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Investigating the behaviour of polyurethane foam for improving passenger car seat comfort

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ABSTRACT

Customer's expectations for comfort in automobile seats rise continuously. As the design parameters for automobile seats are complex, the design and analysis have been always challenging for engineers. Three design objectives, comfort, safety and health need to be satisfied simultaneously. For comfort, Hip joint location (H-point) is a critical design parameter used by car seat manufacturers. Polyurethane foam is most commonly used material for automobile seat. Over the past few years the usage of polyurethane foam in automotive seating applications has increased considerably because of its excellent vibration isolation properties, comfort features and durability. Location of H-point is primarily dependent on quasi-static behavior of foam which is a highly nonlinear as it is viscoelastic material. The objective of this paper is to study the quasi-static behavior of foam. Such study can be very useful for investigating the effects of the seat design, occupant's comfort and ergonomics.

Keywords— H-Point, Comfort, Quasi-Static Behavior, Polyurethane Foam, Nonlinear, Viscoelastic Material.

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I. INTRODUCTION

Polyurethane foam pad is a key component in seat design. It gives the shape and contour to the seat. It's properties affect comfort and H-Point which is the pivot centre of the human torso and thigh. Comfort experience is a combination of many different factors, vehicle package, social, individual, seat including aesthetics. During a journey, car occupants are subjected to both mental and physical stresses when exposed to road vibrations, dense traffic, noise and different weather conditions. Polyurethane foam helps to reduce those stresses. Static equilibrium position is related to the form and support provided by the seat itself, the posture and orientation of the occupant, and location of the occupant relative to certain critical points in vehicle interior. It was seen that the static equilibrium position varies considerably with the type of foam used in the seat design. The equilibrium position was also shown to be dependent on the initial posture of the occupant and the location of springs in the model.

Polyurethane foam is an important engineering material with applications in the fields of mechanical damping, acoustic absorption, impact retardation, automotive seating, etc. Over the past few years the usage of polyurethane foam in automotive seating applications has increased considerably. This is because of it's excellent vibration isolation properties, durability and comfort features. Since most modern car seats are full-foam, the quasi-static and dynamic performance of foam significantly affect the static and dynamic comfort of an occupant in a seat. [2]

I. BACKGROUND

Chemical composition of the foam consists of the following components:

- Standard Polyol
- Polymer Polyol
- Water

• Catalyst

• Surfactants
• Isocyanate
• Release Agents

Of the above components, Polyol and Isocyanate are the most important.

There are two main types of foam pad assembly : (1) encapsulated (2) lay-on. Molding the frame into the foam produces an encapsulated foam pad. An encapsulated foam pad is more difficult to disassemble and recycle than is lay-on pad. The lay-on pad simply sits on the frame of the seat. The lay-on pad is molded separately, without an encapsulated frame.

Methylene diphenyl diisocyanate (MDI) and *toluene diisocyanate* (TDI) are the two technology used to produce foam. In general, the difference lies in amount of heat used to produce and cure the foam. TDI uses less heat than MDI.

Indentation load deflection (ILD) is used as a measure of foam firmness, which determines the amount of penetration. For the same foam composition, ILD is dependent on the thickness of the foam pad. Therefore, care must be exercised when comparing the ILD values from different programs. It should also be noted that ILD measuring techniques vary between different customers. An ILD reading taken at 25 percent compression will not yield the same value as a pad of the same composition and thickness measured at 50 percent compression. Foam thickness and ILD readings for the cushion and back are also critical for H-Point control. ILD is the load required to compress the seat pad to 50 percent of original thickness and is used to assess the firmness of the foam pad. Foam thickness and ILD directly influence the manikin penetration into the seat.

Two physical properties of foam that are important to seats are density and firmness. Density is important for the durability of the foam pad, and firmness is important to understand and control the deflection under the load of an occupant. The higher the foam density the better the durability of the seat. Foam pads are required to take at least 200,000 cycles of durability with a maximum allowable set. Because of this, the cushion density, especially of the front seat, is most important and must be controlled carefully. In order of decreasing importance, it is usually followed by the front seat back, rear seat cushion and rear seat back. The trend towards density reduction whilst maintaining technical performance specifications continues. The higher the density, the higher the cost of the part, because it affects the amount of material dispensed into the mold. A balance needs to be achieved between the engineering performance needs and the cost of the part.

II. EXPERIMENTS

A. Experimental set-up for quasi-static behavior of foam:

Seats are selected in vehicles produced by a different manufacturer from the compact car segment. The foams in seats are distinguished using the letters A through C. For compare the three foams were in similar set-up as follows:
The experimental setup is shown in Fig. 1. Experiments were conducted on a servohydraulic testing machine which can be used for accurate testing under axial loads up to 25kN with standard displacements of 100mm. The foam is placed on hardness tester table with wooden block shall be formed in same way as the back shape of the pad. No lift is allowd between the bearing surface and the back of the pad. Design the base so that the loading surface will be horizontal when the test specimen is placed on the wooden block. The upper plate is attached to the actuator which can be programmed to move along pre-specified paths. For the tests, the actuator displacement specified as a function of time. The load cell locater in the upper plate measures the force in the foam. The displacement is measured using an *linear variable differential transformer*. The result of the quasi-static test on Foam 'C' is shown in Fig. 3. The same tests were conducted on two types of foams 'A' and 'B'. [2]

It can be seen clearly from Fig. 3 that the load–deformation relationship is highly nonlinear. Furthermore, there is substantial difference between the force in the foam during the compression and during relaxation phases. This is due to the viscoelastic nature of foam.

Fig. 1 Experimental setup for quasi-static behavior of foam

It is clear from Fig. 4 that as the density increases it reduces the deflection.

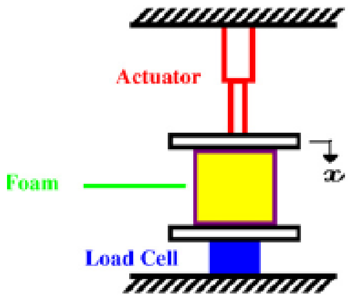

Fig. 2 Schematic of the experimental setup [2]

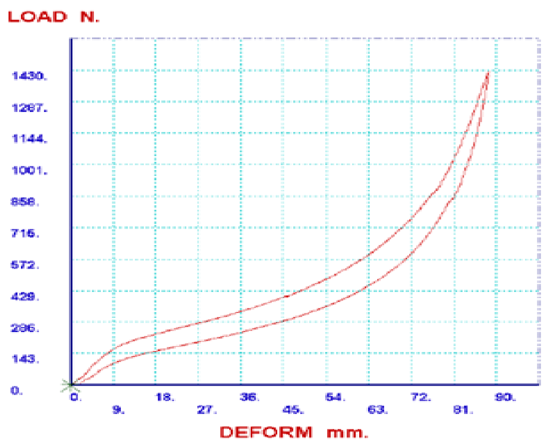

Fig. 3 A graph of load vs deformation for quasi-static behavior of Foam 'C'

TABLE I

Summary of rear seat foams

Sr. No.	Description	Foam A	Foam B	Foam C
1	Hardness @ 25% (N)	197.2	128	243
2	Hardness @ 50% (N)	404.7	235	472
3	Density (Kg/m3)	40	55	60
4	Hysteresis (%)	33	24	20
5	Load Vs Deflection (10Min)	8.9	4	2.3
6	Load Vs Deflection (20Min)	9.9	4.9	3.4
7	Load Vs Deflection (30Min)	10.6	5	3.6

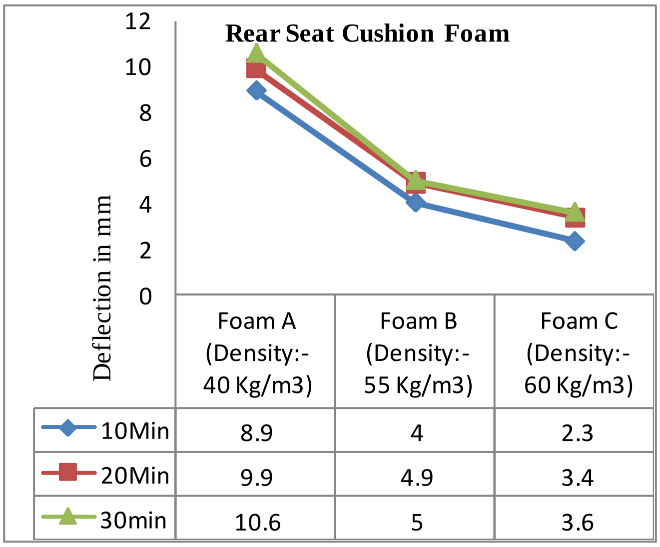

Fig. 4 A graph of deflection vs density.

B. H – Point Measurement:

The procedure was as follow:

- The seatback angle was set to 25^0 from vertical.
- The track position was set to full rear.
- The H-Point manikin was placed in the seat without weights.
- The seat was adjusted until the H-Point manikin was adequately positioned in front of the pedals and steering wheel.
- The H-Point manikin was loaded with weights.
- In this position, the H-Point to heel point relationships and the H-Point manikin's critical angles (i.e. torso, hip, knee, and foot) were determined for each seat.

After setting the seat to the estimated design position, a coordinate system was established in relation to the vehicle. The H-Point was digitized and remove after H-Point measurement. This coordinate system used for scanning seat using a portable coordinate measurement machine (CMM), known as a FaroArm shown in Fig. 5. Once enough, data points were collected, the dots are connect to create line. Center points of the probe were taken. For this reason, the scan lines, in a post processing operation, were offset by the radius of the probe. [4]

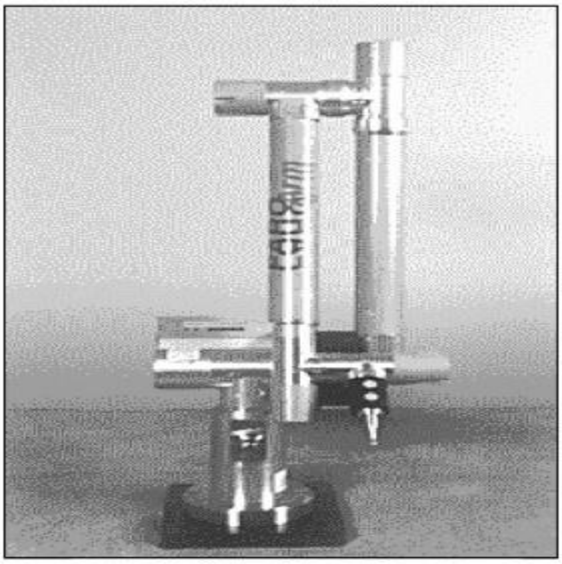

Fig. 5 FaroArm coordinate measurement machine (CMM) [4]

Fig. 6 H – Point measurement set-up

III. CONCLUSIONS

The tests were conducted on three foam pads to determine the quasi-static characteristic of foam. It is observed that as the density increases then it's deflection decreases.

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