CHAPTER V

TECHNOLOGICAL PROPERTIES OF ALUMINIUM POWDER-FILLED VULCANISATES
Fillers are considered as an unavoidable ingredient in most of the rubber compounds. They are added in rubber compounds either to reduce the cost or to enhance the vulcanisate properties. Properties imparted to the rubber vulcanisates by fillers depend on the type of filler and the quantity added. While reinforcing fillers enhance the strength properties, they reduce processability of compounds and adversely affect heat build up and set in compression or tension. With increase in quantity of any filler in rubber compounds, properties such as modulus, hardness, set and heat build up proportionately increase whereas, resilience and elongation at break decrease [1]. Properties such as tensile strength, tear strength and abrasion resistance pass through a maximum with increase in filler content [2]. The quantity of filler required to impart the maximum property to the vulcanisate varies with type of filler; the reinforcing ones attain the maximum property with lower quantity [3]. The vulcanisate properties also depend on extent of crosslinking and types of crosslinks formed during vulcanisation [4,5]. In this chapter of the thesis the effects of aluminium powder on properties of NR vulcanisates are presented in comparison
with those of HAF and acetylene black-filled vulcanisates. Since the same base formulation (I) was used for making all the compounds (except type of filler), it is expected that the observed difference in properties of the vulcanisates is basically due to the effect of fillers. The vulcanisate properties of the compounds under study are given in Table V.1.

V.1 Tensile Strength, Modulus and Elongation at Break

Even though rubber products are seldom elongated to their breaking point during service, tensile strength of rubber vulcanisates is considered to be a quality parameter since any reduction in quality will be reflected in tensile strength also. Tensile strength of aluminium powder-filled vulcanisates was higher than that of the gum vulcanisate (Table V.1) upto 15 volume per cent loading, indicating a semi reinforcing character of this filler. However, at 20 volume loading (53.8 phr), the strength decreased. This could be due to a dilution effect beyond 50 phr, as the polymer content is reduced[6]. At equal volume loadings, HAF and acetylene black imparted higher tensile strength than aluminium powder due to lower particle size of HAF and acetylene blacks compared with aluminium powder. Modulus 300% of aluminium powder-filled vulcanisates increased with increase in quantity of filler. However, as in the case of tensile strength, at
equal volume loadings, the increase in modulus was lower compared with that for HAF and acetylene black-filled vulcanisates, which further indicates its low reinforcing character compared with HAF and acetylene blacks. Elongation at break decreased with increase in quantity of filler and the decrease was less for the aluminium powder-filled vulcanisates compared with the HAF and acetylene black-filled ones.

V.2 Tear Strength

Tear strength indicates the capacity of the vulcanisate to resist cutting, chipping and tearing actions during service. More reinforcing fillers impart high tear strength to the vulcanisate. Even though tear strength increased with increase in quantity of aluminium powder in the vulcanisate, the extent of increase was much lower compared with HAF and acetylene black-filled vulcanisates. This again indicates that the reinforcing activity of aluminium powder is lower compared with that of HAF and acetylene black.

V.3 Hardness

The hardness of the vulcanisates increased with increase in quantity of filler added in the case of all the three fillers. However, the extent of increase in
hardness was not uniform with filler content. At lower loadings of 5-10 volume per cent, aluminium powder and acetylene black-filled vulcanisates gave higher hardness than HAF black-filled vulcanisates. But at higher loadings of 20 volume per cent, HAF and acetylene black-filled vulcanisates gave much higher hardness values than the aluminium powder-filled one. This observation could be explained as follows.

At all levels of filler loading, the vulcanisates containing aluminium powder have higher $V_r$ values than those containing HAF and acetylene black (Table V.1). But aluminium powder is not having much reinforcing action. Thus at lower loadings, the contribution towards increase in hardness is mainly from higher extents of crosslinking. As the quantity of filler is increased, the contribution due to reinforcement increases and at loading of 15-20 volume per cent of filler, the vulcanisates containing the more reinforcing HAF and acetylene blacks showed higher hardness. This explanation is further supported by the nature of change in rebound resilience, compression set and abrasion resistance of these vulcanisates also.

V.4 Rebound Resilience

Normally with any filler, as the quantity of filler in the vulcanisate is increased, the rebound resilience
decreases. This trend is observed in the case of HAF and acetylene black-filled vulcanisates. However, in the case of aluminium powder-filled samples, increase in resilience was noticed at lower loadings. As pointed out earlier, this could be due to higher extent of crosslinking achieved by the vulcanisates containing aluminium powder.

V.5 Compression Set

Compression set results from rearrangement of network structure, degradation of polymer chains, debonding of polymer-filler attachments, etc. It is dependent on type of polymer, nature of crosslinks, type of filler and its quantity [7,8]. In the case of HAF and acetylene black-filled vulcanisates, compression set increased with increase in filler content and the latter showed higher values of set due to high structure of acetylene black used. In the case of aluminium powder-filled vulcanisates, compression set decreased upto 15 volume per cent loading. This is expected to be due to higher extent of crosslinking as indicated by higher $V_r$ values of the vulcanisates. At loadings of 20 volume per cent (53.8 phr) as the quantity exceeded 50 phr, the set value increased. However, it was still less than that of the gum compound. This could be due to more uniform network structure of the 12.5 mm thick test samples at the surface and centre, achieved through improved thermal conductivity
of the aluminium powder-filled vulcanisates as explained in Chapter VI.

V.6 DIN Abrasion Loss

Even though there is no direct correlation between laboratory abrasion and field performance where abrasive loss is involved, laboratory results give an indication of the performance of the compounds under identical conditions. In the case of reinforcing blacks like HAF, the abrasion loss decreased with increase in filler quantity. Acetylene black-filled samples also showed the same trend. However, the DIN abrasion loss values of aluminium powder-filled vulcanisates were substantially lower than that of the above two cases, up to 15 volume per cent loading. The abrasion loss of the 20 volume per cent loaded sample was almost double that of the sample containing 15 volume per cent. Since the reinforcement activity of aluminium powder was lower as indicated by the strength properties of aluminium powder-filled vulcanisates, the reason for the improved resistance to abrasion could be the higher extent of crosslinking (higher $V_r$ values) of the samples containing aluminium powder. The increase in abrasion loss beyond 15 volume per cent loading is due to decrease in total polymer content of that sample.
Table V.1 Physical properties of aluminium, high abrasion furnace black and acetylene black-filled vulcanisates

<table>
<thead>
<tr>
<th>Properties</th>
<th>Gum</th>
<th>AL05</th>
<th>AL10</th>
<th>AL15</th>
<th>AL20</th>
<th>HF05</th>
<th>HF10</th>
<th>HF15</th>
<th>HF20</th>
<th>AC05</th>
<th>AC10</th>
<th>AC15</th>
<th>AC20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimum cure time at 150°C (minutes)</td>
<td>18.0</td>
<td>14.0</td>
<td>13.5</td>
<td>13.0</td>
<td>14.0</td>
<td>16.0</td>
<td>15.0</td>
<td>14.0</td>
<td>13.5</td>
<td>15.5</td>
<td>16.5</td>
<td>16.5</td>
<td>16.0</td>
</tr>
<tr>
<td>Scorch time at 150°C (minutes)</td>
<td>11.0</td>
<td>7.25</td>
<td>7.25</td>
<td>6.5</td>
<td>7.0</td>
<td>9.0</td>
<td>7.50</td>
<td>7.0</td>
<td>6.5</td>
<td>8.25</td>
<td>9.0</td>
<td>9.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Modulus 300% (MPa)</td>
<td>2.3</td>
<td>3.1</td>
<td>3.9</td>
<td>5.0</td>
<td>5.6</td>
<td>4.3</td>
<td>6.2</td>
<td>8.7</td>
<td>14.4</td>
<td>4.6</td>
<td>7.1</td>
<td>9.8</td>
<td>14.4</td>
</tr>
<tr>
<td>Elongation at break (%)</td>
<td>678</td>
<td>668</td>
<td>633</td>
<td>593</td>
<td>548</td>
<td>628</td>
<td>613</td>
<td>590</td>
<td>520</td>
<td>617</td>
<td>570</td>
<td>562</td>
<td>534</td>
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<td>Tensile strength (MPa)</td>
<td>20.7</td>
<td>22.4</td>
<td>22.5</td>
<td>21.2</td>
<td>18.2</td>
<td>24.5</td>
<td>26.7</td>
<td>29.2</td>
<td>30.8</td>
<td>24.8</td>
<td>25.5</td>
<td>26.4</td>
<td>27.5</td>
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<tr>
<td>Tear strength (N/mm)</td>
<td>31.8</td>
<td>34.1</td>
<td>35.8</td>
<td>39.2</td>
<td>41.6</td>
<td>45.0</td>
<td>52.5</td>
<td>75.0</td>
<td>101.0</td>
<td>43.3</td>
<td>48.0</td>
<td>52.3</td>
<td>60.4</td>
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<td>Hardness (Shore A)</td>
<td>37</td>
<td>44</td>
<td>47</td>
<td>50</td>
<td>55</td>
<td>40</td>
<td>45</td>
<td>52</td>
<td>57</td>
<td>44</td>
<td>46</td>
<td>50</td>
<td>58</td>
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<td>Rebound resilience (%)</td>
<td>78.3</td>
<td>83.4</td>
<td>80.6</td>
<td>76.1</td>
<td>72.4</td>
<td>74.6</td>
<td>71.3</td>
<td>65.9</td>
<td>57.4</td>
<td>71.3</td>
<td>68.0</td>
<td>62.4</td>
<td>57.4</td>
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<tr>
<td>Compression set (%)</td>
<td>37.7</td>
<td>30.4</td>
<td>29.1</td>
<td>25.1</td>
<td>34.6</td>
<td>40.0</td>
<td>41.7</td>
<td>44.4</td>
<td>48.9</td>
<td>42.0</td>
<td>46.3</td>
<td>49.4</td>
<td>53.0</td>
</tr>
<tr>
<td>22 h, 70°C</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abrasion loss (mm³)</td>
<td>112.0</td>
<td>95.0</td>
<td>77</td>
<td>53</td>
<td>100</td>
<td>103.2</td>
<td>94.1</td>
<td>85.3</td>
<td>66.1</td>
<td>115.4</td>
<td>108.6</td>
<td>89.1</td>
<td>69.3</td>
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<tr>
<td>V at optimum cure time at 150°C</td>
<td>0.149</td>
<td>0.189</td>
<td>0.197</td>
<td>0.201</td>
<td>0.221</td>
<td>0.157</td>
<td>0.163</td>
<td>0.168</td>
<td>0.170</td>
<td>0.153</td>
<td>0.165</td>
<td>0.170</td>
<td>0.173</td>
</tr>
</tbody>
</table>
V.7 Conclusions

Evaluation of the technological properties of the vulcanisates containing aluminium powder, HAF and acetylene blacks leads to the following conclusions.

1. The reinforcing activity of aluminium powder is lower than that of HAF and acetylene blacks.

2. The strength properties of NR vulcanisates are not adversely affected by adding aluminium powder up to 15 volume per cent.

3. Aluminium powder-filled vulcanisates have higher resilience, lower set and better abrasion resistance (up to 15 volume per cent loading) than HAF and acetylene black-filled samples.
References


