INNOVATIVE TECHNOLOGICA
METHODICAL RESEARCH JOURNAL
ISSN: 2776-0987 Volume 3, Issue 5, May, 2022

ABOUT THE MOVEMENT OF A MIXTURE OF COTTON AND AIR IN A CLOSED CHANNEL

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Abstract
The article is devoted to the movement of a mixture of cotton and air when it is divided into two branches. The goal is to direct the air into the upper channel and the cotton into the lower channel. When the channel is divided into two networks, the occurrence of twists during the flow diversion can have negative consequences. Replacing the boundary of the curves with a curved, smooth curved arc relative to the current requires determining its shape and radius of curvature. The problem was solved using the theory of ideal fluids. Necessary formulas, numerical results were obtained and they can be used in the improvement of the pneumoseparator.

Keywords: a closed channel, motion, a mixture of cotton and air.

Introduction

In the field of the cotton ginning industry, there is a problem of pneumatic transportation and separation of raw cotton from the air. In this regard, this work is devoted to the movement of the cotton-air mixture in a channel with two sleeves at the end of the channel and is considered as a flow of a two-layer medium with different densities.

The task is to direct the top layer of air into one channel, and the cotton mixture into another.

At the end of the channel, when two media are separated in the vicinity of the break points of the contour, flow separation, vortex flows can form, the entire medium can move, and the cotton mixture can twist into bundles and the accumulation of raw cotton and crushing of seeds can occur. In this case, the throughput of the tee deteriorates. To get rid of the above undesirable phenomena, it is necessary to replace the dividing lines of the vortex zone with a curvilinear contour convex in the direction of the flow and determine its shape and radius of curvature and other channel parameters (Figure 1), which ensure a smooth turn of the flow along the arms.

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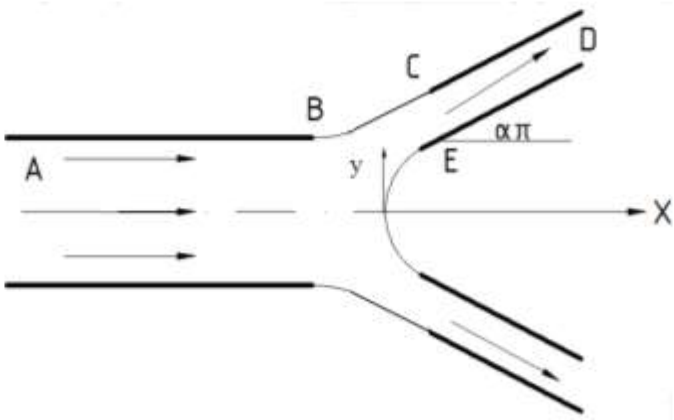

Figure 1.

Currently, various methods have been developed for solving problems of jet flow of ideal rigidity, gas or mixtures with or without free boundaries, which are mainly applied to flat flows. These methods are summarized by prof. A.A.Khamidov [1, 2] for solving problems of spatial jet flows of liquids. The paper shows for the first time the possibility of obtaining the Bernoulli integral for plane potential liquids and suggests ways to develop the Zhukovsky method for multiphase jets of ideal liquids [2]. This work is based on the work and is devoted to the construction of a solution to the two-dimensional problem of the jet flow of a liquid mixture in a curvilinear channel with flow separation into two arms [1, 2]. In this case, the movement of a mixture of two liquids is assumed, in a closed horizontal channel of constant cross section with a smooth turn of the flow into two branches (Figure 1).

The flows are axisymmetric, flat, the flow motion is stationary. The problem is solved by mapping G_t – the upper half-plane onto G_w – the domain of the complex potential and the Zhukovsky function

$$\omega_n(t) = \ln\frac{V_{no}}{V_n} + i\theta .$$

Then it is possible to construct a solution to the problem in a parametric form based on the model of an ideal fluid.

Using the Chaplygin singular point method for the function $W = \varphi + i\varphi$ of the complex potential, we have:

$$\frac{dw}{dt} = \frac{q_n}{\pi(t-d)} = f_0(t), \quad t = \xi + i\eta \qquad (1)$$

Let us introduce a new function [2]:

$$\omega c + 1 = \ln F(\rho_n, V_n)\cdot e^{i\theta} \qquad (2)$$

where,

$$F(\rho_n, V_n) = \sqrt{\frac{\rho_1 V_{10}^2 + \rho_2 V_{20}^2}{\rho_1 V_1^2 + \rho_2 V_2^2}}$$

ρ_1 and ρ_2 mixture density.

Using the limiting values of the Zhukovsky function $\omega_m(t)$ and the Schwartz integral formula, we have obtained:

$$\omega_m(t) = \frac{1}{\pi}\int_{-e_0}^{-1} \frac{\theta_1(\zeta)d\zeta}{\zeta - t} + \alpha\int_{-1}^{1}\frac{d\zeta}{\zeta - t} + \frac{1}{\pi}\int_{1}^{b}\frac{\theta_2(\zeta)d\zeta}{\zeta - t} \qquad (3)$$

$$\omega_m(t) = \begin{cases} 0, & \text{at} \quad -\infty < \xi < -\mathrm{e}_0, \quad \eta = 0 \\ \theta_1(\xi), & \text{at} \quad -\mathrm{e}_0 < \xi < -1, \quad \eta = 0 \\ \alpha\pi, & \text{at} \quad -1 < \xi < d, \quad \eta = 0 \\ \alpha_1\pi, & \text{at} \quad d < \xi < 1, \quad \eta = 0 \\ \theta_2(\xi), & \text{at} \quad 1 < \xi < b, \quad \eta = 0 \\ 0, & \text{at} \quad b < \xi < \infty, \quad \eta = 0 \end{cases}$$

Here $\theta_1(t)$, $\theta_2(t)$ are the angles of the liquid particle vector along the curvilinear contours E_0F and BC, respectively. To determine them, we use the finite-dimensional approximation method

$$\theta_i(t) = At + B = \begin{cases} \alpha\pi, & \text{at} \;\; t = -1 \\ \frac{\pi}{2}, & \text{at} \;\; t = -e_0 \end{cases}.$$

Hence

$$\theta_1(t) = \frac{\pi}{2(1 - l_0)}[(1 - 2a)t + (1 - 2e_0\alpha)].$$

Similarly

$$\theta_2(t) = \mathrm{C}t + D = \begin{cases} \alpha\pi, & \text{at} \;\; t = 1 \\ 0, & \text{at} \;\; t = b \end{cases}.$$

Then

$$\theta_2(t) = \frac{\alpha\pi}{1-b}(t - b),$$

$$\omega_m(t) = \alpha\, ln\frac{t-1}{t+1} + \frac{a}{1-b}\left[(\mathrm{b} - 1) + (\mathrm{t} - \mathrm{b})ln\frac{b-t}{1-t}\right] + \frac{1}{2(1-e_0)}\left[(1 - 2\alpha)(\mathrm{e}_0 - 1) + \right.$$
$$\left. + [(1 - 2\alpha)t + 1 - 2e_0\alpha]\right]ln\frac{1+t}{1-t}.$$

After some simplifications, we finally get:

$$V_n = V_{n0}\left[\sqrt{e}\left(\frac{t+1}{t-b}\right)^{\alpha}\left(\frac{t-1}{t-b}\right)^{\frac{\theta_0(t)}{\pi}}\left(\frac{e_0 + t}{1+t}\right)^{\frac{\theta_1(t)}{\pi}}\right] = V_{n0} f_1(t) \qquad (4)$$

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where $\alpha\pi$ – is the angle of the velocity vector in the upper channel with the Ox. For the geometry of the problem, from (1) and (3) we obtain

$$\frac{d\bar{t}}{dt} = F_0 \cdot f_0(t)[f_1(t)]^{-1} \qquad (5)$$

$$F_0 = \sqrt{\frac{\rho_1 q_1^2 + \rho_2 q_2^2}{\rho_1 V_{10}^2 + \rho_2 V_{20}^2}}, \quad \frac{q_n}{V_{n0}} = \frac{HV_{nA}}{V_{no}} = H \cdot F^{-1} = F_0$$

Using the rules of disclosure of the uncertainty of Bernoulli-Lopital, for the value of the velocity of a fluid particle at the beginning of the channel at point A (t=±∞) we have:

$$V_{nA} = V_{no} \cdot e^{3\alpha - \frac{1}{2}}, \quad 0 < \alpha < \frac{1}{2} \qquad (6)$$

Similarly, the speed at the end of the channel at point D ($t = d$)

$$\widehat{V}_{nD} = N_0 \left| \hat{\hat{V}}(d) \right| \cdot e^{i\alpha\pi} ,$$

where,

$$N_0 = \frac{V_{no}}{V_{nA}} = e^{\frac{1}{2} - 3\alpha} \qquad (7).$$

Integrating equations (3) over t and taking into account $z(-e_0, 0) = 0$, we obtain

$$\bar{z}(t) = F \int_{-e_0}^{t} \frac{d\bar{z}}{dt} \cdot dt \quad (8).$$

The radii of curvature of the curved contours E_0F and BC are determined by the formula:

$$|R_i| = \left| \frac{d\bar{z}}{dt} \cdot \frac{dt}{d\theta_i} \right|, \quad (i = 1,2, ...) \qquad (9)$$

where, $\frac{d\theta_1}{dt} = \frac{\pi}{2}(\frac{1-2\alpha}{1-e_0})$ at $i = 1$ and $\frac{d\theta_2}{dt} = \alpha\pi \cdot \frac{b}{b-1}$ at $i = 2$. Formulas (1)-(9) include unknown display parameters: $e_0>1$, $-1<d<1$ and $b>1$. To determine them from (7) and (9) we have:

$$\begin{cases} \sqrt{e} \cdot (\frac{d+1}{1-d})^{\alpha} \cdot (\frac{1-d}{b-d})^{\frac{\theta_2(d)}{\pi}} \cdot (\frac{e_0+d}{1+d})^{\frac{\theta_1(d)}{\pi}} = 1 \\ R_1(-e_0) = R_1(-1), \\ R_2(1) = R_2(b) \end{cases} \qquad (10).$$

Thus, to solve the problem, all the necessary formulas in the form of analytic functions are obtained that satisfy all the boundary conditions of the problem.
Using the theorem on the change in momentum and mass of a liquid mixture, the resulting force acting on this mass

$$2(P_A - P_0)H - X \qquad (11).$$

Which is equal to the increment per unit time to the amount of motion of the mass of fluid:

$$2(\rho_1 q_1 V_{10} + \rho_2 q_2 V_{20})\cos\alpha\pi - 2(\rho_1 q_1 V_{1A} + \rho_2 q_2 V_{2A}) \qquad (12).$$

Equating (11) and (12) we get

$$2(P_A - P_0)H - X = 2(\rho_1 q_1 V_{10} + \rho_2 q_2 V_{20})\alpha\pi - 2(\rho_1 q_1 V_{1A} + \rho_2 q_2 V_{2A})$$

where x – wall resistance force $E_0 F_D$. According to the Bernoulli integral for the mixture:

$$P_A + \frac{1}{2}(\rho_1 V_{1A}^2 + \rho_2 V_{2A}^2) = P_D + \frac{1}{2}(\rho_1 V_{1A}^2 + \rho_2 V_{2A}^2)$$

an expression for the overpressure is obtained:

$$\Delta P = P_A - P_0 = \frac{1}{2}\left[(\rho_1 V_{10}^2 + \rho_2 V_{20}^2) - (\rho_1 V_{1A}^2 + \rho_2 V_{2A}^2)\right]$$

Hence, equating (11) and (12) for the resistance, we obtain

$$X = H(\rho_1 V_{1A}^2 + \rho_2 V_{20}^2)\left[1 - 2f(\alpha)\cos\alpha\pi + f^2(\alpha)\right] \qquad (13)$$

Then the drag coefficient has the form

$$C_\chi = \frac{1 - 2f(\alpha)\cos\alpha\pi + f^2(\alpha)}{\overline{F}}$$

where,

$$f(\alpha) = \sqrt{\frac{g_{1c} + g_{2c}}{1 + g}}, \quad g_{1c} = \frac{\rho_1}{\rho_2}\left(\frac{V_{1c}}{V_{2A}}\right)^2, \quad g_{2c} = \left(\frac{V_{2c}}{V_{2A}}\right)^2$$

$$\overline{F} = \sqrt{\frac{1 - f_2(1 - g)}{1 + g}}, \quad g = \frac{\rho_2 V_{20}^2}{\rho_1 V_{10}^2}, \quad f_1 + f_2 = 1,$$

f_1, f_2 – phase concentrations. ρ_1 and ρ_2 – mixture density, ρ_1 – air density, V_{iA} and V_{iD} $(i = 1,2)$ – mixture speed at the beginning and at the end of the channel. If we do not take into account the phase concentrations, then

$$q_1 = HV_{1A}, q_2 = HV_{2A}.$$

Then

ISSN: 2776-0987 Volume 3, Issue 5, May, 2022

$$C_{\chi} = 1 - 2\frac{1 + f_0(A)f_0(D)}{f_0(AD) + f_0(A)f_0(D)}cos\alpha\pi + \frac{1 + f_0^2(D)}{f_0^2(AD) + f_0^2(D)}$$

where $f_0(A) = \sqrt{\frac{\rho_1}{\rho_2}\frac{V_{2A}}{V_{1A}}}$, $f_0(D) = \sqrt{\frac{\rho_1}{\rho_2}\frac{V_{2D}}{V_{1D}}}$, $f_0(AD) = \frac{V_{1A}}{V_{1D}}$.

For an ideal incompressible fluid, it is necessary to put $\rho_1 = \rho_2$. For single velocity fluid $V_{1A} = V_{2A}$, $V_{1D} = V_{2D}$ then

$$C_{\chi} = 1 - 2\tilde{V}_A cos\alpha\pi + \tilde{V}_A^2$$

where $\tilde{V}_A = \frac{V_{1A}}{V_{1D}}$, V_{1A} and V_{1D} – flow rates at the beginning and at the end of the channel. The results of numerical analysis show that the drag coefficient fluctuates within the limit $0{,}517 \le C_{\varepsilon} \le 0{,}620$ at $0{,}3 \le g \le 0.781$, $0.21 \le f_2 \le 0.42$ and $\alpha = \frac{1}{6}(30^0)$

In this case, the arc BC is very close to the arc of a circle. The proposed scheme shows that the flow provides uniform flow before and after the turn.

The results of the study can be used in the field of hydraulics, hydraulic engineering, oil and gas, cotton industry, etc. In particular, during the pneumatic transportation of raw cotton and its products.

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