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FLOW DYNAMICS CAUSED BY THE SUDDEN WATER DISCHARGE INTO THE RIVER

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Flow in rivers and channels under non-stationary increasing runoff from the reservoir or the zone of precipitation was modeled in [1–3]. In this case, the phenomenon is accompanied by a sharp change in the shape of the leading edge at considerable distances from the source.

A similar conclusion in the use of various computer models was made in [4, 5].

Problem Statement. Let consider the process of increasing the level of the river. Under sudden discharge of water define the time for which a sudden discharged volume of water will reach the ship.

Let we divide the river basin between the place of discharge of water and the vessel on the river into intervals with the lengths l_p and widths b_p using the longitudinal lines of the HEC RAS program (figure 1).

We choose the partition interval so that within each interval the angle of inclination of the river bed to the horizon α_p does not change. In view of the strong turbidity of the river water due to the presence of silt and various inclusions, we will consider water as viscous and incompressible fluid.

Following [1], we adopt a laminar two-layer flow model. We assume that in the case of a two-layer flow the lower first layer is the steady flow of liquid of height z_{0p} and velocity v_{0p} .

The velocity of propagation of the upper second layer of water in the *p*-th section of the river of the given height z_{1p} and the thickness $\Delta z_p = z_{1p} - z_{0p}$ of the rectangular cross section of the river will be denoted by v_{xp}. Δz_p can be determined by the volume of water discharged in the first interval $\Delta z_p = Q / l_p b_p$. The velocity at the boundary of the two layers is assumed to be equal to the velocity on the surface of the first layer (figure 2).

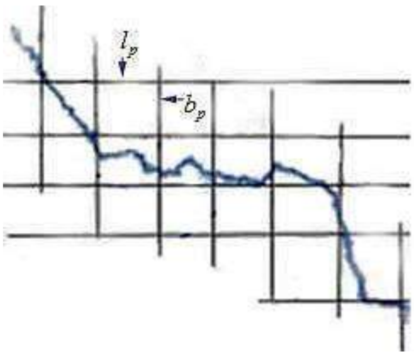

Figure 1 – Splitting the river bed into intervals

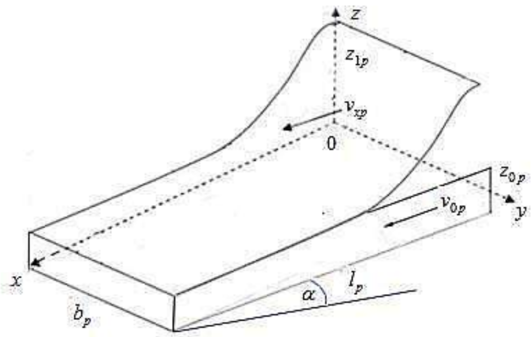

Figure 2 – Two-layer flow in a channel of rectangular cross-section

In [1] the mathematical formulation of the problem is given in the form of the Poisson equation

$$\frac{\partial^2 v_{xp}}{\partial y^2} + \frac{\partial^2 v_{xp}}{\partial z^2} = -D_p, \quad D_p = \frac{g}{\nu}\left(\frac{\Delta z_p}{l_p} + \frac{\Delta H}{l}\right), \tag{1}$$

where $\Delta H / l = \sin\alpha$ is the sinus of the slope of the straight line connecting the beginning and the end of the section of the river, ν is the coefficient of kinematic viscosity of the liquid, *g* is the acceleration of free fall.

The boundary conditions are taken as follows:

$$v_{xp}(y, z_{0p}) = v_{0p}, \ v_{xp}(0, z) = v_{xp}(b_p, z) = 0, \ \partial v_{xp}(y, z) / \partial z\Big|_{z=z_{1p}} = 0.$$

Here v_{0p} was set as the mean $0 \le y \le b_p$ value over the width of the river of water flow rate in the lower layer. In contrast to this work, we take a slightly different formulation.

As is known, the velocity profile of a viscous liquid has a parabolic form

$$v_{xp}(y, z_{0p}) = \sigma_p y(y - b_p). \tag{2}$$

An unknown parameter σ_p can be determined if we take into account that

$$\left\langle v_{xp}(y, z_{0p}) \right\rangle = v_{0p} = \frac{1}{b_p} \int_0^{b_p} v_{xp}(y, z_{0p}) dy. \quad (3)$$

Substituting (2) in (3) and integrating, we find the value of the parameter σ_p: $\sigma_p = 6v_{0p} / b_p^2$.

Thus, we obtain the boundary condition for equation (1) in the form: $v_{xp}(y, z_{0p}) = \frac{6v_{0p}}{b_p^2} y(b - y)$.

The method of the solution. We seek the solution of the problem in the form of a sum of two functions $v_{xp}(y, z) = U(y, z) + \frac{D_p y(b_p - y)}{2}$, where $U(y,z)$ is the solution of the Laplace equation $\frac{\partial^2 U}{\partial y^2} + \frac{\partial^2 U}{\partial z^2} = 0$. To illustrate the profile of the dimensionless velocity in each p-th section between the dividing lines at the points $z_{pj} = z_{0p} + j\frac{\Delta z_p}{m}$, $y_{pi} = i\frac{b_p}{M}$, $0 \le i \le m$, $0 \le j \le M$ we obtain the relation for $v_{xpij}(y_i, z_j) / v_{0p}$:

$$\frac{v_{xpij}(y_i, z_j)}{v_{0p}} = \sum_{n=1}^{\infty} \left(1 - \frac{ch\left[k_2 n\left(1 - \frac{j}{m}\right)\right]}{ch(k_2 n)} \left(1 - \frac{12}{\gamma_p}\right) \right) \frac{2\gamma_p}{\pi n^3} \left[1 - (-1)^n\right] \sin\frac{\pi n i}{M}. \quad (4)$$

Here m and M are, respectively, the number of partitions of the intervals (0, b_p) and (z_{0p}, z_{1p}).

Results. The results of calculations using formula (4) for the first sector of the selected section of the river are shown in the table below. Figure 3 shows the diagram of velocity distribution in the second layer of the river.

Knowing the size of the sections of the partition l_p and the value of $\langle v_x(z, y) \rangle$, we can determine the time of passage of the liquid particles through each p-th section of the partition $t_p = l_p / \left|\langle v_{xp}(z, y) \rangle\right|$.

The time t to reach the flow to the ship will be equal to $t = \sum_{p=1}^{q} t_p$, where q is the number of segments of the partitions.

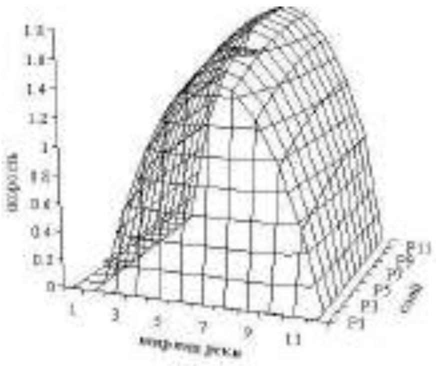

Figure 3 – Diagram of velocity distribution in the second layer of the river

i/j	i=0	i=1	i=2	i=3	i=4	i=5	i=6	i=7	i=8	i=9	i=10
j=0	0.00	0.54	0.96	1.26	1.44	1.50	1.44	1.26	0.96	0.54	0.00
j=1	0.00	0.59	1.01	1.31	1.49	1.55	1.49	1.31	1.01	0.59	0.00
j=2	0.00	0.64	1.06	1.36	1.54	1.60	1.54	1.36	1.06	0.64	0.00
j=3	0.00	0.68	1.10	1.40	1.58	1.64	1.58	1.40	1.10	0.68	0.00
j=4	0.00	0.72	1.14	1.44	1.62	1.55	1.62	1.44	1.14	0.72	0.00
j=5	0.00	0.75	1.17	1.47	1.65	1.71	1.65	1.47	1.17	0.75	0.00
j=6	0.00	0.77	1.19	1.49	1.67	1.73	1.67	1.49	1.19	0.77	0.00
j=7	0.00	0.79	1.21	1.51	1.69	1.75	1.69	1.51	1.21	0.79	0.00
j=8	0.00	0.81	1.23	1.53	1.71	1.77	1.71	1.53	1.23	0.81	0.00
j=9	0.00	0.81	1.24	1.54	1.72	1.78	1.72	1.54	1.24	0.81	0.00
j=10	0.00	0.82	1.24	1.54	1.72	1.78	1.72	1.54	1.24	0.82	0.00

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ОПТИМИЗАЦИЯ ФОРМЫ ПЕТЛИ ДЛЯ РАЗВОРОТА ВАГОНОВ

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При выполнении некоторых технологических операций по обслуживанию вагонов рабочего парка и испытанию новых вагонов требуется разворот подвижного состава. Основные конструкции данных устройств связаны с сооружением разворотных треугольников и петлевых ходов. Расчетная схема петлевого разворота представлена на рисунке 1.

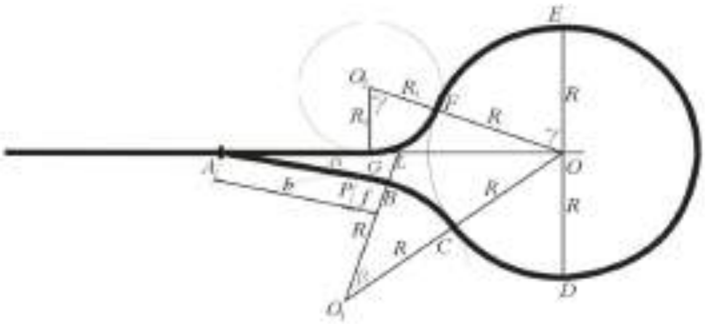

Рисунок 1 – Схема петлевого разворота вагонов

Длина маршрута перемещения вагона *L* с локомотивом по петлевому ходу определяется от точки *G* (начала кривой при движении по прямому пути за стрелку) по круговой кривой через точки *E* и *D* до точки *P* (заднего стыка крестовины стрелочного перевода). Формулы для вычисления длины пути представлены в [1]. Согласно приведенным расчетам

$$\beta = \arccos\frac{R\cos\alpha + (b+f)\sin\alpha}{2R} - \alpha.$$

$$R_1 = \frac{\left(\dfrac{b+f}{\cos\alpha} + \dfrac{2R\sin\beta}{\cos\alpha} - b\right)^2 - R^2}{2R}, \ \gamma = \arccos\left(\frac{R_1}{R_1 + R}\right).$$

Длина искомого маршрута $L = \gamma R_1 + \gamma R + \pi R + (\alpha+\beta)R + \beta R + f$.

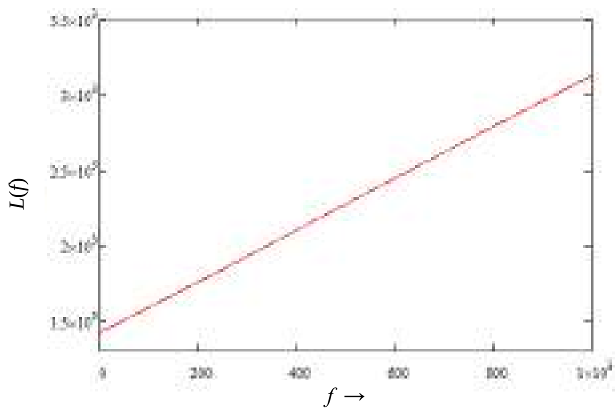

Рисунок 2 – График зависимости длины пути от вставки

Таким образом, задача определения оптимальной траектории петли сводится к нахождению экстремума функции одной переменной *f*, которая легко решается с помощью пакета прикладных программ, например MATHCAD. В качестве иллюстрации найдем, при какой длине прямой вставки длина пути по петле будет наименьшей, если радиус *R*1 дуги, по которой вагон вписывается в прямой участок пути, будет не меньше 180 м, *b* = 15,64 м, tgα = 1/9, *R* = 200 м. Зависимость длины пути от величины прямой вставки приведена на рисунке 2.

Ввиду возрастания функции *L*(*f*) очевидно, что длина пути по петле будет минимальной при наименьшей возможной длине прямой вставки. Зависимость радиуса *R*1 от длины *f* прямой вставки