AIR PERMEABILITY OF FABRICS

E.V. Kondratski

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Air flows through cloth by way of the interfilamentary and intra-
filamentary pores; but, if the cloths are made of threads of sufficient
twist or out of monofils, the distribution of the air will be conditioned
by the passage of air through the interfilamentary pores (the meshes).

According to the existing testing method the air-permeability of cloth
is determined by a fall of pressure of 5 mm of water stream and with falls
in pressure for monofil cloths the states of flow will be turbulent. We
will consider the process of the airflow through the meshes to be adiabatic
and constant. We will also suppose that the air leaves the mesh in a free
turbulent stream and that all the measurements characterizing the process
are conditioned by the mesh cross-section. Then from the equation for the
adiabatics and the equation for the conservation of energy it follows that
the full volume of air \( V \), flowing through a specimen of a unit of area for
a unit of time when the given fall in pressure is \( \Delta p \) will be

\[
V = \mu f \sqrt{2 \frac{\gamma}{\gamma - 1} \frac{p_0}{\rho_0} \left[ 1 - \left( \frac{p_1}{p_0} \right)^{\frac{\gamma - 1}{\gamma}} \right]}
\]

when

- \( f \) - summary area of all the meshes in one unit of area of
  the given specimen;
- \( \gamma = \frac{C_P}{C_V} \) - adiabatic index;
- \( p_0, \rho_0 \) - correspondingly absolute pressure and density of the
  air before the cloth;
- \( p_1 \) - absolute air pressure behind the cloth;
- \( \mu \) - air coefficient, calculating the losses in mechanical
  energy when the air passes and, with friction, passes
  through the mesh and also when the stream is compressed (2).
When there are small drops in pressure and the effect of the change in the air density is small ($\gamma = 1.4; 0.53 < \frac{P_1}{P_0} < 1$) one can assume an approximation:

$$\frac{\gamma}{\gamma - 1} \left[ 1 - \left( \frac{P_1}{P_0} \right)^{\frac{\gamma - 1}{\gamma}} \right] = 1 - \frac{P_1}{P_0}.$$ 

In this case the calculation can be worked out by the approximate formula

$$V = \mu f \sqrt{\frac{2}{\rho_0}} \Delta p.$$  \hspace{1cm} (2)

where $\Delta p = P_0 - P_1$ - the fall in pressure on the material/cloth.

The theory of similarity and regularity allows a system of physical parameters to be determined on which the coefficient of the distribution $\mu$ depends, and it can be expressed by

$$\mu = \mu \left( \frac{l}{h}; \frac{b}{h}; Re; M \right),$$  \hspace{1cm} (3)

when $\frac{l}{h}, \frac{b}{h}$ - the criteria determining the geometrical similarity of the meshes;

$b$ and $h$ - correspondingly the breadth and height of the mesh ($b > h$);

$l$ - thickness of the cloth;

$Re = \frac{\rho_0 u d_2}{\eta_0}$ - Reynolds criterion characterizing the order of the relation of the forces of inertia to the forces of viscosity;

$d_2 = \frac{2bh}{b + h}$ - hydraulic diameter;

$\eta_0$ - coefficient of the dynamic viscosity of air;

$u$ - mean speed of the flow, determined by the longitudinal gradient of pressure;

$M = \frac{u}{\sqrt{\gamma RT}}$ - Max. criterion determining the phenomena linked with the air's compressibility;
\[ R = gR \] - gas constant;

\[ g \] - acceleration of free fall;

\[ R \] - gas constant (for air \( R = 29.27 \text{ m/deg} \));

\[ T \] - absolute temperature in the flow.

At an airflow speed of less than 100 metres per second the air can practically be considered non-compressible\(^{(3,4)}\) and the dimension \( \mu \) can be determined by the formula

\[ \mu = \mu \left( \frac{L}{h}, \frac{b}{h}, \text{Re} \right). \] \( (4) \)

It should be noted that with cloths prepared from yarn the form of the meshes are far from right-angles and the geometrical similarity of such meshes must be determined by the one criterion \( \frac{4f_1}{\pi} \),

when \( d_2 = \frac{4f_1}{\pi} \) - hydraulic diameter;

\[ f_1 \] - the area of the cross-section of the mesh;

\[ \pi \] - the perimeter of the cross-section of the mesh.

Fleeciness has a great influence on the character of the passage of air through the meshes of the named cloths, therefore to the above-mentioned criteria \( (3) \) we must add the criterion for fleeciness.

The formula \( (2) \) was checked on gauzes whose structural characteristics have been entered in Table 1. The diameters of the threads and the dimensions of the meshes were determined by microscope type TEM, the volumetrical air distribution \( V \) through the cloths on instrument type UPV-2 for determining the air-permeability of cloths. The coefficient of the distribution was determined as being \( \mu = \frac{V}{V_1} \),

when

\[ V_1 = f \sqrt{\frac{2}{\rho_0} \Delta p} \] \( (5) \)

is the volumetric distribution of air through a cloth, supposing that \( \mu = 1 \), that is supposing that stream compression and resistance are absent.
Table 1

<table>
<thead>
<tr>
<th>No. Art.</th>
<th>Thickness in texes (number) of thread</th>
<th>Density of cloth in 10 cm² ( n_0 = n_y )</th>
<th>Diameter of thread in mkm</th>
<th>Number of meshes per 1 cm²</th>
<th>Dimensions of mesh in mkm</th>
<th>Surface porosity (coefficient of living section)</th>
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<td>196</td>
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<td>2116</td>
<td>156</td>
<td>0.516</td>
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<tr>
<td>30</td>
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<td>2401</td>
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<td>520</td>
<td>50</td>
<td>2704</td>
<td>142</td>
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<tr>
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<td>&quot;</td>
<td>760</td>
<td>&quot;</td>
<td>5776</td>
<td>82</td>
<td>0.388</td>
</tr>
</tbody>
</table>
Such a distribution is conditionally called theoretical. As the meshes of all cloths under examination have the squares/quadrates \( \frac{b}{h} = 1 \), the coefficient of the distribution is the function of the two determining criteria \( \frac{L}{h} = \frac{L}{d^2} \) and \( \text{Re} \). Reynold criterion was determined by the formula

\[
\text{Re} = \frac{ud_2}{V_0} = \frac{Vd_2}{V_0^2},
\]

when \( v_0 = \frac{n_0}{\rho_0} \) - the coefficient of the kinematic viscosity of the air.

The research carried out showed that within the limits of the change of \( \frac{L}{d^2} \) from 0.48 to 1.22 the coefficient of the distribution \( \mu \) can be considered independent of \( \frac{L}{d^2} \). The dependence \( \mu = \mu(\text{Re}) \), based on the experimental data for all cloths that have been tested has been entered on diagram 1 in a continuous line. On this same graph the dependence \( \mu = \mu(\text{Re}) \) is shown by the dotted line, when

\[
\text{Re}_T = \frac{ud_2}{V_0} = \frac{\sqrt{\frac{2}{\rho_0}} \Delta p d_2}{\rho_0}.
\]

Reynold's theoretical number, calculated from the theoretical speed of flow

\[
\frac{V_0}{f} = \sqrt{\frac{2}{\rho_0}} \Delta p.
\]

Knowing the thickness of the threads and the density of the cloth from known formulae of textile material science \( ^5 \), it is easy to determine the dimensions of the meshes \( b = h = d^2 \) and their area \( f \) on a single specimen.

According to the formula (6) one can determine \( \text{Re}_T \) and from the graph \( \mu = \mu(\text{Re}_T) \) (Fig. 1) you can find the significance \( \mu \). By formula (2) can be determined the volumetrical distribution of air through the cloth. For example, for cloth No. 52 when \( \Delta p = 50 \) threads/square metre the experimental meaning of the volumetrical distribution of air \( V_{\text{expt.}} = 3.57 \text{ m}^3/\text{sec.} \)
According to formula (6)

\[ \text{Re}_\tau = \sqrt{\frac{2}{1.25} \cdot 50 \cdot 142 \cdot 10^{-5}} = 84.6 \]

From the graph \( \mu = \mu(\text{Re}_\tau) \) we find that \( \mu = 0.75 \). From the formula (2) we can determine the volume of the air:

\[ V_{\text{calc.}} = 0.75 \cdot 0.545 \sqrt{\frac{2}{1.25}} 50 \text{ m}^3/\text{sec} = 3.65 \text{ m}^3/\text{sec}. \]

The comparison of the calculated meanings of the volumetrical distribution of air with their experimental meaning (Fig. 2) shows that the deviation from \( V_{\text{expt.}} \) lies in the limits of precision of measurement or the instrument.

CONCLUSIONS

Within the limits of the criterion of the geometrical similarity of the meshes of the cloths \( 0.48 \leq \frac{L}{d^2} \leq 1.22 \) the coefficient of the distribution of air \( \mu \) depends only on the number \( \text{Re}_\tau \).

The calculation of the air-permeability of the cloth structures under examination on the dependence \( \mu = \mu(\text{Re}_\tau) \) gives a good coincidence with the experiment.
REFERENCES


FIGURE CAPTIONS

Fig. 1: The change of the coefficient of the distribution of air $\mu$ depending on the number $Re$ (continuous line) and the number $Re_\tau$ (dotted line) when

$$0.48 \leq \frac{L}{d_2} \leq 1.22.$$

Fig. 2: The comparison of the calculated meanings of the volumetrical distribution of air with their experimental meanings for certain cloths.