ISSN 2307–3489 (Print), ISSN 2307–6666 (Online)

Наука та прогрес транспорту. Вісник Дніпропетровського
національного університету залізничного транспорту, 2017, № 5 (71)

ЗАЛІЗНИЧНА КОЛІЯ

UDC 629.4.016.56/.024.1

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CONSIDERATION OF AERODYNAMIC IMPACT IN SETTING THE MAXIMUM PERMISSIBLE SPEEDS OF HIGH-SPEED TRAIN

Purpose. Studies of the effect of aerodynamic pressure on the maximum permissible speeds of a high-speed train on the existing railway infrastructure. **Methodology.** The study of the magnitude and direction of the aerodynamic pressure, its effect on the maximum speeds of a high-speed train was carried out on a train model composed of axisymmetric bodies with conical forms of head and tail parts. **Findings.** Determined the values of the aerodynamic pressure at different distances from the train are, when the high-speed train moves at a speed of 200 km/h or more. The maximum speeds of a high-speed train are determined taking into account the state of the infrastructure of the existing railway, ensuring the safe operation of a high-speed railway. O**riginality.** Theoretical studies of aerodynamic pressure from secondary air currents formed during the movement of high-speed trains are performed on a model of a train composed of identical axisymmetric bodies with conical forms of head and tail moving in a compressible medium. The results of the research allow the regularity of the change in aerodynamic pressure during the movement of a high-speed train. **Practical value.** The obtained results allow to establish: 1) the maximum permissible speeds of a high-speed train taking into account the technical condition of permanent devices and structures of the existing railway infrastructure; 2) technical parameters of individual objects and structural elements of the infrastructure of high-speed iron subjected to the effect of aerodynamic pressure for a given maximum speed of high-speed trains.

Keywords: railway transport; high-speed train movement; aerodynamics; aerodynamic pressure; railway infrastructure; maximum speeds; technical parameters

Introduction

Half a century of experience in the operation of high-speed railroads, the results of numerous theoretical and experimental studies have shown that with an increase in speed, the character of the aerodynamic field around a moving high-speed train, the magnitude and vector of air currents change dramatically. The resulting air flows have a negative impact on the environment, worsening the safe functioning of the system «high-speed railway – the environment (or surrounding objects)».

The study of air flows generated by trains at high speeds is an urgent task of ensuring safety on high-speed railways.

Conducted the experimental and theoretical research directed carried out are aimed at obtaining information on the speed, direction of the secondary air currents and aerodynamic pressure arising from the movement of high-speed trains; assessment of their impact on the railway infrastructure facilities, surrounding nature, as well as on people; Security and comfort to passengers [1–4]. According to the results of experimental studies, determined the dependences of the aerodynamic drag on the speed [5]; the interaction of a moving high-speed train with objects located along the railway, including trains moving along a parallel path [3, 4, 6–8]; the physics of the formation of aerodynamic flows in separate parts of a moving high-speed train [5, 9].

doi 10.15802/stp2017/113192

Theoretical studies performed on the model of a high-speed train as an axisymmetric body made it possible to establish the magnitude and velocity vector of secondary air currents, as well as aerodynamic effects on railway infrastructure objects and people [10].

Providing traffic safety for trains and passengers; uninterrupted operation of the entire infrastructure of high-speed railway is the main condition for the organization of high-speed and high-speed passenger train traffic. A high degree of security is usually provided at all stages of creating a high-speed highway, i.e. is laid during the design, is provided during construction and is implemented in the course of operation of the infrastructure of high-speed railways. This task is relevant in the design of high-speed train traffic on existing railways, which were designed for the maximum speed of passenger trains of 120–160 km/h.

Since, on existing lines, high-speed traffic is possible after a large-scale reconstruction and modernization of permanent facilities and structures of the existing infrastructure, when designing a high-speed traffic organization using the existing railway infrastructure, the maximum permissible speeds for a high-speed train for each facility should be set separately taking into account their technical condition.

Purpose

To ensure the safe operation of a high-speed railway, it is necessary to consider the aerodynamic impact on people and railway infrastructure objects as one of the main safety criteria for high-speed passenger train traffic, since a train moving at high speed exerts aerodynamic impact on each i-th object by the $P_{\max i}$ value.

In this case, the technical state of the i-th object allows him to perceive the impact with the maximum permissible value of P_{peri} without reducing the safety level of movement high-speed trains.

In connection with the foregoing, in order to ensure the safe operation of a high-speed railway on all sites or structural elements of the infrastructure of the existing path, the condition

$$P_{\max i} \le P_{peri} . \tag{1}$$

Since, according to Bernoulli's law, the aerodynamic pressure varies directly in proportion to the speed of the air flow V_f created by the movement of a high-speed train, let us consider the theoretical aspects of establishing the value of the maximum train speed ensuring the fulfillment of condition (1).

Methodology

The aerodynamic impact, strength and directivity of pressure on an object depend on the maximum speed and duration of the air flow, the spatial location, availability and proximity of the railway infrastructure objects relative to a moving high-speed train.

For each i-th object (or its structural element) of the infrastructure of the existing railway, it is possible to compute a design scheme of the effect of aerodynamic pressure on it (Fig. 1). In all calculation cases, for a known distance B from a moving high-speed train to an object and the maximum permissible impact that a given P_{peri} object can perceive, it is necessary to determine the speed of the high-speed train $V_{\max i}$ and hence the airflow rate V_f that satisfies condition (1).

Thus, the task of determining the aerodynamic impact on object $\boldsymbol{i}$ is reduced to determining the speed of the secondary airflow V_{fi} directly at the i-th object when the high-speed train moves at a speed $V_{\max i}$.

As the development of earlier studies [10] the distribution of the air flow and the determination of its velocity along a moving high-speed train, we investigate on a model of a train consisting of a locomotive and $2n$ wagons. Locomotive and wagons are presented as an axisymmetric body with streamlined forms of the head and tail parts moving in a compressible (acoustic) medium [10].

To simplify the calculations, we assume that the locomotive and all wagons in the cross section have the same shape, i.e. Consist of a circular cylinder with the same shape of the head and tail in the form of cones (Fig. 2).

The axisymmetric wave equation of the aerodynamic field near a high-speed train consisting of a locomotive and $2n$ wagons is solved both for a train consisting of one single wagon [8].

doi 10.15802/stp2017/113192

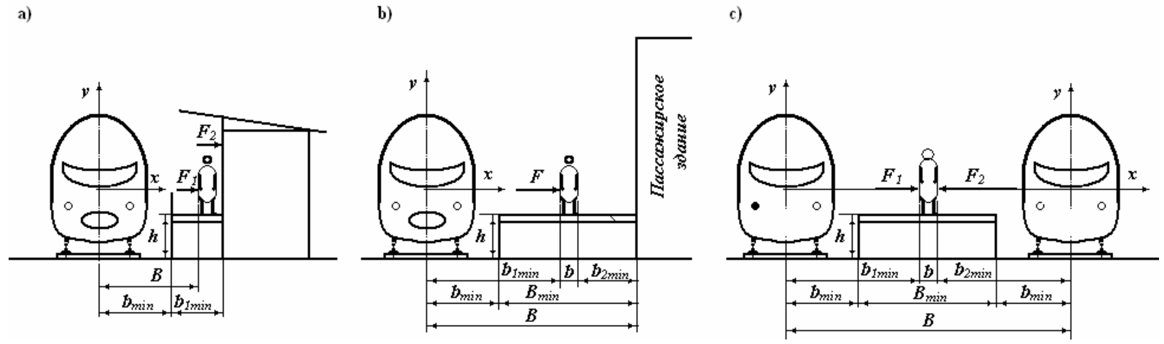

Fig. 1. Calculation schemes for the location of high-speed train and facilities:
a – «train-man-object»; *b* – «train-passenger on the platform-object»;
c – «train-passenger on the platform-train»

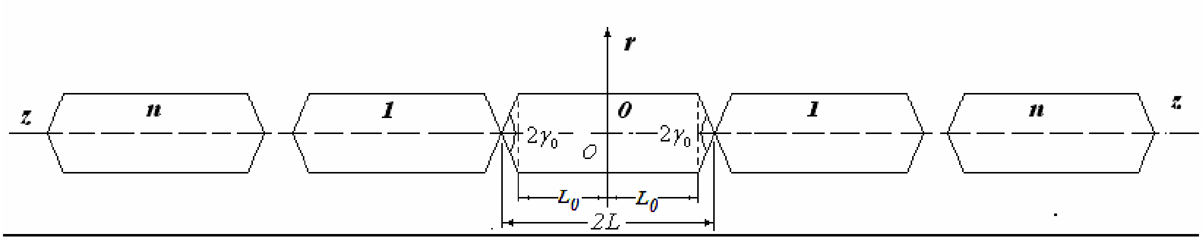

Fig. 2. Scheme of a high-speed train with a locomotive and 2*n* wagons

In the given case, we consider the function $f(z)$ for each wagons can be represented in the form $f_{ij}(z)$, where the index i indicates the ordinal number of the wagons from the center of the train ($j = 0$ corresponds to the number of the middle car), the index j on the geometric shape of the part of the wagons. If we assume that the wagon consists of three geometric parts, i.e. Head, cylindrical, tail parts, then $j = 1, 2, 3$ ($j = 1$ corresponds to the cylindrical part, $j = 2$ the tail part, $j = 3$ the head part).

The propagation of an acoustic wave in the air medium can be represented by the equation (2) with the boundary conditions (3) and (5) [10]. The condition that the component along the velocity axis of the medium on the boundary of the half-space be zero, in contrast to equation (4) [11], takes the following form

$$\frac{\partial \varphi_1}{\partial y} = 0 \text{ at } y = -h - R - f(z). \qquad (2)$$

To find the solution of the equation, the method of sources was used [11]. Considering the function $\varphi(r, z)$ satisfying (2), the boundary conditions (3), (5) [9] and (2), the solution in [10] can be represented in the form

$$\varphi_1 = -\frac{1}{4\pi} \int_{-(2n+1)L}^{(2n+1)L} \frac{q(\xi)d\xi}{\sqrt{(\xi - z)^2 + \alpha^2 r^2}}. \qquad (3)$$

Where $q(z)$ – is the power of the source distributed over the surface of the moving body within $0 < r < f_{ij}(z)$, $-(2n+1)L < z < (2n+1)L$.

For an axisymmetric body from formula (3) to [12], it can be asserted that

$$\frac{\partial \varphi_1}{\partial r} \to \frac{q(z)}{2\pi r} \quad \text{at} \quad r \to 0. \qquad (4)$$

Since the problem is symmetrical with respect to the axis $0z$, a high-speed train consists of a locomotive and $2n$ wagons, the equation of the surface of the body $r = f_{ij}(z)$, as well as the power of the source from each car $q(z)$ and its components can be recorded separately.

For the cylindrical part of the car:

at $2nL - L_0 < z < 2nL + L_0$ and

$(2nL + L_0) < z < -(2nL - L_0)$ $\quad f_{n1} = R \quad q = 0$.

doi 10.15802/stp2017/113192

For the head and tail parts of the wagon located up to the middle of the train:

at $\quad 2nL + L_0 < z < (2n+1)L$

$f_{n2} = \gamma_0[(2n+1)L - z] \qquad q = -2\pi v_0 \gamma_0^2 f_{n,2}$;

and $\quad -(2n+1)L < z < -(2nL + L_0)$

$f_{n2} = \gamma_0[(2n+1)L + z] \qquad q = 2\pi v_0 \gamma_0^2 f_{n,2}$.

For the head and tail parts of the wagon located behind the middle of the train:
at $(2n+1)L < z < (2n+1)L + L_0$

$f_{n3} = \gamma_0[z - (2n+1)L] \quad q = -2\pi v_0 \gamma_0^2 f_{n3}$;

and $\quad -[(2n+1)L + L_0[< z < -(2n+1)L$

$f_{n3} = -\gamma_0[(2n+1)L + z] \qquad q = -2\pi v_0 \gamma_0^2 f_{n,3}$.

For example, for a wagon $i = 1$ and its part $j = 2$ as: $2L + L_0 < z < 3L$; $f_{12} = \gamma_0(3L - z)$; $q = -2\pi v_0 \gamma_0^2 f_{12}$.

Taking into account the symmetry of the problem with respect to the variable z, the power of the source from each car and its components $q(z)$, equation (3) can be represented in the following form

$$\varphi_1 = -\frac{v_0\gamma_0^2}{2}\left\{\sum_{i=0}^{n}\left[\int\limits_{2iL+L_0}^{(2i+1)L} \frac{(2i+1)L-\xi}{\sqrt{(z+\xi)^2+\alpha^2 r^2}}d\xi - \int\limits_{2iL+L_0}^{(2i+1)L}\frac{(2i+1)L-\xi}{\sqrt{(z-\xi)+\alpha^2 r^2}}d\xi\right]\right\} +$$

$$+\frac{v_0\gamma_0^2}{2}\left\{\sum_{i=1}^{n}\left[\int\limits_{(2i-1)L}^{2iL-L_0} \frac{\xi-(2i-1)L}{\sqrt{(z+\xi)^2+\alpha^2 r^2}}d\xi - \int\limits_{(2i-1)L}^{2iL-L_0}\frac{\xi-(2i-1)L}{\sqrt{(z-\xi)+\alpha^2 r^2}}d\xi\right]\right\}. \qquad (5)$$

We introduce a new variable $r_{ij} = r_{ij}(x, y, z)$ expressed by the formula

$$r_{ij} = \sqrt{x^2 + [2f_{ij}(z) + 2h + 2R + y]^2}\,. \qquad (6)$$

And consider the total potential presented in the form

$$\varphi_n = \varphi_1(r, z) + \varphi_1[r_{ij}(x.y,z), z]\,. \qquad (7)$$

The function $\varphi_n(x, y, z)$ satisfies the boundary condition (2), and the function $\varphi_1 = \varphi_1[r_{ij}(x.y,z), z]$ satisfies equations (4) only for $\gamma_0 = 0$. Assuming γ_0 a small parameter and setting $f_{ij} = \gamma_0 f_{0ij}$ the function $1/r_{ij} = 1/\sqrt{x^2 + [2\gamma_0 f_{0ij}(z) + 2h + 2R + y]^2}$, we can expand in powers of this parameter as

$$\frac{1}{r_{ij}} = \frac{1}{\sqrt{x^2 + [2\gamma_0 f_{0ij}(z) + 2h + y]^2}} =$$

$$= \frac{1}{r_1} + \gamma_0 \frac{2(2h + y) f_{0ij}(z)}{r_1^3} + \ldots, \qquad (8)$$

where $r_1 = \sqrt{x^2 + (2h + 2R + y)^2}$.

If we substitute expression (8) into (5), then formula (7) takes the form

$$\varphi_n = \gamma_0^2[\varphi_{01}(r, z) + \varphi_{01}(r_1, z) + \gamma_0 \varphi_{02} + \ldots], \qquad (9)$$

where

$$\varphi_{01} = -\frac{v_0}{2}\left\{\sum_{i=0}^{n}\left[\int\limits_{2iL+L_0}^{(2i+1)L} \frac{(2i+1)L-\xi}{\sqrt{(z+\xi)^2+\alpha^2 r^2}}d\xi - \int\limits_{2iL+L_0}^{(2i+1)L}\frac{(2i+1)L-\xi}{\sqrt{(z-\xi)+\alpha^2 r^2}}d\xi\right]\right\} +$$

$$+\frac{v_0}{2}\left\{\sum_{i=1}^{n}\left[\int\limits_{(2i-1)L}^{2iL-L_0} \frac{\xi-(2i-1)L}{\sqrt{(z+\xi)^2+\alpha^2 r^2}}d\xi - \int\limits_{(2i-1)L}^{2iL-L_0}\frac{\xi-(2i-1)L}{\sqrt{(z-\xi)+\alpha^2 r^2}}d\xi\right]\right\}; \qquad (10)$$

doi 10.15802/stp2017/113192

$$\varphi_{02} = v_0 \left\{ \sum_{i=0}^{n} \left[\int\limits_{2iL+L_0}^{(2i+1)L} \frac{[(2i+1)L-\xi](2h+y]f_{0ij}(z)}{\sqrt{[\{(z+\xi)^2+\alpha^2 r_1^2]^3}} d\xi - \int\limits_{2iL+L_0}^{(2i+1)L} \frac{[(2i+1)L-\xi][2h+y]f_{0ij}(z)}{\sqrt{][z-\xi)+\alpha^2 r_1^2]^3}} d\xi \right] \right\} +$$

$$+ v_0 \left\{ \sum_{i=1}^{n} \left[\int\limits_{(2i-1)L}^{2iL-L_0} \frac{[\xi-(2i-1)L][2h+y]f_{0ij}(z)}{\sqrt{[(z+\xi)^2+\alpha^2 r_1^2]^3}} d\xi - \int\limits_{(2i-1)L}^{2iL-L_0} \frac{[\xi-(2i-1)L][2h+y]f_{0ij}(z)}{\sqrt{[(z-\xi)+\alpha^2 r_1^2]^3}} d\xi \right] \right\}. \qquad (11)$$

In the sum of potentials (9), the first approximation is a function φ_{01} that satisfies equation (6) [10] and boundary condition (2).

The components of the velocity vector of air particles can be determined by the following formulas

$$\frac{\partial \varphi_n}{\partial x} = \frac{\partial \varphi_{01}(r,z)}{\partial r} \frac{\partial r}{\partial x} + \frac{\partial \varphi_{01}(r_1,z)}{\partial r_1} \frac{\partial r_1}{\partial x} = \frac{v_0 x}{2r} \left\{ \sum_{i=0}^{n} \left[\int\limits_{2iL+L_0}^{(2i+1)L} \frac{(2i+1)L-\xi}{(z+\xi)^2+\alpha^2 r^2} d\xi - \int\limits_{2iL+L_0}^{(2i+1)L} \frac{(2i+1)L-\xi}{(z-\xi)^2+\alpha^2 r^2} d\xi \right] \right\} -$$

$$- \frac{v_0 x}{2r} \left\{ \sum_{i=1}^{n} \left[\int\limits_{(2i-1)L}^{2iL-L_0} \frac{\xi-(2i+1)L}{(z+\xi)^2+\alpha^2 r^2} d\xi - \int\limits_{(2i-1)L}^{2iL-L_0} \frac{\xi-(2i-1)L}{(z-\xi)^2+\alpha^2 r^2} d\xi \right] \right\} +$$

$$+ \frac{v_0 x}{2r_1} \left\{ \sum_{i=0}^{n} \left[\int\limits_{2iL+L_0}^{(2i+1)L} \frac{(2i+1)L-\xi}{(z+\xi)^2+\alpha^2 r_1^2} d\xi - \int\limits_{2iL+L_0}^{(2i+1)L} \frac{(2i+1)L-\xi}{(z-\xi)^2+\alpha^2 r_1^2} d\xi \right] \right\} -$$

$$- \frac{v_0 x}{2r_1} \left\{ \sum_{i=1}^{n} \left[\int\limits_{(2i-1)L}^{2iL-L_0} \frac{\xi-(2i-1)L}{(z+\xi)^2+\alpha^2 r_1^2} d\xi - \int\limits_{(2i-1)L}^{2iL-L_0} \frac{\xi-(2i+1)L}{(z-\xi)^2+\alpha^2 r_1^2} d\xi \right] \right\}; \qquad (12)$$

$$\frac{\partial \varphi_n}{\partial y} = \frac{\partial \varphi_1(r,z)}{\partial r} \frac{\partial r}{\partial y} + \frac{\partial \varphi_1(r_1,z)}{\partial r_1} \frac{\partial r_1}{\partial y} = \frac{v_0 y}{2r} \left\{ \sum_{i=0}^{n} \left[\int\limits_{2iL+L_0}^{(2i+1)L} \frac{(2i+1)L-\xi}{(z+\xi)^2+\alpha^2 r^2} d\xi - \int\limits_{2iL+L_0}^{(2i+1)L} \frac{(2i+1)L-\xi}{(z-\xi)^2+\alpha^2 r^2} d\xi \right] \right\} -$$

$$- \frac{v_0 y}{2r} \left\{ \sum_{i=1}^{n} \left[\int\limits_{(2i-1)L}^{2iL-L_0} \frac{\xi-(2i+1)L}{(z+\xi)^2+\alpha^2 r^2} d\xi - \int\limits_{(2i-1)L}^{2iL-L_0} \frac{\xi-(2i-1)L}{(z-\xi)^2+\alpha^2 r^2} d\xi \right] \right\} +$$

$$+ \frac{v_0 (y+2h+2R)}{2r_1} \left\{ \sum_{i=0}^{n} \left[\int\limits_{2iL+L_0}^{(2i+1)L} \frac{(2i+1)L-\xi}{(z+\xi)^2+\alpha^2 r_1^2} d\xi - \int\limits_{2iL+L_0}^{(2i+1)L} \frac{(2i+1)L-\xi}{(z-\xi)^2+\alpha^2 r_1^2} d\xi \right] \right\} -$$

$$- \frac{v_0 (y+2h+2R)}{2r_1} \left\{ \sum_{i=1}^{n} \left[\int\limits_{(2i-1)L}^{2iL-L_0} \frac{\xi-(2i-1)L}{(z+\xi)^2+\alpha^2 r_1^2} d\xi - \int\limits_{(2i-1)L}^{2iL-L_0} \frac{\xi-(2i-1)L}{(z-\xi)^2+\alpha^2 r_1^2} d\xi \right] \right\}; \qquad (13)$$

$$\frac{\partial \varphi_n}{\partial z} = \frac{\partial \varphi_1(r,z)}{\partial z} + \frac{\partial \varphi_1(r_1,z)}{\partial z} = \frac{v_0}{2} \left\{ \sum_{i=0}^{n} \left[\int\limits_{2iL+L_0}^{(2i+1)L} \frac{[(2i+1)L-\xi](z+\xi)}{(z+\xi)^2+\alpha^2 r^2} d\xi - \int\limits_{2iL+L_0}^{(2i+1)L} \frac{[(2i+1)L-\xi](z-\xi)}{(z-\xi)^2+\alpha^2 r^2} d\xi \right] \right\} -$$

$$- \frac{v_0}{2} \left\{ \sum_{i=1}^{n} \left[\int\limits_{(2i-1)L}^{2iL-L_0} \frac{[\xi-(2i-1)L](z+\xi)}{(z+\xi)^2+\alpha^2 r^2} d\xi - \int\limits_{(2i-1)L}^{2iL-L_0} \frac{[\xi-(2i-1)L](z-\xi)}{(z-\xi)^2+\alpha^2 r^2} d\xi \right] \right\} +$$

$$- \frac{v_0}{2} \left\{ \sum_{i=0}^{n} \left[\int\limits_{2iL+L_0}^{(2i+1)L} \frac{[(2i+1)L-\xi](z+\xi)}{(z+\xi)^2+\alpha^2 r_1^2} d\xi - \int\limits_{2iL+L_0}^{(2i+1)L} \frac{[(2i+1)L-\xi](z-\xi)}{(z-\xi)^2+\alpha^2 r_1^2} d\xi \right] \right\} -$$

$$- \frac{v_0}{2} \left\{ \sum_{i=1}^{n} \left[\int\limits_{(2i-1)L}^{2iL-L_0} \frac{[\xi-(2i-1)L](z+\xi)}{(z+\xi)^2+\alpha^2 r_1^2} d\xi - \int\limits_{(2i-1)L}^{2iL-L_0} \frac{[\xi-(2i-1)L](z-\xi)}{(z-\xi)^2+\alpha^2 r_1^2} d\xi \right] \right\}. \qquad (14)$$

doi 10.15802/stp2017/113192

The absolute speed of the air flow constitute by the system of high-speed train cars when it moves at a steady speed at an arbitrary point M (x, y, z) can be defined as

$$v = \sqrt{v_x^2 + v_y^2 + v_z^2}\ . \qquad (15)$$

The airflow pressure can be determined from formula

$$\Delta p = -\rho_0 \frac{\partial \varphi}{\partial t} = \rho_0 v_0 \left[\ \frac{\partial \varphi_1(r,z)}{\partial z} + \frac{\partial \varphi_1(r_1,z)}{\partial z}\ \right]. \qquad (16)$$

Findings

As an example, the establishment of the maximum permissible speed of a high-speed train for a protected rail crossing is considered.

In this case, the most vulnerable object to the effect of aerodynamic pressure is the duty guard on the guarded crossing. In the calculations it is assumed that a high-speed train consists of a locomotive and four wagons, i.e. $n = 2$, the length of the locomotive and wagons $L = 25$ m, the total length of the train $L_{tr} = 125$ m, $R = 2$ m, $\rho_0 = 1.2\ \mathrm{kg/m^3}$, the speed of the train v_0 is assumed to be 160, 200, 250, 350, 400 km/h. For visual study of the influence between wagons space on the magnitude of aerodynamic pressure, space was artificially created.

Based on the results of the calculations, graphs are constructed of the change in the aerodynamic pressure of the air flow during the passage of a high-speed train at a speed of 200 km/h along the duty room of the guard on the guarded crossing (Fig. 3).

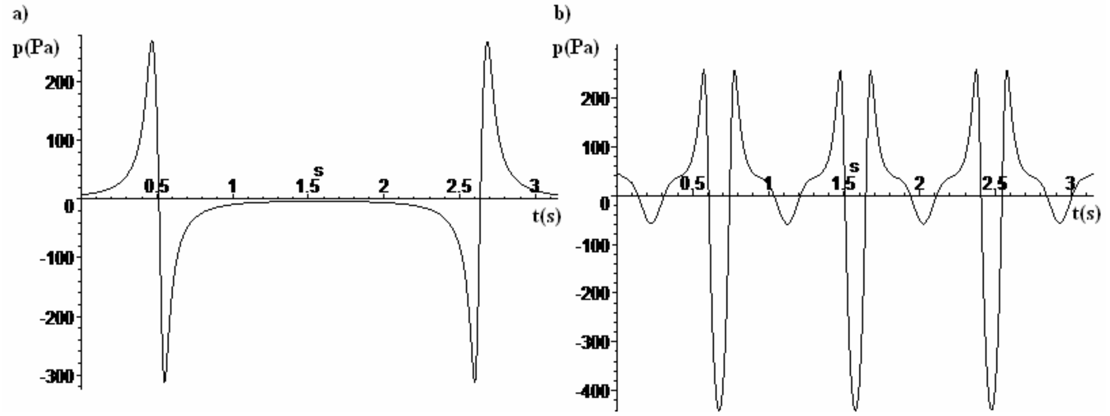

Fig. 3. Graphs of the change in aerodynamic airflow pressure versus time:
a – with closed and *b* – open between wagon spaces

Analysis of the graphs shows that in both cases the negative pressure is greater than the positive one. The reliability of these calculations is confirmed by the results of previous experiments in the US, Russia, Sweden. The effect between the wagons space on the magnitude of the negative (suction) aerodynamic pressure is clearly visible in the graph shown in Fig. 3, b. On the railways of individual states, the movement of dual high-speed trains is practiced. With sufficient streamlining of the head and tail wagons, in places the pairing of trains produces a negative aerodynamic pressure, the value of which considerably exceeds the value of the excess pressure. Similar graphs can be constructed for other velocities and distances.

Thus, it can be argued that in order to ensure the safe operation of the railway infrastructure, it is necessary to take into account the aerodynamic flows and pressures in their independence.

Using the results of calculations, it is also possible to construct a curve for the dependence of the magnitude of aerodynamic pressure on the speed of trains and the distance to the considered point $P_{\max}$ (Fig. 4), similarly to Fig. 3 [7]. Using these dependencies, you can set the maximum permissible speed of a high-speed train along an object. Suppose that in the considered calculation case the permissible value of the aerodynamic impact on the moving attendant is known, which according to the sanitary norms should not exceed 100 PA. In this case, the distance on which the

doi 10.15802/stp2017/113192

office space is located is regulated by the C dimension in accordance with GOST 9238 and should be at least 2.45 m from the track axis. Using the curve $P_{\max}$ shown in Fig. 4, one can find the intersection point of the lines corresponding to the aerodynamic pressure of 100 PA and a distance of 2.45 m, i.e. Train speed.

Thus, when a high-speed train moves at a maximum speed of 150 km/h, the corresponding condition (1) will be satisfied by the value of this point, i.e. safety of the shift attendant.

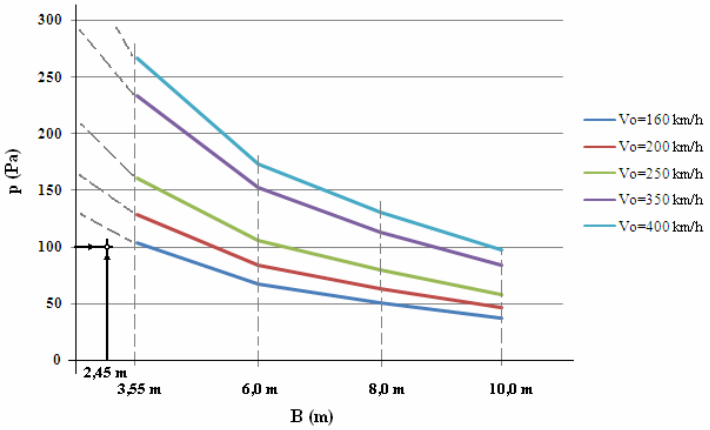

Fig. 4. The curves of the dependence of aerodynamic pressure on the speed of trains (V_0) and the distance to the object (B)

Originality and practical value

Theoretical studies of aerodynamic pressure from secondary air currents formed during the movement of high-speed trains are performed on a model of a train composed of identical axisymmetric bodies with conical forms of head and tail moving in a compressible medium. The results of the research allow us to establish the patterns of variation in aerodynamic pressure during the movement of a high-speed train.

Conclusions

The obtained results allow to establish:

– the maximum permissible speed of a high-speed train, taking into account the technical condition of permanent devices and structures of the existing railway infrastructure;

– technical parameters of individual objects and structural elements of high-speed iron infrastructure subjected to the effect of aerodynamic pressure for a given maximum speed of high-speed trains.

The proposed method can be used in the practice of designing high-speed train traffic both on existing and newly constructed railways.

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УЧЕТ АЭРОДИНАМИЧЕСКОГО ВОЗДЕЙСТВИЯ ПРИ УСТАНОВЛЕНИИ МАКСИМАЛЬНО-ДОПУСТИМЫХ СКОРОСТЕЙ ДВИЖЕНИЯ ВЫСОКОСКОРОСТНОГО ПОЕЗДА

Цель. В работе предполагается провести исследования влияния аэродинамического давления на максимально-допустимые скорости движения высокоскоростного поезда по существующей инфраструктуре железной дороги. **Методика.** Исследование величины и направления аэродинамического давления, его влияние на максимальные скорости высокоскоростного поезда проведено на модели поезда, составленного из осесимметричных тел с коническими формами головных и хвостовых частей. **Результаты.** Определены значения аэродинамического давления на различном расстоянии от поезда при движении высокоскоростного поезда со скоростью 200 км/ч и более. Установлены максимальные скорости движения высокоскоростного поезда с учетом состояния объектов инфраструктуры существующей железной дороги, что обеспечивает безопасное функционирование высокоскоростной железной дороги. **Научная новизна.** Теоретические исследования аэродинамического давления от вторичных воздушных потоков, образуемых при движении высокоскоростных поездов, выполнены на модели поезда, составленного из одинаковых осесимметричных тел с коническими формами головных и хвостовых частей, движущегося в сжимаемой среде. Результаты исследований позволяют установить закономерности изменения аэродинамического давления при движении высокоскоростного поезда. **Практическая значимость.** Полученные результаты позволяют установить: 1) максимально-допустимые скорости высокоскоростного поезда с учетом технического состояния постоянных устройств и сооружений существующей инфраструктуры железных дорог; 2) технические параметры отдельных объектов и конструкционных элементов инфраструктуры высокоскоростных железных дорог, подвергающихся

doi 10.15802/stp2017/113192

воздействию аэродинамического давления при заданном значении максимальной скорости движения высокоскоростных поездов.

Ключевые слова: железнодорожный транспорт; высокоскоростное движение поездов; аэродинамика; аэродинамическое давление; инфраструктура железной дороги; максимальные скорости; технические параметры

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ВРАХУВАННЯ АЕРОДИНАМІЧНОГО ВПЛИВУ ПРИ ВСТАНОВЛЕННІ МАКСИМАЛЬНО-ПЕРЕДБАЧЕНИХ ШВИДКОСТЕЙ РУХУ ВИСОКОШВИДКІСНОГО ПОТЯГУ

Мета. У роботі передбачається провести дослідження впливу аеродинамічного тиску на максимально-допустимі швидкості руху високошвидкісного поїзду по існуючій інфраструктурі залізниці. **Методика**. Дослідження величини та напрямку аеродинамічного тиску, його впливу на максимальні швидкості високошвидкісного поїзду проведено на моделі поїзда, складеного з осесиметричних тіл із конічними формами головних і хвостових частин. **Результати**. Визначено значення аеродинамічного тиску на різній відстані від поїзда при русі високошвидкісного поїзда зі швидкістю 200 км/год і більше. Встановлено максимальні швидкості руху високошвидкісного поїзда з урахуванням стану об’єктів інфраструктури існуючої залізниці, що забезпечує безпечне функціонування високошвидкісної залізниці. **Наукова новизна**. Теоретичні дослідження аеродинамічного тиску від вторинних повітряних потоків, утворених при русі високошвидкісних поїздів, виконані на моделі поїзда, складеного з однакових осесиметричних тіл із конічними формами головних і хвостових частин, що рухається в стискуваному середовищі. Результати досліджень дозволяють установити закономірності зміни аеродинамічного тиску при русі високошвидкісного поїзда. **Практична значимість**. Отримані результати дозволяють встановити: 1) максимально-допустимі швидкості високошвидкісного поїзда з урахуванням технічного стану постійних пристроїв і споруд існуючої інфраструктури залізниць; 2) технічні параметри окремих об’єктів та конструкційних елементів інфраструктури високошвидкісних залізниць, що піддаються впливу аеродинамічного тиску при заданому значенні максимальної швидкості руху високошвидкісних поїздів.

Ключові слова: залізничний транспорт; високошвидкісний рух поїздів; аеродинаміка; аеродинамічний тиск; інфраструктура залізниці; максимальні швидкості; технічні параметри

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Prof. M. B. Kurhan, D. Sc. (Tech.), (Ukraine); Prof. S. S. Fayzibaev, D. Sc. (Tech.), (Uzbekistan) recommended this article to be published

Received: May 17, 2017
Accessed: Sept. 21, 2017

doi 10.15802/stp2017/113192