Research on materials science at the nano level lies at the boundaries of scientific disciplines and often involves branches of nanotechnology such as solid-state physics and electronics. Nanotechnology permits the creation of large structures with different molecular organization. Nanostructures (in the range 1–100 nm) have properties significantly different from those of isolated molecules and particles larger than 100 nm. Nanomaterials consist of an artificially or naturally ordered system of basic elements in the nano range, ensuring new mechanical, chemical, electrophysical, and other properties. In other words, the structural ordering of nanoparticles gives rise to new properties, such as quantum–dimensional, synergetic–cooperative, and other effects. This permits the manufacture of new materials. Nanostructured materials are based both on atoms and on molecules of organic materials—for example, nucleic acids.

In nanotechnology, two approaches to machining are possible: the top-down and bottom-up approaches. In the top-down approach, the minimum size of the element is limited by the wavelength of a laser beam. The laser beam with the smallest wavelength permits micromachining of the material to within 100 nm. This technology is complex and very expensive; therefore, it is poorly suited to mass production.

Study of the adhesion of liquid flowing around a solid surface may significantly change the principles of calculation and action of systems used in nanotechnology.

The further development of nanotechnology requires fundamental research into the adhesive interaction of materials at the atomic–molecular level. Detailed investigation of the physics of adhesion of a liquid flowing around a solid surface may permit a breakthrough in nanotechnology. Despite detailed study of the adhesion between molecules in a motionless liquid boundary layer and laminar flow, it remains unclear how a set of molecular boundary layers characterized by shear strength is formed in the case of capillary obliteration and the filtrational effect in porous bodies. Researchers are only beginning to understand this phenomenon. The unusual laminar liquid flow observed, with a Reynolds number of 6.3, cannot be explained by the existing theory of liquid behavior close to a solid surface [1].

Experimental data on the influence of the capillary diameter and length and the applied pressure on its obliteration (obtained by Vovk, Bashta, Kichin, Pogodaev, and others [2, 3]) indicate that, in obliteration, transformer oil may close a capillary of diameter 200 µm and partially close a 300-µm capillary. In 400-µm capillaries, obliteration is not observed. Water may close a capillary of diameter around 200 µm [3, 5, 6]. Liquid layers capable of immobility, despite the wetting force of the flux, are formed here. Thus, in capillary obliteration, polymolecular liquid layers characterized by shear strength are formed.

Therefore, we may conclude that motionless liquid boundary layers of thickness around 100 µm are formed when liquid flows around a solid surface, under the action of adhesive forces. Suppose that the thickness of the layers is equal to the size of the water molecule. Then more than 3.3 million motionless boundary layers are formed in capillary obliteration by water; this is significantly different from Newton’s hypothesis regarding a single motionless liquid layer at a solid surface. It is evident that, after the formation of the first liquid monolayer, subsequent adhesion occurs between molecules of the liquid monolayer and molecules of the flowing liquid. Thus, we need to determine the cohesive force between the laminar-flow particles and the motionless liquid layer in the case of capillary obliteration. A method of determining the cohesive force between the molecules in laminar flow and the molecules in the motionless liquid boundary layer was considered in [6]; the binding energy of a water molecule in the potential-energy well of molecules bound by attractive Van der Waals forces in the motionless liquid boundary layer was determined. The calculations in [1] show that the transition from internal-friction microprocesses to the macroprocess of capillary obliteration takes around 1 h.

Despite the copious experimental data, a mathematical formulation of the problem does not yet exist. Given the microscopic range of adhesion between the
molecules in the laminar flow and the surface of the motionless boundary layer, the complexity of capillary obliteration and filtration in porous bodies is such that no satisfactory calculation scheme has been proposed. The investigation is complicated by the microscopic scale of the change in thickness of the motionless boundary layer and by the absence of a method capable of detecting this change. In addition, the thickness of the motionless boundary layer cannot be determined, because its molecules are indistinguishable from those of the laminar flow.

Taking account of the time for the internal-friction microprocesses to be converted to the macroprocess of capillary obliteration, the problem may be formulated as follows: to determine the change in thickness of the motionless liquid boundary layer in the case of capillary obliteration.

### THICKENING OF THE MOTIONLESS BOUNDARY LAYER

In the case of a special type of laminar flow (Re = 6.3), the closure of the capillary cross section depends on the time, as shown in the figure. Suppose that the capillary cross section is \( \pi r_n^2 \) before obliteration and \( \pi r_n^2 \) after obliteration. Then the function determining the decrease in the capillary cross section in the case of special laminar flow takes the form [1]

\[
S_{nl}(t) = \frac{\pi r_L^2}{\pi r_n^2}.
\]

In obliteration, the capillary radius \( r_n \) declines over time to the size of the adhesive molecules (\( \Delta r \)). This process may be written in the form

\[
S_{nl}(t) = \frac{r_L^2}{r_n^2} = (r_n - \Delta r)^2/r_n^2 = (1 + \Delta r^2/r_n^2) - 2\Delta r/r_n, \tag{1}
\]

where \( (1 + \Delta r^2/r_n^2) \) reflects the processes before the formation of the initial motionless liquid boundary layer; \( 2\Delta r/r_n \) is a constant characterizing the relative decrease in capillary radius (on account of adhesion of molecules of the laminar liquid flow to the capillary wall) within 1 h. The term \( \Delta r^2/r_n^2 \) is very small and may be neglected.

Hence, Eq. (1) may be written in the form

\[
S_{nl}(t) = 1 - 2\Delta r/r_n. \tag{2}
\]

We now find the change in cross section over time in the case of capillary obliteration \( \int_0^t (2\Delta r/r_n)dt = (2\Delta r/r_n)t_\xi \), where \( t_\xi \) is the total time of capillary obliteration.

If the change in cross section corresponding to increase by \( 2\Delta r/r_n \) in 1 h is \( \xi \), we find that

\[
S_{nl} = 1 - \xi t_\xi, \tag{3}
\]

where \( S_{nl} = 1 \) corresponds to laminar liquid flow in a tube with no increase in thickness of the motionless

![Graph](image-url)

**Table 1. Variation in the Thickness \( \xi \) of the Motionless Boundary Layer in 1 h, for Various Materials**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Temperature, °C</th>
<th>Pyrex glass</th>
<th>Molybdenum glass</th>
<th>Corrosion-resistant steel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>distillate</td>
<td>bidistillate</td>
<td>distillate</td>
</tr>
<tr>
<td>1 16</td>
<td>0.003</td>
<td>0.0037</td>
<td>0.0127</td>
<td>0.0104</td>
</tr>
<tr>
<td>2 0.0028</td>
<td>0.0039</td>
<td></td>
<td>0.0132</td>
<td>0.0100</td>
</tr>
<tr>
<td>3 0.0029</td>
<td>0.0035</td>
<td>–</td>
<td>0.0132</td>
<td>0.0100</td>
</tr>
<tr>
<td>4 0.0026</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.0098</td>
</tr>
<tr>
<td>1 30</td>
<td>0.0026</td>
<td>0.0039</td>
<td>0.013</td>
<td>0.0110</td>
</tr>
<tr>
<td>2 0.0030</td>
<td>0.0048</td>
<td>–</td>
<td>0.0109</td>
<td>0.0204</td>
</tr>
<tr>
<td>3 0.0034</td>
<td>0.0050</td>
<td>–</td>
<td>0.0116</td>
<td>0.0210</td>
</tr>
<tr>
<td>4 –</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.0100</td>
</tr>
<tr>
<td>5 –</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.0106</td>
</tr>
<tr>
<td>6 –</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.0144</td>
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