

Expansion of the Use of Recycled Bumper Materials through the Modification of Properties

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ABSTRACT

To expand the scope of parts incorporating recycled bumper materials, material property enhancement methods were developed to meet the requirements demanded in the individual parts. The parts targeted in the research were 1) Aerial under cover; 2) Side spacer; 3) Evaporator case; 4) Rear shelf; and 5) Floor carpet. The following methods were used to modify the properties of the material for the respective parts: 1) Melt flow was improved through the addition of low molecular weight additives; 2) Flexural strength was improved with additives to chemically bond filler and matrix resin; 3) Shrinkage performance was improved and flexural modulus was increased by the addition of filler and resin with high flexural modulus; 4) Flexural modulus was increased by the addition of filler; and 5) Tensile elongation was improved by the addition of an elastomer compatibilizer. In each case, these methods enabled the use of recycled materials at an equivalent cost to virgin materials.

1. Introduction

In 2001, the Home Appliance Recycling Law in Japan was introduced. In the one year since the introduction of this law, approximately 8.5 million electrical appliances have been collected.

With respect to automobiles, the market in Japan currently scraps approximately 5 million automobiles annually. The successful implementation of a recycling system is an important objective for automobile manufacturers.

Honda has developed a bumper recycling process and has collected old bumper parts that have either been repaired or replaced⁽¹⁾. To date, these collected bumpers have been reprocessed as recycled bumper material (referred to as recycled material hereafter). This material has been used for splash shielding and sandwich injection molding for application in new vehicle bumpers⁽²⁾. The amount of bumper material collected by Honda is increasing every year, with 585 tons collected in the 1995 fiscal year and 1,186 tons

collected in the 2001 fiscal year.

As the amount of bumper material collected continued to increase, research was conducted to expand the scope of parts in which newly recycled material can be used. This report describes this research activity.

2. Course of Development

The application of unmodified recycled materials to other parts raises a number of issues. Of particular note is the reduction in the surface quality of the products caused by paint film flakes included in recycled materials. For example, when unmodified recycled material is applied to exterior design parts such as the cowl top garnish, it gives off an undesirable finish due to the added flake component. Such testing of these exterior parts has led to the conclusion that untreated recycled material is not suitable.

Bumper materials contain 30% elastomer components,

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which have a lower relative mold shrinkage. The difference in the shrinkage rate of virgin materials used for parts and of recycled materials creates a large gap when assembled to the vehicle.

Recent processing methodologies applied to recycled materials for reuse have been investigated. Also, targets have been set for recycled materials with equivalent costs for virgin materials for making new parts.

3. Perspectives on the Physical Properties of Recycled Materials and Approaches for Improvement

3.1. Processing of Collected Bumper Material

The recent methods employed for processing recycled bumpers and the results of the studies conducted are given below.

a) Removing paint film

Paint on recycled bumpers reduces impact resistance and also exhibits poor surface quality. To resolve these problems, a paint film removal process is applied. One method of this process is machine shearing exfoliation. The other is the method that uses solvent to swell up the paint film thereby reducing its adhesion to allow the film to be removed. The problem with these methods is the increased cost resulting from the cost depreciation of the specialized equipment used and the requirement for a process to dispose of the removed paint particles.

b) Fine particle processing

This process cools the collected bumper material to a temperature below that of the glass transition temperature and pulverizes it to a particle size less than 100 μm . Because this process is able to create fine particles of the paint film, it minimizes loss of impact resistance property. The problem with this process however is the increased cost resulting from the depreciation of the equipment used.

c) Blend mix processing

This is the granulation process that follows the pulverization and washing of the recycled bumper material. This process adopts a simplified treatment process and can be administered with already existing multipurpose equipment. Although the cost of this reprocessing is inexpensive, it does not assimilate processing to the paint film, which leaves the problem of reduced impact resistance and surface quality.

From the investigation into the different processes described above and from the perspective of enabling a sustainability, the blend mix processing was selected as the simplest process which can be employed at the lowest cost. This process was selected as a basis for research into its applicability to parts that do not require surface design finesse or impact resistance properties.

3.2. Techniques for Resolving Problems

Figure 1 provides a comparative illustration of the material properties of bumper material recycled through blend mix processing versus virgin bumper material. The radar chart indicates the percentage rate of material property retention for recycled material versus the virgin bumper material. As the figure shows, the recycled material exhibits a reduction in material properties.

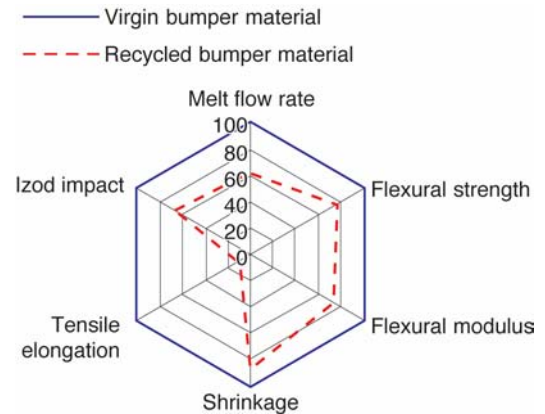


Fig. 1 Material properties of virgin bumper material and recycled bumper material

From the insights gained on these material properties, Table 1 lists the applicable parts selected for determining the applicability of modified material properties.

In the application of each part, as the recycled materials only exhibit reduced material properties, the compound material selected for each part is added to the recycled material to improve the overall physical properties of the materials.

The physical properties of the materials required for each part listed in Table 1 and the means for improving the materials are described below.

1) Aerial under cover

As this is a large part requiring thin structural formations, the melt flow of this material needs to be improved. Adding constituents with low molecular weight is an effective means of improving flow.

2) Side Spacer

To provide the side spacer with the necessary strength for supporting the bumper, the flexural strength of the constituent materials needs to be improved. To improve the flexural strength, filler and matrix resin surfaces have been chemically bonded and a filler with a large aspect ratio (in the longitudinal direction) has been added.

3) Evaporator case

To achieve dimensional accuracy in the current mold and to improve the flexural modulus required to maintain the shape of the part the shrinkage performance needed to be

Table 1 Applicable parts and requirements

● mark: Requirement

Applicable parts	Requirement					
	Melt flow rate	Flexural strength	Flexural modulus	Shrinkage	Tensile elongation	Izod impact
1) Aerial under cover	●					
2) Side spacer		●				
3) Evaporator case			●	●		
4) Rear shelf			●			
5) Floor carpet					●	

improved. To increase the flexural modulus and improve the shrinkage performance, homo-polypropylene (PP) without any elastomer constituency was added.

4) Rear shelf

To preserve the shape of the part required that the flexural modulus be increased. This was achieved by the addition of inorganic filler.

5) Floor carpet

To provide formation support when the part is molded, the tensile elongation needed improvement. This was achieved by the addition of an elastomer compatibilizer.

4. Improving Material Properties and Identifying Targeted Parts

This section describes the techniques applied to the parts targeted for this research.

4.1. Determining Applicability to the Aerial Under Cover

Figure 2 shows the positioning and shape of the aerial under cover. This part requires thin panel construction over the large part. Since recycled materials have low melt flow, this was targeted for improvement. The targeted value of the fluidity property was set according to the thickness of the panel, the size of the molding machine, and the number of mold gate points.

Since the fluidity of materials is dependent largely on molecular weight, the degree of fluidity could be improved by adding material with a low molecular weight. The material property has been improved by adding a 40% component of a high flow PP with a high degree of low molecular weight constituency.

Figure 3 illustrates the rate of Melt Flow Rate (MFR) achieved against the targeted MFR value of 100%. Adding

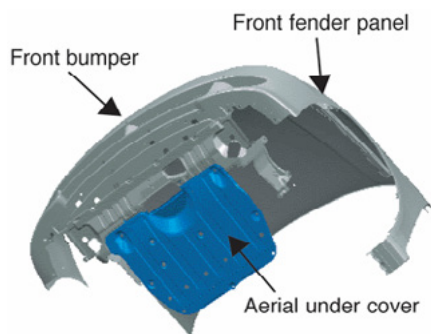


Fig. 2 Aerial under cover

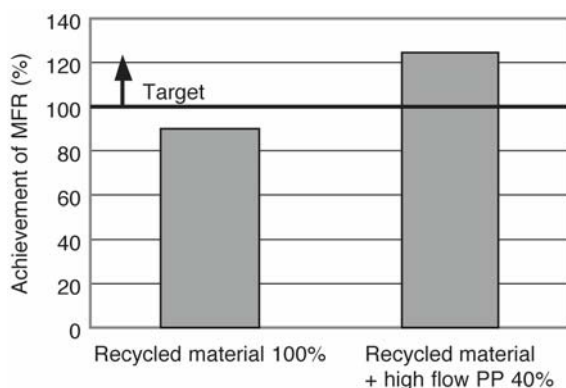


Fig. 3 MFR data

the high flow PP has improved the MFR by 35% in comparison to untreated recycled material. This method successfully attained the targeted value required for material fluidity.

4.2. Determining Applicability for the Side Spacer

Figure 4 shows the positioning and the shape of the side spacer, which fixes the bumper. As a single bumper panel weighs approximately 4 kg, a sufficient amount of strength is required. The targeted strength value was determined according to the flexural load exerted on the part at elevated vehicle velocities.

To provide the required degree of strength, the part has been interfaced with chemically bonded filler and matrix resin. The selected process for chemical bonding was achieved by adding silane surface treated short glass fibers and PP modified with grafted functional groups to the recycled material.

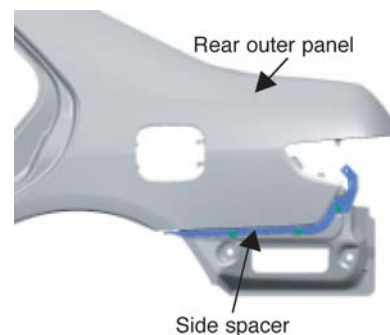


Fig. 4 Side spacer

Figure 5 shows photographs of scanning electron microscope (SEM) images of glass fiber and PP treated surfaces. These images have illustrated that for the material compound composed of surface treated glass + modified PP, the glass fiber surface is sufficiently wet to indicate that they have been successfully chemically bonded⁽³⁾. Figure 6 illustrates the rate of flexural strength achieved for the materials against the targeted value 100%. A 5% improvement over the targeted value for flexural strength has been achieved in material that has been treated by adding surface-treated glass fiber + modified PP. A 40% improvement in flexural strength was achieved over materials that have been supplemented with glass that has not been surface treated.

By employing this treatment method, the flexural strength was improved by 330% over untreated recycled materials. It has also been verified that this does not cause any problem when the vehicle is traveling.

(a) Recycled material + GF30% (b) Recycled material + surface-treated GF30% + modified PP 1%

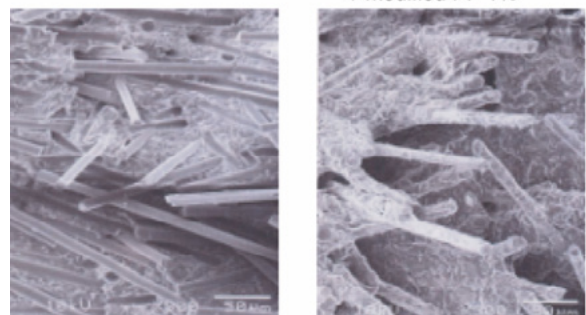


Fig. 5 SEM photographs of test pieces

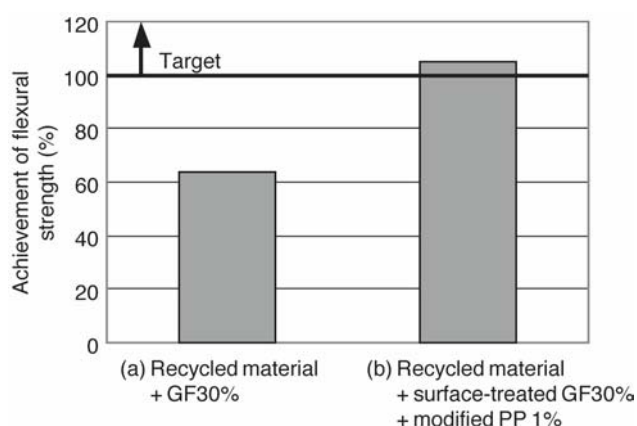


Fig. 6 Flexural strength data

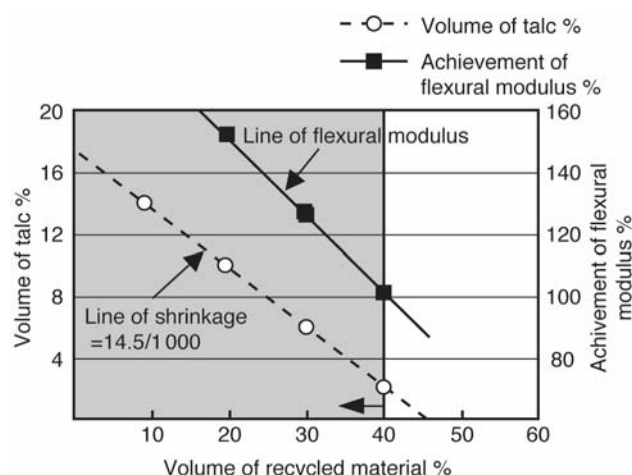


Fig. 8 Relationship between volume of recycled material and talc and flexural modulus data

4.3. Determining Applicability for the Evaporator Case

Figure 7 shows the evaporator case (referred to as the evapo case hereafter). This is used as the air conditioning cooling unit case and fits inside the instrument panel. To preserve the shape of the part required that the flexural modulus be increased. It was determined that the recycled material for this part be used with the existing mold for mass production. Therefore, the targeted value of the flexural modulus was set in accordance with the thickness of the part. The targeted value of the shrinkage performance was set to 14.5/1000, the shrinkage performance level of the current material.

Because recycled materials contain high elastomeric content, the mold shrinkage rate is less than that for other PP based materials and the flexural modulus is lower. This required that the shrinkage be increased and the flexural modulus improved. Adding homo PP was effective in improving the level of shrinkage performance. Talc has been applied to improve the flexural modulus.



Fig. 7 Evaporator case

Figure 8 shows the relationship, expressed by the dashed line, between the volume of recycled material with a shrinkage value of 14.5/1000 and applied volume of talc, and the level of flexural modulus achieved in relation to the volume of recycled material, expressed by the solid line. The volume of homo PP was calculated by subtracting the volume of recycled material and talc from 100. According to the dashed line in the figure, the volume of constituent content of the recycled material, which satisfies the required shrinkage performance, is less than 46%. Similarly, the solid line in the figure shows that the volume of constituent content of recycled material, which satisfies the required shrinkage performance, is less than 40%.

To achieve the desired level of shrinkage performance and flexural modulus described above, the constituent content of the recycled material must be less than 40%. To improve the flexural modulus, the amount of recycled material used needs to be decreased. However, since it is desired to use a greater amount of recycled material, the volume of constituent recycled material used has been set to 40%.

From the above results, the composition of the part consists of 40 wt% recycled material, 2.5 wt% talc, and 57.5 wt% homo PP. Figure 9 shows the data for the physical properties of the flexural modulus of this composition. The physical modulus was improved by 48% in comparison to untreated materials. This method has successfully yielded the targeted value for flexural modulus and delivered a targeted value of 14.5/1000 for the shrinkage performance.

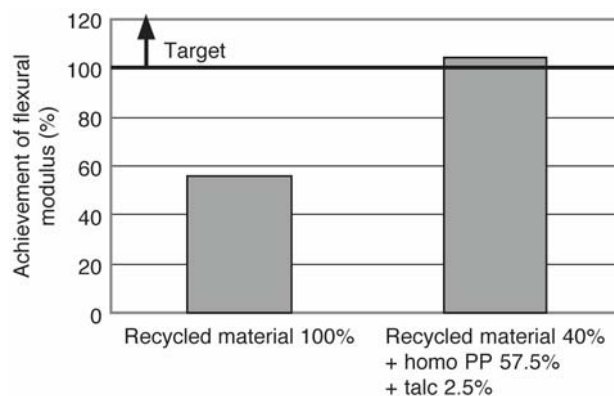


Fig. 9 Flexural modulus data

4.4. Determining Applicability for the Rear Shelf

The rear shelf part is used typically in hatchback type vehicles and separates the cabin area and the trunk space. The rear shelf is exposed to direct sunlight and must be able to support high loading. For these reasons, it is constructed of heat resistant resin base material containing core reinforcement material. Current resin materials are a blend of PP and wood powder and the targeted value for flexural modulus has been set according to this material.

As recycled materials contain approximately 30% elastomer components, it has a low flexural modulus in comparison to the current resin material. Talc has been added

to supplement the reduced flexural modulus and the material properties have been adjusted as required. Figure 10 shows the flexural modulus data and the level of flexural modulus achieved against the targeted value of 100%. The same graph shows that the addition of recycled material reduces the flexural modulus by 20%. However, adding talc brings a 7% improvement over the targeted value to achieve acceptable rigidity. This method has successfully achieved the targeted value for flexural modulus.

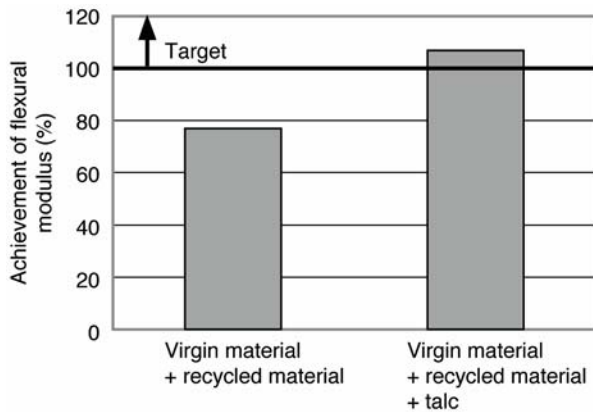


Fig. 10 Flexural modulus data

4.5. Determining Applicability for the Floor Carpet

To preserve the shape of the floor cover after it has been molded with the floor cover under surface, a low density polyethylene material is used for the underside of the floor carpet. Tensile elongation is required for the complex molding shape applied to the floor carpet underside material. A target value was set for the tensile elongation required in the floor carpet molding.

Recycled materials containing paint film flakes are low in tensile elongation properties. Recycled materials are also made of olefin type resin which is similar to polyethylene. However, in the simple blend process applied to such recycled materials, tensile elongation is not sufficient due to incompatibility of the immiscible component resins. To supplement this low tensile elongation, a compatibilizing agent made of olefin and styrene type elastomers is added to improve tensile elongation. Figure 11 shows the tensile elongation data associated with the floor carpet underside material. The tensile elongation was improved 18% above the targeted value. This process has satisfied the targeted value requirement for tensile elongation.

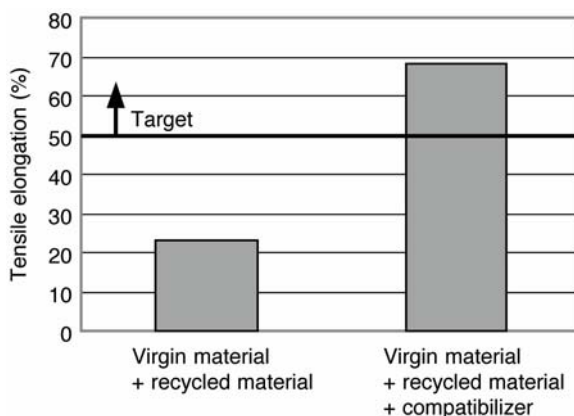


Fig. 11 Tensile elongation data

5. Summary

Methods for improving recycled materials have been developed to expand the applicability of parts and to increase the amount of recycled materials used in such parts. The various technologies that have been developed are described below.

- 1) Melt flow was improved to expand the applicability of materials to the aerial under cover. PP with high fluidity properties and low molecular weight has been added to constituents to improve the degree of fluidity by 130%.
- 2) Flexural strength was improved to expand the applicability of materials to the side spacer. Silane surface treated glass fibers and functional group grafted PP has been added to improve flexural strength by 330%.
- 3) Flexural modulus and shrinkage performance have been improved to expand the applicability of materials to the evaporator case. Homo PP and small amounts of talc have been added to improve the flexural modulus by 190% and control the part dimensions.
- 4) Flexural modulus has been improved to expand the applicability of materials to the rear shelf. Talc has been added to improve the flexural modulus by 30%.
- 5) Tensile elongation has been improved to expand the applicability of materials to the floor carpet. An elastomer type compatibilizing agent has been added to improve the flexural modulus by 90%.

The application of these material blending technologies has achieved the same level of cost as the initial targeted production cost employing virgin materials. The amount of recycled material used is now expected to increase 200 tons annually.

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