Offering High Performance and High Functionality of TPE for Airbag Cover Applications

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Airbag devices installed to protect passengers in cars are veiled with a part that is called an "airbag cover" made of TPE. The impact performance at low temperature and durability to maintain performance after many years, are important requirements for TPE used for airbag covers. Recently in line with an increase in the types of vehicles being equipped with airbags and in installation locations, the demand characteristics required from TPE for airbag cover applications have changed due to differences in the construction and shape of airbags. In this paper, we present the approaches on offering high performance and high functionality of TPE for airbag cover applications with examples of the airbag devices for drivers and for passengers.

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Introduction

While thermoplastic elastomers (TPE) exhibit a rubber-like elasticity at normal temperatures, they plasticize and exhibit fluidity at high temperatures. Therefore, they are materials that can be processed by molding in the same manner as thermoplastic resins such as polyethylene and polypropylene. Because TPE is easy to use and easy to recycle, the amount that is used is increasing every year. TPE is roughly divided into olefinic, styrenic, polyvinyl chloride based, urethanic, ester based and amide based according to the constituent components, and currently, it is said that the annual consumption of TPE worldwide is approximately 3,000,000 tons.1)

Of these, olefinic TPE made from olefinic resins such as polypropylene (PP) and polyethylene (PE) and olefinic rubber such as ethylene-propylene rubber (EPDM, EPR, etc.) have the following characteristics.2)

(1) These are the lowest density TPEs and are therefore useful for reducing weight.
(2) They have superior heat resistance and cold resistance, making for a broad allowable range of use.
(3) They have excellent light resistance and ozone resistance.
(4) Their chemical resistance to acids, alkali and polar solvents is excellent.
(5) They have low hygroscopicity, and their electrical insulating properties are excellent.
(6) They are suitable for various types of molding machines for thermoplastic resins, including injection molding, extrusion molding, blow molding and calender molding.
(7) Blending with PP, PE and other general-purpose olefinic resins and two-color molding are possible.
(8) Coloring is possible for any product by applying paint or mixing in colorants.
(9) They are less expensive than other TPEs.

Olefinic TPEs are used for a variety of applications centered on those for automobiles, and it is said that olefinic TPEs make up approximately 40% of the total volume of TPE used.1) The main applications for olefinic TPE are components for automobiles, and examples of their use are shown in **Fig. 1**.

Airbag covers are one of the applications of olefinic TPEs in automobile components. Airbags were first installed in the center of the steering wheel for the driver's side and in the passenger's side instrument panel for the passenger's side (**Fig. 2** and **3**) in luxury cars in the 1980s to protect passengers in the vehicle. In the 1990s, they started being installed in most models of vehicles.3), 4)

When the vehicle makes impact, an acceleration sensor reacts, and the acceleration information is sent from the sensor to the airbag electric control unit (ECU). A determination is then made to deploy or not deploy the airbag. When the airbag is deployed, it is set up so that the airbag instantly inflates with the generation of gas by a device called an inflator. The airbag unit,

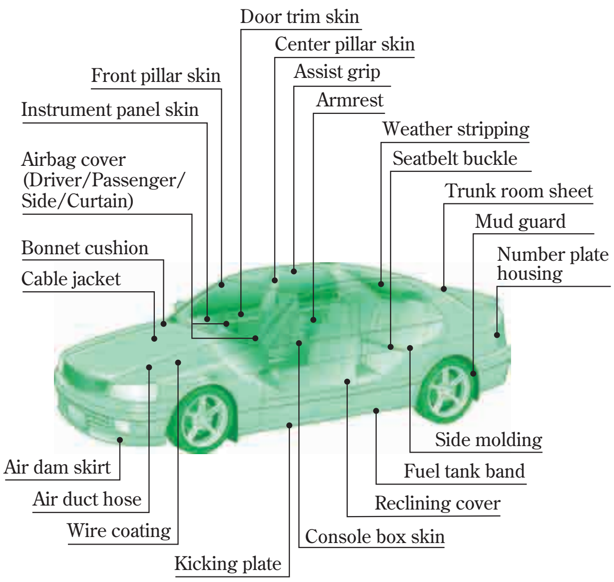


Fig. 1 Applications of olefinic TPEs for automobile

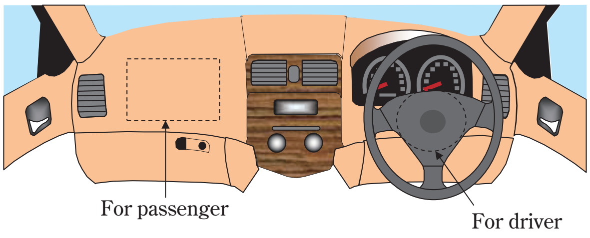


Fig. 2 Installation position of airbags

Fig. 3 Product examples of airbag devices

which is made up of components such as this airbag and the inflator, is covered by components known by terms such as cover, storage case, or lid, (given the general name of airbag cover in the following). This airbag cover is provided from the beginning with grooves called tear lines or tear seams (called tear lines in the following) that have a thinner structure, and the structure is such that only the tear line parts break with the force of expansion from the airbag, allowing the airbag to deploy.3), 5), 6)

When airbag devices were first installed in automobiles, covers made from urethane foam embedded with mesh sheets of nylon or another reinforcing material were used for these airbag covers.7) With airbags becoming standard equipment, there was a reassessment of these types of covers with their complex molding processes and low productivity, and we have moved to the present where there has been progress in replacing them with airbag covers that make use of TPE. Based on Sumitomo Chemical's close relationship with manufacturers of airbag components, we have been working hard to supply materials with the required performance. As a result, the amount of olefinic TPE used for this application has continued to increase with the increases in the number of vehicles manufactured and the number of air bags installed. In this article, along with a short review, we will introduce some of our work on high performance, highly functional olefinic TPE for airbag covers.

Olefinic TPE

Olefinic TPE is TPE that makes use of PP, PE and other olefinic resins in the hard segment and EPR, EPDM and other olefinic rubber in the soft segment to give the characteristics described previously.

Olefinic TPE is roughly divided into cross-linked types and non-cross-linked types according to its structure. In the compounding process for the rubber component and resin component for cross-linked types, the rubber component is cross-linked through the addition of a cross-linking agent, and a morphology where tiny cross-linked rubber particles are dispersed in the resin component matrix is formed. **Fig. 4** shows a transmission electron microscope (TEM) image of cross-linked TPE with a structure where cross-linked EPDM is dispersed in the PP matrix. The rubber elasticity is superior because the rubber component is cross-linked, and it exhibits performance similar to vulcanized rubber which has permanent low compression and low strain characteristics.

The first use of cross-linked olefinic TPE in automotive applications was in covering materials for components such as instrument panels and door trims instead of soft polyvinyl chloride. Thereafter, because of the superior recyclability due to its not needing a vulcanization process, it was used as a replacement for vulcanized rubber in applications such as body sealing materials such as glass-runs and weather stripping, air duct hoses, mat guards, grips and gaskets.

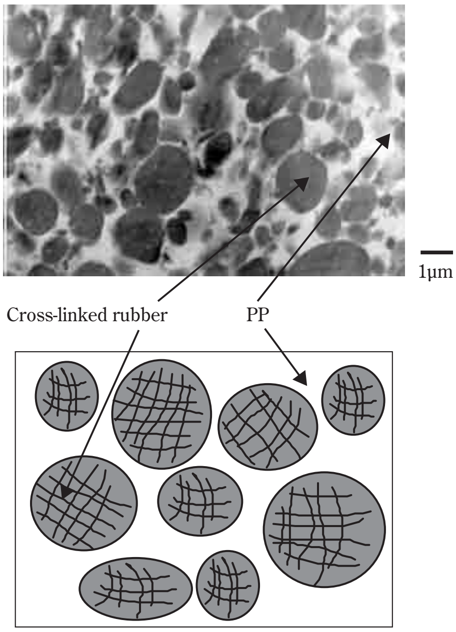


Fig. 4 TEM image of crosslinked-type TPE

On the other hand, with the non-cross-linked type where the rubber component, which is the soft segment, is not cross-linked, there are types created by polymerization known as reactor TPO (RTPO) and simple blends. The hardness and rigidity of these TPE materials, which are one point in the selection of materials for use in various applications, are shown in **Fig. 5**. Non-cross-linked TPE is widely used for airbag covers.[8)]

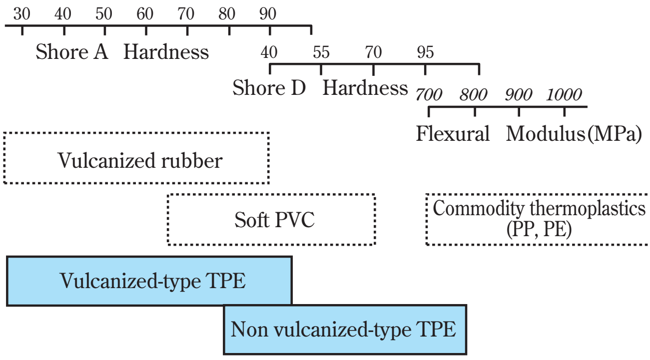


Fig. 5 Stiffness property of olefinic TPE

TPE for Airbag Covers

1. Basic required performance

As mentioned previously, there is a structure where grooves called tear lines that are thinner are provided in the airbag cover, and when the airbag is deployed only the tear lines break and open because of the force of expansion to allow the airbag to deploy. **Fig. 6** shows an example of this shape of airbag tear lines. The airbag cover itself is required to break open without scattering the pieces and without breakage occurring at places other than the tear lines in the range of environmental temperatures for use in automobiles, which vary widely from low temperatures to high temperatures.

In addition, since this component is an interior component, the durability performance in terms of factors such as heat resistance and light resistance is important. In addition, there have recently been requirements for reducing volatile organic compounds (VOCs) from the standpoint of improving the environment inside automobiles. **Fig. 7** and **Fig. 8** show the aging performance for heat resistance in airbag cover TPE, and **Table 1** gives an example of VOC properties. From the beginning, the aging performance for heat resistance of olefinic TPE has been excellent, and it can be seen that the low temperature Izod impact strength is maintained after the aging tests as shown in **Fig. 7**. Aging performance for light resistance is affected by the presence or absence of coatings and the nature of the coloring, but as with aging performance for heat, olefinic TPE has

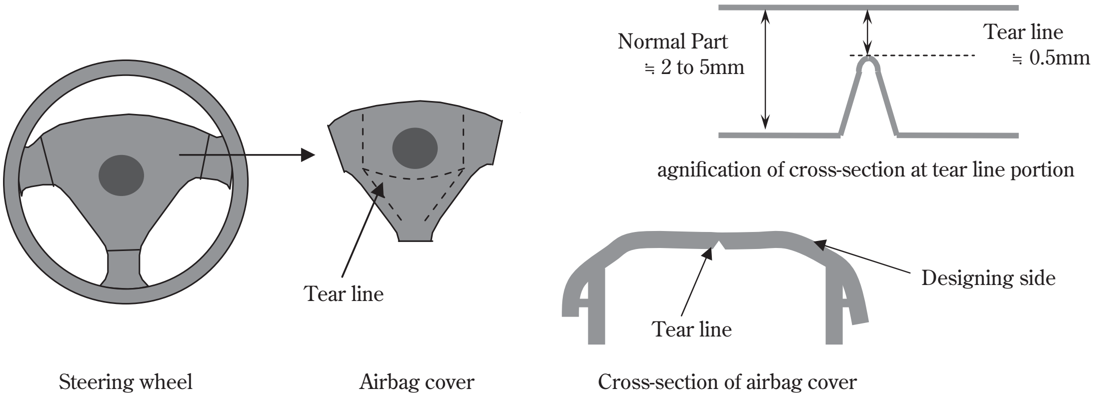


Fig. 6 Example of configuration of tear line

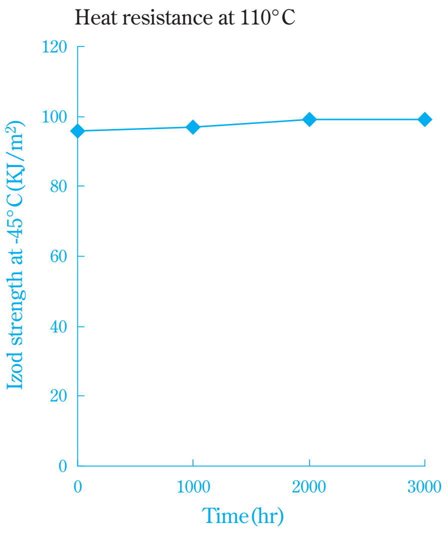


Fig. 7 Example of heat resistance of TPE

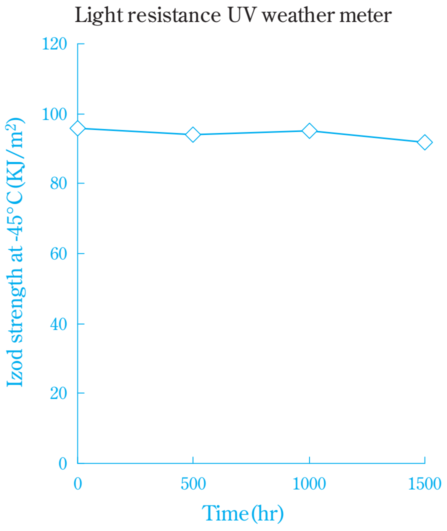


Fig. 8 Example of light resistance of TPE

Table 1 Example of VOC properties of TPE

Condition			40°C×2hrs	Quantitative Analysis Limit (Q.A.L)
Sample area		mm^2	8000	
Ingredient	Formaldehyde	$\mu g/m^3$	Less than Q.A.L	50
	Acetaldehyde		Less than Q.A.L	50
	Toluene		12	10
	Xylene		Less than Q.A.L	10
	Ethyl benzene		Less than Q.A.L	10
	Styrene		Not detected	10
	p-Dichlorobenzene		Not detected	10
	Tetradecan		Not detected	10

excellent aging performance for light resistance as shown in **Fig. 8**. Strict confirmation of these evaluations of properties is also implemented by component manufacturers using actual products.

When airbags deploy at low temperatures, they require stable breakage only at the tear lines, and normally they are required to maintain these properties to something in the neighborhood of –30°C to –40°C. When an airbag cover breaks with a brittle fracture in this temperature range, it invites breakage in locations other than the tear line parts,[9] so impact performance at low temperatures is also an important performance requirement. The low temperature impact performance of olefinic TPE is controlled by the glass transition temperature of the starting material polymer, the ratio of the PP and rubber composition and the morphology. The effect of morphology on low temperature impact is shown in **Table 2** and **Fig. 9**. They show the low temperature impact performance of two TPE samples with different dispersed rubber particle diameters obtained by adjusting the kneading conditions with the same ratio of composition for the same starting materials (PP and EPR). Izod tests and a high rate impact

Table 2 Impact properties of TPEs at low temperature

		TPE-1	TPE-2
Izod(–50°C, notched)		Break	Non Break
HRIT (–50°C, 5m/sec)		Brittle	Ductile
Average diameter of rubber particle	µm	1.04	0.67

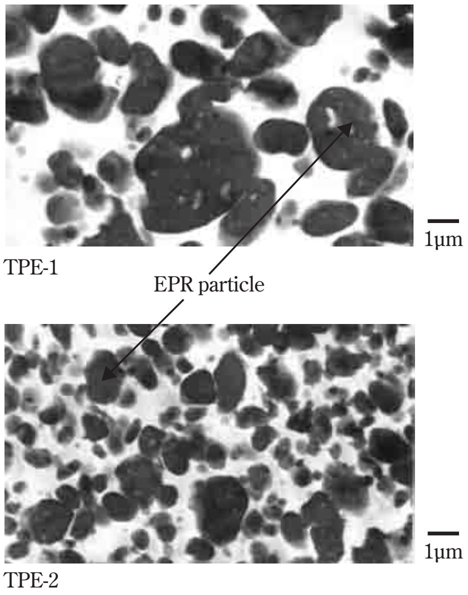


Fig. 9 TEM image of TPEs

tester (HRIT, **Fig. 10**) were used to carry out evaluations of the low temperature impact performance. The smaller the rubber particle diameter is, the better the low temperature impact performance is.

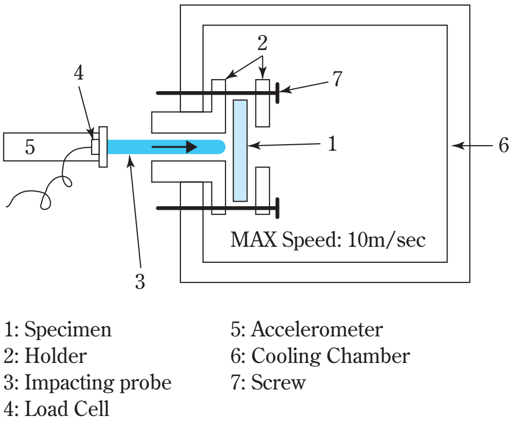


Fig. 10 Outline drawing of high rate impact tester

Airbag covers are mainly manufactured by injection molding, and the characteristics shown below are necessary for the molding process.

(1) Cleavage of molecules in the material must not occur easily even at high temperatures and a high shear velocity.
(2) They should not contain moisture, volatile substances or substances that thermally decompose, or these must not occur easily.
(3) They should have superior fluidity.
(4) They should not contaminate molds or lack tackiness.

From the beginning, olefinic TPE is superior in these required properties, but these properties can be improved through the structure of the raw material and optimization of the composition as well as techniques for treating with additives.

2. Driver's side airbag covers

The driver's side airbag cover, which is installed in the center of the steering wheel, often has a decorative surface applied to it to improve the quality of the appearance. However, from the standpoint of reducing costs and reducing the environmental impact of operations due to the solvents in coatings, there is a growing need for uncoated materials, in other words, materials with excellent quality of appearance without applying coatings. When airbag covers are made without coatings, the greatest problem for the quality of appearance is the phenomenon of a luster appearing along the tear lines (this phenomenon of poor appearance being called "glossy tear line" in the following).[10] **Fig. 11** shows a photograph of observations of the surface of a molded product where a glossy tear line has occurred.

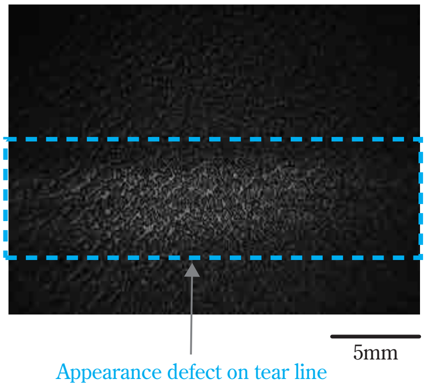


Fig. 11 Glossy phenomenon on tear line

This glossy tear line presumably occurs because of defective transcription to the surface of the mold because of unstable resin flow due to the thickness of the edges when the molten resin passes through the tear line parts in the cavity during injection molding, and a sudden rise in the viscosity of the resin due to the cooling effect of the mold at the tear line parts.

Fig. 12 shows the presumed mechanism for these glossy tear lines. A mold for obtaining molded products in a box shape simulating an airbag cover as shown in **Fig. 13** was used in the tests, and the flow behavior at the tear line parts was confirmed in a short shot molding.

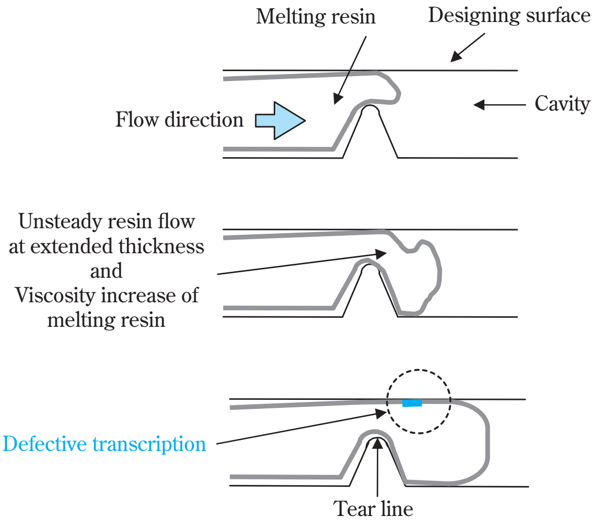


Fig. 12 Estimated outbreak mechanism of glossy tear line

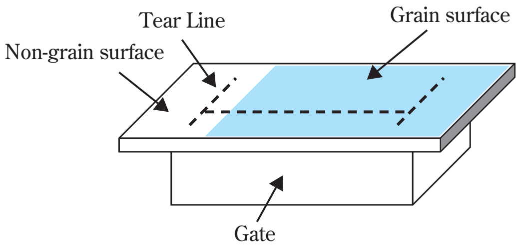


Fig. 13 Overall image of quasi-airbag cover

The shape of this tear line part is shown in **Fig. 14**. The results of observing the flow front state directly after passing the tear line part from the grained surface side are shown in **Fig. 15**. A trace formed by an unstable flow that arises at the flow front directly after it passes the tear line part is observed.

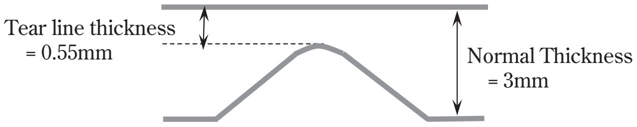


Fig. 14 Magnification of tear line portion

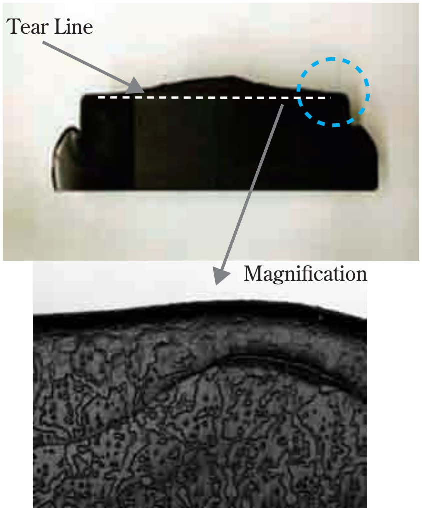
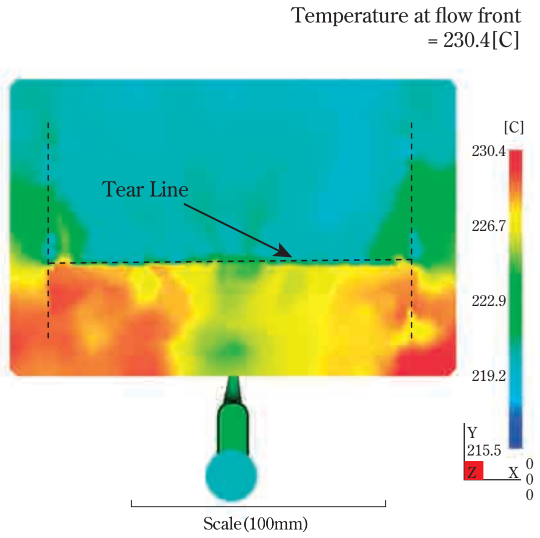


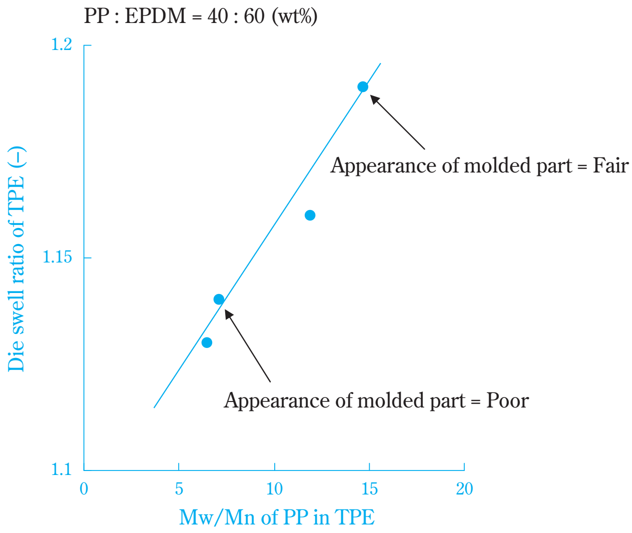
Fig. 15 Observation of flow front by short-shot molding

In addition, **Fig. 16** shows the distribution of resin temperature from a flow analysis at the flow front during the injection molding. From these flow analysis results, we find that the risen temperature suddenly drops when the molten resin passes the tear line parts. These short shot test results and flow analysis results may be thought of as supporting the presumed mechanism described previously for the cause of glossy tear line at the tear line parts. Based on the presumed mechanism for occurrences of glossy tear line at the tear line part showed in **Fig. 12**, we focused on the fluid characteristics (die swell properties) and the crystallization time of TPE and made improvements regarding this failure phenomenon. In other words, we thought that the defective transcription to the mold due to the increase in the viscosity of the TPE when the molten TPE passes the tear line part could be controlled by lengthening the crystallization time if the swell were large and the transcription to the mold surface were improved. **Fig. 17** shows an example of improving the die swell ratio, which shows the



Calculation condition: Resin temperature = 220°C,
Mold temperature = 40°C, Injection time = 3sec.

Fig. 16 Calculation result by flow analysis



<Measurement condition>
Temperature = 200°C, Shear rate = 365 sec^{-1}

Fig. 17 Effect of die swell ratio on inhibiting glossy tear line elastic properties of the molten resin, in olefinic TPE and controlling the glossy tear line at the tear line parts. The die swell ratio was measured using a capillary rheometer, and **Fig. 18** shows an overview of the device and definitions of its parts. When PP with differing distributions of molecular weight is used in the TPE, the wider the distribution of molecular weight in the PP becomes, the greater the increase in the die swell ratio for the TPE is and the better appearance of the molded part is.

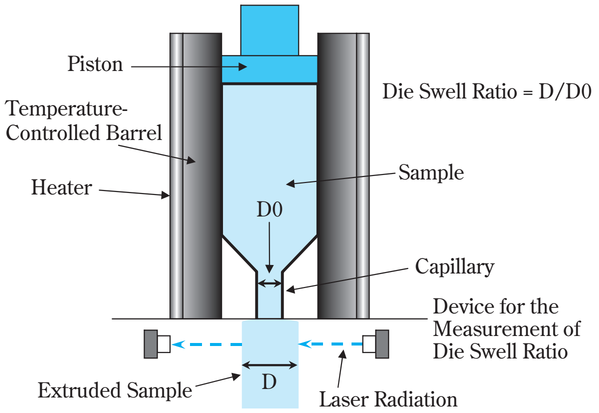


Fig. 18 Outline of capillary rheometer

Next, we will discuss the results of controlling the glossy tear line at the tear line parts by lengthening the crystallization time for the TPE. The effect on controlling glossy tear line at the tear line parts if the crystallization time is extended by adding a propylene-ethylene copolymer elastomer (called C'3-C'2 elastomer in the following) to the TPE is shown in **Fig. 19**.

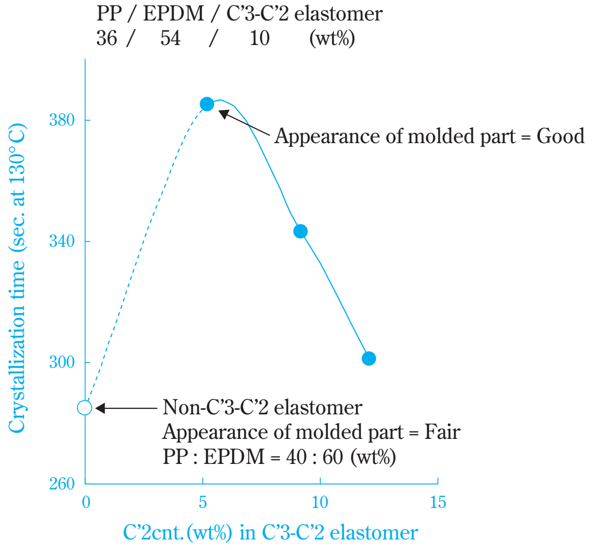


Fig. 19 Effect of addition of C'3-C'2 elastomer on inhibiting glossy tear line

Evaluation of the crystallization time used a differential scanning calorimeter (DSC). The samples were melted by keeping them at 220°C for 5 minutes. Next, the temperature was rapidly reduced to 130°C, and the thermal emission curves were measured starting when maintenance at that temperature began. The crystallization time was set at the time until the thermal emission curve peak was observed.

It is possible to extend the TPE crystallization time by adding the C'3-C'2 elastomer, and we confirmed that glossy tear line at the tear line parts was controlled. It is thought that by finely dispersing an elastomer component in PP with high crystallinity, this elastomer component delays the crystallization of the PP during the process of crystallization (hardening) from the molten state. In addition, variations in the effects are brought about through the ratio of the composition of the ethylene and propylene in the C'3-C'2 elastomer that is added. It is thought that when the ethylene content in the C'3-C'2 elastomer is low, the compatibility in the PP is increased, and the effect of delaying the TPE crystallization is more easily expressed. Here, we have introduced an example of improvements for the phenomenon of defects in the appearance required for airbag cover TPE for the driver's side focusing on the swell properties and crystallization time. However, these are provided as materials that meet other property requirements through a combination of the structure of the various raw materials, ratios of composition and compounding techniques, and furthermore, they have been made practical as airbag cover products inclusive of the processing technology and mold design technology.

3. Passenger's side airbag covers

We will discuss an example of the development of airbag cover materials used for the passenger's side airbags installed to protect people in the passenger seat. Most passenger's side airbag covers are installed on the back side of thermoplastic resin molded products, typically PP, that form the base material for the instrument panel. In this case, there are few requirements for quality of appearance similar to the ones for driver's side airbag covers. Conventionally, the attachment of the molded base material for the instrument panel and TPE airbag covers has been forming a single unit by vibration welding of the two molded products from the standpoint of reducing the number of attachment processes and reducing costs.11), 12) **Fig. 20** shows a cross-sectional image of a passenger's side instrument panel. Ribs are provided on the TPE airbag cover surface which forms the surface in contact with the base material for the instrument panel, and this ribbed part forms the point of contact with the base material for the instrument panel when the vibration welding is done. Vibration welding is a processing method where one of two thermoplastic resin components, which are under pressure, is vibrated back and forth. Heat from friction arises in the contacting surfaces. They melt and fuse to form a unit. The TPE that forms the material for the airbag cover has been found to have excellent strength of adhesive bonding after being formed by vibration welding into a unit with the base material for the instrument panel, which is made from a thermoplastic resin. The strength of vibration welding depends on the processing conditions during the vibration welding (such as depth of fusion and vibration frequency) and the shape of the airbag cover ribs that were described previously. However, it is possible to increase the freedom in the processing conditions and shape of the molded product by increasing the adhesive strength of the material itself.

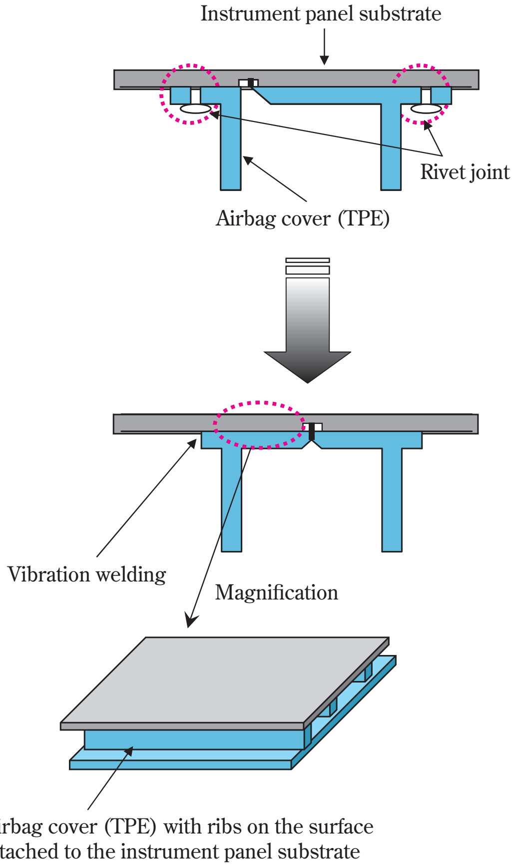


Fig. 20 Cross-section shape of passenger's side instrument panel

In terms of methods for improving the adhesive strength of the TPE material with the PP material of the instrument panel using vibration welding, we will give examples of the effects of the structure of the PP used in the TPE. The relationship between the melting point of the PP used in the TPE and the welding strength with the PP-based material after vibration welding and the test method are shown in **Fig. 21**. The smaller the difference between the melting point of the PP used in the TPE and the melting point of the base material PP is, the greater the welding strength obtained is.

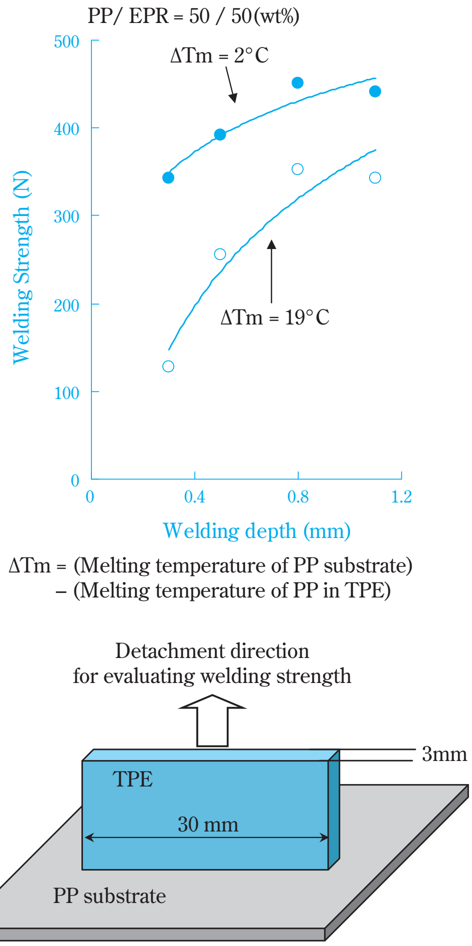


Fig. 21 Effect of melting temperature on welding strength to PP substrate

When the difference between the melting point of the PP used in the TPE and the melting point of the base material PP is large, in other words, when the melting point of the PP used in the TPE is lower than the melting point of the base material PP, it can be assumed to be easy for only the TPE side to melt, so the amount it melts into the PP base material is reduced. On the other hand, it can be assumed that when the melting point of the PP used in the TPE and the melting point of the base material PP are the same, the TPE melts deeply into the PP base material. This difference in the depth of the fusion is thought to affect the welding strength. Here, we have discussed the effect of the melting point of the PP used in the TPE on the vibration welding strength of the TPE structure; this property may also be increased by controlling the rubber structure and the morphology.

Conclusion

In this article we have introduced one part of the development of TPE for driver's side and passenger's side airbag covers, but with improving automotive safety as the background airbag devices are basically a standard installation for the driver's side and passenger's side. Furthermore, there is an increase in automobiles which are installed with knee airbags that protect the lower extremities of the passengers, side airbags and curtain airbags for side impact.

The properties required for the TPE used in the covers have become different for each of these airbag locations.

The development of olefinic TPE is supported by increasing the performance of the PP and rubber starting materials, the compounding techniques and processing techniques for these, as well as structural analysis technology. Moving forward, we would like to continue developing this technology and respond to the changes in automobile structures and the changing requirements for properties jointly with component manufacturers.

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