Viscoelastic Properties of Nanocomposites

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Why Viscoelastic Materials?

Energy dissipation capabilities, i.e., \textit{damping}, of viscoelastic materials are crucial in all those applications where structures are subjected to \textit{cyclic loading}.
Research Objectives

NATURAL RUBBER + NANOFILLERS

Carbon Black  Graphene

Dissipated Energy

Displacement

Force

Displacement

Force

New compounds with enhanced **damping** properties, **multifunctionality**

Research Group

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*XP Project: "Graphene/Elastomer Nanocomposites for Applications in Pneumatic Tyres "*
From February 2012
- Lecturer in Composites Engineering @ ACCIS
- Mechanical Characterization of Carbon Black-Filled Rubber

Viscoelastic Properties of Nanocomposites
**Results:** Model the hysteresis losses during finite deformations of the material

- **Characteristic frequency of the deformation due to rolling:** $10 - 100$ Hz
- **Low Tan $\delta$ at the characteristic frequency**
  - **Decrease Rolling Resistance**

- **Characteristic frequency of the deformation due to road roughness:** $10^4 - 10^6$ Hz
- **High Tan $\delta$ at the characteristic frequency**
  - **Increase Wet Grip**

**Remark:** Need of a constitutive equation able to describe the large strain behaviour for selecting the optimal material/structural configuration
Large strain viscoelasticity

Some shortcomings were highlighted and a new viscoelastic formulation was proposed. After this work, the ABAQUS model was changed (from Abaqus 6.9).

Polymer Nanocomposites

Carbon Black (CB)

- Easy to process
- Inexpensive
- Good thermal properties
- Good electrical properties

Graphene / Graphene Oxide (GO)

- High mechanical strength
- Large interfacial area could lead to increased dissipation properties
- Graphene membrane only one atom thick is impermeable to standard gases
- Excellent electrical properties also at very low volume fraction
- Functional groups similar to elastomeric polymer can be grafted on the graphene surface
Preliminary Experimental Results

Dynamic Tests

<table>
<thead>
<tr>
<th>Material</th>
<th>G'@5Hz</th>
<th>Perc. Var.</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR</td>
<td>800 kPa</td>
<td>-</td>
</tr>
<tr>
<td>NR+GO (0.25phr)</td>
<td>956 kPa</td>
<td>+19.5%</td>
</tr>
<tr>
<td>NR+GO (0.50phr)</td>
<td>1082 kPa</td>
<td>+35.2%</td>
</tr>
</tbody>
</table>

Increased stiffness
Better Dry Handling
Preliminary Experimental Results

Fatigue Tests

<table>
<thead>
<tr>
<th>Material</th>
<th>$\varepsilon_{\text{min}}$ @ 50th cycle</th>
<th>$\varepsilon_{\text{max}}$ @ 50th cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR</td>
<td>0.56</td>
<td>0.80</td>
</tr>
<tr>
<td>NR+GO (0.25 phr)</td>
<td>0.25</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Huge increase in Fatigue Resistance

NR
NR+GO (0.25 phr)

August 2012

Viscoelastic Properties of Nanocomposites
Conclusions

- A natural rubber compound reinforced with GO has been produced
- Preliminary results on fatigue tests show a massive increase in fatigue resistance
- The introduction of GO increases both storage and loss moduli

Further Developments

- Larger GO content
- DMA tests at higher frequencies
- Measure the conductivity of the GO filled rubber during deformation
- Rubber vulcanisation (addition of sulphur based curatives)

Acknowledgements

ACCIS Doctoral Training Centre for supporting the Extended Project: “Graphene/Elastomer Nanocomposites for Applications in Pneumatic Tyres”