The development of special quenching oils possessing increased cooling capacity, thermal oxidation stability, bright hardening, and other properties has promoted the development and introduction into production of modern methods of heat treatment and has made it possible to provide the growing requirements of various branches of machine building with high quality production.

LITERATURE CITED


POSSIBLE MEANS OF REDUCING THE FILM PERIOD OF BOILING IN HARDENING IN PETROLEUM OILS


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The effectiveness of modern quenching oils depends primarily upon their cooling capacity and is related to the process of boiling on the surface of the hot metal. There are three basic periods in quenching, film boiling, bubble boiling, and convective heat exchange, which are characterized by different methods of heat transfer and, accordingly, intensities of cooling. Consequently the rules in the change in cooling properties of quenching oils must be explained individually in investigation of each period.

The literature does not contain up-to-date concepts of the reasons for the change in cooling capacity of mineral oils with a change in their component composition. This creates definite difficulties in the development of fast-cooling quenchants.

In this article the possibility is shown for reducing the length of the ineffective film period of boiling, which retards heat flow from the surface of the metal in the area of high temperatures.

In immersion of a heated metal part (to approximately 800°C) in a liquid a portion of the latter changes to vapor and then some quantity condenses with the relatively cold oil. However, as the result of the high temperature differential in the initial period of cooling (\(\Delta T = T_{\text{hot surf.}} - T_{\text{boil.liq}}\)) the rate of evaporation prevails over the rate of condensation, creating the area of film boiling.

It is known that the pressure created by the vapors of the liquid with the film \(p_f\) is in dynamic equilibrium with the atmospheric pressure \(p_{\text{at}}\), the pressure created by the column of liquid \(p_{\text{col.1}}\), and the pressure created by surface tension \(p_{\text{s.t}}\) [1]:

\[
p_f = p_{\text{at}} + p_{\text{col.1}} + p_{\text{s.t}}.
\]

Since the heat flow through the vapor film is insignificant, in this zone superheating and an increase in pressure above the equilibrium are observed. This leads to rupture of the continuous oil shell and transition to the second period of quenching, bubble boiling. Consequently, the earlier a pressure exceeding the equilibrium is created in the film, the shorter this period.

According to Dalton's Law, the pressure of the gas is equal to the sum of the partial pressures of its constituents \(p_f\)

\[
p = \sum p_i.
\]

### TABLE 1

<table>
<thead>
<tr>
<th>Index</th>
<th>300...350°C</th>
<th>350...400°C</th>
<th>400...450°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>paraffin</td>
<td>naphthenic</td>
<td>aromatic</td>
</tr>
<tr>
<td>Density ($p_0^0$)~kg/m³</td>
<td>792</td>
<td>856</td>
<td>876</td>
</tr>
<tr>
<td>Kinematic viscosity at 50°C·10⁻⁶, m²/sec</td>
<td>4.0</td>
<td>6.74</td>
<td>6.64</td>
</tr>
<tr>
<td>Fractional comp., %</td>
<td>302</td>
<td>324</td>
<td>290</td>
</tr>
<tr>
<td>Start of boiling</td>
<td>312</td>
<td>341</td>
<td>307</td>
</tr>
<tr>
<td>10% boiled off</td>
<td>336</td>
<td>361</td>
<td>337</td>
</tr>
<tr>
<td>50%</td>
<td>359</td>
<td>372</td>
<td>363</td>
</tr>
<tr>
<td>90%</td>
<td>337</td>
<td>357</td>
<td>352</td>
</tr>
<tr>
<td>Avg. boiling point, °C</td>
<td>337</td>
<td>357</td>
<td>352</td>
</tr>
</tbody>
</table>

Fig. 1. Cooling curves of narrow fractions of different oils: 1-3) fractions with boiling points of 300-350°C; 4-6) 350-400°C; 7, 8) 400-450°C; 1, 4, 7) aromatic oils; 2, 5, 8) naphthenic; 3, 6) paraffin.

Fig. 2. Cooling curves of oils with the optimum quantity of additives: 1) original oil; 2) with calcium naphthenate; 3) with NS-480; 4) with PMS-A; 5) with alkenyl succinimide.

that is, the greater the quantity of gaseous products in the vapor phase and the higher their partial pressure, the greater the pressure created by them in a unit of volume.

It must be taken into consideration that in mineral oils under the action of high temperatures not only evaporation occurs but also a breakdown of the hydrocarbon molecules. With an increase in boiling points of oils their volatility decreases and the capacity for breakdown increases. Depending upon its structure and the temperature of action the breakdown of a hydrocarbon molecule leads to the formation of two or more molecules of gaseous products.

On the basis of this it may be concluded that under otherwise similar conditions the length of maintenance of the film period of boiling must be shorter in those oils which are less thermally stable. The control index of the length of film boiling of the base mineral oils may be their fractional composition (mean boiling point) and with the addition of various additives the additional thermal stability of the products introduced.

Taking into consideration the proposals of the model, the cooling properties of both the base oils and of oils containing various additives were investigated.

The cooling capacity of the oils was determined from the cooling curves of a silver sphere from 800 to 300°C.

As the base mineral oils narrow fractions of oils with boiling points of 300-350, 350-400, 400-450, and 450-500°C and mixtures of them separated from a single petroleum were used. The characteristics of the oils and the cooling curves are given in [2]. It was established that the temperature of the transition from film to bubble boiling ($T_{f-bub.}$), which indirectly characterizes the length of film boiling, is in direct relationship to the average boiling point of the oil.