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# The use of recycled and waste materials in selected automotive applications

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## Abstract

This report is an account of a project that went under name 'Light AND Sound' or the acronym 'LANDS'. The objective was to investigate the potential use of recycled and waste materials in automotive components. Five components were selected for the investigation. All of them had the potential to be manufactured from waste and recycled materials. The trial materials which included recycled polypropylene and a particulate industrial solid waste stream, were processed into prototype components that were evaluated and compared with the respective production counterparts. Finally a life cycle assessment was carried out for each prototype component that was also compared with the current part. The overall results indicated a clear potential for the use of the project materials in their respective application.

## Introduction

The automotive industry needs to reduce carbon emissions in line with 2020 and 2050 targets and comply with end of life vehicles (ELV) regulations. As a result all of the automotive industry is involved in a wide range of activities with this objective in mind.
Vehicle manufacturer was involved in this project was. One of their plans related to this subject was on the development of alternative materials for vehicle applications based on natural materials, recycled materials and waste materials. This would have the potential to reduce the whole lifecycle impact of a vehicle, rather than a focus solely on tailpipe emissions. The LANDS project was undertaken as part of this plan. Five target components were selected for the investigation. Each one had the potential to be made at least in part using either recycled materials or waste material. A important consideration for the selection of the project materials was that they had to be able to be subsequently recycled effectively. With this in mind the materials selected for the project were;

Recycled polypropylene (PP Rec)
Recycled polypropylene (PP Rec) fibres
Recycled polyethylene terephthalate (PET Rec) fibres
calcium carbonate cake (CCC) (a waste product from the production of sugar)

These materials were used to produce compounds and blends that were assessed for their potential use in the five target components. A comparison was made between the project materials and those currently used in the selected applications. In addition to comparing the physical and chemical properties of the materials, a detailed life cycle analysis (LCA) comparison was conducted on all of the target applications.
The selected target components are listed in the following section.

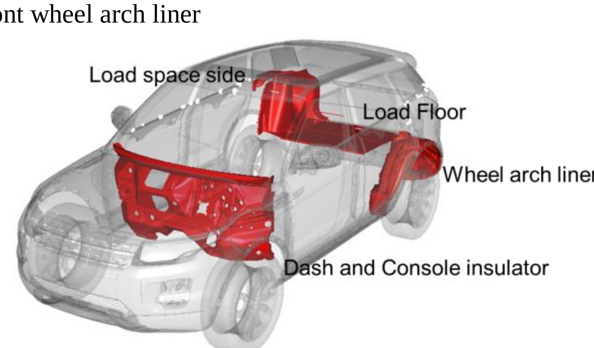
## Materials and Experimental procedure

Target Components and Materials

**Figure 1 is a schematic diagram of the location of the target applications. The front wheel arch liner has been left out for clarity.**

**Figure 1. The target components**

Front wheel arch liner




The front wheel arch liner that was considered is currently made from a recycled PP containing 20-22%wt of mineral filler. 5-7wt% of the filler content is composed of various materials that were inherited from the original components. The remaining filler content was made up with the addition of powdered talc.

The objective for this component was to investigate the possibility for replacing the talc content of the compound with a solid waste material generated in the sugar refining process.

This material is essentially a calcium carbonate powder that was formed by precipitation from an aqueous solution. This precipitate is used to extract the final residues in the sugar refining process. It leaves this process as a compressed sheet known as calcium carbonate cake, CCC. The cake can be dried to leave a well dispersed powder. The main difference between the CCC powder and precipitated calcium carbonate powder is that the CCC particles are coated with the residues that were extracted in their primary function. Particle size analysis of the CCC powder showed that it had a similar particle size distribution to pure precipitated calcium carbonate powder. This gave an indication that CCC could be used as an alternative filler material in plastics processing to filler powders that are used directly from a non-renewable resource.

The resins used for this component were supplied by MBA polymers, one of the project partners. The two grades supplied were, MBA2126 and MBA2143. Both were produced from recycled automotive components. The former was an impact modified grade.

**Rear wheel arch liner**

The requirements for this component were, water resistance, low weight and low sound transmission.

The current part is made by compressing a loose fibre mat composed of a mixture of virgin PP and PET fibres.

The project materials that were used as an alternative for the current materials were recycled PP carpet fibre and waste PET fibres from the production of duvets and pillows. In addition the PET fibres were, in turn, produced from recycled material.

The quantities of both of these waste/recycled materials are able to sustain the requirement for production of the Jaguar Land Rover rear wheel arch liner.

**Load floor**

The production load floor is made from a board composed of polyurethane, glass fibre and paper. The parts are compression moulded to the desired shape and had a weight of 2.76 Kg.

When considering this component for alternative materials attention was drawn to a sheet production process that was being developed in the industry. In this process a flax fibre mat is bound in a matrix of a mineral filled thermosetting resin to form sheets that are bonded to a honeycomb paper core section to give a stiff light board with a sandwich structure.

The objective here was to evaluate this process for the manufacture of a load floor board. The load floor board was an application on which this potential could be assessed.

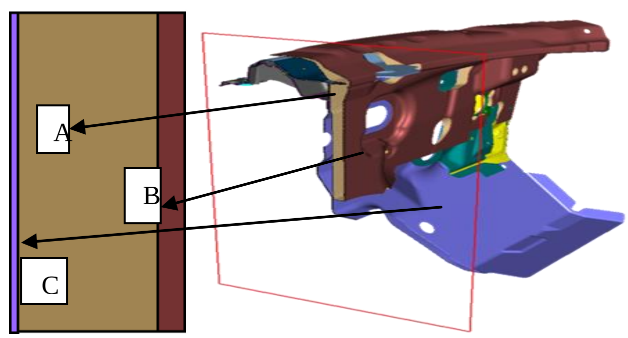
**Load space side**

The load space side is currently made from a 15% mineral filled virgin PP compound and the part weight is 3.196Kg. The objective was to determine if this component could be made from a compound of PP Rec filled with CCC powder.

**Dash and console insulator**

The sound insulating layer is composed of a low density fibre or foam mat that is bound to a dense flexible layer (heavy layer). This structure is then placed behind the front steel or aluminium bulkhead in the vehicle. Diagrams to illustrate the structure of the assembly are shown in figure 2.

**Figure 2 The diagram on the left shows the structure of the component. The diagram on the right is a schematic diagram of the installed component.**




A –Felt or Foam layer, 18mm thick
B –Heavy layer sheet, 6mm thick
C –Steel/aluminium vehicle plate, ~1.2mm thick

The sound properties of the complete metal-low density layer-heavy layer sandwich have to be measured when the insulating properties of the trial materials are evaluated.

The current low density layer is a polyurethane foam that is back injected onto the heavy layer. The project materials considered for this layer were loose fibre mats of recycled thermoplastic fibres and mats with mixtures of thermoplastic and natural fibres.

The current heavy layer was made from a thermoplastic elastomer composite heavily filled with chalk and barium

sulphate powders. This section has low sound transmission properties that result from a combination of a low elastic modulus (~ 70MPa) and a high density (~2.0 g/cc).
The objective for this component was to produce heavy layer material with the calcium carbonate content of the current compound replaced with CCC powder. The acoustic and mechanical properties of the compounds were then to be compared with the current heavy layer.

**Wheel arch liners**

**Front wheel arch liner**

PP Rec compounds with 50%wt of CCC powder were produced using a 40mm co-rotating twin screw extruder. The compounded pellets were then dry blended with additional matrix resin pellets to give a 20%wt CCC. The blend was then placed in the hopper of a 150t injection moulder and mechanical test pieces were produced. Two types of samples were produced, an ISO R527 tensile bar 4mm thick and a 150x150x4mm flash-gated plate. The tensile bars were used to measure the tensile and flexure properties of the compounds and the plates were cut into quarters to give four samples for a standard instrumented dropped weight impact test.

**Rear wheel arch liner**

The fibre mats were formed on a pilot needle punching line at Anglo Recycling. The component fibres were first blended in the same fibre ratio of PP and PET that was used to produce the current rear wheel arch liner. The blend was then fed evenly onto a thin PP fibre backing sheet that carried it to the needle punching stage after which the mat was finally trimmed and wound onto the take up spool. The thickness of the uncompressed fibre mats was 6mm. The area density of the mats was 210 g/m2.

The area density of the wheel arch liner compressed sheet is approximately 1073 g/m2. For the production of the project wheel arch liner, 4 layers of the 6mm thick needle punched mat were stacked up to give an area density of 840 g/m2. This would produce a part weight lower than the production moulding but it also meant that the moulding cycle time would fit the commercial production rate of the parts. The layers were compressed in a hot press in the following way; the fibre mat was preheated to a temperature that lay between the melting points of the PP and PET. The mat was then transferred to the compression mould tool, which was controlled at a temperature below the melting point of PP, where it was compressed to form the component. The result was that the PP fibres that were melted in the pre heating treatment encapsulated the PET fibres and fused them together to form the compressed rigid structure of the part. This form of the compression moulding process provides for a very short moulding cycle time compared to other forms of the process that cycle the mould tool temperature for each moulding. Consequently this process is widely used in the automotive industry.

**Load space floor and side**

**Load floor**

The novel sheet structure mentioned in section 2 is currently being developed in the industry. This structure is light, stiff and strong was ideal for being considered for the vehicle load space floor panel. At the time the filler that was being used for the skin sections of the sheet was calcium carbonate powder. Samples of the skin layers were produced with CCC as the filler and trial load space parts were produced. A significant feature of the process was that the curing of the matrix resin for the skin layers required a small amount of water in the mixture. This meant that the CCC could provide this and would thus not need to be fully dried which is a requirement for the other applications considered for the CCC.

**Load space side**

The same compound of PP Rec filled with 20%wt CCC powder that was used for the front wheel arch component, was also used for injection moulding samples of the load space side using current production tooling.

**Dash and console insulator**

Samples of fibre mats produced on an industrial needle punching line were prepared for inclusion as the low density layer in the trial dashboard insulation.

The material for the heavy layer section of the trial component was compounded using a co-rotating twin screw extruder. Two compositions of the material were produced. Both of them contained the same weight content of ceramic filler and the same proportion of resin and extender oil as that used in the production heavy layer material. The difference between the two compounds was that for one of them the barium sulphate component was replaced with the same weight content of additional CCC powder.

The compounded pellets were then formed into sheets by compression moulding. Test pieces for the acoustic and mechanical evaluation of the compounds were cut from the sheets.

Front wheel arch liner (and load side)

The processing of the CCC project compounds produced samples that possessed a distinct and slightly unpleasant odour. The presence of the odour was considered to be a possible problem for the materials if they were to be used for components in and around the interior of the vehicle.
The origin of the odour was attributed to the presence of the coating on the CCC particles that was deposited during their work in the sugar refining process. Samples of the processed materials were subjected to Jaguar Land Rover's in house odour testing procedure. The conclusion, based on these tests, was that the odour would not be a problem for the selected target applications. There were, however issues with the stronger odour that was produced during the processing of the compounds. As a result of this, it was decided to investigate methods for the removal of the odour. The most effective method was to subject the CCC powder to a temperature of at least 250ºC for a time that was dependant on the heating conditions. The details and the results of these trials are presented in a separate report.

The mechanical test results for the 20%wt CCC filled PP Rec compounds and a currently used material are shown in figure 4. The tests were carried out with a cross head speed of 1mm/min for the measurement of the modulus (taken between 0.1 and 0.15% strain) and 5mm/min for the remainder of the test. At least six samples were tested for each compound.

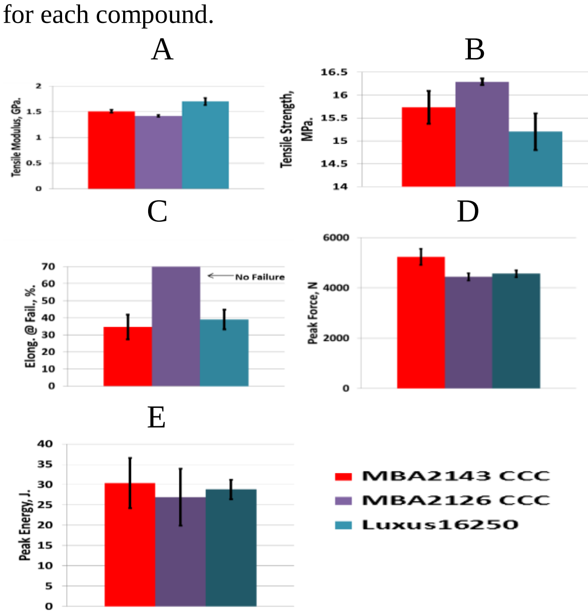



**Figure 4. Comparison of the mechanical properties of the compounds of the two MBA recycled PP resins filled with 20% CCC with the virgin compound currently used in the target application: A, tensile modulus, B, tensile strength, C, tensile elongation at failure, D, dropped weight impact peak force, E, drop weight impact peak energy.**

The tensile modulus of the virgin compound is slightly higher than that of the two PP Rec/CCC compounds. Thus is possibly due to the talc filler in the virgin that is known to provide a greater stiffening effect than calcium carbonate in PP compounds. The other results show that the CCC compounds are approximately equivalent or significantly better than the virgin compound. The MBA 2126 compound did not fail after an extension of 120% at which point the test was terminated. This result reflected the fact that the MBA2126 material contained an additive to improve the toughness of the reclaimed material.

The error bars shown in the figure indicate that the performances of the CCC filled compounds are at least equivalent to the talc filled virgin resin. It can be concluded, therefore, that the CCC powder can be used as an effective and reliable filler in PP compounds. Additional support for this is presented in another report.

The results for this application demonstrated that the CCC material could be used as an effective and reliable filler for the PP Rec resins. The mechanical performance of the compounds could match those of the currently used talc filled PP Rec. The economic and environmental implications for the compounds in the front wheel arch liner and the load side components were assessed in a life cycle analysis, LCA, of the components. The results of this are given in section 5.

**Rear wheel arch liner**

A series of trial wheel arch liners were compression moulded from the recycled PP/PET blended fibre mat as described in section 3.1.

A slight modification had to be made to the heating profile of the mat to take account of the lighter felt weight compared to the commercial material. The cycle time for the mouldings was kept the same as for the production parts so that the process kept in line with the downstream operations of the line.

The trials were very successful with no problems encountered. The samples were lighter than the production part (the initial mat had a lower area density than the production material). A parts check showed that there was no significant difference in size to the production part and they fitted to the vehicle in a normal manner. The result of an LCA for this component is presented in section 5.

4.2 Load floor

The samples with the CCC filler produced by this method did not possess the odour that was evident in the thermoplastic compounds. The thermoset resin appears to have locked in the odour from the CCC. This means that the CCC from the sugar processing only needs to be dried to the point where the level of the moisture left is that which is required for the thermosetting cure.

The performance of the project component samples was comparable with the current part and thus the full potential for the material was assessed with an LCA.

## Results and discussion

**Summary**

The results of this life cycle assessment have shown that LANDS alternatives have an overwhelmingly positive impact on each of the impact assessment categories considered.

The change in material content reduced the material production impacts and when this was combined with the reductions in part weight, substantial impact reductions occurred. A synopsis of the global warming potential reductions achievable through the implementation of the LANDS alternatives are shown in table 3.

A Current ~KgCO2e
B LANDS~KgCO2e Saving
C ~KgCO2e Saving
% Saving

| | A | B | C | % |
|---|---|---|---|---|
| Front Wheel arch Liner | 34.3 | 34.6 | 0.2 | 0.7 |
| Rear Wheel Arch Liner | 15.6 | 11.3 | -4.3 | -27.8 |
| Load Space Side Moulding | 32.4 | 31.0 | -1.4 | -4.3 |
| Load Floor Board | 44.9 | 29.1 | -15.8 | -35.2 |
| Dash Board Insulation | 88.8 | 76.4 | -12.4 | -14.0 |
| Total Parts | 216 | 182.3 | -33.7 | -15.6 |

**Table 3. Overview of global warming potential impact assessment results.**

### 6 Conclusion

The LANDS project has shown that the five selected automotive components can be made with materials that would contribute to the production of a vehicle with a lower carbon footprint than one using the current components.

The main benefits from the materials property aspect are a reduction in weight for the dash board insulator and the load floor board and a potential improvement in the acoustic performance of the dash board insulator. The mechanical properties of the project components gave no improvement on the current components.

The project also demonstrated that the CCC powder could be used as an effective and reliable filler in thermoplastic compounds and, therefore, has the potential for use in applications outside the automotive industry.

The application of the bench top sound testing equipment proved effective for the initial assessment of trial materials for applications requiring acoustic insulation properties. The limitations of this test method were demonstrated when the test sample had a high sound transmission loss value.

The LCA showed that the use of the LANDS materials in the selected components could result in up to a 35% improvement in the global warming potential impact of the parts. The only component to show a negative effect on this was the front wheel arch liner. The overall effect, if all of the parts were made from the LANDS materials, would be approximately a 16% improvement.

The partners put the results into the production of all of their vehicles and estimated that the components would save approximately 2,019t of CO2 a year, the equivalent of 32 luxury vehicles over their entire lifetime.

### 7 Acknowledgements

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