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Research for Closed-loop Recycling of Used Bumpers into New Bumpers

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Abstract

Recently, in order to improve the global greenhouse effect, which is pointed out as the cause of abnormal weather phenomena due to rapid climate change, many efforts to reduce CO2 are being expanded to all industries. To this end, the automobile industry is also making efforts to measure and reduce the amount of CO2 generated from material production to scrapping by introducing the LCA method for the CO2 emissions generated in the entire life cycle of vehicle development, use, and scrapping. Closed-loop recycling for bumper is an activity consistent with the Circular economy advocated by the EU. After collecting and processing the used bumper, it can be compounded with virgin PP for new bumper material. At this time, we can save fossil-base resources according to portion of recycle source. This is an activity to reduce CO2 emission by minimizing it. We tried to increase recycling content as far as we can. However, because of compatibility by using different PP compounding applied to bumpers by each automaker, so we tried to find the best mixing ratio through several compounding tests to determine the optimal mixing ratio. Finally, we add other industry PCR resource in order to increase recycling ratio for the optimal compounding and prevent from deterioration of physical properties due to lack of compatibility.

Keywords

Sustainability; Closed Loop Recycling; Bumper Recycling.

1. Background and Introduction

In response to the situation in which the loss of life and property of a large number of people is increasing due to climate change, which changes rapidly every year due to global warming, the United Nations adopted the Paris agreement in 2015 as a countermeasure against global warming and proposed a code of conduct to limit the global average temp. to less than 2 degrees Celsius (1.5 degrees Celsius as much as possible). As a result, efforts to reduce CO2 emissions, which are one of the major factors of global warming, are underway across all industries. In the automotive industry, we are also trying to reduce total CO2 emissions through vehicle LCA evaluation. In the case of EVs, which are the direction of vehicle development in recent years, the main focus of CO2 reduction is batteries and automotive components, and in the case of batteries, CO2 reduction activities are underway for all materials used, and the development of LOW CO2 materials is also actively underway[4].

In the case of recycled materials[5], closed-loop recycling, which collects and processes waste products produced in the industry to produce new products, is very efficient in reducing CO2 because it can reduce fossil base resources. This is in line with the direction of the circular economy that the

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EU ultimately wants to implement. The bumper has a large usage of 7~10kg per vehicle after the tire, so it is a component that requires very much technology for recycling.

In order to implement this, GEELY Automobile implemented a recycling supplier chain, and through this, recycled raw materials were made through a processing process using waste bumpers[6,7,8] disassembled from collected vehicles, and chemical material companies used them to develop materials that meet the required physical properties of automobile bumpers.

2. Development Details

2.1 Set Closed-loop Recycling Material Development Goals and Establish a Recycling Supplier Chain

2.1.1 Target Parts and Material Development Goals

As a target part for closed-loop recycling, it weighs 7~8kg per unit among the parts in the car, so it has a large recycling effect, and it is relatively easy to disassemble and is not restricted by odor because it is an external part, so it was selected as the first part to be developed. The bumper is composed of a thermosetting resin film from the surface layer, a primer layer for interfacial adhesion to the PP surface, and a composite PP layer consisting of PP coefficient paper, EPDM rubber, inorganic filler, and the like.

As for the material requirements of the target parts, it was selected as Class A2, which is the bumper requirement physical property of GEELY automobiles, and the main required physical properties are as follows, see Table 1.

Table 1. Main required physical properties

Test items	Unit	Requirement	
		Class A1	Class A2
Density	g/cm^3	1.05±0.02	1.05±0.02
Tensile Strength	MPa	≥17	≥17
Flexural Modulus	MPa	≥1,500	≥1,800
Izod impact (23°C)	KJ/m^2	≥30	≥30

2.1.2 Configuring Supplier Consortium for Closed-loop Recycling Implementation

In order to implement closed loop recycling of automotive parts, it is necessary to have a junkyard that can collect the end-of-life vehicle and disassemble the parts, a recycler that can process the disassembled parts into a recycling source, and a chemical company that can compound to meet the physical property requirements of the automobile company using the recycled source of the processed waste bumper. The bumper raw materials made through this process are provided to the bumper molding company to mold the bumper, assemble it at the automobile company, and apply it to the finished car.

The bumpers disassembled and collected by J Company, which has a cooperative relationship with GEELY, are transferred to W Company, which is in charge of recycling source production, and the waste bumper is crushed, paint peeled, and extruded to produce recycled raw materials. In this process, if the paint film is not sufficiently peeled off, the coating film should be able to peel sufficiently through chemical and physical methods, because the appearance defect will occur in which micro bubbles are generated on the surface during injection after compounding, or the impact resistance and fracture elongation will be decreased.

The pictures of the supplier consortium that can make this happen, see Figure 1,2,3.

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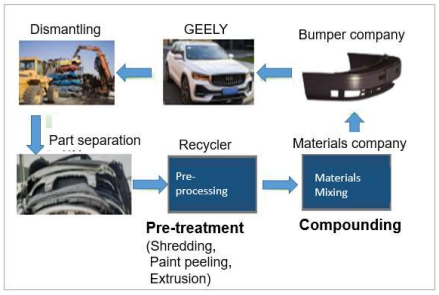

Figure 1. Consortium for Closed-loop recycling

Figure 2. Bumper dismantling

Figure 3. Shredded bumper

1) Peeling of the Paint Film of the Crushed Bumper

The coating film remaining on the crushed bumper surface greatly affects the compounding quality of the post-process, so it is necessary to treat it sufficiently so that no residual paint film remains as much as possible. The following is a diagram of the crushing and paint peeling process of the waste bumper, see Figure 4.

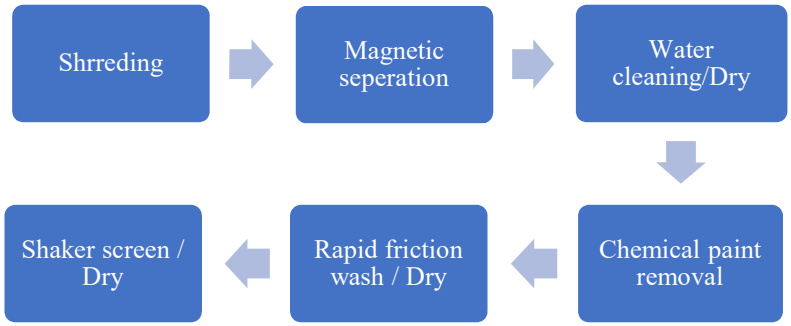

Figure 4. Recycling process for used bumper

The collected waste bumper is removed for foreign materials and crushed through manual sorting, and then the brackets composed of steel are removed using a magnetic separator, and then dried after cleaning. The dried shredded bumper is removed the paint film by chemicals, and then proceeds with the process for separating the residual paint film using washing water, and separates and dries the paint deposits generated at this time. At present, there are various methods of paint separation, but in terms of cost and efficiency, chemical treatment and cleaning methods using high-pressure water are mainly used. The chemical treatment uses a chemical solvent to soften or partially dissolve the primer layer attached to the PP surface in the coating film constituting the paint to exfoliate the paint, and as a chemical solvent, a solvent mixed with butyl acetate, ethanolamine, ethanol, etc.

The chip that has been peeled and dried with paint is palletized through an extrusion process. At this time, antioxidants can be added to prevent oxidation of materials in the processing process and deterioration of physical properties.

2.1.3 Bumper Material Compounding

1) Evaluation of Crushed Bumper Properties

In the case of bumpers collected from scrapped cars, since they were collected from various automobile companies and models, it is expected that each of them may have different physical properties, so in order to proceed with compounding in the direction of satisfying the current GEELY automobile standards, the mechanical properties of the recycled source processed from pure waste bumpers were measured, see Table 2.

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Table 2. Prior check the material of used bumper

Processing Table		*Bumper PCR 100%*			Reference		Remakes
		A	B	C	*Class A1*	Class A2	
Density	g/cm^3	1.029	1.021	1.053	1.03-1.07	-	-PCR A,B seems similar to target Class A1,when inferred from this test
Tensile Strength	MPa	19	20	17	≥17	≥17	
Flexural Modulus	MPa	*1,570*	*1,600*	*1,410*	*≥1,500*	≥1,800	
Izod impact (23℃)	KJ/m^2	*8.5*	*6.3*	*6.5*	*≥30*	≥30	
Izod impact (-30℃)	KJ/m^2	-	-	-	≥3	≥3	
HDT	℃	95	95	84	*≥95*	≥95	

The physical properties of the unprocessed pure waste bumper showed results that did not satisfy the physical properties of the current bumper standard Class A2, and in particular, the flexural elasticity and IZOD impact strength showed properties close to Class A1.

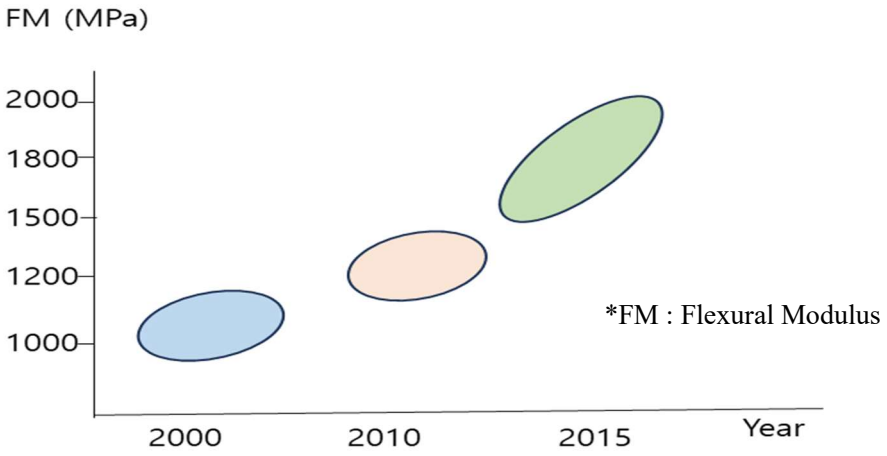

Figure 5. Bumper development trend for FM*

The reason why the physical properties of PCR 100% waste bumper are similar to Class A1 is that it is seen that it matches the material developed in the past 2010~2015 in the technical tendency to reduce the bumper wall thickness by increasing the flexural elasticity in relation to weight reduction. In recent years, most of the bumpers produced by auto makers show a tendency of FM 1,800~2,000MPa, and the thickness is 2.5~2.3mm, see Figure 5.

2) Check the physical properties of the crushed bumper by content

When the PCR content of the shredded bumper was mixed with 30% and 50% and compounding, the following results were obtained. The main purpose is to set-up the direction for optimal compounding, see Table 3.

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Table 3. Prior compounding and result

Test items	Unit	Requirement		
		Class A2	PCR 30%	PCR 50%
Density	g/cm^3	1.05±0.02	1.037	1.056
Tensile Strength	MPa	≥17	16	14
Flexural Modulus	MPa	≥1,800	1,260	1,100
Izod impact (23℃)	KJ/m^2	≥30	27	30

In case of flexural modulus, 1400 ~ 1600 MPa was shown when the physical properties were evaluated with PCR 100%, but the second evaluation showed lower results. The main reason is that the bumper recycled source is manufactured using various bumpers from various car companies, and each bumper contains a different composition depending on the production timing, and the duration of exposure to sunlight and outdoors is also different, which leads to the deviation of the physical properties of the waste bumper source by lot. In view of these factors, various types of additives were adjusted and additional physical property tests were carried out for each PCR content of the bumper. According to these reasons reflect that the physical property can not satisfy including flexural modulus and IZOD impact value. In consideration of the LOT deviation for each type of use of the waste bumper, it is important to develop a compounding recipe that can maintain stable mechanical properties, so the optimal formulation ratio has been developed through several formulation tests. The optimal compounding recipe and result, please see Table 4.

Table 4. Optimal compounding recipe and result

Test items	Unit	Requirement		
		Class A2	PCR 30%	PCR 50%
MI	g/10min	-	20	29
Density	g/cm^3	1.05±0.02	1.041	1.042
Tensile Strength	MPa	≥17	20	22
Flexural Strength	MPa	≥24	27	27
Flexural Modulus	MPa	≥1,800	1,860	1,820
Izod impact (23℃)	KJ/m^2	≥30	32	31
HDT	℃	≥95	106	107

Although the mixture ratio change test was conducted several times, the total content of PCR was maintained at the target value, but the content of the waste bumper was adjusted for stable physical property quality. That is, the PCR 30% and PCR 50% are mixed ratios of 10~20% of waste bumper PCR and 10%~40% of other industrial PCR, and accordingly, it was possible to secure a stable material that satisfies the required physical properties of automobile bumper parts. In the next few years, according to the bumper application trend, vehicles equipped with high elasticity (FM 1,800MPa or more) bumpers will be discarded, if we apply these recycle source, it is expected that we can included the bumper PCR content up to 50% without decrement of mechanical property.

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3. Conclusion

The purpose of this development activity is to establish a supply chain between automotive companies and related recycling industries to manufacture new bumper materials using waste bumpers, and to confirm the possibility of closed-loop recycling.

(1) The waste bumper currently collected from the dismantling company is a bumper which is manufactured 7 ~ 10 years ago and has a lower modulus than the current bumper, so it needs to increase flexural modulus and IZOD impact by optimal compounding to improve mechanical property.

(2) In order to ensure the stable quality for recycled bumper materials, the remaining paint film on the crushed waste bumper must be sufficiently removed using chemical and physical methods, and if the unremoved paint film remains, after compounding, cratering that affects the appearance quality and mechanical property deterioration may occur.

(3) For uniform and stable physical properties, recycled plastics from other industries with comparatively simple compositions were added in addition to recycled bumpers to derive the optimal compounding ratio. So, we can increase recyclability and prevent deterioration of physical properties due to lack of compatibility.

Acknowledgments

Research Field: Compliance analysis and control of vehicle recycling and prohibited substances, green product design and low-carbon design technology development, etc.

References

[1] Yamaka Woraphon, Phadkantha Rungrapee, Rakpho Pichayakone: Economic and energy impacts on greenhouse gas emissions: A case study of China and the USA, Energy Reports, Vol. 7(2021) No. S3, p.240-247.

[2] Tu Qingshi, Hertwich Edgar G, A mechanistic model to link technical specifications of vehicle end-of-life treatment with the potential of closed-loop recycling of post-consumer scrap alloys, Journal of Industrial Ecology, Vol.26(2021) No. 3, p. 704-717.

[3] Anna Schulte, Benjamin Kampmann, Christina Galafton: Measuring the Circularity and Impact Reduction Potential of Post-Industrial and Post-Consumer Recycled Plastics, Sustainability, Vol.15(2023) No.16, p. 12242.

[4] Shengyun Zhang, Wenbo Wei, Rui Wang: Analysis and Summary of Carbon Emission Reduction of a Pure Electric Vehicle of Geely, Auto Time, Vol.21(2024) No. 4, p.138-140.

[5] Harriëtte L. Bos, Daan S. van Es, Paulien F.H. Harmsen: On the intrinsic recycling potential of carbon-based materials and products; an assessment method and outlook, Journal of Cleaner Production, Vol. 458(2024), p. 142413.

[6] Son Younggon: Study on a recipe of recycled bumper and pristine materials for application of vehicle parts, Journal of the Korea Academia-Industrial cooperation Society, Vol. 17 (2016) No. 1, p.175-180.

[7] Cruz Heidy, Son Younggon: Developent of a new technique removing paint from recycled car-bumper, Journal of the Korea Academia-Industrial cooperation Society, Vol. 15 (2014) No. 5, p.3298-3303.

[8] Guo Wei, Li Ke, Fang Zhigang, Feng Tao, Shi Tianwen: A sustainable recycling process for end-of-life vehicle plastics: A case study on waste bumpers, Waste Management, Vol. 154(2022), p.187-198.