NEW TECHNOLOGIES

Use of Recycled Plastic as Truck and Bus Component Material

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Abstract

An effort to effectively utilize recycled materials and develop new plastic recycling technology, a study was carried out to find a method that enables using recycled plastic as material of truck components.

As the result of the study, it is now possible for recycled plastic materials from painted passenger-car bumpers to be used as material for production of trucks' black exterior parts. The study also includes establishing a method to use paint-free materials recycled from other industries for those interior and exterior parts in which use of recycled plastic materials from painted bumpers is not acceptable due to paint on pellets.

Keywords: *Recycling, Environment, Plastic*

1. Introduction

As with other companies, Mitsubishi Motors has recognized the fact that protection of the environment is a crucial business activity, and accordingly, efforts are being made to reduce the levels of environmentally unfriendly materials – such as the lead, mercury, and cadmium as used in automobile components – and also to promote the usage of recycled materials in order that environment-related problems may be tackled. Although a large amount of metal, plastic, rubber, and other depletion type resources are used in automobiles, when considered from the point-of-view of recycled material utilization, it can be seen that plastic has inferior recycling properties to those of metals, and furthermore, development of the corresponding technologies is not progressing at the desired rate. Accordingly, the usage both of polypropylene (PP) which has been recycled from passenger car bumpers and of recycled materials from other industries was studied in order that the effective usage of recycled materials could be promoted and that the corresponding recycling technologies could be established. The following provides a summary report regarding this study project.

2. Utilization study for recycled bumper materials

2.1 Recycling material recovery and regeneration methods

Passenger car bumpers which have been removed during replacement by dealers are used in this project, and these are manufactured from PP. These removed bumpers are collected at recovery sites by dealers, and after other materials (i.e., brackets, bolts, etc.) have been removed, they are re-pelletized by a secondary material dealer and are provided to vendors in the form of recycled material. The majority of bumpers manufactured in recent years have been provided with coatings, and in situations where recycled materials from which these coatings have not been removed are used, segments of the coating can be present on the surface of the components manufactured from recycled bumper materials, thus impairing the overall appearance. Although technologies for removing coating segments during re-pelletizing are available, these remain comparatively expensive, and therefore, this study dealt with the usage of recycled materials from which coating has not been removed.

2.2 Physical properties of recycled materials and studied components

(1) Effect of mixing ratios on material properties and appearance

In order that a suitable mixing ratio for the recycled materials could be determined, materials manufactured with a range of different mixing ratios were subjected to physical property measurement and to investigation of the effect on appearance. Specifically, recycled material mixing ratios of 100 %, 50 %, and 30 % were evaluated. As shown in **Fig. 1**, change in the mixing ratio has no marked effect on the physical properties of the materials; it can also be seen that as the recycled material's mixing ratio becomes higher, the appearance degrades as a result of the effect of coating segments. In addition, when components manufactured from recycled materials are themselves provided with coating, segments of the original coating remain visible on the coated surface of the new products, thus continuing to impair appearance. For this reason, it was determined that the usage of recycled materials for components to be coated is not possible.

(2) Variations in recycled material fluidity (MFR[*1])

In accordance with the reduction in thickness of

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bumper material which began in 1997, materials with higher levels of fluidity during molding are being implemented at an increasing rate. For this reason, it is considered that the portion of recovered materials with high MFR values will continue to increase in the future, and this is expected to have an effect on both physical properties and dimensions (i.e., shrinkage rate variation). Accordingly, two different types of recycling material with MFR values of 17 and 35 respectively were used in the following evaluation. Specifically, the MFR 17 material has the lowest levels of field recovery, and the MFR 35 material is currently being used as a virgin raw material.

*1: When the melt flow rate (MFR) is higher, the level of viscosity will be lower and liquidity will be higher. Units: g/10 minutes

(3) Components to use recycled materials

Since recycled bumper materials are black in color and usage with coated materials is impossible when the original coating is not removed, components which may used the recycled materials are limited to those which are black and unpainted. **Table 1** shows the components selected for use of recycled materials so that these conditions may be satisfied (all of these are injection-molded components). These were then categorized into classes A through C in accordance with usage requirements, and an investigation into recycled material usage was carried out based on the required characteristics.

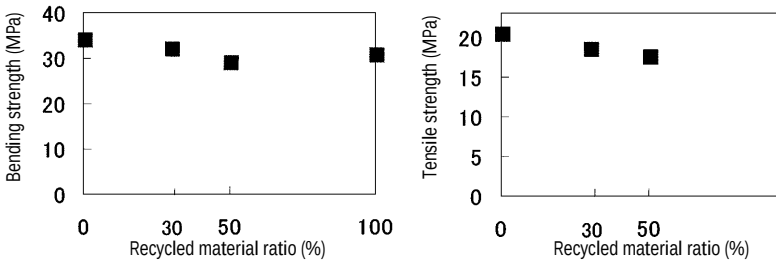

Fig. 1 Physical properties of materials with differing recycled material ratios

Table 1 Components using recycled bumper materials

	Required properties	Study component	Recycled material ratio (%)
Class A	Appearance is not important	Upper shield panel	100
		Lower shield panel	
		Cab side cover	
Class B	Material which strength is required (PP-GF 20)	Air cleaner case	30
Class C	Appearance is relatively important	Dust cover	50
		Tilt control cover	
		10 other components	

Table 2 Evaluation results for Class A components

	Upper and lower shield panels		Cab side cover
Progressive weather resistance	○	○	○
Vibration resistance	○	○	○
Humidity and heat cycle resistance	○	○	○
Impact resistance	○	○	○

(Same results for MFR17 and MFR35)

2.3 Usage study results

Since those components from Class A are not subject to severe appearance-related requirements, studies were carried out with a recycled material blending ratio of 100 %, and this allowed the component's performance requirements to be satisfied (**Table 2**). Furthermore, the degree of dimensional stability of this material is equivalent to that of the current virgin raw materials, and it was therefore determined that this material is suitable for recycling. **Fig. 2** illustrates an upper shield panel which was manufactured from this material.

In the case of the air cleaner case from Class B (**Fig. 3**), sealability and other strength-related demands are relatively strict, and PP-GF 20 is currently being used as the virgin raw material. Accordingly, evaluation of performance requirements was carried out using a PP-GF 30 base with 50 % (GF 15 %) and 30 % (GF 20 %) ratios of recycled material blending. The results of this evaluation showed that, although the material with 50 % (GF 15 %) blending did not satisfy the property requirements of tensile strength and wear resistance testing, these were satisfied by the 30 % (GF 20 %) material. This material was also determined to be suitable for recycling (**Table 3**).

Since appearance of the Class C components is relatively important factor, evaluation was carried out using a recycled material blending ratio of 50 %. However, coating segments resulted in poor appearance, and it was determined, that application of recycled materials would not be possible in this case.

3. Usage study for recycled materials from other industries

3.1 Recycling material recovery and regeneration methods

In the evaluation of possible usage of recycled materials from other industries, this project adopted container-case recycled materials for study. The term "container-case recycled materials" refers to the recycled materials from cases used to hold containers of beer, soft drinks, milk, and the like. Since these cases are put to use in severe environments, PP with excellent physical properties are used in their manufacture. For this reason, the material from those cases which have exceeded their field-service life or which have become dam-

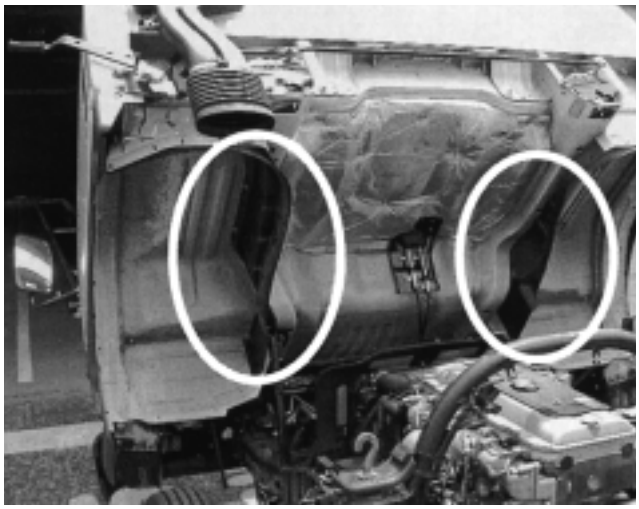

Fig. 2 Upper shield panel

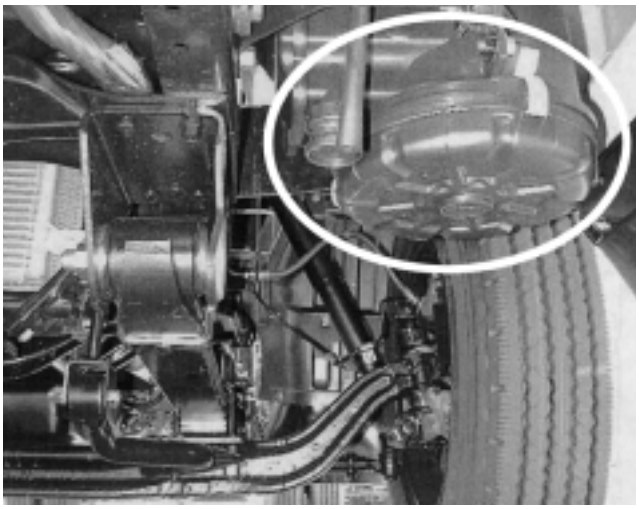

Fig. 3 Air cleaner case

aged is still suitable for use, and this is recycled in the same way as for bumper materials. Due to container-case requirements, a wide range of different colored materials become mixed upon recycling, and carbon or some other pigment is generally added at the re-pelletizing stage to ensure that the resulting material is black.

3.2 Physical properties of recycled materials and studied components

(1) Effect on color tone

Adding black coloring to container-case recycled material of a specified color by the secondary material dealer before the delivery of this material to the component manufacturer, is complex in nature, and therefore, it poses an obstacle to the assurance of supply material. Accordingly, it will be necessary to determine a means of control whereby black material may be achieved within a specific color-tone range regardless of the original material color and the mixture ratio. For this reason, a study was undertaken to determine the effect which the color of original container-cases has on the finished component's color tone.

The container-case recycle materials recovered by secondary material dealers are mainly red, blue, white and mixture of them in color. Carbon was added to each of these colored materials to tint them black. Then, a color difference meter was used to measure the color difference (E^{*2} between the black-colored recycled material and black virgin raw material. In order that an appropriate ratio for mixture of carbon may be found, recycled material samples added with carbon at ratios of 1 %, 2 %, 5 %, and 6 % were prepared. The results are shown in **Fig. 4**.

A color difference (ΔE) of 1.5 or less was determined to be insignificant in a visual sense. It was confirmed that such a degree of color difference resulted from a carbon mixture ratio of 1 %, and that, between the sample containing 5 % of carbon and the one containing more carbon, there was almost no change in color difference. Accordingly, it was determined that a carbon mixture amount of between 1 % and 5 % would be suitable. In the study conducted, components produced from mixed color materials with 2 % carbon added were used.

Table 3 Evaluation results for air cleaner case Class B parts

	Component with 50 % recycled material (GF 15 %)	Component with 30 % recycled material (GF 20 %)
Heat/aging resistance	○	○
Tensile test	×	○
Sealability	○	○
Wear resistance	×	○

(Same results for MFR17 and MFR35)
○: acceptable
×: unacceptable

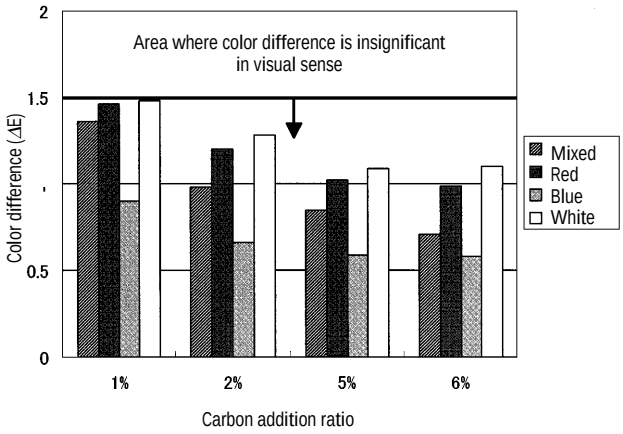

Fig. 4 Carbon addition ratios and change in container material color (ΔE)

*2: The color difference ΔE is a quantitative representation of the degree by which a color varies from a base color.

(2) Suitable components and recycled material properties

A study was undertaken to evaluate the usage of recycled container-case material – a recycled material not affected by coating segments – and this was done

Table 4 Physical property comparison for recycled container-case material and current virgin raw material

Material grade		Recycled container-case material	Current virgin raw material I	Current virgin raw material II	Current virgin raw material III
Produced component		–	Dust cover	Tilt control cover	Side gate board
MFR	(g/10 minutes)	10	40	30	1.5
Bending strength	(MPa)	30	37	33	–
Elastic modulus in bending	(MPa)	1,130	1,400	1,180	980
Tensile yield strength	(MPa)	27	29	26	27
Izod impact strength (at 23 ˚C)	(kJ/m^2)	8	7	8	18
Load deflection temperature (at 0.45 MPa)	(˚C)	110	125	120	–

Table 5 Evaluation results for Class C components

Evaluation item \ Produced component		Dust cover	Tilt control cover
Resistance to heat cycles		○	–
Progressive weather resistance		○	○
Vibration resistance		○	○
Humidity and heat cycle resistance		–	○
Fogging resistance		○	–
Anti-static	Surface resistivity	×	–
	Dust adherence	○	–
Flame resistance		○	–

○: acceptable
×: unacceptable

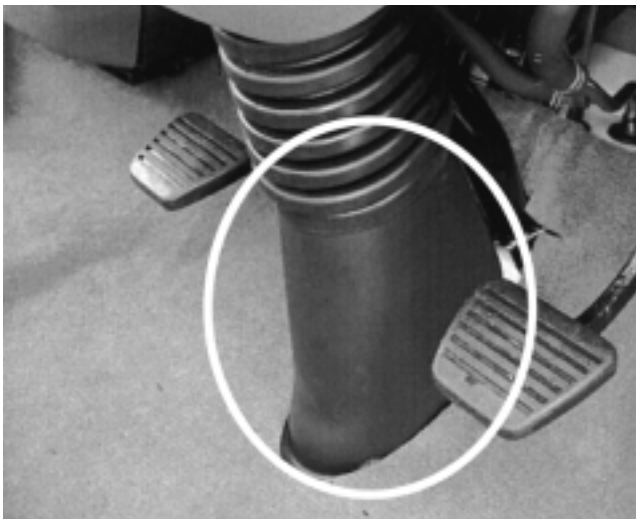

Fig. 5 Dust cover

by applying the material to Class C components with which coating segments impaired the appearance in the above-mentioned bumper material study. Furthermore, a study was also conducted by applying the material to the extrusion-formed, side gate boards of medium-duty trucks, for which black PP virgin raw material is currently used. The physical properties of the virgin raw materials used in the components under study and of the recycled container-case material are shown in **Table 4**. With the exception of the MFR value, there are no significant differences in these properties, and it is therefore considered that no problems will exist other than those associated with moldability; however, it was decided that judgement on possible usage should be made based on the component's required properties.

3.3 Study results

(1) Injection-molded components

Since container-case material is not affected by coating, evaluation was carried out with a recycled material mixture ratio of 100 %. No problems associated with moldability were identified, and the results of evaluation of the required performance are shown in **Table 5**. The dust cover (**Fig. 5**) failed to satisfy electrostatic requirements; however, the adherence of dust was identical to the trouble-free level of the current virgin raw material. All performance requirements were satisfied for the tilt control cover. Consequently, this material was determined to be suitable for the usage.

(2) Extrusion-formed components

Large differences in MFR exist between the recycled container-case material and the current virgin raw material. Since side gate boards (**Fig. 6**) are manufacture by extrusion forming, it can be foreseen that moldability is adversely affected by low MFR of the recycled material. Accordingly, confirmation of moldability was carried out using 50 % and 30 % recycled material mixture ratios. Although this property did not stabilize for the 50 % mixture ratio, adequate stability was achieved for the 30 % mixture ratio, and evaluation was therefore carried out using a component manufactured with this

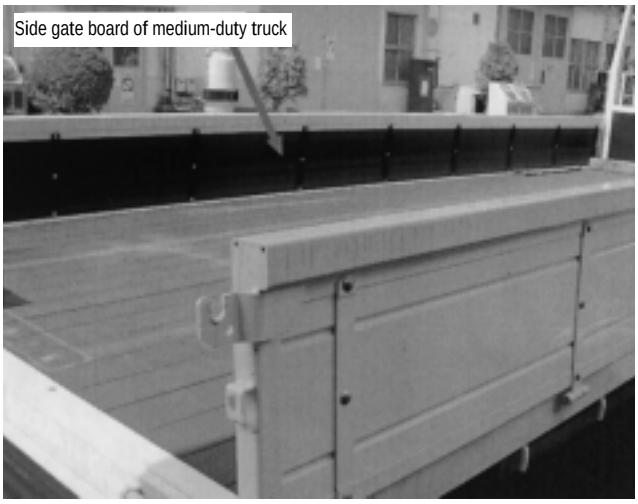

Fig. 6 Side gate board (medium-duty truck)

Table 6 Dimension and weight accuracy of side gate board

Measurement item		Standard value	30 % recycled material product	Current virgin raw material product
Total width	(mm)	338.0 – 341.0	339.2	338.7
Thickness	(mm)	22.0 – 23.0	22.5	22.5
Central shrink	(mm)	1 mm or less for every 50 mm	0.7	0.6
Unit mass	(kg/m)	2.24 – 2.76	2.60	2.54

material.

All product dimensions were found to be in conformance with standard values (**Table 6**), and furthermore, since product properties are equivalent to those of components manufactured from the current virgin raw material, it was determined that this material is suitable for the usage (**Table 7**).

Table 7 Physical properties of side gate board

Test item			30 % recycled material product	Current virgin raw material product
Three-point bending test	Bending strength	(MPa)	13.5	13.1
	Elastic modulus in bending	(MPa)	351	333
Compression test	Compression strength	(MPa)	4	4
Coefficient of linear expansion	20 – 80 ˚C	(x 10E-5/˚C)	15.7	16.3

4. Summary

Through the study described so far, the technology required for usage of recycled materials for PP components has technically been established. Using this technology, approximately 20 tons per month of recycled materials are being used for components of trucks and busses alone. The enactment of Japanese vehicle recycling legislation will give rise to a need for more effective and practical recycling activities, and it will also become necessary to carry out further research into the usage of recycled materials. It is therefore intended to focus on plastic materials other than PP in the future in order that expanded usage of recycled materials may be promoted.

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