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The Status of Recycling Technology of Hyundai and Kia

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Abstract

Global automobile manufacturers have made a lot of efforts to comply European Union (EU) end-of life vehicles (ELVs) Directive. Hyundai and Kia have also made a lot of studies to eco-friendly treat our ELVs. Some results of studies have already reflected on our models to produce eco-friendly vehicles. This paper introduces our status of the recycle technology and our measures to respond to EU ELVs Directive.

Key words : ELV, EU Directive, Dismantling, Material Recycle, ASR

요 약

세계적인 자동차회사들은 EU 폐자동차 처리 규정을 맞추기 위하여 많은 노력을 기울이고 있다. 현대기아자동차 또한 폐자동차를 환경친화적으로 처리하기 위한 기술개발에 많은 연구를 수행하여 왔으며 연구결과가 이미 자동차 제작공정에 반영되고 있다. 본 논문에서는 폐자동차 재활용기술 현황과 EU 폐자동차 처리규정을 맞추기 위한 현대기아자동차의 기술개발에 대하여 소개하고자 한다.

주제어 : 폐자동차, EU 폐자동차규정, 해체, 부품재이용, ASR

1. INTRODUCTION

Conventionally the automobile manufacturers had paid attention to environment in restricted fields like production process, fuel consumption, emission, and noise. However, the latter half of 20th century the environmental problem due to ELVs treatment emerges to the critical issue in the automobile industry. As automobile manufacturers are more involved in the eco-friendly treatment of ELVs, they are asked to share the economic burden and the technical assistance from the related industries. The global automobile manufacturers have made every effort to satisfy the social demand. Hyundai and Kia Motor have actively invested to develop technology at a high level.

Especially, EU ELVs Directive requires automobile manufacturers to respond to free take-back, compliance of recycling rate, heavy metal ban, recyclability type approval, recycle technology development, information offer and so on.

This paper presents our effort and direction of technology development to cope with the environmental regulations.

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2. STATUS OF ELVs TREATMENT

The number of automobile registered in Korea was about 14,580,000 as of December, 2003 and 500,000 of ELVs are generated annually. Among the total number of ELVs, 80,000 ELVs are exported and 420,000 ELVs are dismantled(Fig. 1 & 2).

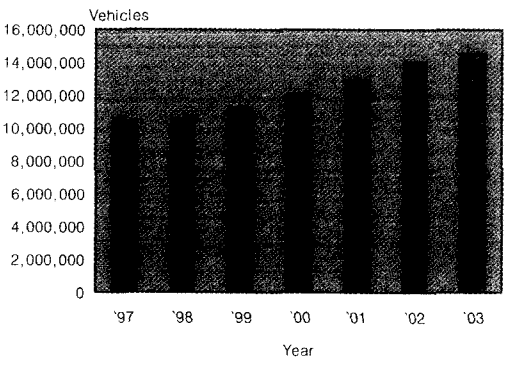


Fig. 1. The Number of Automobiles in Korea.

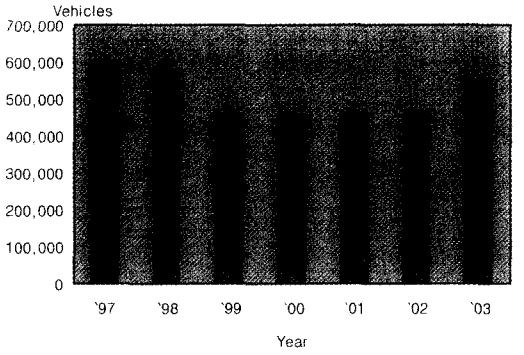


Fig. 2. The Number of ELVs in Korea. (Korea Automobile Manufacturer Association, 2004)

As shown in the Fig. 2, the number of ELVs temporarily decreased to 460,000 from 1999 to 2002, then increased to 550,000 in 2003. It is expected that the number of ELVs will increase to 1,000,000 in 2008.

Therefore, eco-friendly treatment of ELVs will be a more important issue if this trend persists.

In the mean time, as shown in Table 1, the automobile is comprised with 70~75% of ferrous and nonferrous metal, 25~30% of plastics and other materials. Because of the improvement of fuel efficiency, the weight reduction and the increase of electronic part's use, the usage of nonferrous metal and plastic has increased recently. In domestic markets, some potential recyclable components such as tires, fluids and reused parts are dismantled during ELVs treatment and sold. Once they are dismantled, the rest parts of ELVs are compressed and crushed, among which ferrous and nonferrous metal are collected by magnetic selection. Finally, the rest parts besides ferrous and nonferrous metal are incinerated as Automobile Shredder Residue (ASR) or landfilled. At present, it is estimated that the recyclability of ELVs is 75% or so. Therefore, in order to meet ELVs Directive, it is necessary to develop dismantling equipment and technology which enables to break down the potential recyclable components easily. Furthermore, technologies in the fields of remanufacturing, recycling of rubber and plastic, as well as heat recovery of ASR are to be developed.

3. BRIEF OF ELVs DIRECTIVE

Since ELVs regulation came into effect in Germany and Sweden in 1998, ELVs regulations had spred from the developed countries which hold a number of automobiles in limited land. These regulations are based mostly on EU ELVs Directive and each country has adopted regulations upon one's situation. EU ELVs Directive provides the common framework for Member States to transpose their national regulations and it sets out the responsibility for economic operator (producers, manufacturers, importers, distributors, collectors, motor vehicle insurance companies, dismantlers, shredders, recoverers, recyclers and other treatment operators of end-of life vehicles) related in ELVs. Each economic operator has the various responsibilities for entire process of ELVs treatment. This paper discusses only the responsibility of manufactures.

3.1. Free Take Back

Directive requires that the last holder and/or owner can deliver the end-of-life vehicle to an authorized treatment facility without any cost as a result of the vehicle having no or a negative market value. It also requires that producers meet all or a significant part of, the costs of the implementation of these measures; the normal functioning of market forces should not be hindered.

3.2. Reuse, Recycling and Recovery for ELVs

Directive requires that the following targets are attained by economic operators: (a) no later than 1 January 2006, for all end-of-life vehicles, the reuse and end-of-life recovery shall be increased to a minimum

Table 1. Material composition used in manufacturing automobile (Midsize Passenger Car).

	Steel	Non-metal	Plastics	Rubber	Glass	Fuel & Oil	Tires	Etc.	Total
Weight (kg)	835	119	148	11	32	66	46	59	1316
Composition (%)	63.5	9.1	11.2	0.8	2.4	5.0	3.5	4.5	100

of 85% by an average weight per vehicle and year. Within the same time limit the reuse and recycling shall be increased to a minimum of 80 % by an average weight per vehicle and year; (b) no later than 1 January 2015, for all end-of-life vehicles, the reuse and recovery shall be increased to a minimum of 95% by an average weight per vehicle and year. Within the same time limit, the re-use and recycling shall be increased to a minimum of 85% by an average weight per vehicle and year.

3.3. Heavy Metal Bans

Directive sets out that materials and components of vehicles put on the market after 1 July 2003 do not contain lead, mercury, cadmium or hexavalent chromium other than in cases listed in Annex II under the conditions specified therein.

3.4. Recyclability Type Approval

EU Commission has amended recyclability type approval Directive 70/156/EEC which requires re-usable and/or recyclable to a minimum of 85% by weight per vehicle and re-usable and/or recoverable to a minimum of 95% by weight per vehicle.

3.5. Material Marking

It is required that material marking on plastics above 100 gram and rubber above 200 gram in accordance with International Standard Organization (ISO) since July first of 2003.

3.6. Dismantling Information

Directive requires that producers provide dismantling information for each type of new vehicle put on the market within six months after the vehicle is put on the market.

4. Effort for Developing of Recycling Technology

As mentioned above, it is necessary to develop dismantling technology to treat fluid, battery, and airbags eco-friendly during ELVs treatment as to increase the recycling rate of ELVs. This technology enables to dismantle recyclable components easily, remanufacture products, and recycle plastics and rubbers generated from ELVs. Furthermore, it is important to develop technology to recover energy from inflammable ASR. This section introduces several ELVs dismantling technology that Hyundai and Kia have implemented.

4.1. Dismantling Technology

In practice, it requires many hours to dismantle an ELV since a vehicle is consisted with various materials and complex structure of components. During ELVs treatment, it costs most money to dissemble more components from ELVs to increase recycling rate of ELVs.

The current ELV dismantling technology has required dismantling equipment in full scale to treat a number of ELVs effectively. In particular, Germany and Sweden in Europe have actively involved to develop dismantling equipment. ARN professional dismantler in Netherland, has developed six series of ELV dismantling treatment during which all components are completely dismantled.

Hyundai and Kia have also developed our own ELV dismantling system with high efficiency. This system can be used to evaluate recyclability of vehicle at vehicle development stage as well. ELVs are treated on the conveyor in series so that a number of ELVs can be treated more effectively(Fig. 3).

If fluid is not removed completely from ELVs, it is possible to contaminate environment. Therefore, it is essential to establish appropriate operation for fluid removal. Hyundai and Kia have developed the machine forcing to be drained the fluid from the upper and the lower part simultaneously from ELV. In this

Fig. 3. ELVs Dismantling System.

way, all kinds of fluids are removed by type of fluid (Fig. 4).

In general, it takes about 30 minutes to remove fluids but Hyundai and Kia have developed equipment that takes only 15 minutes to remove 8 different types of fluids including engine oil. The collecting rate of fluid is above 95% and it is possible to remove fluid completely unless fluid is in contact with surface of component. In order to meet recycling quota required by ELVs directives, it is necessary to develop dismantling technology and equipment to make components recyclable and dismantled more easily. With this equipment, large plastic component like bumper and complex structure like instrument panel can be recyclable.

We have also developed system which can determine structure of components and designate position for dismantling and is equipped a multi-joint robot. With these fractions, this system can dismantle bumper and instrument panel. Hyundai and Kia expect to the use of this system will increase since components are packaged into the moduel with large size and assembled at once(Fig. 5).

4.2. Technology Treatment on Explosive Component

As customers' demand on safety increases, explosive components like air bags, seat belts, and pretensioners more are employed on the vehicle. Since these components are explosive, it can cause problems such as noise nuisances or damage when they are treated improperly. According to EU and Japanese Directives, the potential explosive components have to be treated eco-friendly before ELV shredding. There are two different methods to treat explosive components. The first one is called as Off Board Type which treat explosive component after dismantling component. The latter one is On Board Type which to treat explosive component without dismantling component.

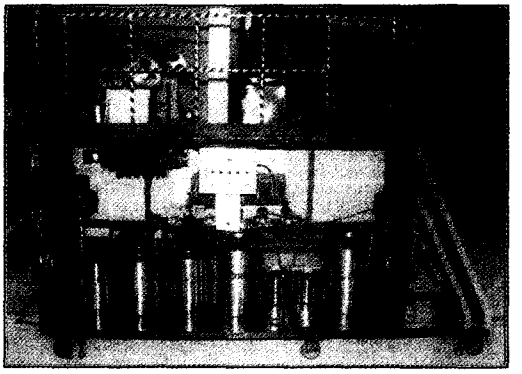


Fig. 4. Oil Draining and Recovery Equipment.

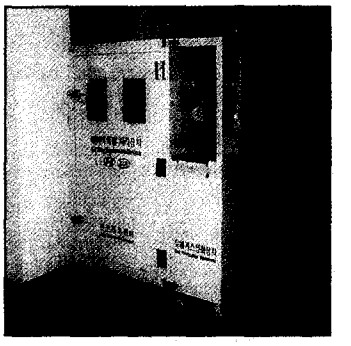


Fig. 6. Airbag Treatment Equipment (Off Board Type).

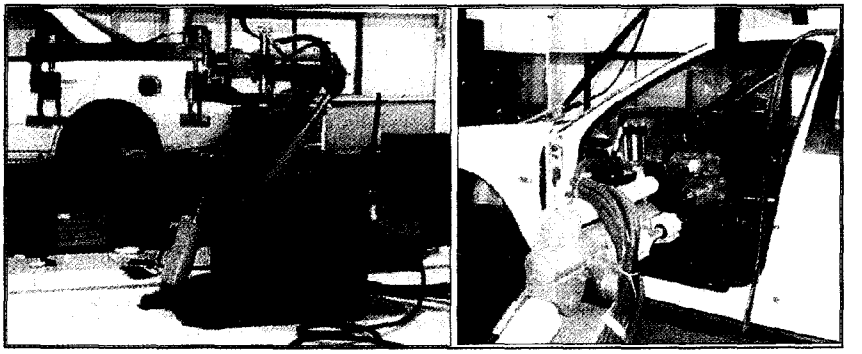


Fig. 5. Dismantling Operation.

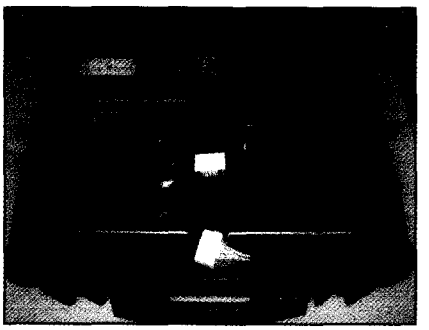


Fig. 7. Airbag Treatment Equipment (On Board Type).

Hyundai and Kia have developed both methods of Off Board Type and On Board Type(Fig. 6 & 7).

4.3. Remanufacturing Technology

In general, 'reuse' is the most economical operation since components of ELVs can be used for the same purpose for which they were conceived. However, only some of components are reused in practice since all components have different quality and they have different life cycle. Remanufacturing technology involves the whole processes which consist of disassembling components from ELVs, cleaning, repairing, and replacing sub-component. Finally these components are manufactured to the equivalent or better level of new product.

Since the life cycle of vehicle has increased to more than 10 years, Hyundai and Kia have developed remanufacturing technology to provide high quality and cost-optimized product to meet the demands of customer.

4.4. Material Recycling Technology

The most effective way of reducing environment impact at ELVs treatment stage is to recycle used components as raw material for making automotive components. So Hyundai and Kia have tried to develop various recycling technology for the large automotive components such as bumper fascia, backbeam, and seats. Some of the recycled parts are being applied as other components.

4.4.1. Bumper Recycling Technology

(1) Bumper Fascia

Bumper has a multifunction such as impact energy absorption and dissipation. And bumper is one of the largest automotive components and it is made of homogenous materials. Automobile manufacturers have already developed bumper recycling technology on their own.

The used bumpers are usually recycled as another raw material for other automotive components or even for components in other industries. The main reason of low mechanical properties of recycled bumper is that thermoset paints contains impurities in recompounding process. Hyundai and Kia developed new pretreatment method to peel off paint using high pressure water jet injection. In comparison with previous techniques such as hydrolysis of Toyota, organic solvent salts of Nissan, and compress & vibration method of EIN, Hyundai and Kia pretreatment system (high pressure

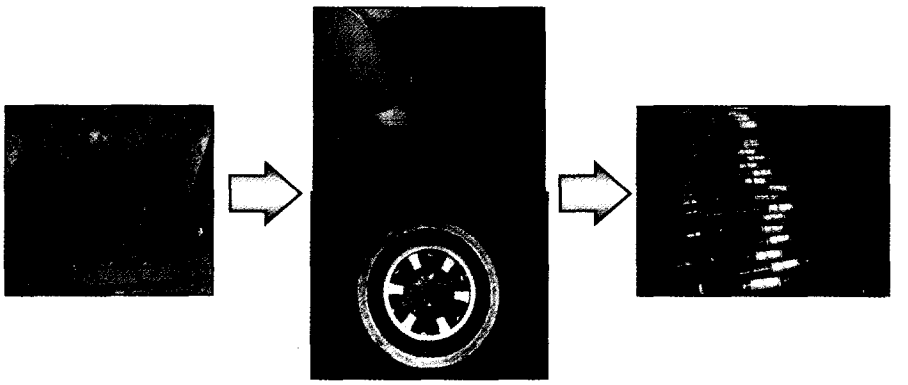


Fig. 8. Remanufacturing Process of CV Joint Component.

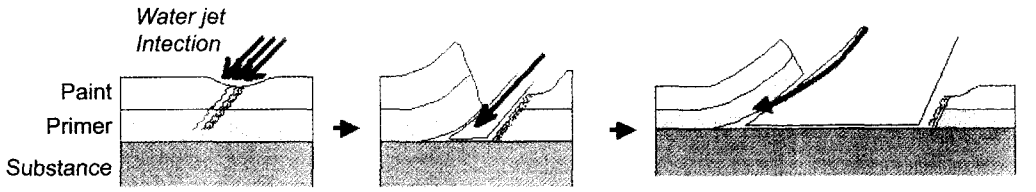


Fig. 9. Mechanism of High Pressure Water Jet Injection.

Peeling-Off using Robot System Peeled-Off Bumper

Fig 10. Paint Remove Technology of High Pressure Water Jet Injection.

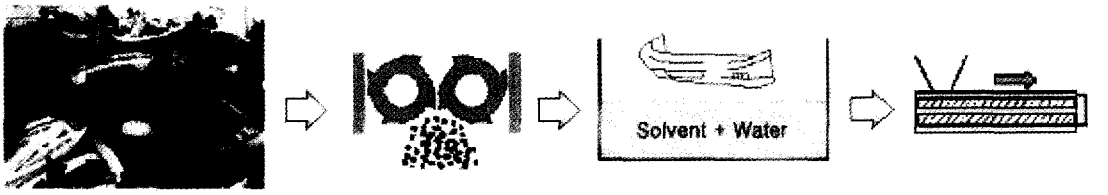


Fig. 11. Paint Remove & Recycling Technology of Used Bumper Fascia using Organic Solution.

water jet injection & solvent melting) is most economical and practical method to use used bumper as raw material for other bumper fascia.

This new peeling-off method using high-water jet stream is different from other previous method in using 100% pure water for peeling-off media. It selectively removes just coated paint, so the production rate of failure components can be reduced and environmental impact is minimized. So bumper manufacturers are using this new and eco-friendly technology

In addition to water jet injection method, Hyundai and Kia have also developed another paint peeling-off method to recycle used bumper fascias generated from ELVs treatment or repair shop. The new paint peeling-off technology consists of crushing, washing, peeling off solution, and extrusion. The recycled bumper fascia resin is used to make bumper fascia (Fig. 11).

(2) Bumper backbeam

Automotive bumper consists of fascia, energy absorber, backbeam and stay. Backbeam absorbs most of impact energy and it is usually made of steel, PC/PBT alloy, Glass Mat Thermoplastics (GMT). Especially, GMT is a glass fiber mat reinforced polypropylene and it is used mainly for automotive bumper backbeam which demands high stiffness and strength. However, GMT bumper backbeam comes from ELVs or crashed car. Due to better mechanical properties of GMT, it is very difficult to crush GMT bumper backbeam even for the disposal of it. Furthermore, the crushed glass fiber can float in the air and the fine dust is very harmful to human body.

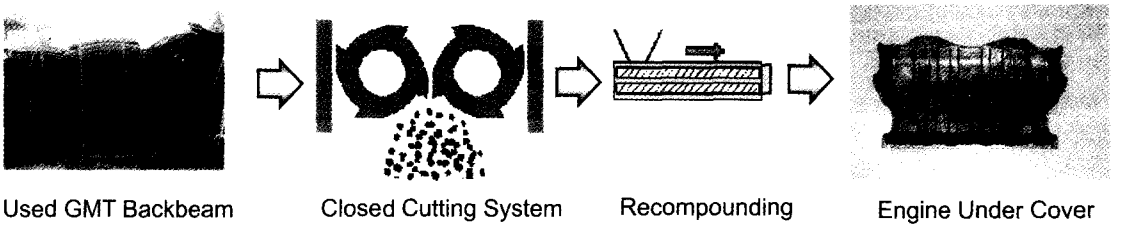


Fig. 12. Material Recycling Process of GMT Bumper backbeam.

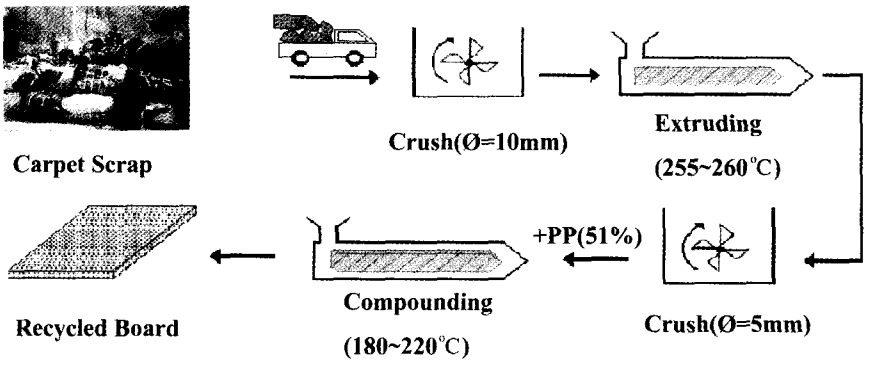


Fig. 13. Recycling Technology of Carpet.

Consequently, used GMT bumper backbeam is mostly landfilled or incinerated except the limited application as the process agent to improve flowability in a virgin GMT manufacturing.

Hyundai and Kia have developed new GMT recycling technology using Reactive Recompouding Method for the first time in the world. The recompounded materials are injection-molded again and it is used to make other automotive components such as engine under cover and battery tray.

(3) Construction of Closed-loop recycling system for used bumper (Fascia & backbeam)

Hyundai and Kia have constructed closed-loop recycling system that is applicable in whole process of collection, crushing, washing, and supplying for used bumper. This system is different from the conventional method which was that used bumper was collected from direct service facility or collaboration factory. It is more favorable since it reduces the deviation of the quality in the final product made with it.

4.4.2. Carpet Recycling Technology

The carpet is the multi-laminated component made of polyamide, polyethyleneterephthalate, and low density polyethylene. The carpet is required to have the function of sound absorption and provide fresh feeling more than any interior trim for automobile. Especially, as the carpet is comprised of the material which has no compatibility, it is difficult to recycle. So the carpet has been landfilled or incinerated.

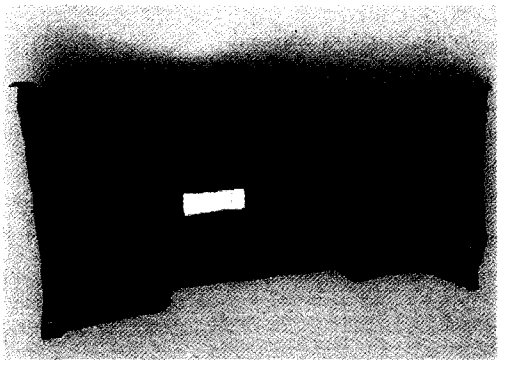


Fig. 14. Application of Waste Carpet Recycled Board.

The carpet recycling technology developed hereto is the material recycling method using compounding and the monomer recovery method in high pressure and

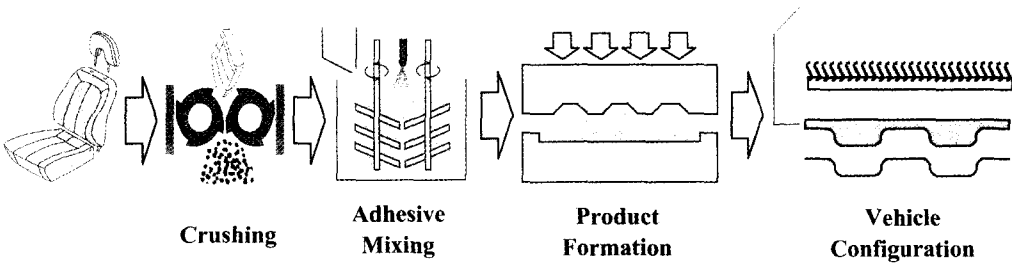


Fig. 15. Recycling Technology of Seat Cloth & Foam.

high temperature. They requires huge petrochemical process plant but not economical. So Hyundai and Kia have developed technology of manufacturing sheets which can be recycle as material for the interior trims with Partial Melting Method and compounding technology (Fig. 13). With this recycling technology, Hyundai and Kia can apply recycled material to the material for trunk side trim and luggage trim of car (Fig. 14).

4.4.3. Seat Cloth and Foam Recycling Technology

The automotive seat consists of seat cover, soft urethane foam and frame which provide the mechanical support and additional function. The seat foam is the thermoset so it is difficult to recycle. But recently new recycling technology of chip mold type was introduced using binder after grinding. The use of seat foam gradually increases as the substitute material of conventional styrofoam and it is partially used for the material of sound absorption. Hyundai and Kia have developed advanced manufacturing technology of Chip Mold Foam using existing urethane foam to recycle seat foam as floor mat insulation using skin material. Although this manufacturing method is similar to that of conventional chip mold foam, it has difference that grinding, binding and forming of both the seat cloth and urethane foam become possible. However, unlike the general recycled product of urethane foam, the seat foam is more effective to apply to high density product.

4.4.4. Rubber Weather Strip Recycling Technology

Rubber is used for functional material in automobile because it has elasticity due to sulfur vulcanization, and about 20~30 kg of rubber except tires is used in single vehicle. Rubber is difficult to recycle because of its cross-linked structure. Rubber is also difficult to crush so most of rubber is used for heat resources like Cement Kiln. In particular, weather strip take up 50% of rubber material in an automobile and it contains metal insert to maintain the shape. Therefore, it requires fractionation technique to recycle it. Recycling technologies of weather strip are divided into devulcani-zation technology and powdering technology. Toyota developed the continuous devulcanization process using high temperature & shear but it can't apply to waste component in which metal insert is contained. Therefore, it is limited to apply since it uses only scrap rubber.

Fig. 16. Application of Chip Mold Using Waste Seat Cloth & Foam.

Our continuous material separation technology enables to recycle scrap rubber and waste rubber containing metal insert from weather strip rubber. The coil removal operation separates metal insert and vulcanized EPDM rubber which becomes 100 μm powder at ambient temperature. After surface activation treatment, the weather strip can be recycled as raw material of weather strip

Hyundai and Kia have applied this technology into small-sized passenger car.

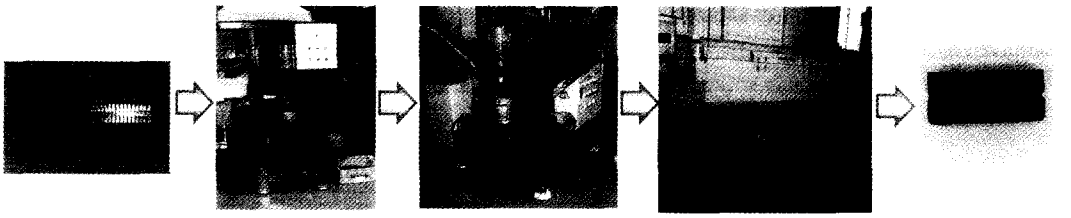


Fig. 17. Recycling Technology of EPDM Weather Strip.

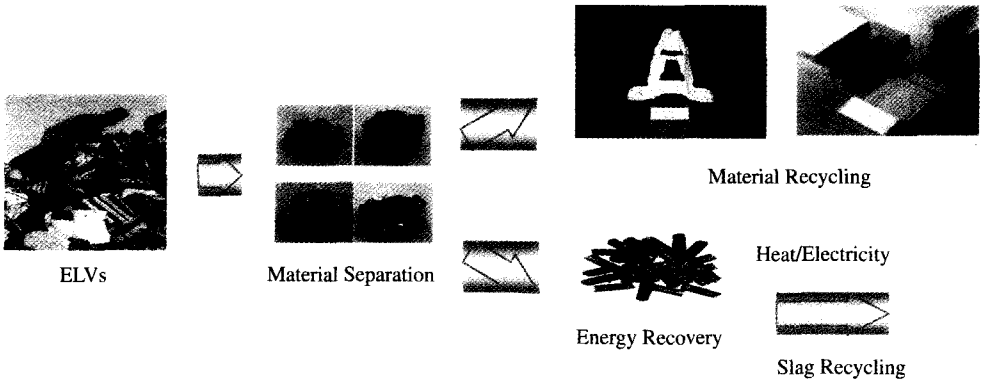


Fig 18. The Concept of ASR Recycling System.

4.5. ASR Recovery Technology

The EU ELVs Directive requires automobile manufacturers to meet 85% of recycling in Jan. 2006 and 95% of that Jan. 2015. Hyundai and Kia have tried to establish new ASR recycling and recovery technology. Though there is no standard method for ASR recycling, various systematic and active approach is ongoing worldwide to develop the ASR recycling technology. Vehicle Recycling Partnership (VRP) in USA develops monomerization using polymer separation from ASR and Volkswagen in Germany also establishes Si-Con project in which material recycling and gasification technologies are involved. In Japan other various energy recovery methods such as Rotary Kiln, gasification, and high price nonmetal recovery technologies are investigated. Especially, Toyota has established its a subsidiary company to carry out effective ASR recycling and has built a pilot plant to operate the material selection and energy recovery. Also, the Recycled Sound-Proof Products (RSPP) is produced from the recycled ASR polymer and it is applied to automotive component.

Hyundai and Kia have been trying to develop effective, economical and eco-friendly recycling ASR system which consists of the selective material recovery, energy recovery for other industry like cement plant, and gasification melting operation.

4.6. Heavy Metal Compliance

Hyundai and Kia have actively prepared to satisfy all environmental requirements. With regard to the heavy metal ban, our own Material Specification was becoming effective in 2002. In all design drawings, these new requirements were added and passed on to all suppliers.

In 2004 Hyundai and Kia have joined International Material Data System (IMDS) to systematically mange substances in our products. Therein our entire supply-chains (tier1 to tier n) have submitted their relevant material data including information about all substances in materials and components via IMDS. This is part of our processes, Initial Sample Inspection Report Process (ISIR). This process enables to check suppliers' components in particular the compliance

with the heavy metal ban (Fig. 19).

The Material Specification requires that the alternative material and components to be launched under consideration of the shipping time and the national time frame for compliance. The entire in any case at least 6 months prior to the grace period, listed in Annex II of Directive 2002/525/EC. The quality control department checks if suppliers substitute alternative material and they assure if materials meet the requirement according our own Material Specification by carrying out analytical test on materials.

4.7. Material Marking (Coding)

Since July 1992 Hyundai and Kia have marked all plastic parts over 100 grams and all rubbers over 200 grams in passenger vehicles and light trucks. In order to meet EU ELVs Directive, our own material coding standard was revised in 1996 to be in line with International Standard Organization (ISO). All drawings are applied to comply marking standard. Our marking standard requires to mark material over 50 grams to facilitate reasonable material separation during ELVs treatment. When EU Directive (2003/138/EC) was enforced, our components and materials of all models were checked if they were marked correctly according to EU Directive. The design department checks all drawings whether marking requirements are added at the pre-assessment and quality control department also checks the marking compliance of components and materials as well.

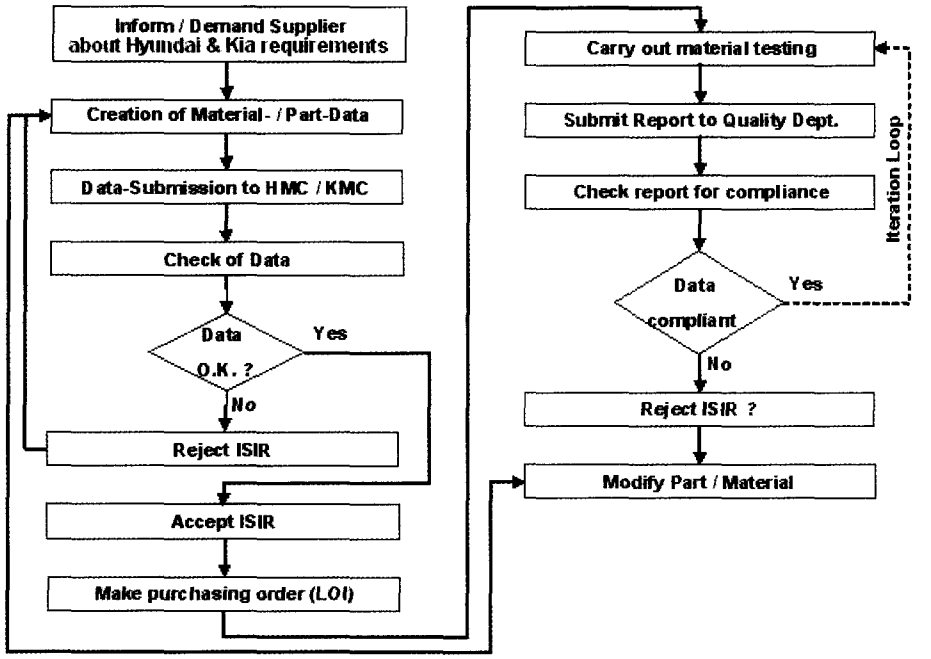
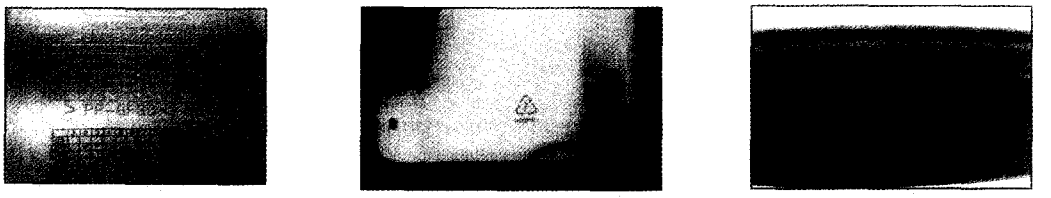


Fig. 19. Procedure of Heavy Metal Compliance.



Plastic injection mold marking | Plastic container marking | Rubber marking

Fig. 20. Marking on Components and Materials.

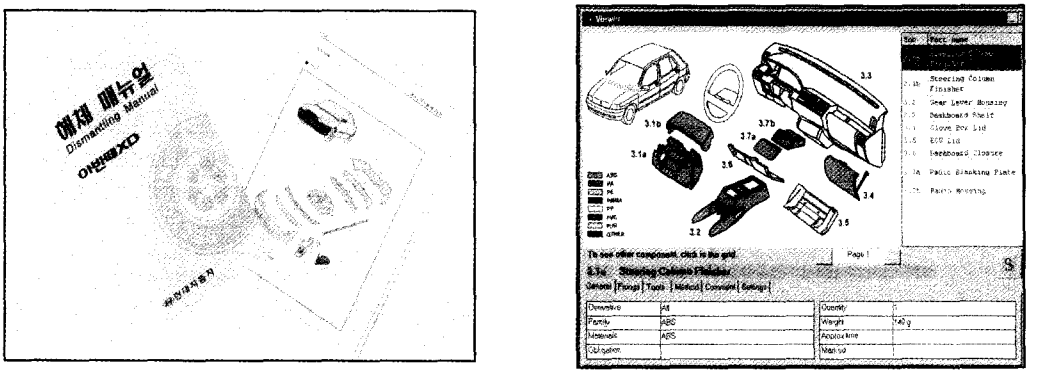


Fig. 21. Dismantling Manual.

4.8. Dismantling Information

Since 1999 Hyundai and Kia have joined the International Dismantling Information System (IDIS) to provide dismantling information to dismantlers. So far dismantling information for all 28 Hyundai and Kia models is available in current IDIS. Hyundai and Kia have provided dismantling information of each new type of vehicle put on market within 6 months.

5. CONCLUSION

For our market highly depends on trade and has paid little attention to environment technology than the developed countries, the competitiveness of our goods weakens in world market. In particular the automobile industry taking a big portion of national industries is facing the crisis as more restrictive and advanced environmental regulations are enacted over the world. If a company does not satisfy these regulations, one's being is threatened. Therefore, companies take the environment as not a choice but an obligation. If companies consider that environment costs money only, they might not survive in the 21st market. As stated above, EU ELVs Directive has been enforced since 2000 and the environmental performance on vehicles is being considered to be adopted in the law to take as type approval requirement for exported vehicles in 2005. So if companies do not take proactive measures on environmental regulation, their import would be restricted.

Consequently, it is predicted that the systematic and continuous technical development are progressing more actively to treat ELVs eco-friendly and recycle them. It is also required to establish cooperation models with government, automobile manufacturers, component and material manufacturers, dismantlers, and other treatment operators of ELVs. The automobile manufacturers and their relative industries need to develop technologies to separate the recycle potential material, recycle materials, and treat ELVs eco-friendly. In addition, technologies of eco-friendly design, hazard material reduction, and waste disposal should be considered as well. The automobile industries will emphasize more on recycling technology of ELVs with stability, usability and performance in vehicle development.

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