali Petrochemical Ltd., for their valuable suggestions during the course of this investigation.

REFERENCES

1. Sims G.L.A. and Bennet J.A., *Polym. Eng. Sci.*, **38** (1998) 134-142.
2. Greco A. and Lionetto F., *Polym. Eng. Sci.*, **49** (2009) 1142-1150.
3. http://www.sti.nasa.gov/tto/Spinoff2005/ch_6.html (accessed on 25-03-2010).
4. Defloor T., Bacquer D.D. and Grypdonck M., *International Journal of Nursing Studies*, **42** (2005) 37-46.
5. Herrington R. Low Resiliency Flexible Polyurethane Foams, Tech Note /Report to WFC, Dow Plastics/Vortex (2000).
6. Kageoka M., Inaoka K., Kumaki T. and Tairaka Y., *PU China 98, Shanghai*, (1998).
7. Kageoka M., Inaoka K., Kumaki T. and Tairaka Y., *Journal of Cellular Plastics*, **36** (2000) 15-27.
8. Parfondry A., *The Polyurethanes Book*. Editors Randall D, and Lee S., John Wiley & Sons Ltd. UK (2002).
9. Krishnaprasad R. et al., Indian Pat. Appl (2010).
10. Farkas P., Stanciu R. and Mendoza L., *Journal of Cellular Plastics*, **38** (2002) 341-354.
11. Hager S., Richard S., Sebastien T. and Faouzi J., *Journal of Cellular Plastics*, **37** (2001) 377-399.