LINEAR PROBLEM OF TRAIN TUNNEL ENTRY WITH FORMATION OF VARIABLE WIDTH ISOBARIC WAKE

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ABSTRACT

The article considers a linearized non-stationary problem of train movement with the formation of an isobaric wake in a tunnel of variable width. The influence of the kinematic and geometrical characteristics of the pressure distribution flow, which leads to the emergence of a force, has been established. The complex potential and its partial derivatives are expressed using the Terentiev A.G. formula. The research results can be useful in assessing and calculating the force impact on high-speed trains when passing through various structures: tunnels, fences, etc., as well as on a vessel moving in a canal.

KEYWORDS: *Aerodynamics, Linearized Non-Stationary Problem, Complex Potential, Partial Derivatives, Complex Velocity, Hydrodynamic Flow Characteristics, Drag Coefficient.*

INTRODUCTION

A plane problem of the symmetric motion of a thin body in an ideal incompressible and weightless fluid filling a channel of variable width is considered. The results of the research can be useful in assessing and calculating the force impact on high-speed trains when passing through various structures: tunnels, fences, etc., as well as on a vessel moving in the canal **[1-4]**.

With the rapid movement of the body at the breakpoints, a flow stall can occur and an attached stagnant zone can form behind the head part, the pressure in which is assumed to be a constant value.

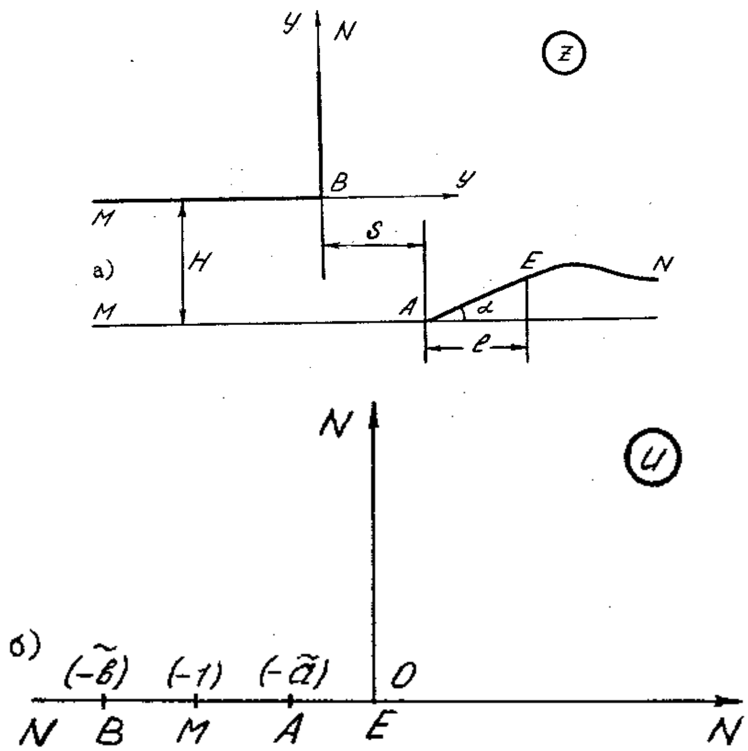

Fig.1.

The movement scheme is shown in Fig.1. A wedge with a vertex angle of$2\propto$moves at a constant speed$V$=*const.*

The mapping function is easily obtained from the Schwartz integral **[5]**

$$Z = \frac{H}{\pi b^{0,5}} \int_{a}^{\varsigma} \frac{(\varsigma + b)^{0,5}}{\varsigma} d\varsigma + S - Hi. \qquad (1)$$

Here and below, the origin of coordinates in the plane coincides with the corner point B (Fig. 1b). If the length of the body is taken as$l$, then the equality must hold:

$$l = \frac{H}{\pi b^{0,5}} \int_{a}^{1} \frac{(\varsigma + b)^{0,5}}{\varsigma} d\varsigma. \qquad (2)$$

Abscissa point$A$

$$S(t) = x(a) - x(-b) = \frac{H}{\pi b^{0,5}} \int_{-b}^{a} \frac{(\varsigma + b)^{0,5}}{\varsigma} d\varsigma. \qquad (3)$$

Characterizes the position of the body relative to the tunnel. Integral (3) exists in the sense of Cauchy's principal value. Equalities (2) and (3) for given$\frac{H}{l}$and$\frac{S}{l}$orm a system of two equations for the unknowns$a$and$b$.

Mapping function

$$Z=\frac{H}{\pi\sqrt{b}}\left[2\left(\sqrt{\varsigma+b}-\sqrt{a+b}\right)+\sqrt{b}ln\frac{a\left(\varsigma+2b-2\sqrt{(\varsigma+b)b}\right)}{\varsigma\left(a+2b-2\sqrt{b(a+b)}\right)}\right]+S-Hi. \quad (4)$$

For unknown parameters and from (2) and (3), taking into account (4), we obtain the following system of algebraic equations:

$$\frac{H}{e\pi\sqrt{b}}\left[2\left(\sqrt{1+b}-\sqrt{a+b}\right)+\sqrt{b}ln\frac{a(1+2b-2\sqrt{(1+b)b})}{(a+2b-2\sqrt{b(a+b)})}\right]=1; \quad (5)$$

$$\frac{H}{e\pi\sqrt{b}}\left[\sqrt{b}ln\frac{a}{(a+2b-2\sqrt{b0(a+b)})}-2\sqrt{a+b}\right]=-\frac{S}{l}. \quad (6)$$

Dependence$x(\tau)$is determined from (4) with a real argument$\varsigma=\tau$.

In the auxiliary half-plane$J_m\varsigma>0$in this case we arrive at the Hilbert problem:

$$\psi_t=\begin{cases}0; & \xi\epsilon(-\infty,a)\\ -V^2\alpha; & \xi\epsilon[a,1]\end{cases}\varphi_t=0; \;\; \xi\epsilon(1,\infty). \quad (7)$$

If displayed using the function

$$U=i\sqrt{\varsigma-1} \quad (8)$$

the upper half-plane$J_m\varsigma>0$to the second square of the plane W (Fig. 2.) and take into account that on the imaginary axis in accordance with (1) $\varphi_t=0$, then the function$W_t=0$can be extended to the entire upper half-plane. Therefore, we arrive at the Schwarz problem for theW_t:

$$\psi_t=\begin{cases}0; & ReU\epsilon(\left(-\infty,-\sqrt{1-a}\right);(\sqrt{1-a},\infty))\\ & V^2\alpha; \;\; ReU\epsilon(-\sqrt{1-a};\sqrt{1-a})\end{cases} \quad (9)$$

Applying the Schwartz operator, we find the solution:

$$W_t=-\frac{\alpha V^2}{\pi}ln\frac{U-\sqrt{1-a}}{U+\sqrt{1-a}} \quad (10)$$

Using equality (8), we can express$W_t$in terms of the variableς:

$$W_t=-\frac{\alpha V^2}{\pi}ln\frac{\sqrt{1-\varsigma}-\sqrt{1-a}}{\sqrt{1-\varsigma}+\sqrt{1-a}} \quad (11)$$

The longitudinal force acting on the wedge is determined using the formula [3]:

$$X=\frac{2\rho V^2\alpha^2 H}{\pi^2\sqrt{b}}\int_a^1 ln\left|\frac{\sqrt{1-\varsigma}-\sqrt{1-a}}{\sqrt{1-\varsigma}+\sqrt{1-a}}\right|\frac{\sqrt{b+\varsigma}}{\varsigma}d\varsigma \quad (12)$$

Fluid pressure at infinity on the left in a channel

$$P_E = -\rho\varphi_t(0) = +\frac{\rho V^2\alpha}{\pi} ln\frac{1+\sqrt{1-a}}{1-\sqrt{1-a}} \qquad (13)$$

It is easy to show that in the limit at$S \to -\infty$from (12) and (13) the well-known expressions for the pressure at the point M and the resistance in the channel with a cavitation flow around the Kirchhoff scheme follow [2]:

$$P_M = \frac{\alpha V^2\rho}{\pi} ln\frac{e^\gamma + \sqrt{2sh\gamma}}{e^\gamma - \sqrt{2sh\gamma}} \qquad X = \frac{\rho V^2\alpha^2 H}{2\pi^2} ln^2\frac{e^\gamma + \sqrt{2sh\gamma}}{e^\gamma - \sqrt{2sh\gamma}} \qquad (14)$$

when$\gamma = \frac{l\pi}{H}$.

If$S \to -\infty$ $(a \to 1;\ b \to 0, \frac{H}{l} \neq 0)$formulas (12) and (13) give a known value:

$$X = \frac{4\rho V^2\alpha^2}{\pi} \qquad (15)$$

for the drag coefficient of a wedge in an unbounded Kirchhoff flow (Bobylov's problem).

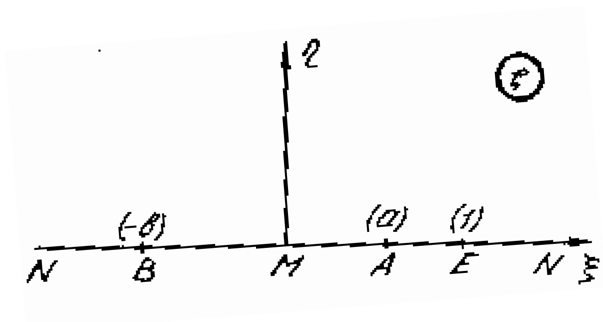

Fig.2.

Making (12) passage to the limit$\frac{H}{l} \to 0; b \to 0$and using the asymptotic relations [5], we obtain the formula. for the resistance of the wedge when moving towards a solid wall:

$$X = \frac{\rho V^2\alpha^2 H}{\pi\sqrt{1-a}} \int_a^1 ln\frac{\sqrt{1-\varsigma} + \sqrt{1-a}}{\sqrt{1-\varsigma} - \sqrt{1-a}} \cdot \frac{d\varsigma}{\sqrt{\varsigma}}. \qquad (16)$$

Again at$S \to -\infty$ $(a \to 1)$from (16) we obtain the well-known formula (15)

Figures 3 and 4 show the dependence curves of the pressure coefficient$K = \frac{2P}{\alpha V^2\rho}$and the drag coefficient$C_x = \frac{2x}{\rho V^2\alpha^2 l}$on the relative wedge distance$\frac{S}{l}$and width$\frac{H}{l}$

The research results can be useful in assessing and calculating the force impact on high-speed trains when passing through various structures: tunnels, fences, etc., as well as on a vessel moving in a canal.

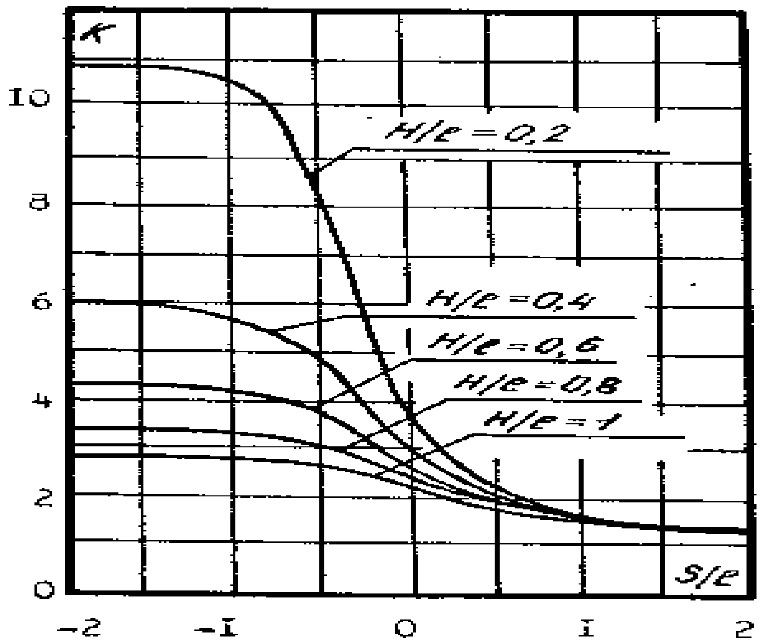

Fig.3.

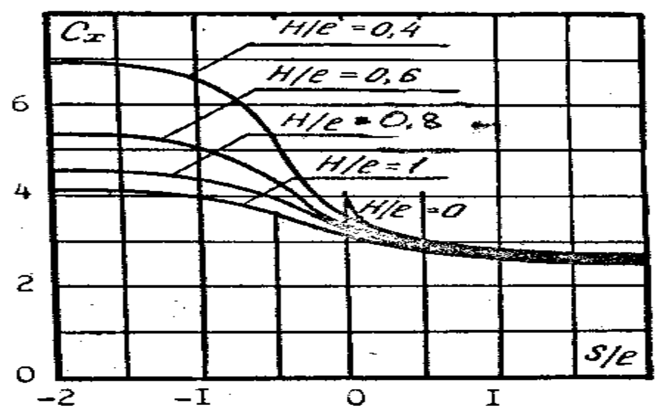

Fig.4.

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