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**METHODS FOR DETERMINING THE FORM OF CHANNELS SPRAY
DEVICE DRYERS**

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A method of constructing a geometric shape of the flow channel, which provides a slow transition between the intermediate section of the channel, enabling to reduce the unevenness of the velocity field in the channel and to reduce the aerodynamic losses of spray drying device settings.

Key words: Channel, flow, modeling, dryers, spray equipment.

The spray drying equipment efficiency depends on the spray devices operation. The existent spray drying devices are equipped with pneumatic and mechanical atomizers of different size and shape. They waste energy whenever gas (liquid) flows, and that's caused primarily by the unevenness of the velocity field and detachable occurrences. The methods of flow investigation are well-known (a method of contour integration in relation, electrodynamic analogy etc.) [1, 2]. It's recommended to perform the calculation of the boundary layer to be performed based on the established model of plane boundary layer [3]. The graphic-analytical method of constructing the flow of the channel is the most efficient for solving this problem. In accordance with it, the task is set to build a flowing part of the channel with smooth transitions at a great number of intermediate generators. The chart of radii of cross-sections can be obtained from the graph of the cross flow change by its inverse quadratic transformation. The following symbols are used: \vec{r}_{ij} – radius vector of random section of j -th beam; $\alpha_{ij} = K_{ij} - 1$ – radial coefficient of section completeness. Changing K or α along channel axis in the direction of all rays we get a certain set of values for any L_i and the configuration of intermediate sections of the channel. To determine the value of K_{ij} we use a linear law of variation.

So:

$$K_{ij} = K_{0j}[1 - (L_i/L)] + K_{nj}[1 - (L_i/L)], \quad (1)$$

$$K_{0j} = C \vec{r}_{ij} / R_0; K_{nj} = C \vec{r}_{ij} / R_n. \quad (2)$$

To get the complex of polar radii for each intermediate section:

$$\vec{r}_{ij} = K_{ij} R_i. \quad (3)$$

Channel with smooth transitions can be built on the two-dimensional potential theory. The shape and area of input and output sections of the channel, the position of the axis are known.

We assume that the initial and final section of the channel are similar and closed looped equipotential lines $\varphi_0 = \text{const}$ and $\varphi_n = \text{const}$. The same is true for the flow lines $\psi_0 = \text{const}$ and $\psi_n = \text{const}$. Intermediate sections are built in the shape of the equipotential

lines $\varphi_i = \text{const}$ (or the flow lines $\psi_i = \text{const}$) of plane-parallel steady-state field that is between the selected contours.

The formula of the channel cross-sectional areas change is as below:

$$F_i = K_i F_0, \quad (4)$$

where F_0 – area of the initial section; K_i – multiplication factor that takes in count expansion (contraction) of the channel section $0 \leq i \leq n-1$; $n-1$ – a number of intermediate sections.

The velocity potential and stream function in polar coordinates r, θ ; are as below:

$$\varphi = \left(r + \frac{1}{r} \right) \cos \theta; \quad (5)$$

$$\psi = \left(r - \frac{1}{r} \right) \cos \theta. \quad (6)$$

Tech lines from the dipole lie inside the circle and are tertiary close-looped curves. The zero line corresponds to the initial flow channel cross section and has the shape of semicircle. The penultimate section is outlined by $n - 1$ flow line. The last section is a circle.

Let's assume that $\psi = C_i$, where C_i – some constants, that needs to be defined further. Then we can get the non-dimensional radius vector of the i -th line from this equation (6):

$$r = \left(C_i \pm \sqrt{C_i^2 + 4 \sin^2 \theta} \right) / \sin \theta. \quad (7)$$

After analysing the formula (7) we can claim that the values of $C_i < 0$ and the positive sign of the square root correspond to the current lines that lie within the upper semicircle. If the value is $C_0 < 0$, we obtain a limit line $OAB < 0$. In case when $C_i \rightarrow \infty$, curves described by equation (7) become circular curves, with areas close to zero. Nondimensional area of the intermediate circuit is calculated by the formula

$$F_i = \frac{C_i}{2} \int_0^n \frac{\sqrt{C_i + 4 \sin^2 \theta}}{\sin \theta} d\theta + \frac{\pi}{2} \quad (8)$$

Basing on elliptic integrals of the first genus the expression (5) is as follows:

$$F_i = \frac{\pi}{2} \left\{ 1 - \frac{C_1^4}{\sqrt[8]{C_1^2}} \left[1 + \frac{3C_1^2}{4(4 + C_1^2)} + \frac{5C_1^4}{32(4 + C_1^2)} + \alpha \right] \right\}, \quad (9)$$

where α – other members of the range that are sufficiently small compared to the first members.

The area of the input section is (9): $\vec{F}_0 = \pi/2$.

The scaling factor for the i -th countour outline is defined by the formula

$$\vec{F}_i = \vec{F}_0 = m_i. \quad (10)$$

Out of this equation (10) using expression (9) we'll get:

$$m_i = 1 - \frac{C_1^4}{8\sqrt{4 + C_1^2}} \left[1 + \frac{3C_1^2}{4(4 + C_1^2)} + \frac{5C_1^4}{32(4 + C_1^2)^2} \right]. \quad (11)$$

Basing on the law (4) considering formula (10) for dimensional radius vector of i -th section we'll get:

$$\vec{r} = \vec{r}_i \sqrt{\frac{2K_i F_0}{\pi m_i}} \quad (12)$$

C_i constant that is in the equation (7) is calculated as below. First of all the equipotential line of the greatest length should be drawn — line *ODEL* (fig. 1).

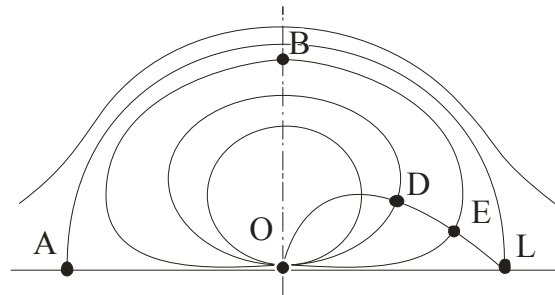


fig. 1. The scheme of the dipole

Since the equation of the streamlines are presented in the coordinate system r, θ , we mark the equipotential components *ODEL* in the new coordinate system and $\vec{r} \beta$ with the beginning

$$\vec{r} = (1 - \sin \beta) / \cos \beta, \quad (13)$$

where $0 < \beta < \pi/2$.

The *ODEL* line is divided into n – intervals of the same length $\Delta l_I = h$. The length of each interval Δl_I is calculated by the formula

$$h = \frac{1}{\cos^2 \beta_{i=1}} \sqrt{\cos^2 \beta_{i=1} + (1 - \cos \beta_{i=1})^2 \Delta \beta_i}, \quad (14)$$

where $\Delta \beta_i = \beta_i - \beta_{i-1}$, it follows that

$$\beta_i = \beta_{i-1} \frac{h \cos^2 \beta_{i=1}}{\sqrt{\cos^2 \beta_{i=1} + (1 - \cos \beta_{i=1})^2}}. \quad (15)$$

If the beam $\beta = \beta_i$, and crosses the line *ODEL* at a point $D(\beta_i, \vec{r}_i)$, So $\beta_i = \beta_i$, $\vec{r}_i = r_i$.

Out of the formula (15) we find the value of β_i keeping in mind that the length of the interval is h . $\vec{r}_i = r_i$ can be get from expretion (13) where r_i , and C_i can be get out of formula (7). Thus in the equation (7) instead of the value θ we use β_i . Then out of formula (11) m_i is calculated and the value of the radius vector \vec{r}_i is get out of (12). The obtained values of the radius vectors are used to build the desired contours of intermediate sections of the channels.

In case of complex profiles of the initial and final sections of the channel, the use of this method is based on certain mathematical difficulties. Then it's convenient to build the intermediate section graphically using a *MathCAD* package.

At first the initial and the final section of the channel are drawn according to the selected scale (fig. 2).

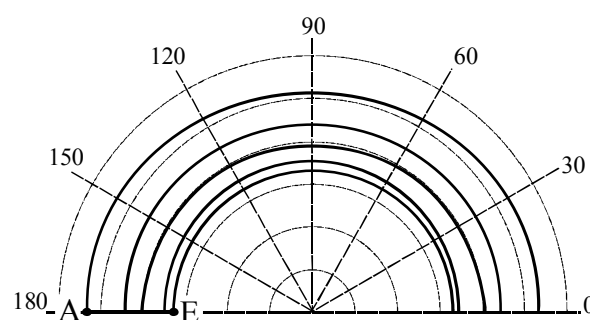


fig. 2. Building ekipotentsialov.

After that a long flow line AE , is drawn, which is divided into segments of the same length, equal to the number of selected sections of the channel.

Then, a method of electrical modeling is applied to draw the lines of equal potential that are crossing the ends of the segments. The crossed-looped lines that are created as a

result are the required form of the intermediate sections. Planimeter determines the area F_i^* , limited by the i -th equipotential. To calculate the scale m_i we use the formular similar to (10):

$$m_i = F_i^* / F_0^* . \quad (16)$$

The increase or decrease of the crossing sections is performed using a pantograph, having a scaling factor $(K/m_i)^{0.5}$, where, K_i takes to account expansion (contraction) of the section channel, the same way as in the formula (1).

This method allows to avoid errors at the design stage of channels and branch pipes of spray drying devices and may be used in the design of converging and difussing channels with various forms of input and output sections.

Conventional signs:

F – area of the section of the channel,	δ^* – displacement thickness,
m^2 ;	m ;
L – distance along the channel axis, m ;	φ – velocity potential;
r, θ – polar coordinates;	ψ – flow function;
β – azimuth direction angle;	\vec{r} - radius vector
R - the radius of an equivalent circle section of the channel, m	

Indices:

0 – section at the channel beginning;	$i - 0 \dots n$ – section numbers;
n – section at the channel end;	j – radius vector direction.

Conclusions

The simple and pretty precise method has been developed to build the channels of spay devices that are widely used in the spray drying units.

The method allows to calculate and design channels and pipes with a small unevenness of the velocity field and low aerodynamic drag.

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