

Material and Design Innovation Techniques for Expanded Polypropylene (EPP) Products Used in Automotive Interior Applications

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ABSTRACT

The use of Expanded Polyolefin foams including Expanded Polypropylene (EPP) material for interior applications has grown over the years to include applications throughout the vehicle. The demand for weight and cost reduction has forced designers to seek out the most versatile material available to satisfy the need for performance, durability, as well as design flexibility. The role of light-weight materials such as EPP has expanded. As such, the design challenges have also enabled the use of EPP in applications requiring energy management, as well as structural, acoustic, and storage/stowage functions.

This paper will review the design guidelines that enable EPP to be used in numerous automotive interior applications. As EPP foam becomes more widely specified, and as the applications become more multifunctional, it is important to understand the potential solutions available to satisfy all aspects of design, performance, quality, and safety.

Recent material developments and innovations allow for EPP to be specified in a wide range of densities, and with a variety of surface finishes and textures, as well as surface properties that allow it to be used in applications subject to NVH (Noise, Vibration and Harshness) requirements, and those requiring material compatibility.

Technical innovations now allow for material optimization, which enable EPP to conform to the stringent performance requirements and BSR (Buzz, Squeak and Rattle) guidelines for today's automotive interiors. Performance can be affected using either mechanical or chemical solutions to satisfy OEM requirements.

This paper will also highlight current production examples of EPP applications and their latest design and performance characteristics. Examples of recent performance studies will be cited; including graining and textured surfaces, acoustic enhancements, low friction solutions, and molded part operational and attachment methods.

INTRODUCTION

The use of Expanded Polyolefin bead foams such as EPP has increased by an order of magnitude over the past 10 years in the automotive industry. The use of EPP has grown from energy absorbing applications in bumper cores to newer applications such as side impact bolsters, knee bolsters, tibia pads, head impact pads and other energy management areas. EPP is also being widely used in stowage and storage systems, trunk and floor spacers. More recently, EPP is being incorporated into seating systems including rear seat risers, seat bolster, seat bottoms, and seat backs and supports. The illustration in [Figure 1](#) shows the use of EPP in automotive applications in 1998 and in 2008.

The flexibility of polyolefin bead foams have enabled the production of a single piece door panel with integrated exterior skin, molded-in substrate, energy absorber, wire harness clips, fasteners, and structural frame all in a single step. Further advances in the past 5 years have allowed for expanded polyolefin bead foams to be combined with several different types of fasteners, as well as inserts and support bars, and other hardware to create a multifunctional component part molded in a single step.

The types of expanded polyolefin bead foams now used in automotive applications has grown from EPP to EPE (Expanded Polyethylene) Foam; which is used in some trunk

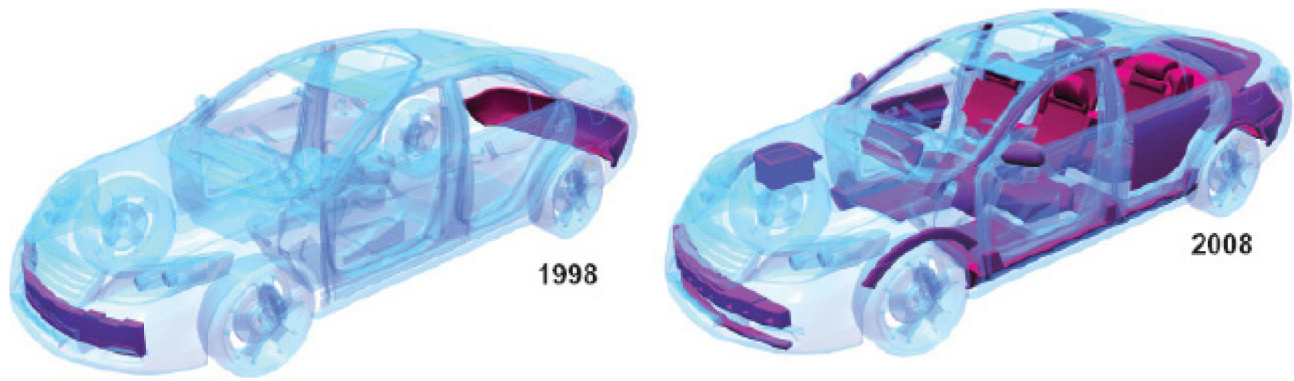


Figure 1.

storage applications. Softer foams like xEPE (Cross-linked Expanded Polyethylene) Foam is also being used to replace soft and semi-rigid PU foams in seat bolsters and headrests. Specialty EPP foams including PEPP (Porous Expanded Polypropylene) Foam, which provides unique energy management properties coupled with unique acoustical benefits such as sound absorption and controlled air flow are also being used. Newer developments in Expanded Polyolefin bead foam technology includes the use of Bio-based foam blends, foams with unique surface resistivity for sensitive electronic packaging as well as foams with unique additives or surface textures used to provide NVH countermeasures such as squeak, and ease of removal. The use of fasteners and integrated support structures both insert molded and secondarily attached is also growing and expanding into multiple applications.

DESIGN AND PERFORMANCE INNOVATIONS

With the use of expanded polyolefin foams like EPP continuing to grow, it is important to understand the advantages of EPP and the numerous design options available in the area of performance and cosmetic or aesthetic.

One of the features of expanded polyolefin bead foam is the ability of the stress-strain curve to maintain a consistent shape throughout the varying density ranges. The linear correlation between stress-strain and density allows for a specific density to be chosen for each part design. See [Figure 2](#) below for a comparison on [quasi] static stress-strain curves for various EPP densities of 30, 60, 90 and 150 g/l.

Expanded polyolefin bead foams like EPP have been modeled over the years and currently provide for a very robust material model for design optimization. The strain rate dependency of expanded polyolefin bead foams allow for predictive modeling for virtually all impact velocities ranging from a quasi-static speed of 10 mm/minute to over 10 m/s (36 kph).

One of the benefits of expanded polyolefin bead foam materials like EPP is the ability to match competitive material performance based on the stress-strain characteristics. EPP has replaced a variety of competitive materials throughout the automotive interior. These details of these are shown below in [Figure 3](#):

Unlike most PU based materials and other solid resin injection molded materials, both of which are used for support, and energy management, the polyolefin bead foam stress-strain curve does not contain the wide plateau region associated with these types of materials. [Figure 4](#) illustrates a comparison of several types of Polyolefin Bead Foam materials including EPP, PEPP, EPE, xEPE. Note that all curves represent the same molded density; in this case 30 g/l (1.9 pcf). It is important to note that the shape of the stress-strain curve for each material type is similar across all densities, with a corresponding shift upward in Stress as the densities increase.

Depending on the specific automotive interior application, different Expanded Polyolefin Bead Foam materials can be specified to meet a specific performance requirement, and in most cases, at a lower density, and henceforth a lower part weight.

COMPARISON OF PP & PE BASED FOAM PERFORMANCE

When comparing the energy management performance of all bead foams, it is important to understand the inherent properties of polyolefin bead foams including those comprising both PP and PE materials. As an expanded bead foam material, EPP offers a good blend of toughness, resilience, impact strength and stress/crack resistance. It offers good low temperature performance, and good chemical resistance. On the other hand, as an expanded bead foam material, EPE (standard and cross-linked) offers excellent resilience, excellent tensile properties, and excellent chemical resistance. It also offers a very low coefficient of friction,

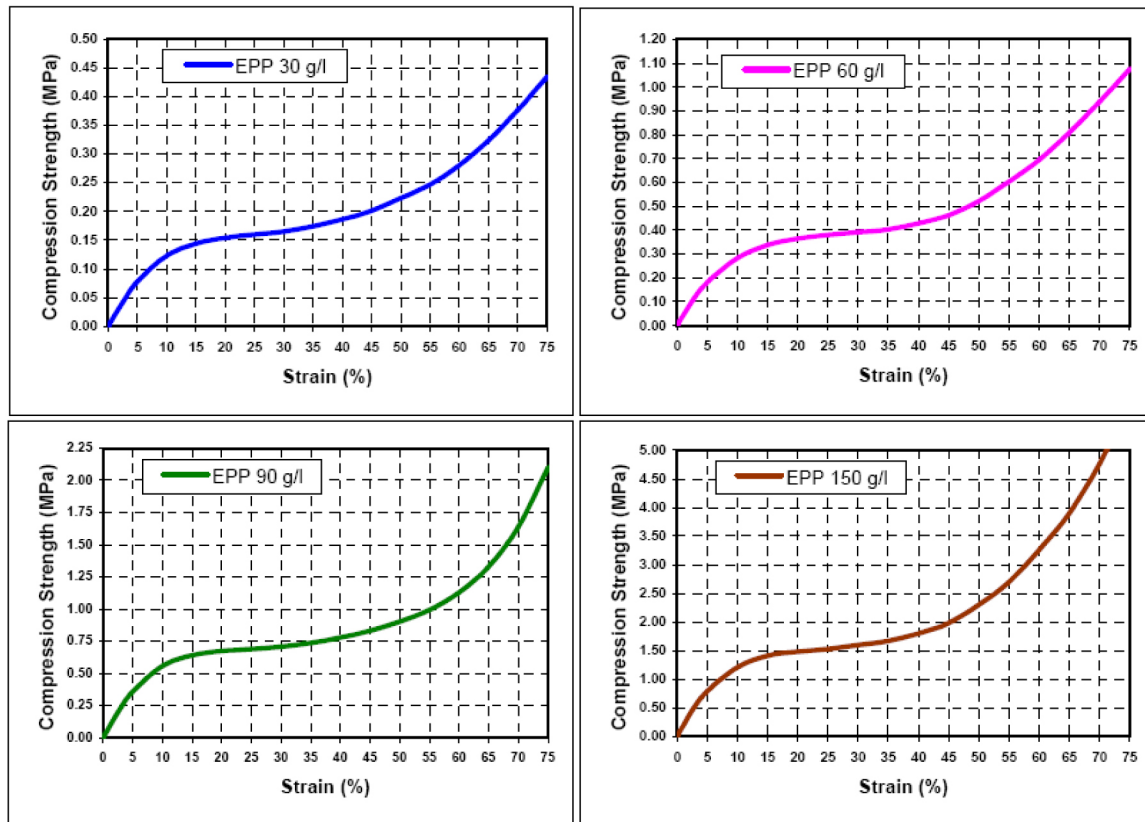


Figure 2.

which is beneficial for cushioning applications and for housing products in need of abrasion protection. This characteristic of EPE foams is due to inherent nature of PE resin as well as the nature of the EPE foam, which is comprised of very small cells ($<100\ \mu\text{m}$). Both EPP and EPE materials can be optimized for a specific end application based on the selection of the specific base resin.

When comparing the relative ‘hardness’ (a.k.a. ‘softness’) of various expanded foams, the term Indentation Force Deflection (ILD) is sometime used. This term (found in ASTM D3575) refers to the load a specific foam will manage across a specific surface at a given thickness when compressed 25%. It is an industry term used to characterize relative foam ‘hardness’ for purposes of applications ranging from cushioning, seating, padding, and packaging. Polyolefin Bead Foams can meet specific hardness requirements by specifying a given density.

With Expanded Polyolefin Bead Foams gaining wide acceptance within the automotive interior, other methods of characterizing the material ‘hardness’ are being employed. In the case of EPP replacing other semi-rigid materials such as TPE's, TPV's, and TPU based materials, specific material hardness standards are being referenced for comparison. Several industry standards exist including ASTM D2240 and

F1957 as well as other OEM and International Standards. These standards include the use of different types of hardness indicators (durometers) which utilize hardness scales such as Shore A, Shore C, Shore D and JIS/Asker C. Each of these scales are referenced for a specific class of materials, including thermoplastics, thermoplastic elastomers, and thermoset rubbers.

The most common durometer scale recommended for EPP is the Type C or Asker Type C scale. The chart in [Figure 5](#) below characterizes the hardness scale vs. density for EPP, EPE and xEPE.

When replacing these TPE, TPV, and TPU materials with Polyolefin Bead Foams, it is important to understand the specific scale used to compare the materials. While the hardness of EPP encompasses several hardness scales, including Shore A, Shore D and JIS/Asker C, specific densities can be referenced to achieve a specific hardness specification. On the other hand, softer Polyolefin Bead foams like EPE and xEPE fall within the Shore A and JIS/Asker C scales only. In fact, at the lower end of these scales, softer foams may require the use of a different durometer scale such as Type O, OO or even OOO depending on the application. [Figure 6](#) illustrates the hardness ranges and