Ultra-fine Tyre Powder in Truck Tyre Retreads

This case study describes operational trials for using ultra fine ground post consumer tyres in the compounds used in the manufacture of retread truck tyres.
Key facts

Note: In the context of this case study the term “truck tyre” relates to all tyres, for wheel diameters 17½ inches and above, for use on trucks or buses for road use.

- UK manufacturers retread on average 950,000 truck tyres per year.

- 19kg of rubber compound is added to a typical (super single) truck tyre during the retreading process.

- Inclusion rates of up to 5% of recycled rubber powder may be achieved in the retread compound with no loss of technical performance.

- At 3% inclusion rates, rubber powder from approximately 550 tonnes of tyres would be used for truck tyre retreads in the UK annually.

- There are no technical reasons why the process cannot be extended to the car and light truck tyre sector.
Overview of truck tyre retreading

Retreading of tyres is a widely practised procedure which entails the removal of a worn tread and part of the sidewall from the used tyre surface and its replacement with new rubber compounds. Most tyres manufactured for commercial vehicles can be remanufactured in this way because of the inherent high quality and durability of the tyre’s structure. Many truck tyres are retreaded three or four times during their life, thereby maximising the use of the materials and energy required to make each tyre.

A large (super single size) truck tyre consumes approximately 60kg of natural and synthetic rubber compound and consumes a significant amount of energy in its manufacture. Major environmental benefits accrue from retreading. They are:
- Some 40kg of the original materials are re-used;
- There is a significant delay in the ultimate end-of-life disposal of the tyre, and
- Retreading consumes less energy than that used in the manufacture of the original tyre.

In addition to the material and energy resources saved by this process, and the reduction in the quantity of tyres that must be scrapped, there are commercial benefits to fleet operators. For this reason retreading is an accepted procedure in the commercial sector and other applications such as aviation, earth moving and motor cycles. The retread market for commercial vehicle tyres in the UK is well-established and has remained relatively constant since 1995 at between 900,000 and 1 million units per year.

It is hypothesised that further environmental and economic advantages could be achieved if significant quantities of recycled, vulcanised rubber could be incorporated into retread tyre compound. It is the understanding of the team carrying out the trials described in this case study that the current use of recycled tyre rubber in the manufacture of new and retread tyres is limited. An internet review yielded no public research on this subject.
Operational trials: the background

Current end uses for size reduced tyre rubber in the UK are limited to relatively low technology applications such as play and sports surfaces and low performance moulded products. This case study describes trials to utilise recycled tyre rubber in a higher performance end use application, specifically the manufacture of retread tyres.

Crumb Rubber Ltd, based in Plymouth, produces a novel ultra-fine recycled rubber powder derived from post consumer truck tyres through a novel mechanical grinding process. The plant used to produce the powder is the first of its kind in the UK.

The powder has exceptional surface area to volume ratio. This feature facilitates significant improvements in mechanical and chemical bonding with virgin materials thereby having the potential to be incorporated into relatively high technology products, such as new and retreaded tyres.

In October 2005, Crumb Rubber was successful in gaining financial support from the Waste and Resources Action Programme (WRAP) to conduct operational trials for using the powder in the manufacture of tread compounds for retreaded truck tyres.

This case study summarises the trials, the objective of which was to establish the maximum potential inclusion rate of rubber powder in the virgin remould blend without impacting existing performance characteristics such as durability, reliability, safety and service life of the remoulded tyre.

The trials were conducted in conjunction with Bandvulc Tyres Ltd, of Ivybridge, Devon, and their subsidiary company Devon Rubber Ltd. Bandvulc is one of the largest independent manufacturers of retreaded truck tyres in the UK and Europe, producing approximately 150,000 retread tyres per year.
The project commenced in January 2006 with laboratory based trials. Tests were carried out to identify the maximum rate of inclusion of the recycled rubber powder for both processing and performance characteristics. In the second phase of the work, which commenced in November 2006, mouldings incorporating recycled rubber powder were used in the manufacture of retreaded tyres for safety testing and ultimately for road trials on a fleet of local trucks.

The fleet road trials have not been completed at the date of compiling this case study. Measurements are due to be taken at the end of March 2007 to compare the degree of wear of the treads with that of control tyres fitted to the same vehicles. Thereafter, the trials will continue until the tyre treads have worn to the accepted limits, ensuring that the maximum amount of data can be compiled relating to the performance of the material used.

<table>
<thead>
<tr>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubber particle size</td>
<td>Sub 177 µm powder (80 mesh)</td>
</tr>
<tr>
<td>Material Source</td>
<td>Truck tyres</td>
</tr>
<tr>
<td>Process</td>
<td>Ambient size reduction</td>
</tr>
<tr>
<td>Rubber content</td>
<td>0.4kg per average truck tyre retread</td>
</tr>
<tr>
<td>Equivalent used tyre weight</td>
<td>0.6kg per average truck tyre retread</td>
</tr>
<tr>
<td>Potential UK used tyre demand</td>
<td>550 tonnes tyres p.a. (applied to truck retreads only)</td>
</tr>
</tbody>
</table>
Case study

Laboratory trials

Feedstock

The original feedstock material for the trials was clean cut truck tyre chips, 20mm to 25mm particle size, which were relatively steel free. This feedstock was size-reduced by Crumb Rubber Ltd down to an ultra fine 80 mesh powder, with particle size below 177µm, using a novel ambient mechanical grinding process. During the process all remaining contaminants, such as steel and textile, were removed.

Sample mixing

Mixing and testing of the initial sample compounds was carried out at Bandvulc's subsidiary company, Devon Rubber Ltd.

The recycled rubber powder was included at discrete increments into virgin truck tyre tread compound, supplied by Devon Rubber, in a conventional Banbury-style closed mixer producing 2kg samples. Sample inclusion rates were set at:

Zero (control sample), 1%, 2%, 3%, 5%, 8%, 13%, 21%, 34%, 55%, and 100%.

Two samples were made of each mix. Mixing conditions were as follows:

- Virgin compound was introduced to the mixer chamber, and the compound was mixed for 20 seconds;
- The chamber was opened and a weighed portion of the rubber powder was added;
- The powder and compound were mixed for 60 seconds;
- The chamber was opened and the mix was discharged;
The discharged mix was milled in a conventional laboratory scale double mill compounder for approximately 10 passes and sheeted for testing. The mixer temperature was maintained at between 30ºC and 40ºC.

Milling efficiency decreased marginally as powder inclusion rates rose above 5% and the effect was more marked beyond 13% inclusion.
A second series of mixes between 2% and 13% inclusion rates was undertaken in which the recycled powder was pre-treated with a proprietary oil-based process aid in an endeavour to improve the adverse processing characteristics.

Sample testing

All samples were laboratory tested for the key physical characteristics of hardness, specific gravity, abrasion, elasticity, elongation at break, ultimate tensile stress, and tear strength. Results were plotted against the control (zero inclusion) standard.

It was found that, at inclusion rates of up to 15% the samples complied with generally acceptable physical performance standards in that they had characteristics within 10% of those of the control blend. However, compounds with inclusion rates of powder above 5% evidenced reduced tack, increased stiffness and
bagging during the milling process. The addition of the oil-based processing aid had a positive effect on the milling process but returned noticeably lower performance in critical characteristics such as abrasion, elasticity, elongation at break and tear strength. Furthermore, it was considered that the quantity and cost of the process aids required to achieve the process improvement would have had a detrimental effect on the economics of the application.

Test equipment at Devon Rubber

Conclusions of laboratory trials

From the laboratory trials it was concluded that the process limitation would effectively restrict inclusion rates to 5% or less, unless the processing difficulties can be overcome. It was therefore decided that compounds using 3% and 5% recycled rubber powder would be used to manufacture retread truck tyres for external drum (roll resistance) testing.
Drum testing

From January 2004, amendments to the Motor Vehicle Tyres Safety Regulations (1994) have made it compulsory for retreaded tyres to meet United Nations Economic Commission for Europe (ECE) regulations.

The specification for retreaded tyres for commercial vehicles has been clearly defined by Regulation ECE 109, “Retreaded pneumatic tyres for commercial vehicles and their trailers”. These regulations not only define the process of retreading and tyre structure but also the specifications for their use and the testing procedures required.

Retread tyres for drum testing
Four tyres were retreaded using tread manufactured from the compound incorporating the recycled rubber. Of these, two tyres were constructed using 3% compound treads and two using 5% compound treads. One trailer tyre and one tractor unit drive tyre were made from each blend.

The tyres were subject to load and speed endurance testing carried out at an external test house in accordance with Regulation ECE109, Annex 7. In these tests the tyres were subjected to 47 hours drum testing at varying loads and speeds. All of the tyres passed the tests which confirmed that they were safe for road usage. However, tests were still required to establish how the tyres performed in practice and, in particular, what would be the rate of wear of the tread using recycled content compared to that of a tread using virgin rubber compound.

**Fleet trials**

A road test plan was established which would adequately test a number of tyre types under a range of driving conditions. Tyre types included tyres for tractor drive units (23mm tread depth), trailers (17mm tread depth) and “double-decker” trailers (14mm tread depth). Tyres are removed from the vehicle when the tread depth is worn down to 3mm. The objective was to monitor tread performance - in particular, wear rates - for the life of the tread under the varying conditions of axle load, wheel location on the vehicle, inflation levels and driving techniques.

Sixty truck tyres were manufactured for the fleet road trials. Of these, thirty incorporated treads made from virgin rubber compound, for control purposes, and thirty were made using treads manufactured from a 3% mix of recycled rubber.

45 tyres were fitted to road vehicles belonging to a local vehicle fleet and the remainder are being kept as spares in case some
tyres suffer damage or failure. Test and control tyres were fitted to the same vehicle in each case so that wear rates could be compared.

Fleet vehicles used in road testing

As noted above, these road trials are continuing at the time of writing this case study. A final report on the performance of the tyres will be compiled when all of the test tyres, or their control tyres, have worn down to the legal limit.
Commercialisation

Assuming that the fleet road trials of the tyres using recycled rubber are successful, commercial use of the ultra fine powder in retread compound would be possible.

A super single size retread truck tyre weighs approximately 84kg, made up as follows:

<table>
<thead>
<tr>
<th></th>
<th>kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prepared (buffed) casing</td>
<td>65</td>
</tr>
<tr>
<td>Tread</td>
<td>18</td>
</tr>
<tr>
<td>Added sidewall material</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>84</td>
</tr>
</tbody>
</table>

By incorporating 3% of recycled rubber in the tread compound, a total of 0.54kg of recycled rubber is used in each retreaded tyre. This is equivalent to 0.83% of the weight of the casing. The average weight of worn truck and bus tyres collected by the secondary tyre industry in 2004 was 49kg\(^1\). At 3% inclusion rates in the tyre tread, the average amount of recycled rubber, across the range of tyre sizes currently in use in the UK, would be approximately 0.83% \(\times 49\)kg = 0.41kg per tyre.

Based on an average UK market for retread truck and bus tyres of 950,000 units per year, the potential annual usage of recycled rubber for this application, at 3% inclusion rate for the tread compound, would be c.400 tonnes.

Given that a tyre contains approximately 70% rubber, this equates to an annual usage of used tyres of 550 tonnes.

Further work in this area will look at increasing the inclusion rates to 5% and above, and extending the concept to the light commercial vehicle (LCV) and the passenger car retread tyre industries. There is no technical reason why the process could not be applied to the manufacture of LCV and car retreads, although these markets are currently limited in size compared to the truck

---

\(^1\) WRAP Used tyre statistics 2004
and bus market\textsuperscript{2}. It is expected that, by increasing the inclusion rates and by proving the concept in the other markets, the potential annual demand for tyre derived powder for retread compound in the UK could rise above 1,000 tonnes.

\textsuperscript{2} See case studies ‘Remoulds and Retreads: the re-use of tyres by Biffa Waste Services Ltd’ and ‘Remoulds and Retreads: the re-use of tyres for cars and light trucks’ available on http://www.wrap.org.uk/applications/publications/tyres/
Cost savings and environmental benefits

Cost benefits

The ultra fine rubber powder produced by the Crumb Rubber plant has an ex-works cost of c.£300 per tonne, at current costs of the feedstock shred. This compares favourably to the cost of virgin and synthetic rubber in excess of £1,000 per tonne. It follows that savings in production costs of the retread of a minimum 30p per tyre could be achieved.

Environmental benefits

Following successful completion of the trials described in this study, environmental benefits will accrue from the displacement of, potentially, 1,000 tonnes of virgin rubber compound per year in the manufacture of retread tyres.
Details of parties

Clients

Crumb Rubber Ltd
10, Thornbury Road
Estover
Plymouth
PL6 7PW
Tel: 08700 331133
www.airportbusiness centre.net

Contacts: Ted Pedersen, David Young

Bandvulc Tyres Ltd
Gillard Way
Lee Mill Industrial Estate
Ivybridge
Devon PL21 9LN
Tel: 01752 893559
www.bandvulc.com

Contact: Patrick O’Connell
This case study was developed for WRAP by:

OAKDENE HOLLINS

Disclaimer: WRAP and Oakdene Hollins Ltd believe the content of this report to be correct as at the date of writing. However, factors such as prices, levels of recycled content and regulatory requirements are subject to change and users of the report should check with their suppliers to confirm the current situation. In addition, care should be taken in using any of the cost information provided as it is based upon numerous project-specific assumptions (such as scale, location, tender context, etc.).

The report does not claim to be exhaustive, nor does it claim to cover all relevant products and specifications available on the market. While steps have been taken to ensure accuracy, WRAP cannot accept responsibility or be held liable to any person for any loss or damage arising out of or in connection with this information being inaccurate, incomplete or misleading. It is the responsibility of the potential user of a material or product to consult with the supplier or manufacturer and ascertain whether a particular product will satisfy their specific requirements.

The listing or featuring of a particular product or company does not constitute an endorsement by WRAP and WRAP cannot guarantee the performance of individual products or materials. For more detail, please refer to WRAP’s Terms & Conditions on its web site: www.wrap.org.uk.