

# High-Scratch Resistant Polypropylene for Instrument Panels

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## ABSTRACT

## 要 旨

In an effort to reduce cost and foster an all-olefin material direction, a polypropylene material has been developed to perform without paint in applications traditionally requiring paint. An existing instrument panel polypropylene's scratch resistance has been enhanced by talc encapsulation, increased surface lubricity and reduced talc particle size. The additive loadings and types were balanced with physical property performance and material cost. Mold flow analysis and a sequential valve gate molding process were used to optimize the part appearance. The result is an impact-modified polypropylene with scratch characteristics equivalent to painted polypropylene with a minimal cost increase.

コスト低減及びオールオレフィン化を促進するため、従来は塗装が必要であったインストルメントパネル素材に対し、無塗装でも適用可能な PP 素材を開発した。無塗装化で懸案となる耐傷付き性の向上対策として、タルクのコーティング、潤滑性の更なる付与、タルクのサイズダウン等を行った。この際、添加剤の種類及び添加量は、効果と機械的特性及びコストを考慮して決定した。その結果、耐衝撃性に優れ、無塗装でも塗装と同等レベルの耐傷付き性が得られる安価な PP 素材を開発することが出来た。部品適用に際しては、シーケンシャルバルブゲートの適用と合わせて、流動解析によりウェルド、フローマーク等の最小化を行ない、外観を向上させた。

## 1. Introduction

Injection-molded polymers are the preferred construction for most interior parts. Instrument panels, however, have traditionally used skins or paints to cover their injection-molded retainers in order to meet quality expectations (scratch resistance, weld lines, etc.). In response to cost and weight reduction initiatives, the skin construction has given way to a painted polymer construction. The use of semi-crystalline polymers has made this construction expensive because special paint formulations are required to meet the instrument panel quality expectations. These circumstances have created an opportunity to reduce cost by eliminating paint. This opportunity has been successfully seized on small segment vehicles in the European and Japanese markets. However, seizing opportunities on full-size vehicles is more difficult due to the higher quality expectations.

Thus the goal was to develop a polypropylene that does not require paint to meet full-size vehicle quality expectations without increasing the polymer's cost.

Injection-molded instrument panels are generally one-piece designs, however, some models use multi-piece designs that provide an opportunity to remove paint

selectively. Removing the paint from vertically oriented parts and not the horizontally oriented parts prevented the material from being subject to veiling glare requirements. Thus, the objectives became, in order of priority: scratch resistance, mold shrinkage, physical properties, molded-part appearance and cost.

## 2. Methodology

The primary concern with mold-in-color applications is scratch resistance. Paint prevents the base material from being scratched and increases the scratch resistance of the construction. To increase the scratch resistance of the substrate material to a level that does not require paint, two methods were considered; decreasing the size of the scratch and hiding the scratch <sup>(1)</sup>. Increasing the hardness and surface lubricity will decrease the size of the scratch. However, increasing the material's hardness was found to diminish the overall quality and increase the cost without a significant improvement in scratch resistance and was therefore abandoned. Encapsulating the talc, reducing the talc particle size and optimizing the talc's adhesion within the polymer matrix helps to hide the scratch. The final strategy was to hide the

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scratch as mentioned above and decrease the scratch size by increased surface lubricity.

The mechanism of scratching a polymer was analyzed. This analysis determined how to characterize a material's scratch susceptibility, provided an approach to additive selection and identified appropriate scratch test equipment. The depth and color of the scratch were used for characterization and two pieces of test equipment were used; the Taber scratch machine (Fig. 1) and the Five-finger scratch machine (Fig. 2).

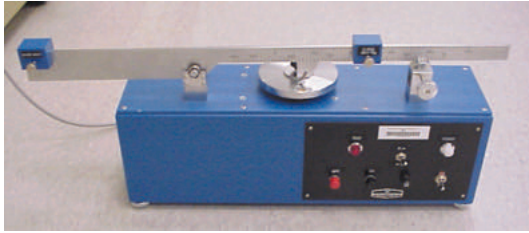


Fig. 1 Taber scratch machine

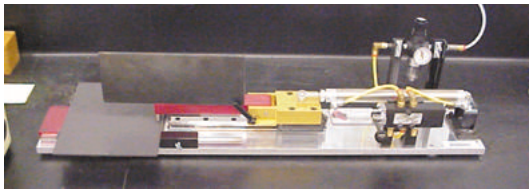


Fig. 2 Five-finger scratch machine

Exposed talc and titanium dioxide ( $\text{TiO}_2$ ) are the primary contributors to the white appearance. Encapsulating the talc and increasing the interfacial bond strength between the talc and the polymer, minimize the white appearance. Optimizing the dispersion prevents significant exposure of the  $\text{TiO}_2$  (Fig. 3).

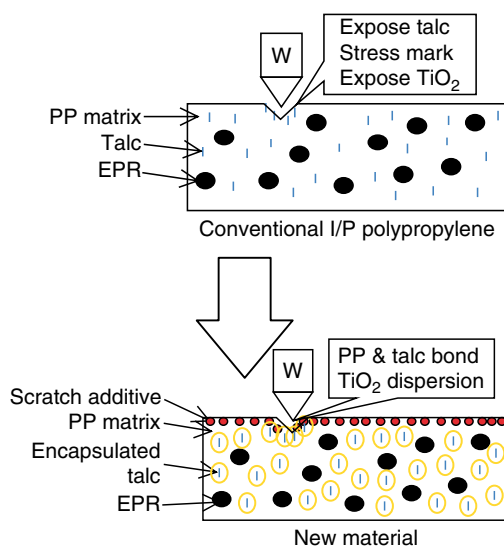


Fig. 3 Scratch mechanism

Optimizing the molding process and the gate configuration was intended to minimize appearance defects (weld lines, flow marks, etc.).

### 3. Results

The scratch was characterized by whitening <sup>(2)</sup>. That is, the depth of a scratch is intrinsic to the polymer family and not the grade. This ideology coincides with our conclusion to not increase the material's hardness.

To create the final formulation, several additives and additive combinations were considered. Additives A through E were evaluated as well as pigment-dispersing agents and talc. Additive A successfully increased the surface lubricity, however it also increased the cost, decreased the molded-part appearance and decreased the flexural modulus. Additive B strengthened the polypropylene's bond to the talc, which minimized the talc's contribution to a white appearance after being scratched. A loading range of 1.2 – 2.0% was optimum for maintaining the molded-part appearance and increasing the scratch resistance (Fig. 4).

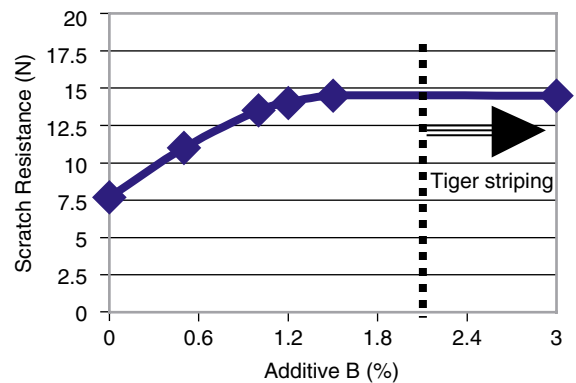


Fig. 4 Scratch resistance vs. additive B (with D)

Additive C aided surface lubricity but increased our haze percentage beyond the maximum value that meets the fogging target and was canceled. However, additive D increased the surface lubricity while having a lesser effect on the fogging level (Fig. 5).

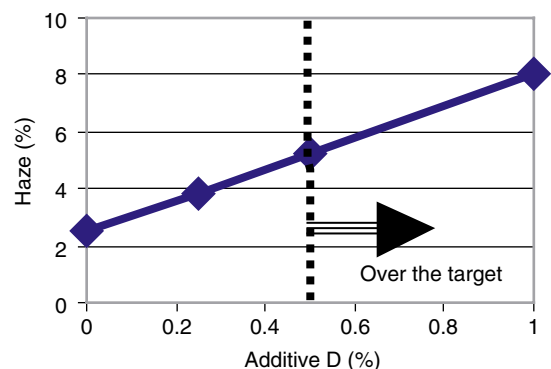


Fig. 5 Fogging vs. additive D

A loading range of 0.2 – 0.5% of additive D is sufficient to optimize scratch resistance and fogging performance (Fig. 6).

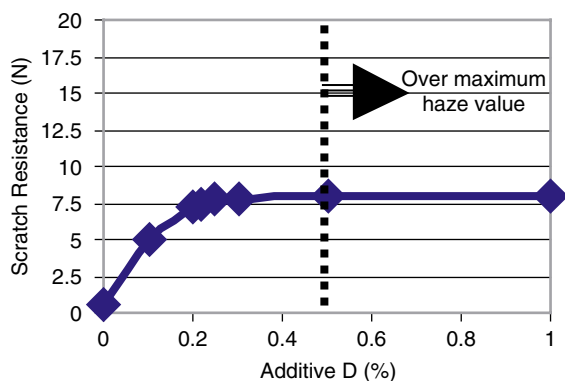


Fig. 6 Scratch resistance vs. additive D

Additive E increased the material's crystallinity and minimized the amount of whitening caused by stress. However, Additive E does affect the physical properties (Fig. 7).

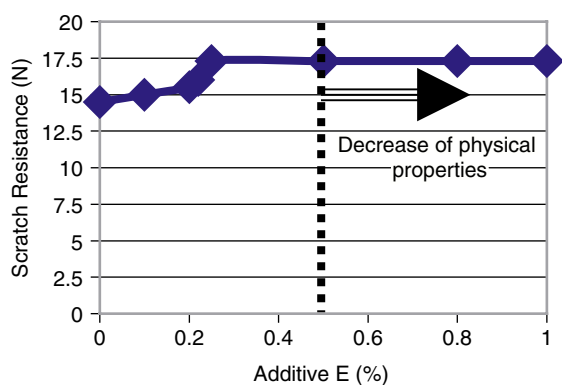


Fig. 7 Scratch resistance vs. additive E (with B & D)

A loading range of 0.2 – 0.5% of additive E is optimum for meeting the flexural modulus target while maximizing the scratch resistance (Fig. 8).

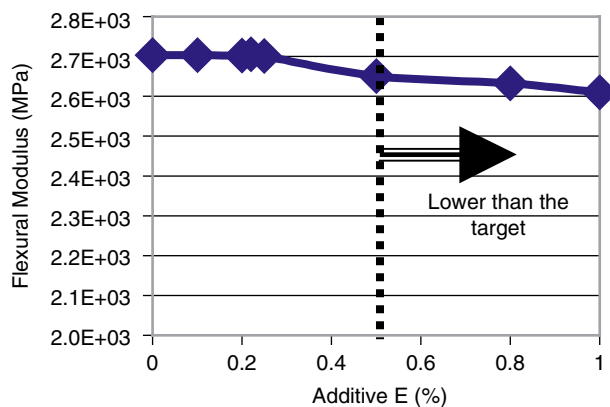


Fig. 8 Flexural modulus vs. additive E (with B & D)

Of the target colors, Fern (G59L) and not gray (NH361L), exhibited the most whitening when scratched. Light colors, such as Fern, contain more  $\text{TiO}_2$  than dark colors and thus have a higher probability to whiten when scratched. The primary causes are poor dispersion of the  $\text{TiO}_2$  and the talc particle size. Therefore, the magnesium stearate pigment-dispersing agent was replaced with a more effective high-density polyethylene pigment-dispersing agent. The monomer molecular weight was reduced by 96%. Additionally, the talc particle size was reduced from 7mm to 2mm. These changes improved the Fern's scratch resistance from 13N to 17N and did not adversely affect physical performance.

Table 1 summarizes the final formulation.

Table 1 New material formulation consideration

| Constituent      | Description           | Benefit                                                         | Limitation                                                    |
|------------------|-----------------------|-----------------------------------------------------------------|---------------------------------------------------------------|
| Additive A       | Siloxane              | Increases surface lubricity                                     | Increased cost, reduced physical properties & poor appearance |
| Additive B       | Grafted polyolefin    | Talc bonding (+6N)                                              | >2% loading yields tiger stripes                              |
| Additive C       | Fatty acid amide      | Increases surface lubricity                                     | Increased cost and poor fogging                               |
| Additive D       | Fatty acid amide      | Increases surface lubricity (+2N)                               | Increased cost and >0.5% loading yields NG fogging values     |
| Additive E       | Petroleum resin       | Maintain physical properties and reduces stress whitening (+2N) | >0.5% loading yields NG flexural modulus values               |
| Dispersion Agent | Polyolefin            | Improved dispersion of $\text{TiO}_2$ and additives (+1N)       | None foreseen                                                 |
| Talc             | Reduced particle size | Minimizes the potential for talc exposure (+3N)                 | >70% reduction affects physical properties                    |

The aforementioned formulation yields a Five-finger scratch performance improvement of 3N to 17N over convention polypropylene as depicted in figures 9 and 10 respectively.

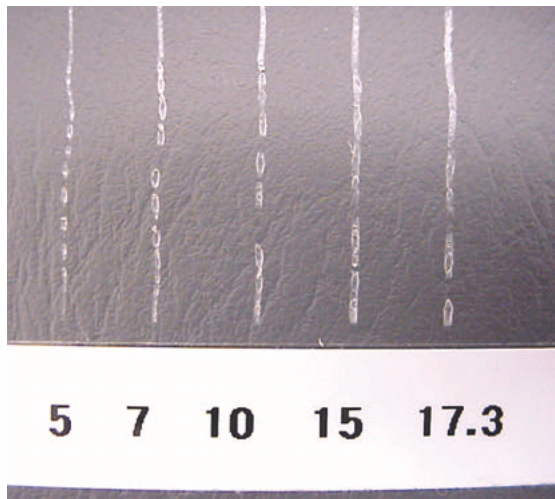


Fig. 9 Conventional TPO

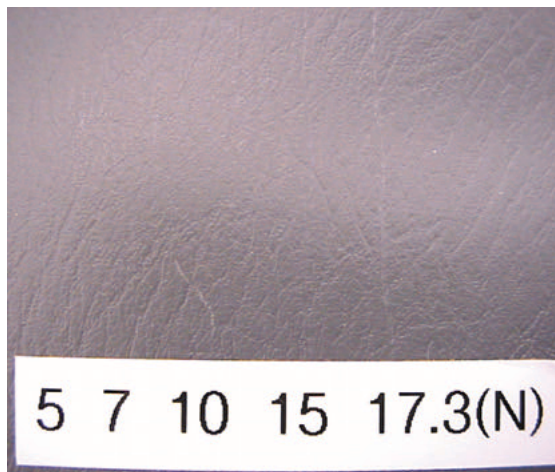


Fig. 10 New material

While realizing the scratch resistance improvement, the target physical properties were maintained (Table 2).

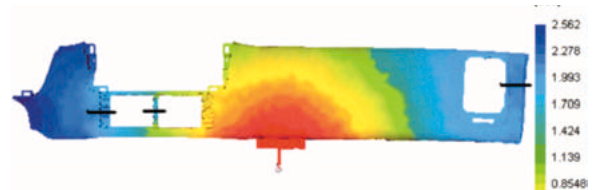
Table 2 Key physical properties

| Property                     | Units | Honda I/P target | New material |
|------------------------------|-------|------------------|--------------|
| Izod Impact Strength (-30°C) | J/m   | 44               | 45           |
| Tensile Strength             | Mpa   | 23               | 23           |
| Flexural Modulus             | MPa   | 2780             | 2700         |
| HDT (0.45MPa)                | °C    | 131              | 131          |
| Density                      |       | 1.06             | 1.06         |
| Scratch Resistance           | g     | 200              | <b>800</b>   |
| Fogging                      | %     | 4.2              | 4.1          |

## 4. Part Performance

### 4.1. Molded-part Appearance

The molded-part appearance of the conventional polypropylene and the new scratch-resistant polypropylene were evaluated using a mass production Side Sill Garnish tool. An injection machine capable of sequential valve gating was selected to take advantage of the latest technology. A mold-flow analysis was used to optimize gate design and locations for the final tool. The straight black lines in figures 11 and 12 indicate weld line locations. The initial  $10 \times 1.5$ mm fan gate design resulted in three weld lines (Fig. 11).

Fig. 11 One  $10 \times 1.5$ mm fan gate

The final gate arrangement consisted of an 8mm bore channel, one  $10 \times 1.5$  fan gate and three  $5 \times 1.5$ mm valve gates (Fig. 12).

Fig. 12 One  $10 \times 1.5$ mm fan gate and three  $5 \times 1.5$ mm valve gates

This arrangement resulted in two weld lines placed in the least observable regions. A melt temperature of  $210^{\circ}\text{C}$  and mold temperature of  $60^{\circ}\text{C}$  were found to be acceptable. Additionally, fill time, cavity pressure, and feed configuration were optimized to minimize the weld line's appearance and control their positions (Fig. 13).

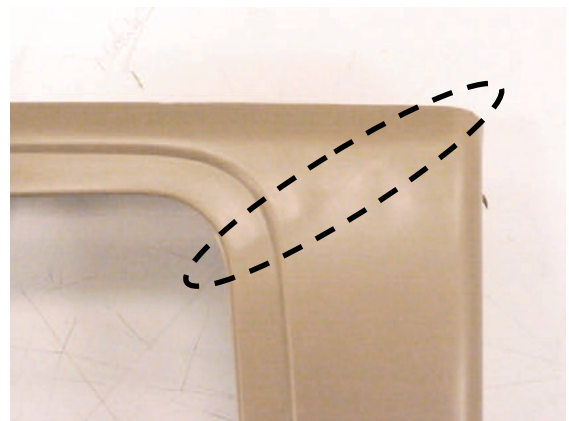


Fig. 13 Mass-production tool without grain

The mass production tool was not grained before development was scheduled to finish and the Side Sill Garnish grain was not deep enough to predict weld line appearance in an instrument panel grain (H-280C; 80m). In order to make this prediction in time for mass production, a weld line was introduced into a plaque having the H-280C grain on one side and no grain on the other. The weld line on the non-grained plaque was matched to weld line on the non-grained injection-molded parts. The weld line on the flip side of the plaque with the H-280C grain was used to predict the appearance on grained parts. As predicted, the mass production part meets all the appearance requirements. (Fig. 14).

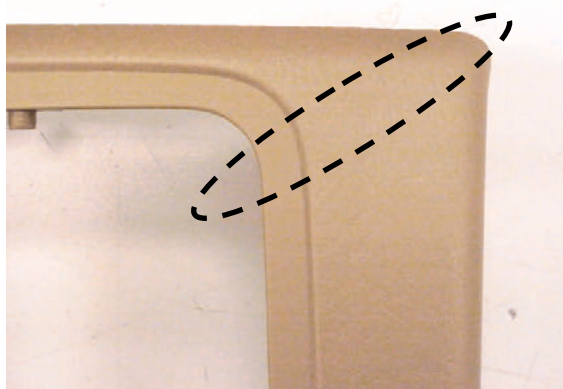


Fig. 14 Mass-production part with grain

The appearance of weld lines in the new material is no more noticeable than that of the conventional material. Therefore, the new material obeys the standard theory that deep, animal-like grains will make weld lines

The tiger stripe appearance was removed by eliminating an additive that was incompatible with the polypropylene (Additive A), implementing sequential-valve gate molding and optimizing the mold temperature.

The new material can be painted using Honda's solvent or water-based paint systems at recommended bake conditions for low-gloss Honda colors <sup>(3)</sup>.

#### 4.2. Part Testing and Application

The physical properties of the new material matched those of materials that have met our cold-impact and thermal cycle requirements using similar designs. Once the formulation was stable enough, parts were molded and then evaluated for cold-impact and thermal cycle performance.

The parts molded in the mass production tool performed as expected in the instrument panel assembly; passing the cold-impact and thermal cycle requirements. A nominal wall thickness of 2.5 mm was sufficient for this material to meet the aforementioned standards. This material has been applied to the Honda Pilot's mid panel parts (Fig. 15, 16).



Fig. 15 DR Mid Panel



Fig. 16 AS Mid Panel

## 5. Conclusion

Through formulation optimization a high-scratch resistant polypropylene material for instrument panels has been developed.

- (1) Impact-modified polypropylene's scratch resistance improved from 3N to 17N.
- (2) The per/pound cost was not increased.
- (3) The molding characteristics were not adversely affected.
- (4) The physical property performance was not adversely affected.
- (5) The part performance was not adversely affected.
- (6) The part cost was reduced by 80% (S9VA AS/DR Mid Panels; figure 14 and figure 15).

The next generation of this material will be engineered to meet instrument panel veiling glare and visual feeling targets.

## 6. Acknowledgments

We appreciate the efforts of Color & Composite Technologies and Greenville Technologies.

## 7. References

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