

Development of Soft-feeling In-mold Paint for Urethane Steering Wheel Grip

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ABSTRACT

The steering wheel is the interior component that is touched with the highest frequency. To improve the feel of the steering wheel, this project developed a soft feeling in-mold coating that can be used in existing in-mold processes. The target was to achieve the feel of aniline leather, which is the most pleasant leather to touch. Equipment measuring the sense of friction was utilized to obtain values to which a standard deviation was applied, enabling measurement of softness and the sense of grip necessary for steering. The combination of a soft polyester resin and urethane resin beads in the paint formula, in combination with a soft-type polyester-denatured hexamethylene diisocyanate (HMDI) hardener gives the paint a very soft feel.

1. Introduction

When a driver sits in an automobile, the first thing they touch to operate the vehicle is the steering wheel. The function of the steering wheel is to transmit the driver's intention to control the vehicle in the desired direction. However, in addition to its function as a steering device, the steering wheel has functions such as an air bag mount to help protect the driver as well as containing various switches for operating electrical components. The gripped portion (hereafter referred to as "grip") was formerly made of materials such as wood or PVC resin, but currently most steering wheels are molded from semi-hard polyurethane. In addition, other commercialized options combine functionality, a high margin of safety (MOS) and design properties, such as leather wrapping to improve the feel, or printing a wood grain onto a hard resin to improve the visual aesthetic properties for higher class vehicles as shown in Fig. 1. Amidst this background, the recent trend particularly among European vehicles is to simply produce a soft feeling part by coating plastic products with a pleasant feeling paint, and to

also create a luxurious appearance by suppressing the gloss.

This project developed new technology to provide a soft feel with paint technology that could formerly be achieved only by leather wrapping. The content of this paper reports the development of these materials and describes a method for quantitatively measuring softness.

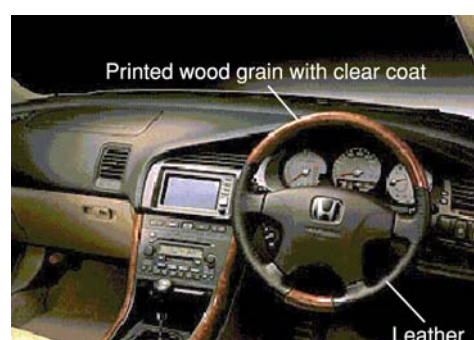


Fig.1 Honda INSPIRE steering wheel

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2. Development Goals

The fabrication method for the steering wheel grip consists of molding polyurethane over steel, magnesium alloy, or other metal core by an in-mold process, and simultaneously applying an in-mold paint to the surface. The function of the paint is to match color and gloss with other interior components and also to improve durability. These processes are shown in Table 1.

Table 1 RIM-Urethane steering wheel grip manufacturing processes

No.	Manufacturing processes	Purpose / Content
1	Applying mold release paint	To release the urethane steering wheel grip
2	Applying in mold paint	· A barrier of void occurring from formed urethane · Match other interior low gloss parts
3	Armature set to dies	Hardness, impact resistance
4	Mold closed	Preparation for urethane injection
5	Injection of RIM urethane	Urethane injection of a fixed quantity
6	Mold opened	Release product
7	Safekeeping calmly	Room temperature turn of a product

The theme of this project was to develop a new paint with the aim of proposing a desirable grip that allows comfortable operation by providing a softer feel than the current in-mold paint used.

3. Targets

3.1. Target Feel

The ideal feel desired for the grip is currently thought to be that of leather, which not only has a pleasant appearance and smell, but also has a soft texture and provides functionality. Of the various types, aniline leather, which is used for high grade furniture, is considered to have a particularly good feel. Therefore, the target feel was set as equivalent or better than aniline leather.

3.2. Processability

The target was a coating which does not require changes or modifications to existing production facilities. The material should have spray properties (atomization), a batch process viscosity stability (pot life) and demold properties (die demold properties) equivalent to the current in-mold paint.

4. Quantification of Surface Feel and Target Values

Surface feel was quantified by using the KES-SE friction tester (KATO TECH CO., LTD) shown in Fig. 2. Property

values obtained using a piano string jig that simulates a human fingerprint have a high correlation with sensory evaluation⁽¹⁾. This project also applied this measurement method to set quantitative values for softness which were used as the target values. Figure 3 shows an example KES-SE measurement chart.



Fig.2 Friction tester KES-SE (KATO TECH CO.,LTD)

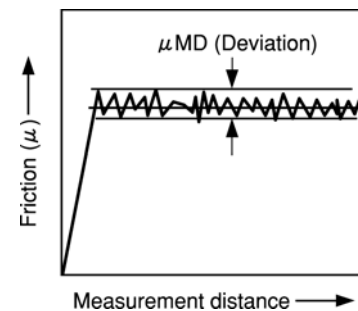


Fig.3 Fixed quantity test

As the friction grip force μ increases, the surface becomes less slippery and the grip force increases. Also, a small standard deviation μMD indicates a smooth and even surface. When dividing the friction force (μ) by the standard deviation (μMD) results in a high value, this indicates high friction and a smooth surface, which represents a soft feel. When applying this to the steering wheel grip, the operational function of grasping must be taken into account, so the surface feel must be improved without lowering the friction force (μ), which is the grip force. Therefore, evaluation criteria was based on softness feel ($\mu/\mu MD$) and friction force (μ).

Using aniline leather as the goal, grip force and softness feel target values were set as follows:

- Grip force (μ): 0.0927
- Softness feel ($\mu/\mu MD$): 30.3

5. Development of Soft Touch Paint

5.1. Investigation of Soft Touch Paint Composition

Table 2 shows the general components of the 2K curing soft touch paint that is applied to provide a pleasant feel to products such as automotive interiors and household appliances.

This soft touch paint is comprised of main resins consisting of acrylic and polyester polyol resins which make up the binder, filler materials, additives to maintain the

Table 2 Components of soft-feeling paint

	Components
Main resin	Polymer
	Pigment
	Filling
	Additive (Activator, UVA, etc)
	Solvent
Hardener	HMDI (Hexamethylene diisocyanate)
	Solvent

stability (accelerator, UV absorber, etc.), solvents, and the hardener which consists of HMDI, which is the subject activator for the polyol curing reaction, and a solvent. Based on these materials, a new soft feel in-mold paint was developed.

5.2. Selection of the Main Resin and Filler Material

Acrylic and polyester were selected as the main resins used in the soft touch paint based on feel and durability. Hard acrylic, soft polyester and a blend of these two resins were investigated to confirm the difference in the feel. In addition, the paints shown in Table 3 were prepared by mixing three types of filler materials with the main resins. The filler materials used were silica which is generally used as a flattening agent, polyurethane beads that are a texturing agent, and a mixture of collagen and soft wax that is thought to improve the texture by providing a feel of absorbed moisture. Test pieces were fabricated using the in-mold method, and the friction feel of each paint was measured. Figure 4 shows these results.

The results showed that the paints containing polyurethane beads as the filler material provided the most pleasant feel. In addition, soft polyester was found to be the best main resin. Paints containing silica or collagen/soft wax had a lower grip feel compared to polyurethane beads or silica. The surface conditions of paints No. 6, 7 and 8 were

photographed to analyze this phenomenon. Figure 5 shows these photographs.

Minute bumps occurred in paint containing polyurethane beads, which are thought to have contributed to the soft feel.

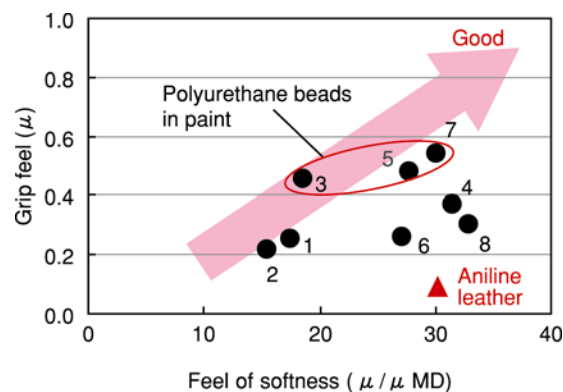


Fig.4 Friction of base polymer and variant filling in in-mold paint

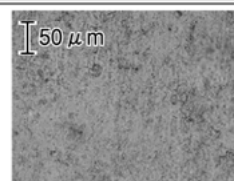
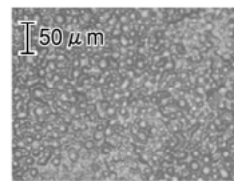
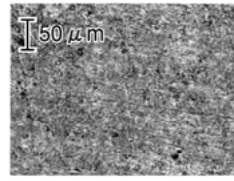
Paint No.	Surface photo
No.6 (Silica in paint)	
No.7 (Polyurethane beads in paint)	
No.8 (Collagen, soft wax in paint)	

Fig.5 Surface of in-mold paint

Table 3 Components of base polymer and variant fillings

Paint No.	Base polymer	Hardener	Filling
1	Hard acrylic	HMDI (Hexa methylene diisocyanate)	Silica
2			Acrylic beads
3			Polyurethane beads
4	Hard acrylic + polyester		Silica
5			Polyurethane beads
6	Soft Polyester		Silica
7			Polyurethane beads
8			Collagen/Soft wax

In contrast, the paint films that used silica or the collagen and soft wax had smooth surfaces. This indicated that the silica and collagen/soft wax mixtures were not present in the surface layer after in-mold processing. This phenomenon is thought to occur because the silica and collagen/soft wax are oriented on the inner mold exposed surface or dispersed in the film, so they do not contribute to the outer side of the actual molded product. In other words, these fillers are oriented on the inner die face during the in-mold painting process, so they are not present on the outermost surface of the actual molded product. Figure 6 shows pattern diagrams of these conditions.

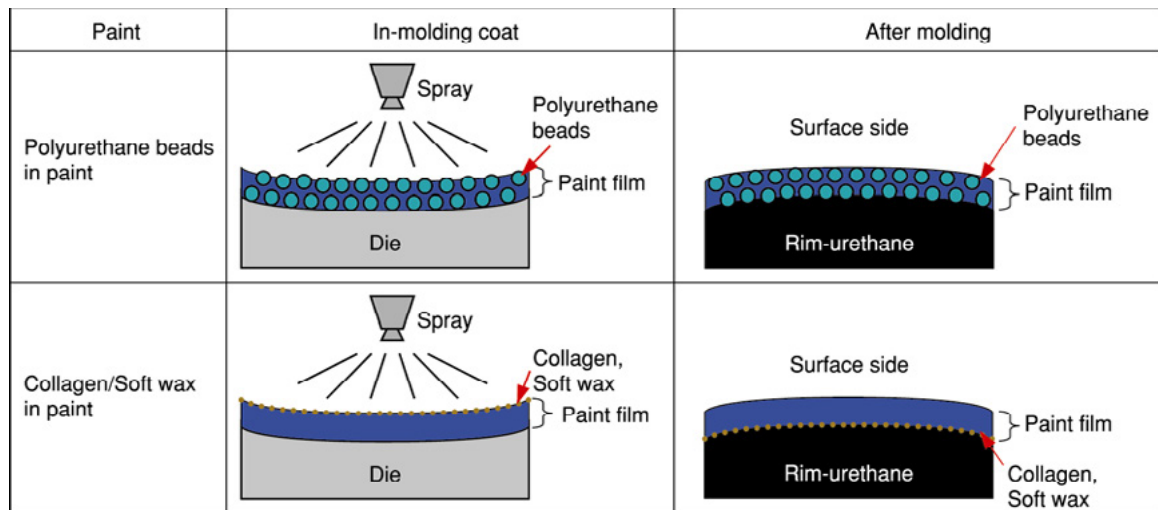


Fig.6 Image of soft filling effect at paint method

5.3. Selection of Hardener

The effects of the hardener were investigated using the base mixture of soft polyester as the base resin and polyurethane beads as the filler material. The paint hardness can be varied by modifying the hardener. The paint mixtures shown in Table 4 were made with three types of hardeners consisting of normal HMDI and two modified HMDIs. Modifications were based on adding polyester to the HMDI frame. Test pieces were fabricated using the in-mold method, and the friction of each paint was measured. Figure 7 shows the results.

These results confirmed that hardeners with a higher degree of modified polyester provide a more pleasant feel. There are two theoretical reasons behind this phenomenon.

Table 4 Variation in hardener components

Paint No.	Base polymer	Hardener (HMDI)	Filling
7-1	Soft polyester	Normal	Polyurethane beads
7-2		Polyester-low graft	
7-3		Polyester-high graft	

· HMDI softness : Polyester-high graft > Polyester-low graft > Normal

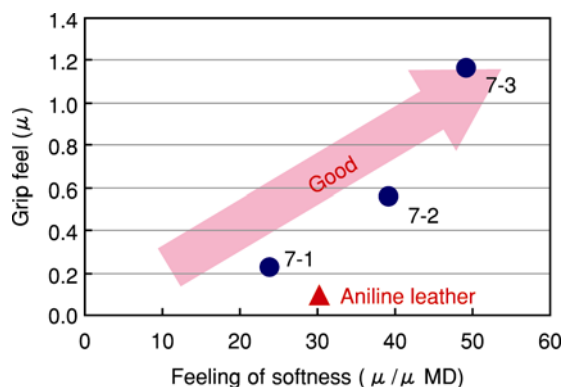


Fig. 7 Friction of in-molding paint with different hardness

First, the hardener itself was modified by the polyester to become softer. Secondly, the clearance between the base resin in the hardener and reaction components (functional groups) increased, thus expanding the cross linking structure of the cured paint film and causing the stiffness to drop. Figure 8 shows a schematic diagram of this condition.

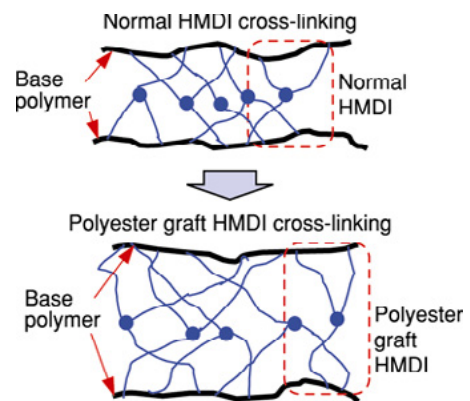


Fig.8 Image of paint bridge formation

6. Processability

Investigating various mixtures enabled development of an in-mold paint with a very soft feel by using a polyester polyol as the base resin, polyurethane beads as the filler material, and isocyanate with a polyester modified hardener. Therefore, the paint properties were confirmed on an actual steering wheel fabrication line. At this time the paint viscosity was found to increase faster than the current paint during the application window. When the paint viscosity rises quickly, the time that the paint can be used after mixing is limited, causing an increase in waste. This has a large impact on paint line workability and cost.

Therefore to counter measure, the addition of a solvent inhibitor was investigated to block the organic tin catalyst effects at normal temperature when mixing the paint. Figure 9 shows the results confirming the effects of mixing this solvent inhibitor on the friction feel.

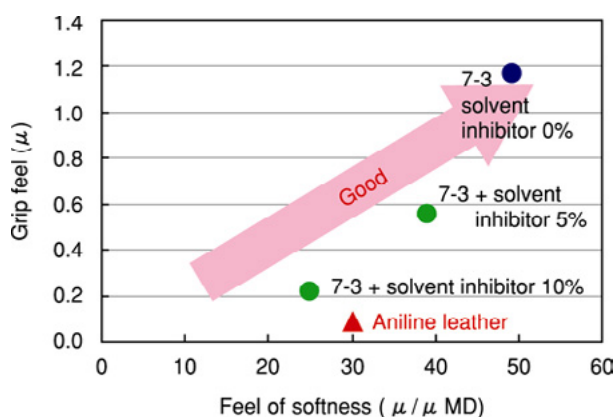


Fig.9 Friction of paint containing solvent inhibitor

Adding 5% and 10% solvent inhibitor for blocking the catalyst to prototype paint 7-3 caused the friction feel to drop. This phenomenon is presumed to occur because the solvent inhibitor limited the catalyst effect during the curing step of the in-mold painting process. Therefore, the reaction format between the base resin and the hardener differed depending on the presence of the solvent inhibitor.

Table 5 shows results for the performance of paint containing 5% solvent inhibitor.

Table 5 Performance of in-mold paint containing 5% solvent inhibitor

Item	Result
Pot life	Same as current
Storage stability	Same as current
Paint atomization	Same as current
Painting machinery conformity	Same as current
Mold-release stability	Same as current

These results confirmed that there were no problems with pot life and storage stability, which affect the paint properties, or with the atomization properties using the same application equipment as the current material. In addition, compatibility was also confirmed with existing production facilities, painting equipment, and die demold properties showed to be equivalent to the current paint. Therefore, paint containing 5% solvent inhibitor was determined as the final paint formulation.

7. Coating Performance

Table 6 compares the coating performance of the newly developed and the current in-mold paint.

The newly developed in-mold paint exhibited performance equal to or better than the current mass production paint in areas such as chemical resistance and long-term durability. In addition, the low-gloss appearance matches with other interior components and the friction property was also superior to the current in-mold paint. This is thought to be a result of the flat appearance produced by

Table.6 Coating performance

Test item	Soft in-mold paint	Current in-mold paint
Light resistance	Pass (Grade 4)	Pass (Grade 4)
Heat resistance	Pass (Grade 4)	Pass (Grade 4)
Humidity resistance	Pass (Grade 4)	Pass (Grade 4)
Chemical resistance	Pass (Grade 4)	Pass (Grade 4)
Wear resistance	Pass (Grade 5)	Pass (Grade 4)
Gloss (60°)	2.0	3.2

· Grade 5 : No defect

· Grade 4 : Some inferior, but almost unnoticeable

the minute texture of the polyurethane beads. Also polyurethane beads maintain a degree of high durability compared to the flattening agents used in the current in-mold paint, which suppresses the rise in gloss due to wear.

8. Surface Feel Survey

As described above, surface feel was quantified by measuring the friction, and a soft paint mixture was developed. Then, sensory evaluation using steering wheel grips was conducted to determine whether a soft feeling was actually obtained.

Three grips were fabricated using the newly developed paint, the aniline leather target and the current paint. A survey was conducted with 12 male and female subjects. The survey was based on Sheffe's pair comparison method, which is suitable for touch sensation where other samples for which quantitative numeric expression is difficult. In addition, of the various Sheffe's pair comparison methods, the Nakaya modified method which allows individual repetition was used⁽²⁾. Figure 10 shows the survey results.

The responses were divided relatively with "like" to the right and "dislike" to the left of the center 0. The order of preference was found to be the newly developed paint, aniline leather and then the current mass production product. As in the friction feel measurement results the newly developed paint was rated more favorably than aniline leather.

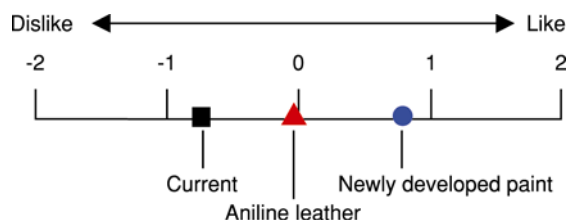


Fig.10 Result of paired comparisons survey

9. Conclusion

A soft feel in-mold paint was newly developed for steering wheel grips, and the obtained surface feel is softer than aniline leather. The knowledge acquired through the

development of this new paint is as follows:

- (1) Soft polyester resin provides the most pleasant feel results as the main component for the in-mold paint.
- (2) Adding polyurethane beads as the filler material produces bumps on the paint film surface after molding and provides a pleasant texture.
- (3) Softer hardeners are effective for improving the feel by increasing the degree of modification to the polyester in HMDI.
- (4) Polyurethane beads give the newly developed soft in-mold paint a surface pattern that reduces surface gloss and improves friction property compared to the current paint.
- (5) Adding a solvent inhibitor to block the effects of the curing catalyst reduces the appeal of the surface feel.
- (6) Grip feel [μ] and Softness [$\mu/\mu\text{MD}$] measurements obtained using the KES-SE friction tester are effective for quantifying the feel, and match closely to the results of the sensory survey.

This newly developed soft in-mold paint was adopted for the new 2003 model ACCORD (Japan, U.S., Asia, China).

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