Pilot scale pyrolysis products

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The 24th Annual Tyre Recycling Conference
Focus on the future : Circular Economy

22 – 24 March 2017 - The NH Sablon Hotel, Brussels
AIM

- The aim of the paper is to present Pyrolysis of EoL tyres at

- **TRL 7** – *system prototype demonstration in operational environment*

- offering the recycling sector an opportunity to see the *latest challenges and opportunities towards defining standards.*
Circular Economy

Tyre recycling is facing a number of challenges towards taking its place in the Circular Economy. This work on Pyrolysis is exploring these challenges with the aim of identifying solutions and opportunities for recyclers especially in terms of material and energy options.
A circular economy is restorative and regenerative by design, and aims to keep products, components, and materials at their highest utility and value at all times. The concept distinguishes between technical and biological cycles.
The concept of a circular economy and ELT’s

Recycled tyres become secondary raw materials that go into new products.

As a result, the tyre circular economy is open and ELTs become an enabler for several other industries (from agriculture to mining, from construction to the food industry).
Slow Rotary Kiln Pyrolysis

Rotary Pyrolysis Technology and products will be presented along with evaluating their characteristics.

This can be part of the discussion on meeting demands for sustainable materials including oil, pyrochar or other carbon materials among others, as well as metals and textiles in various formats.
Data collected at TRL 7 level for pyrolytic outputs from DEPOTEC an EU LIFE+ project will illustrate how this sector is promising as a means of generating high returns for those who manage to control the input and the output to obtain products with consistent standards within the environmental constraints set out in European and National environmental laws.
The 24th Annual Tyre Recycling Conference

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The project will be completed in 36 months (05/09/2011 - 31/12/2015)
• Several laboratory and bench scale (conventional or more innovative) tyre pyrolysis reactors are documented, while there are only few pilot/demonstration or industrial applications.

• Pilot units operated so far, are mainly based on batch rotary kiln reactors, aimed at producing both energy and carbon materials. The operation conditions reported, demand temperature ranging from 400°C to 600°C under atmospheric pressure.
1. Laboratory captive sample reactor (High Heating rates). It is mostly used for kinetic parameter determination.

2. Laboratory fixed bed reactor (Moderate Heating rates-High Final Temperatures). More detailed collection of the products is achieved, despite several limitations.

3. Rotary kiln reactor (quartz). It is an evolution of the above mentioned, since Heating Rate, Final Temperatures are variables. The collection of the gas, liquid and solid products in a proper form minimizes losses in balance material.
ACTIVATION EXPERIMENTS at lab

1. Laboratory fixed bed reactor (Moderate Heating rates - High Final Temperatures). Activation agent used is steam under high temperature and for a long residence time. Preliminary results showed burnoff level of over 60% creating activated carbon with $S_{BET}$ surface in the area of 500-600 m$^2$/gr.

2. Rotary kiln reactor (quartz). The aim of this project is to develop the process in the exact same pyrolysis reactor.

3. Furthermore, the use of the produced pyrolytic gas as activation agent is also promoted. Activation due to its characteristics (high temperatures and high residence time in a rotating quartz tube) created problems. Necessary alterations were made.
Pyrolysis at pilot scale
Design and development of an integrated system

Scale up from laboratory to pilot
DEPOTEC LIFE+ END OF PROJECT WORKSHOP

Depolymerisation Technology for Rubber with Energy Optimisation to Produce Carbon Products

EU Life Project Reference: LIFE10 ENVIE/000895

Wednesday 25th November 2015
The Anner Hotel, Thurles, Co. Tipperary, Ireland

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Characterisation of pilot scale pyrolysis products

### Operating Conditions

<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>Heating rate (°C min⁻¹)</th>
<th>Residence time (min)</th>
<th>Continous operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>550</td>
<td>20</td>
<td>12</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### Sampling of ELTs pyrolysis products

<table>
<thead>
<tr>
<th>Code Name</th>
<th>Pyrolysis Temperature (°C)</th>
<th>Liquid Yield</th>
<th>Solid Yield</th>
<th>Gas Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>550</td>
<td>L1</td>
<td>S1</td>
<td>G1</td>
</tr>
<tr>
<td>L2</td>
<td>550</td>
<td>L2</td>
<td>S2</td>
<td>G2</td>
</tr>
<tr>
<td>L3</td>
<td>550</td>
<td>L3</td>
<td>S3</td>
<td>G3</td>
</tr>
<tr>
<td>L4</td>
<td>550</td>
<td>L4</td>
<td>S4</td>
<td>G4</td>
</tr>
<tr>
<td>L5</td>
<td>550</td>
<td>L5</td>
<td>S5</td>
<td>G5</td>
</tr>
</tbody>
</table>

Gas fraction: $14.5 \pm 0.3$ wt%

Liquid fraction: $37.5 \pm 0.1$ wt%

Char fraction: $48.0 \pm 0.1$ wt%
Gas product composition

Evolution of gas composition and gas LHV over sampling time

<table>
<thead>
<tr>
<th>Sample</th>
<th>H₂ (v/v%)</th>
<th>CO (v/v%)</th>
<th>CO₂ (v/v%)</th>
<th>CH₄ (v/v%)</th>
<th>C₂H₄ (v/v%)</th>
<th>C₂H₆ (v/v%)</th>
<th>N₂ (v/v%)</th>
<th>O₂ (v/v%)</th>
<th>HHV (MJ Nm⁻³)</th>
<th>LHV (MJ Nm⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G5</td>
<td>12.12</td>
<td>0</td>
<td>12</td>
<td>26.27</td>
<td>0.42</td>
<td>0.58</td>
<td>21.98</td>
<td>2.44</td>
<td>12.67</td>
<td>25.64</td>
</tr>
</tbody>
</table>

**Pyrolysis gas composition**

**LHV** (MJ Nm⁻³)

**Combustible fuel**

Sample G5 Exhibits comparable composition to the gaseous product from lab scale pyrolysis

Scale up from laboratory to pilot
Liquid product composition

Elemental analysis

<table>
<thead>
<tr>
<th>Sample</th>
<th>TPO-L5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ultimate analysis wt. %</strong></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>86.04</td>
</tr>
<tr>
<td>H</td>
<td>12.47</td>
</tr>
<tr>
<td>N</td>
<td>n.d</td>
</tr>
<tr>
<td>S</td>
<td>0.54</td>
</tr>
<tr>
<td>H/C ratio</td>
<td>1.74</td>
</tr>
<tr>
<td><strong>Heating value</strong></td>
<td></td>
</tr>
<tr>
<td>GCV (KJ/Kg)</td>
<td>44.22</td>
</tr>
</tbody>
</table>

Rheological characteristics

<table>
<thead>
<tr>
<th>Sample</th>
<th>TPO-L5</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TPO density at 15°C (Kg L⁻¹)</strong></td>
<td>0.863</td>
<td>0.83</td>
</tr>
<tr>
<td><strong>Kinematic viscosity at 40°C (cSt)</strong></td>
<td>2.92</td>
<td>2.58</td>
</tr>
</tbody>
</table>

Scale up from laboratory to pilot
**TPO from pilot scale operation**

1. Has higher heating value
2. Better H/C ratio
3. Higher percentage of gasoline and diesel fractions
4. Lower density
5. Lower kinematic viscosity

*Compared to TPO from laboratory scale operation*

TPO includes alkanes, alkenes and valuable chemicals (limonene)

And can be considered as a heavier diesel fraction

**Combustible fuel**
Solid product composition

**ELTs char from pilot scale operation**
Exhibits comparable characteristics to **ELTs char from laboratory scale operation**

(i) Can substitute common fossil fuels to reduce the energy demand of the unit
(ii) Is comparable to low grade CBs
(iii) Can be used as precursor for AC production

**Porous characteristics of the obtained ELTs char**

<table>
<thead>
<tr>
<th>Sample</th>
<th>$N_2$ BET Surface Area ($m^2 \cdot g^{-1}$)</th>
<th>Pore volume (cc $g^{-1}$)</th>
<th>Pore diameter (nm)</th>
<th>ASTM classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>S5</td>
<td>50.82</td>
<td>0.39</td>
<td>303</td>
<td>N4xx</td>
</tr>
<tr>
<td>ELTs char (laboratory scale)</td>
<td>67.86</td>
<td>-</td>
<td>-</td>
<td>N4xx</td>
</tr>
</tbody>
</table>

1. High ash content

**Commercial product**

**Depollution applications**

Scale up from laboratory to pilot
ELTs-char based AC: Characteristics and proposed uses

The produced ELTs char based AC:
1. Has satisfactory $S_{BET}$ area.
2. Can be used in a wide range of applications.

AC from ELTs char from pilot scale operation
1. Steam activation: 3 % lower BET surface area and 8 % lower yield.
2. KOH activation: 4.5 % lower BET surface area and 7.5 % lower yield.

Compared to AC from ELTs char from laboratory scale operation:
- Has satisfactory $S_{BET}$ area.
- Can be used in a wide range of applications.

Commercial product

Liquid phase applications
- Dyes
- Heavy metals
- Water purification
- Removal of organics (including phenols and aniline derivatives)

Gas phase applications
- Flue gas decontamination
- Odour removal for sewage treatment operations
- Acid and corrosive gases (H$_2$S & SO$_2$) removal
- Formaldehyde capturing
Steel

• The steel element recovered from all tyres is of an extremely high quality and is, when clean, in demand by the steel industry as scrap feedstock for the production of new steel.

• The lower the level of contamination of the steel, the higher the value.
Energy balance of the process

Sankey diagram of the pilot scale pyrolysis process (steady-state) with energetic valorization of gaseous and liquid products.

1. Energy sustainable operation
2. Production of valuable products
3. Reduced CO$_2$ emissions

Target
Conclusions

DEPOTEC technology

- Can process up to 876 tonnes of ELTs annum⁻¹ (continuous operation).
- Sustainable operation.
- Energy surplus is expected.
- 420 tonnes of char are produced.
- Char has a low value if not treated.
- Steam activation can be performed in the same reactor.
- In a continuous operation, 118 tonnes of steam prepared AC can be produced with a high surface area and considerable selling price.
- The obtained product yields and product characteristics are of high reproducibility and high accuracy.

DEPOTEC technology

- Operated by 1-2 persons per shift
- Validated technology
- Ready for commercialization
Thank you for your attention