

Polyurethane-Free Lightweight Automotive Seat

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ABSTRACT

Flexible polyurethane (PU) foam has been widely used for seat cushions in automotive passenger vehicles due to the excellent cushioning performance and the ability to shape mold. Originally introduced in the late 1950's, it has been used for more than 50 years. However, there is a limitation using polyurethane foam with efforts to reduce the weight and address ever increasing risks to environment.

This paper provides information about a new automotive seat concept which does not use polyurethane foam at all. Expanded polyolefin foam is used for this application to replace polyurethane foam and achieve comparable cushioning performance. Other features of the material include 100% recyclability, and no VOC's. By replacing polyurethane foam with expanded thermoplastic foam, hazardous outgassing is eliminated during the seat cushion production, thus improving workplace environmental health and safety.

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INTRODUCTION

After mass production technology of polyurethane foaming was established in the late 1950s, flexible polyurethane foam has been used as cushion pad of automotive seat for many years replacing conventional metal springs and/or natural fibers. Polyurethane foam is dominantly used today in the market of cushions and comfort pads due to the excellent compression properties, ease of adjustment for hardness, excellent resilience and ability to mold shapes.

However, when using flexible polyurethane foam for cushioning it is necessary to increase the density to achieve the required hardness and structural properties. In addition, as the material itself does not have enough rigidity, it is required to use metal pan or spring to support a seat pad from the bottom. For these reasons, it has been difficult to simplify the total seat structure design and to significantly reduce seat weight.

From a health and environmental aspect, polyurethane foam has a risk of generating toxic gas during the production process which causes respiratory disease. Products containing polyurethane foam can continue to emit amine gas and VOCs. There is also the issue of recycling methods used for

polyurethane foam. Recyclability is limited to reuse, as no cost effective method of melt processing polyurethane foam exists. A majority of waste polyurethane has been disposed by land filling or incineration. The burden of polyurethane on the environment is not small.

This paper describes an automotive seat core made exclusively of expanded polyolefin foam plastic, thus replacing flexible polyurethane foam, while achieving significant weight reduction. The features of this material include 100% recyclability, water resistance, chemical resistance, and no VOCs. The environmental impact is significantly reduced compared with flexible polyurethane foam.

Cushioning Material Replacing Flexible Polyurethane Foam

While flexible polyurethane foam has open cell structure, general expanded thermoplastic plastics has closed cell structure. Contained air in closed cell of expanded polyolefin foam plastic contributes to the compression hardness and resilience property of the material. However it is generally considered too hard and rigid to be used as cushioning material for an automotive seat core. This material is generally

used as an impact pad, bumper, spacer, or other structural element for automotive parts and has not typically been used as a substitute for flexible polyurethane foam.

Various types of mesh and netting materials are also used for automotive seat structure, which support the passenger's weight by using the tension of the material on the frame since it has excellent elasticity. However, this mesh or netting material, which supports the human body like a hammock, is difficult to optimize for performance and address location specific hardness requirements within the seat design. To achieve desirable performance as a seat cushion, it is necessary to use a combination of flexible polyurethane foam, and some type of structural reinforcement of the frame to maintain enough tension for the mesh support or netting material. It is generally accepted that seat designs using only a mesh and/or netting material for support; while potentially offering space and weight reduction, are not adequate substitutes for polyurethane foam.

Expanded Thermoplastic Plastics for Cushioning Material

The possibility of using expanded polyolefin foam; or more specifically, expanded polypropylene (EPP) foam, for seat cushion design has been investigated. Expanded polyolefin foam offers cost effective design flexibility and superior environmental performance as automotive seat cushion. However, expanded polyolefin foam is too rigid to achieve adequate cushioning performance and meet the comfort requirements for automotive seating when the material is compressed and deformed under load of passenger.

Like most expanded polyolefin foams, EPP foam's viscoelastic properties allow for shape restoration after it is bent or flexed. While there are several expanded polyolefin foams with a similar properties, EPP offers the optimal mechanical properties, heat resistance, chemical resistance and flammability performance required for automotive parts. EPP was developed in 1982 by JSP Corporation and has been widely used for automotive parts such as energy absorbing

bumpers, door bolsters, headrests, floor spacers, luggage boxes, sun-visors, seat cores, etc. The use of EPP foam in automotive applications continues to grow.

Using EPP foam, a seat cushion design was conceived whereby the EPP is used in a beam-formed structure which takes advantage of the material's flexibility and recovery/rebound characteristics, while supporting the load of a passenger. This design using EPP as a seat cushion, also allowed for an adequate level of passenger comfort. It is very unique design for EPP foam, which takes advantage of the flexural strength and recovery properties of the material. Traditional designs using flex or bending typically use materials such as metal leaf spring, metal bars, or solid resin.

From a mechanical property standpoint, flexural strength is proportional to the thickness of the beam squared. When the flexural strength is compared between solid resin and expanded foam resin with the same weight, it differs substantially. Regarding recovery characteristics; i.e. compressing 20 mm at center of an EPP part which has a thickness of 40 mm and a length of 450 mm, the compression ratio of center will be 50%. If the same dimensions are used with both sides supported (as a beam structure), compression stress and tensile stress will occur only partially along the beam structure, but with less than 1% deformation at the center, meaning that the stress and deformation of EPP will remain within its elastic region. Therefore creep will not occur even after repetitive flexing and/or bending. This is the basic design concept for the new EPP seat cushion.

SEAT DESIGN AND STRUCTURE

When comparing the level of compression deformation of EPP vs. PU foam using the same load, EPP has a much smaller deformation and is more difficult to compress vs. PU. However, like PU foam, EPP is flexible in a bending condition. [Figure 1](#) demonstrates the flexibility of EPP using a small radius. In this test, the diameter of the tip (black) is 5.0 mm and the thickness and width of the EPP test piece (white) is 20 mm. The new EPP seat cushion design uses this same flexibility concept.

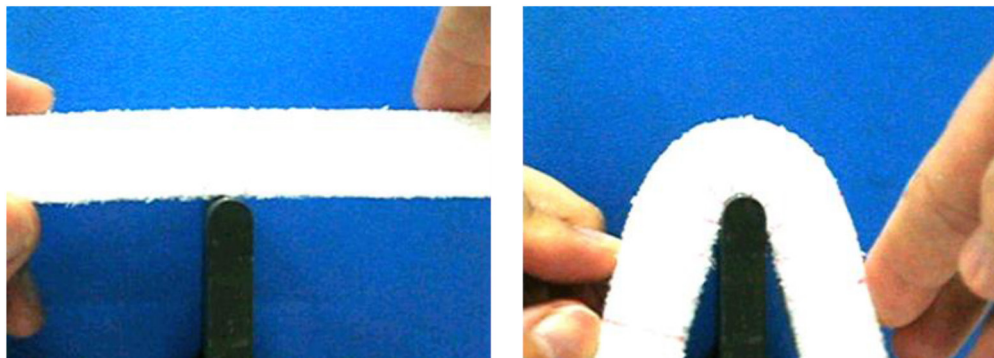


Fig.1. EPP Bending Test

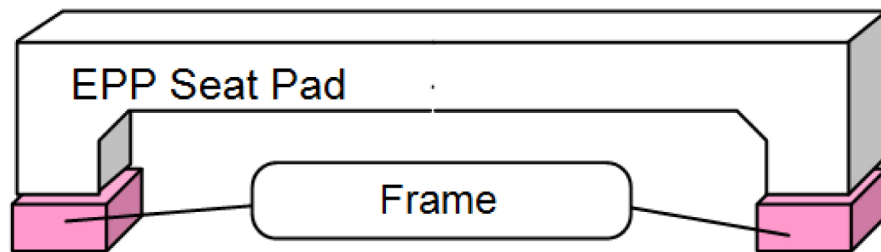


Figure 2. Cross-section of EPP Seat Pad and Seat Frame Structure

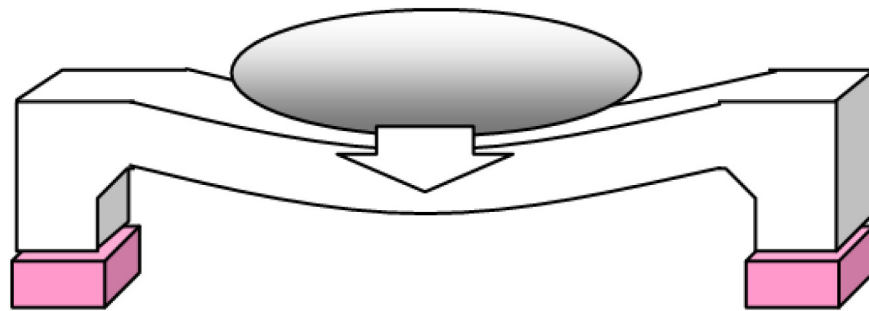


Figure 3. Change in EPP Seat Pad Shape by Addition of Load

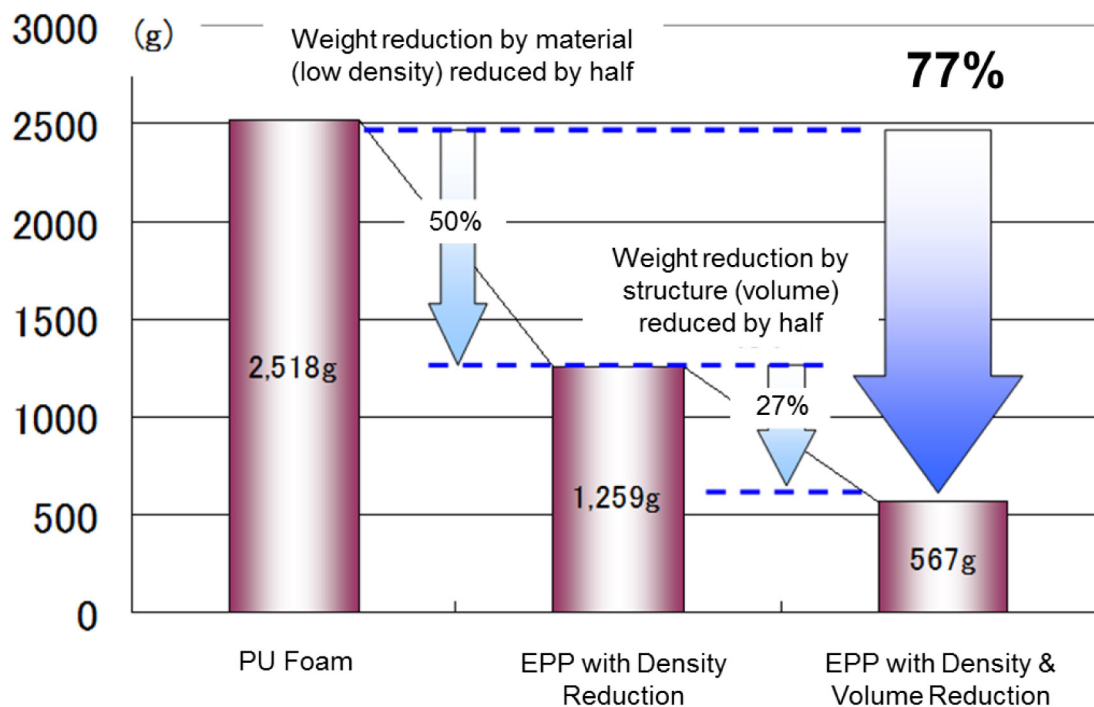


Figure 4. Material Reduction - Measurement of Prototype Samples

New Seat Cushion Design

The basic design of the new seat cushion structure of EPP seat pad specifies a flat or bar shaped EPP surface, which is supported by the seat frame on both sides as shown in [Figure 2](#). Applying this concept, the EPP foam surface is flexible and is able to bend and flex as shown in [Figure 3](#).

Depending on the design and size requirements of the EPP seat cushion, the shape can be optimized to allow for controlled bending and flexing. When EPP is used as seat cushion, the bending angle is minimized (unlike the condition

shown in [Figure 1](#)), and the bending area does not converge at a single point. Therefore, when a load is applied to the EPP, the cushioning properties are determined by a combination of EPP flexing and bending which can be optimized for the specific seat design. In case of PU foam seat cushion, the seat frame or springs in the bottom of seat pad are required to achieve cushioning performance. In the case of the EPP seat cushion, it will not be necessary to use these structures as long as both ends are supported.