EFFECT OF MECHANICAL FACTORS ON RUBBER WEAR IN AGGRESSIVE MEDIA

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The effect of mechanical factors on rubber wear in aggressive slurries has been investigated. As the mechanical action becomes more intense, the effect of the aggressive medium increases. Rubber wear in an abrasive flow is a two-stage process; the aggressive medium modifies the surface layer, which is then worn away by the abrasive.

Apart from the aggressivity of the medium and temperature [1], wear in an abrasive flow is strongly affected by such basic mechanical factors as the solid-phase concentration of the slurry, the velocity of the slurry solids relative to the rubber, the granulometric composition of the abrasive, and the initial stretch of the rubber.

The effect of certain mechanical factors on rubber wear has been investigated only in relation to sand-water slurries on apparatus of the impacting-jet type [2] and, to some extent, on apparatus with rotating specimens [3]. It has been found that rubber wear increases with increase in impact velocity [2] and particle size [2, 3]. The data on the effect of the solids concentration of the slurry reported in these two studies are not comparable. There are no data on the effect of mechanical factors on rubber wear in aggressive slurries.

For purposes of investigation we used slurries composed of 1KO315 molding sand with a mean particle size 0.315 mm and synthetic white corundum No. 6, 16, 20, 32, 40 and 80 with mean particle size 0.06, 0.16, 0.20, 0.32, 0.40, and 0.60 mm in water, 30% nitric and 30% acetic acid. The following rubbers were selected: chemical-resistant butyl rubber (B), neoprene rubbers extended with carbon black (N1) and carbon white (N2) commercial butadiene-styrene rubbers with furnace black (N3) and with carbon with (N4), as well as unfilled natural rubber vulcanizate (NR).

The rubbers were investigated by the method previously described in [4], that is, specimens in the form of short tubes were fitted over a spindle rotating at high speed in a vessel containing the aggressive slurry, in which the abrasive was uniformly distributed. The rate of wear \( v_{13} \) under steady-state conditions

\[
\frac{i_{13}}{v_{13}} = \frac{\text{weight change}}{\text{time} \times \text{min}}
\]

where \( i_{13} \) is the wear (loss of weight relative to the original weight of the specimen) in time \( t \) with allowance for swelling of the rubber in the aggressive medium. The reproducibility of the results was determined on 18, 6, and 3 specimens. The coefficients of variation for 18, 6, and 3 specimens were ±9.1, ±11.8 and ±13.0%, respectively. Accordingly, in subsequent experiments we generally tested three specimens or, in the presence of a nonmonotonic dependence of the wear on various factors, six. The experiments were conducted in a thermostated apparatus at 20° C.

The prestretched rubbers were tested at the same end thickness. The deformation was calculated from the outside diameter.

The effect of the concentration of sand in the slurry is shown in Fig. 1. The wear rate increases up to a solids concentration of approximately 30-35% by volume and then remains constant both in water and in nitric acid. Calculations show that at any monodisperse particle sizes a solids concentration of about 30% by volume corresponds to a distance between particles equal to their size.

![Fig. 1. Effect of sand concentration (particle size 0.315 mm) on the wear of rubbers in water (1, 2, 3) and 30% HNO₃ (1a, 2a, 3a) at 20° C; n = 8900 rpm (1a), n = 9700 rpm (1b), n = 8100 rpm (1c); 1, 1a, 1b, 1c B; 2, 2a) Sb; 3, 3a) Sw. C_{SOL}-solids concentration, % by volume.](image)
aggressive medium than for water. A similar dependence (increase in wear rate only up to a concentration of 30-35%) is observed when corundum No. 20 is used as the abrasive, and also at different speeds (9700, 8100, and 8900 rpm).

It is clear from Fig. 2, which shows the effect of the speed of the specimens on wear in a sand slurry, that on the narrow range investigated (7000–10 000 rpm) the dependence of the rate of wear of various rubbers on the spindle speed is closely approximated by a straight line. This holds true both for the same wear time (1, 1a, 2a, and 3, 3a) and for the same path traversed by the specimens (1b and 3b), both in water and in nitric acid. However, if we start from the fact that the impact velocity of the abrasive is proportional to the speed of the specimen, since the abrasive is specifically retarded and its velocity can be neglected, the $v_S = f(v_C)$ curves should pass through the coordinate origin (since at $v_C = 0$ m/sec, $v_{1S} = 0$), and in more general form the dependence of the rubber wear on spindle speed is nearly quadratic in accordance with the fact that the kinetic energy possessed by two bodies on impact is related with their velocity according to a quadratic law. The most rapid increase in wear rate is observed in the presence of an aggressive medium in the slurry and also in the case of least wear-resistant rubbers. A similar relationship between rubber wear and the speed of the specimen is also observed in a corundum No. 20 slurry. In studying the effect of particle size on rubber wear it should be taken into account that the mass of the particle $m$, which determines the amount of energy released when a single particle of abrasive strikes the surface of the rubber, increases as the cube of the linear dimensions. However, the total mass of the particles $M = mm$ (where $n$ is the number of particles) striking the specimen does not depend (at a constant solids concentration) on their dimensions.

Accordingly, one would expect the ratio $A = v_{1S}/M$ not to depend on the size of the abrasive particles. However, as maybe seen from Table 1, the values of

### Table 1

<table>
<thead>
<tr>
<th>Rubber</th>
<th>Nb</th>
<th>NW</th>
<th>Sb</th>
<th>Sw</th>
<th>Nb</th>
<th>NW</th>
<th>Sb</th>
<th>Sw</th>
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<tbody>
<tr>
<td>$\nu_{1S}/M$ as a Function of Abrasive Particle Size</td>
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<tr>
<td>Synthetic Corundum</td>
<td>$\nu_{1S}/M$</td>
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<tr>
<td>Nb</td>
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<tr>
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<tr>
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<td>430</td>
<td>485</td>
<td>560</td>
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<tr>
<td>Sw</td>
<td>180</td>
<td>240</td>
<td>340</td>
<td>390</td>
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Fig. 3. Effect of abrasive particle size $\delta$ on the wear of rubbers in water (1, 2), 20% acetic acid (1a, 2a), and 30% nitric acid (1b, 2b) at 20°C, solids concentration 35% by volume and $n = 8900$ rpm. 1, 1a, 1b) $S_w$; 2, 2a, 2b) $S_b$. 

Fig. 4. Effect of abrasive particle size $\delta$ on the wear of rubbers in water (1, 2), 20% acetic acid (1a, 2a), and 30% nitric acid (1b, 2b) at 20°C, solids concentration 35% by volume and $n = 8900$ rpm. 1, 1a, 1b) $S_w$; 2, 2a, 2b) $S_b$. 

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