

Development of Automotive Shredder Residue (ASR) Recyclate Application

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ABSTRACT

Recently, with increased concerns about global environmental issues, European car manufacturers have been using thermoplastic recyclate resin and natural raw materials for application to automotive components in order to make effective use of the limited oil resources.

In Europe, where the demand for application of recyclate is growing stronger, attention is being turned to ASR (Automotive Shredder Residue) coming from disused cars. Polypropylene, separated and extruded from automotive shredder residue, has been used to develop recyclate with an excellent balance between rigidity and impact performance, that meets the requirements for under body components. This material has been applied to 2006 model year CIVIC in Europe.

Cost has been reduced with these technologies, whilst making effective use of oil resources.

要 旨

近年、地球環境問題への関心が高まるにつれ、欧州自動車メーカー各社は、熱可塑性リサイクル樹脂や天然素材を積極的に車両用部品に適用し、限られた石油資源の有効活用に努めている。

欧州において、リサイクル材適用の要求が強まる中、廃車残さ ASR (Automotive Shredder Residue) に着眼し、この ASR から分離したポリプロピレン再生材を用い、アンダーボデー部品に適用可能なリサイクル材料を検討した。

その結果、剛性と耐衝撃性のバランスに優れ、アンダーボデー部品としての要求性能を十分満足するリサイクル材を開発し、2006年モデル欧州専用 CIVIC に適用することができた。

これらの技術により、石油資源を有効活用するとともに、コスト削減を達成した。

1. Introduction

The End-of-Life Vehicles (ELV) Directive came into force in Europe in 2000 and sets overall targets of 80% recycling and 85% recovery by 2006, and 85% recycling and 95% recovery by 2015⁽¹⁾. Currently the reuse and recycling levels in Europe vary between 80-85%. The recycling mainly includes ferrous and non-ferrous metals and some plastic parts which can be dismantled. The remaining automotive shredder Residue (ASR) is mainly going to landfill. To achieve the ELV directive the total amount of waste that can be disposed of should be reduced to 5%. New ways to treat and recycle ASR are fundamental in achieving this. Rising landfill cost in Europe also contributes to treatment of the ASR becoming more important.

These new ways of recycling aim at more cost effective ways of recycling plastics from automotive waste. One way is to look at the plastic content of ASR and technologies that can be applied to recover and recycle that waste.

Traditional ways of recycling are mainly aimed at pre-shredder recycling, where parts are dismantled before recycling and is only economical viable for large plastic mouldings. In post shredder recycling plastics are separated and recovered after the shredder process (from ASR) and is economical viable for recovery of plastics from large and smaller parts. This paper considers Honda's activities in Europe developing ASR recycled polypropylene grades for mass production application to 2006 model year CIVIC in Europe.

2. History of Honda Recycling in Europe

Honda is at the forefront of environmental awareness and aims to minimize the environmental impact of its activities. To this end Honda promotes activities to enhance the recyclability of cars and the use of recycled materials. Recycled materials are used instead of virgin materials in order to reduce use of natural resources. Materials that were wasted are once again used in the production for new parts. For example, in the case of bumpers consistently polypropylene has been used which

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can be easily recycled. Honda has applied plastic recyclates recovered from repair bumpers for over ten years in Japan and Europe^{(2), (3)}.

3. Automotive Shredder Residue

3.1. Automotive Shredder Residue Composition

Automotive Shredder Residue (ASR), is the either organic or inorganic residue from which metals have been removed during the shredder process. The composition of ASR is mainly resin, polyurethane foam, fibres, rubber and glass (Fig. 1) and comprises up to 25 percent of every vehicle, which means that, without the ability to effectively recycle such materials these potentially end up in the solid waste stream. The increase in the amount of residue is especially attributable to the plastics content, as its use has significantly accelerated due to weight and cost reduction measures. The separation of thermoplastics from ASR on an industrial

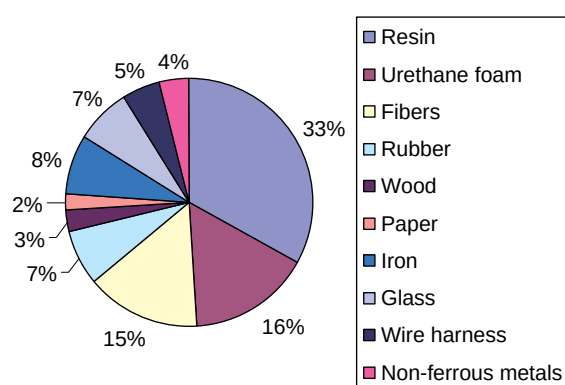


Fig. 1 Automotive Shredder Residue (ASR) composition

scale can be described in three basic steps (Fig. 2)⁽⁴⁾:

- (1) Shredder process
- (2) Post shredding sorting
- (3) Plastic separation

The first step is the shredder process where the ferrous metals are removed. The remaining non-ferrous (NF) mix and fluff are fed into the Shredder Residues Treatment Line (SRTL) where the ASR is separated.

3.2. ASR and Plastics Separation

The ASR separation process starts with the metal reclaiming operation, which grinds the ASR to around 25mm bits. These go through a large trommel, or rotating cylindrical screen, for classification into a light thermoplastic fraction and a heavy thermoset fraction, next air classification removes textiles and PUR foam. The remaining thermoplastics and thermoset rubbers go through eddy-current separators to remove copper. The thermosets can be used as fuel in the operation, further maximising process efficiency. The plastics are then put through a series of four modified dense media (DM) separation drums containing liquids of different densities⁽⁵⁾. In this continues process the plastics are separated in four different fractions, including the concentrate of thermoplastics which is treated as a separate stream⁽⁵⁾. The following thermoplastics are being recovered from the pre-concentrate:

- Olefins: Polypropylene (PP), Polyethylene (PE) and talc-filled Polypropylene (PP-T);
- Styrenics: Polystyrene (PS) and Acrylonitrile Butadiene Styrene (ABS).

The high accuracy in density separation of the thermoplastics pre-concentrate is achieved with a

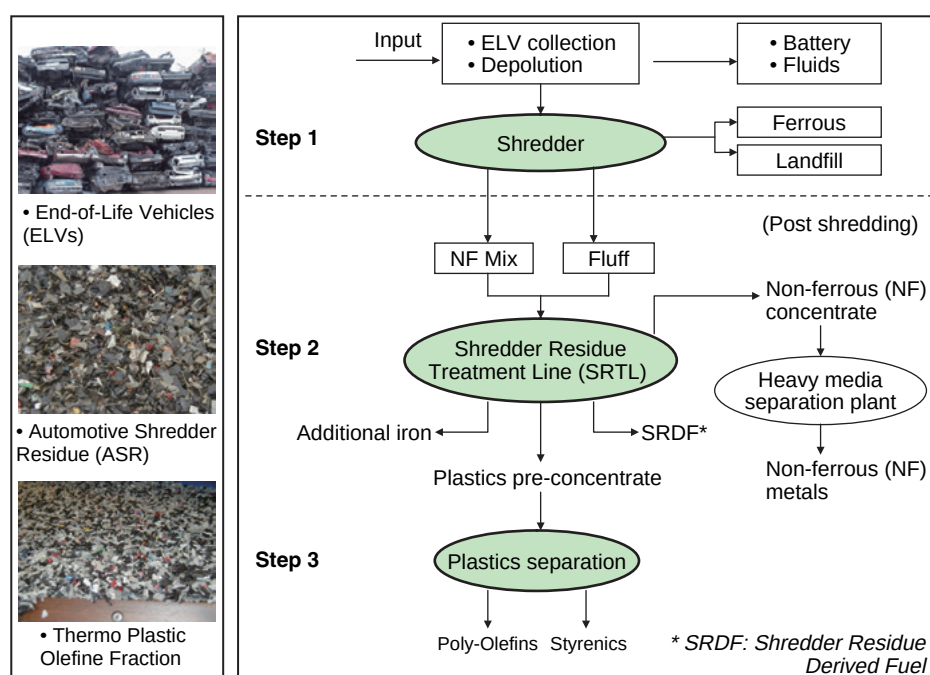


Fig. 2 Automotive Shredder Residue (ASR) Separation

hydraulic static separator using heavy media. The pre-concentrate is subjected to a static dense media dissociation that uses large vats, where materials between 0.9 and 1.5 cm³ density are separated with an accuracy of 0.002 g/cm³. Heavy fractions are removed by augers from the bottom while light fractions are skimmed off the top. Compared to dynamic separators such as cyclones, there is practically no mix produced.

PP is isolated from PE and PS while ABS and PP-T are separated from the remaining plastics of 1 to 1.1 g/cm³, which are landfilled⁽⁶⁾.

In the final compounding operation, fast moving conveyors bring the mix of plastic chips from the ASR resource to continuously feed the compounding extruders (Fig. 3)⁽⁶⁾. At this stage before extrusion the ASR recycle material can be mixed with other treated material from recycling sources like bumpers or bottle caps to achieve the required target material specification, but in all cases 100% recycle grades are produced. The material is pelletized, packaged and shipped to injection moulders.

4. Concept of Development

4.1. Objectives

The direction of Honda in Europe reflects the current European trend to continue the increase in application

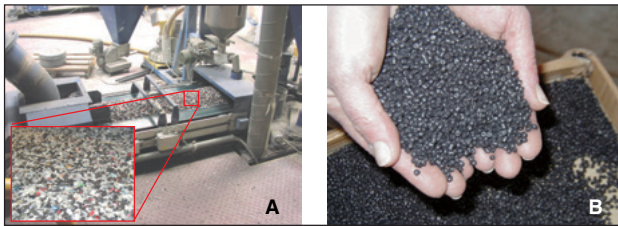


Fig. 3 Mixed polypropylene from ASR resource (A) feed compounding extruders and final product after pelletizing (B)

of plastic recyclates. The objective in this development is to:

- increase the application of polypropylene recycle;
- introduce the application of ASR derived recycle;
- achieve material cost reduction.

Target parts for this development are Inner Fender and Floor Under Cover for European 2006 model year CIVIC (Fig. 4). These parts combined represent a significant weight and therefore opportunity to introduce ASR recycle and achieve a considerable cost reduction.

Both parts are under body components and have similar requirements with regard to impact performance, while other requirements like for example for stiffness are different and more specific dependent on part shape and assembly method.

Honda ASR recycle grades have to be developed for both applications based on achieving part performance suitable for the EU market. A material specification based on 100% recycle application specific for Inner Fender and for Floor Under Cover had to be established. The recycle grades for both parts had to achieve a balance of impact performance and flexural



Fig. 4 Floor Under Cover and Inner Fender for 06 model year CIVIC

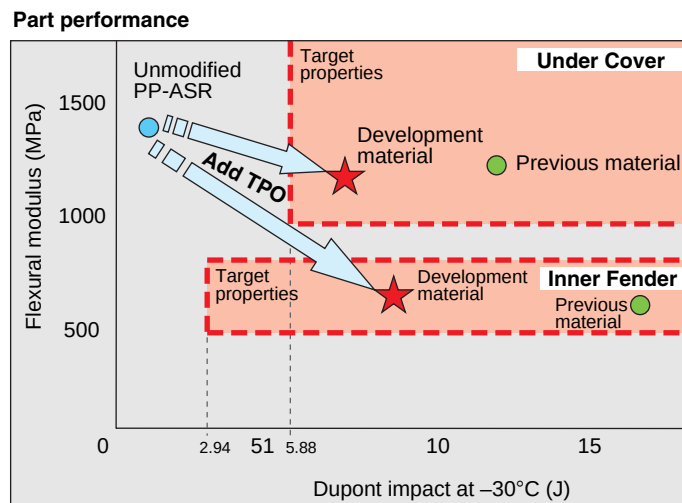


Fig. 5 Development target properties for Inner Fender and Floor Under Cover based on part performance

Table 1 Floor Under Cover and Inner Fender development material (part evaluation)

Item	Unit	Development			
		PP-ASR	Material A	Material B	Material C
				Floor Under Cover	Inner Fender
Recyclate content		100% PP ASR	90% PP ASR 10% TPO	70% PP ASR 30% TPO	60% PP ASR 40% TPO
Melt index	g/10min	4.25	6.3	7.3	8.6
Flexural modulus	MPa	1420	1340	999	540
Dupont impact strength (-30°C)	J	>1.47	>3.92	>9.8	10.8

Table 2 Deflection at high temperature of Floor Under Cover

Test condition	Splash Shield 2001 model year CIVIC	Floor Under Cover 2006 model year CIVIC
	Honda Bumper Recyclate	Material B
80°C	28mm max.	17mm max.
100°C	—	26mm max.

modulus required to meet part performance. Sufficient mouldability (melt index) is also required especially considering large surface area of Floor Under Cover and complex shape of Inner Fender.

4.2. Under Cover and Inner Fender

Under Cover is applied for the first time to 2006 model year CIVIC to enhance aerodynamics, because of the large surface area of Floor Under Cover part stiffness has to be sufficient. Impact performance is important for under body parts to resist stone impact, especially at low temperature.

In Europe Honda has no experience with the application of recyclate for Inner Fender. Similar to Floor Under Cover good impact performance is required. Part stiffness, however has to be lower to allow enough flexibility during the assembly process.

5. ASR Recyclate Development

5.1. Properties of ASR Recycled Polypropylene

The polypropylene derived from ASR recycling was evaluated first. This material was the basis from which the grades for both Inner Fender and Under Cover were developed. Secondly this material was enhanced in order to meet the specific target requirements. The correct balance of minimum impact performance and flexural modulus had to be achieved. Actual part performance was confirmed and compared to existing mass production parts, after which the recyclate material specifications could be fixed. Noticeable is the relative high rigidity and low impact performance of unmodified PP-ASR compared to the current grades applied for Inner Fender and Splash Shield. The target was to modify the PP-ASR to meet the requirements for each specific part and achieve a 100% recyclate application (Fig. 5).

5.2. Compounding of ASR Recycled Polypropylene (TPO Application)

Part requirement for impact performance was

evaluated by Dupont impact at -30°C. Unmodified PP-ASR could not meet this requirement for either application.

The flexural modulus for Inner Fender was also too high to allow for sufficient part flexibility. Minimum flexural modulus, however, is required for Floor Under Cover to guarantee part stiffness which is especially critical at higher temperatures.

A specific grade with target properties had to be developed for both applications by compounding the PP-ASR with TPO recyclate to enhance the properties to target level (Table 1).

5.3. Part Test

Confirmation of part performance for 2006 model year CIVIC was required after the basic material composition had been established. For both applications part stiffness and impact performance were evaluated on actual parts in ASR recyclate and previous mass production material, HD/LD PE for Inner Fender and Honda bumper recyclate for Splash Shield, allowing a direct comparison between current and developed technology to be made.

Part stiffness of Floor Under Cover in Material B has been tested at high temperature and compared to mass production Splash Shield and the maximum deflection evaluated to specification for under body applications. The result for Floor Under Cover meets the development target and is better then achieved for Splash Shield on previous model (Table 2).

The flexural modulus, critical for Inner Fender, was achieved by compounding PP-ASR with 40% TPO (Material C) and has resulted in flexural modulus comparable with HD/LD PE. Evaluation of the Inner Fender on actual vehicle shows that sufficient part flexibility has been achieved.

Impact performance has been evaluated and compared with competitor OEM parts for both Inner Fender and Floor Under Cover by testing at -30°C

Table 3 Dupont impact (-30°C) of Floor Under Cover and Inner Fender

		Test result		
		Honda	Competitor A	Competitor B
Dupont impact (-30°C) (J)	Floor Under Cover	5.8 (>3.43)	2.94 (>1.96)	5.8 (>2.94)
	Inner Fender	9.8 (>5.8)	3.92 (>2.45)	6.68 (>4.9)

Table 4 Heavy metal analysis ASR recyclate grades

Element	ELV Directive limits (2000/53/EC)	Total heavy metal analysis ppm total element per material	
		Material B	Material C
Antimony	Not applicable	0.5	1.0
Arsenic	Not applicable	<0.5	<0.5
Cadmium	100 ppm	10	1.5
Chromium	1000 ppm	4.5	2.5
Lead	1000 ppm	15	10.0
Mercury	1000 ppm	<0.5	<0.5

on actual parts. The resulting impact performance for both parts in ASR recyclate is similar to this of competitor OEMs and is acceptable for the European market (Table 3).

5.4. Process Control

The source of ASR recycled polypropylene is ELV components where different polypropylene grades are applied. The properties of these input materials (i.e. ASR-PP, TPO) used for compounding the ASR recyclate grades can vary depending on the source material. It is important that properties of the compounded materials meet specification for each production batch and are stable over a long period to guarantee mass production quality. In the mass production process the input material and ratios are varied to control the material specification. The following procedure is followed:

- (1) The quality of the input materials is confirmed after the separation process.
- (2) The compounding ratio and input components to meet specification are established and fixed for batch production.
- (3) Input materials and additives are mixed at the extrusion line.
- (4) Material is extruded and pelletized, quality controlled online (melt index).
- (5) Final specification confirmation before shipment (certificate of conformity).

For each batch production this process is repeated. The recyclate grades (compounding ratio) for Inner Fender and Under Cover can therefore vary for each batch production to guarantee the specification.

For example shrinkage of the recyclate has to be stable to allow for assembly and fit and finish. Shrinkage data has been evaluated for the ASR grade over a one year period (Fig. 6). The result shows it is controlled within +/- 0.25% which is sufficient tolerance for mass production.

5.5. Contamination

The ASR and plastic pre-concentrate separation process has shown to be highly accurate (high tolerance). The level of contamination in produced single plastics streams is low. A purity of minimum 99.8% is achieved for the polypropylene grades recycled from ASR. Annex II of Directive 2000/53/EC limits the use of heavy metals lead, hexavalent chromium, mercury and cadmium to a maximum concentration per material ⁽¹⁾. Especially in the light of this Directive it is important that no banned substances are present in the recyclate grades so contaminated materials are not introduced to new models.

Separate analysis was done of development grades, which confirms that all heavy metal contaminations are well within the limits set in the Directive (Table 4).

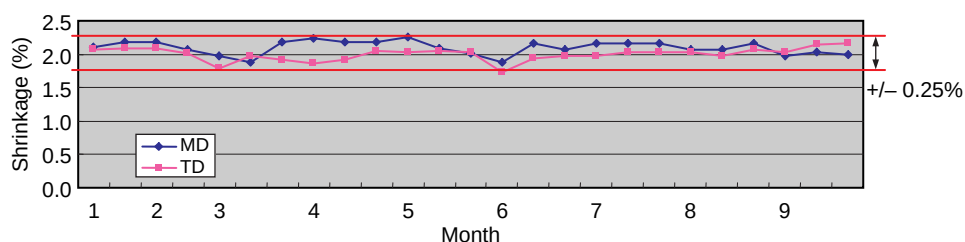


Fig. 6 Shrinkage variation over time

6. Cost Benefit

The cost reduction achieved for the developed ASR recyclate grades compared to existing mass production materials is shown in Fig. 7.

For Floor Under Cover a cost reduction of 60% per kg has been achieved by applying ASR recyclate compared to the Honda Bumper recyclate. Honda Bumper recyclate is continued to be applied for new CIVIC Cover Assy Front Bulkhead Cover. The cost reduction for Inner Fender compared to the previously applied material is 12%. The cost of ASR recycled plastics is relatively stable and independent of fluctuations in oil prices.

7. Conclusion

This development has shown that 100% recyclate grades from ASR could be developed successfully for Inner Fender and Floor Under Cover and applied for 06 model year CIVIC in Europe.

- (1) Plastics can be separated with high accuracy from ASR, leaving low contamination;
- (2) By modifying polypropylene recycled from ASR with recycled TPO the balance of properties could be achieved for Inner Fender and Under Body application;
- (3) Significant cost reduction has been achieved; 60% material cost down for Floor Under Cover and 12% for Inner Fender;
- (4) Total recyclate application on 2006 model year CIVIC has been increased;
- (5) The compounding process applied takes into consideration the varied quality of input materials and is based to guarantee material specification.

This development has shown the potential of ASR recycled polypropylene. It opens the way to look at other applications of plastics recovered for ASR contributing to more cost reduction and less dependence on natural resources.

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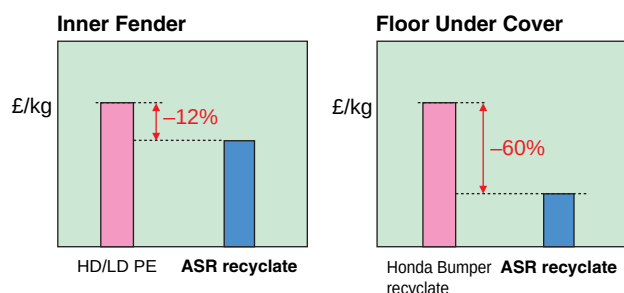


Fig. 7 Material cost reduction achieved for ASR recyclate application

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