Raw material for Polyurethane improving the ride comfort of a car

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It is not an overstatement to say that the ride comfort of a car is determined by the automotive seat. Molded flexible polyurethane foam is used for automotive seats because it is porous, light, and can be easily formed into various shapes.

In the 1960s, Sanyo Chemical was the first company in Japan to produce polyol (PPG), the raw material for polyurethane foam, and Sanyo Chemical has been marketing a wide variety of PPGs for automotive seats.

In this paper, we introduce "SANNIX KC-737", which was developed to improve the ride comfort of automotive seats.

Ride Comfort Performance of Automotive Seats

The ride comfort performance of an automotive seat is composed of two major elements. The first one is comfort against vibration transmitted from the road and car body. Since the human body is most uncomfortable with vibrations around 6 Hz, it is particularly effective to reduce the transmission coefficient at 6 Hz **[Fig. 1]**.

The second one is sitting comfort. When the seat supports to the shape and movement of the passenger's body, postural stability is enhanced and seating comfort is improved **[Fig 2]**. It is also important for postural stability that there is no deflection (stress relaxation) of the seat even after sitting for a long time **[Fig. 3]**. This not only reduces the strain on the body, but also to prevent safety problems caused by changes of the driver's eye position while driving.

Polyurethane foam

Polyurethane foam is a porous resin made by foaming a polymer obtained by chemically reacting polyol and polyisocyanate components with gas (carbon dioxide) generated simultaneously with the reaction **[Fig. 4]**.

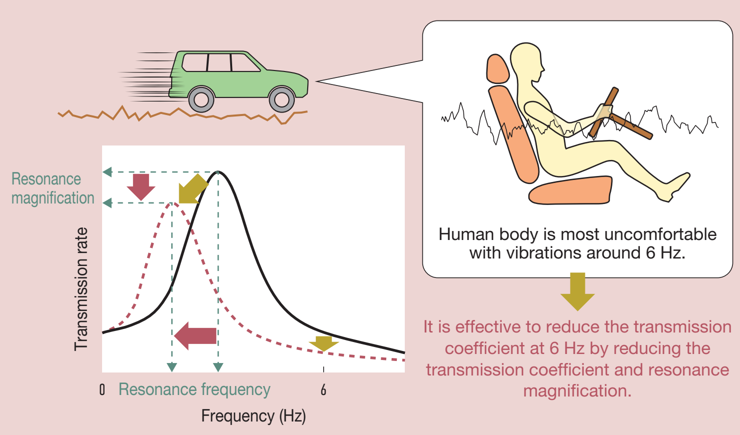


Fig. 1 Ride Comfort Performance and vibration absorption

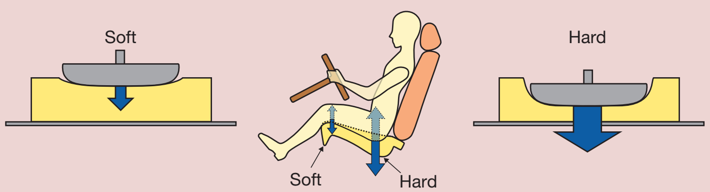
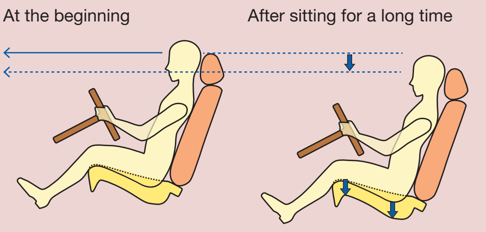


Fig. 2 Relationship between seating comfort and seat softness



This not only reduces the strain on the body, but also to prevent safety problems caused by changes of the driver's eye position while driving. Because of the stress relaxation of seat, driver's eye position changes.
⇒It is effective to reduce the stress relaxation rate.

Fig. 3 Influence of the stress relaxation of seat on the postural stability

Polyurethane reaction (resin formation)

HO—R'—OH (Polyol) + OCN—R—NCO (Polyisosyanate)

⟶ ⫞OCONH—R—NHCOO—R'⫞ (Urethane bond in polyurethane foam)

Ureaization reaction (gas generation and resin formation)

2 OCN—R—NCO (Polyisosyanate) + 2 H_2O (Water)

⟶ ⫞R—NHCONH—R—NHCONH⫞ (Urea bond in polyurethane foam) + 2 CO_2 (Carbon dioxide (Generated gas))

Fig. 4 Chemical reaction formula of polyurethane foaming

Polyurethane foam for automotive seats is generally composed of the formula shown in **Table 1**.
The main raw material for the polyol component is polyoxypropylene polyol (PPG), which is produced by the addition polymerization of propylene oxide (PO) and ethylene oxide (EO) to polyfunctional alcohols. By adjusting the number of functional groups and molecular weight of PPG, polyurethane foams with a wide range of physical properties can be manufactured. Polymer polyols (POP) are made by polymerizing and dispersing vinyl monomers in PPG, and are used to add hardness to foams.

Table 1 Example of car seat cushion formulation

Formulation		Weight part
Polyol	PPG	50~100
	POP	0~50
	Cell-opening agent	0~2
	Closslinking agent	1~5
	Amine catalyst	~0.5~
	Silicone	~1.0~
	Water	2.0~5.0
Isocyanate		40~70

The following is an explanation of the relationship between foam raw materials and the improvement of the ride comfort of automotive seats.

Improvement of vibration characteristics

In order to improve the vibration characteristics, it is effective to reduce the vibration transmission coefficient at 6Hz, which humans feel uncomfortable.
Each material has its own natural vibration, and when it is exposed to vibrations of the same frequency, the vibrations are amplified. This phenomenon is called resonance. One of the most common ways to reduce the 6Hz transmission rate is to lower the frequency at which the road or car body resonates with the automotive seat (resonance frequency) by changing the physical properties of the foam. Another way is to lower the vibration transmission rate at resonance (resonance magnification) **[Fig. 1]**.
The frequency represents the frequency of vibration per second, and the larger the mass of a material and the easier it is to stretch, the lower the frequency of natural vibration tends to be. In other words, in order to reduce the resonance frequency, it is effective to make the foam highly elastic. The details of making the foam highly elastic will be discussed later.
On the other hand, with regard to the reduction of resonance magnification, the higher the viscosity of the foam, the higher the vibration damping rate (hysteresis loss), and the more the foam absorbs the vibration from the car body, the less it is transmitted to the passenger.
However, since the high elasticity and high viscosity mentioned above are contradictory in general foams, it is difficult to achieve the reduction of resonance frequency and resonance magnification by controlling only the polyurethane resin composition. Therefore, there are measures to reduce the resonance frequency by

Table 2 Comparison of PPG properties

	SANNIX KC-737	Conventional PPG
Appearance	Colorless to pale yellow liquid	Colorless to pale yellow liquid
Hydroxyl value (mgKOH/g)	24.0	24.0
Unsaturated degree (meq/g)	0.03	0.12
Viscosity (mPa·s at 25°C)	1400	1400

Table 3 Form physical characteristics of SANNIX KC-737 system

Foam properties	SANNIX KC-737	Conventional PPG
Total density (kg/m³)	61.6	61.2
25% Compressive hardness (N/314cm²)	233	203
Impact resilience (%)	73	67
Resonance frequency (Hz)	3.27	3.82
Resonance magnification	3.66	3.51
Vibration transmission rate at 6Hz	0.61	0.93

making the foam highly elastic, and to reduce the resonance magnification by reducing the air permeability of the foam and increasing its apparent viscosity. Another strategy is to change the polyisocyanate component from the current mainstream TDI/MDI blend to the All-MDI system, which has better vibration characteristics, in order to lower the transmission of vibration in all frequency ranges.

Improvement of ride comfort

In order to improve postural stability, which contributes to seating comfort, the seat must deform to the shape and movement of the body, increasing the contact area and improving fit. However, if the foam is too soft, the body will sink into it, resulting in poor posture. Therefore, it is desirable to minimize the amount of displacement in the high-load region where the body weight is applied, while increasing the displacement of the surface layer that touches the body even at low loads. To achieve this, it is effective to reduce the hardness of the surface layer while maintaining the hardness inside the foam. The polyisocyanate component has a large influence on the reduction of the surface hardness, and it has been reported that the All-MDI system is more effective than the TDI/MDI blend system.

High Elasticity foam with Low TU PPG "SANNIX KC-737"

To improve seating comfort, it is also important to reduce the deflection (stress relaxation) of the foam after sitting for a long time. For this purpose, it is effective to increase the elasticity of the foam.
It was mentioned earlier that high elasticity of foam is also effective as a measure to reduce resonance frequency.
The high elasticity of foam can be achieved by increasing the molecular weight of polyurethane resin, and the high elasticity of foam using PPG can be achieved by increasing the molecular weight of PPG, reducing the byproducts in PPG, and increasing the effective number of functional groups. On the polyisocyanate side, increasing the TDI ratio is effective, but since All-MDI foams are superior in terms of vibration absorption properties and surface hardness reduction, All-MDI (TDI ratio 0) foams are expected to increase in the future.
The byproduct that lowers the effective functional group number of PPG is a monool with terminal unsaturated bond, which is isomerized by hydrogen extraction from the methyl group of PO. In general, as the molecular weight of PPG increases, the monool content increases, so it is difficult to increase the molecular weight of PPG without lowering the effective functional group number using conventional manufacturing methods. As a countermeasure to this problem, it is generally known to use an alkali catalyst (cesium hydroxide) with a large ionic radius **[Fig. 5]**.
However, there were issues with the production process for practical use.
Therefore, by reviewing the production process, Sanyo has developed a high molecular

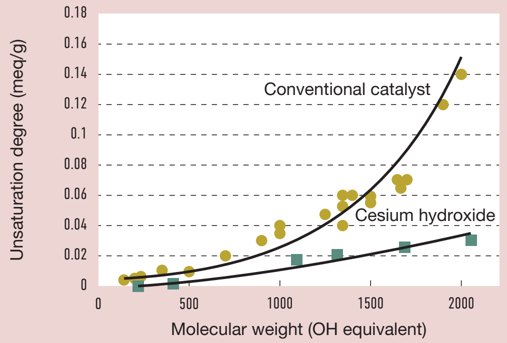


Fig. 5 Relationship between PPG molecular weight and unsaturation degree (monool content)

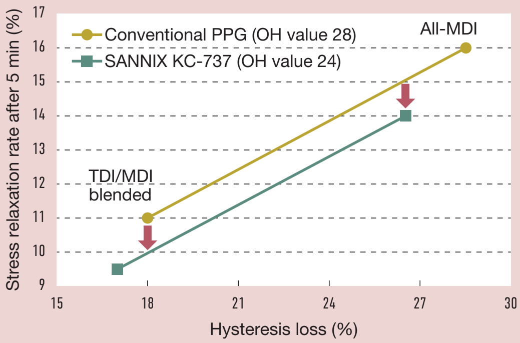


Fig. 6 Relationship between hysteresis loss and stress relaxation rate due to difference in isocyanate

weight PPG with low monool content, "SANNIX KC-737" **[Table 2]**.

As a result, the resonance frequency of the foam using SANNIX KC-737 was reduced and the vibration transmission coefficient at 6Hz was also reduced **[Table 3]**.

In addition, when "SANNIX KC-737" was evaluated using the All-MDI formulation, the effective number of functional groups of PPG increased and the cross-linking density of the resin increased, which made it possible to reduce stress relaxation while maintaining the same hysteresis loss **[Fig. 6]**.

In this way, "SANNIX KC-737" can make foam more elastic, which is effective in improving vibration characteristics and ride comfort by reducing stress relaxation.

Future development

In recent years, automotive interior materials, including automotive seats, are required to be more health and environmentally friendly. We will continue to develop PPGs to meet these needs and contribute to the improvement of automotive performance.

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