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Shkvar Ye.O., E Shi-ju, Kryzhanovskyi A.S.

ENGINEERING IMPLEMENTATION OF HIGH-SPEED TRAIN DRAG REDUCTION TECHNOLOGY, BASED ON MICROBLOWING

Introduction

Turbulent Flow Control is one of the most perspective directions for improvement of modern transport properties. In particular, the possibilities and preferences of application of one of turbulent flow control methods, called microblowing (injection of a small amount of fluid through the penetrable streamlined surface into the turbulent boundary layer), to high-speed trains (fig. 1) have been proposed and analyzed in [1] on the base of the elaborated mathematical model of turbulent external flow. This paper is dedicated to developing the engineering scheme of microblowing technology implementation and analysis of its various aspects.

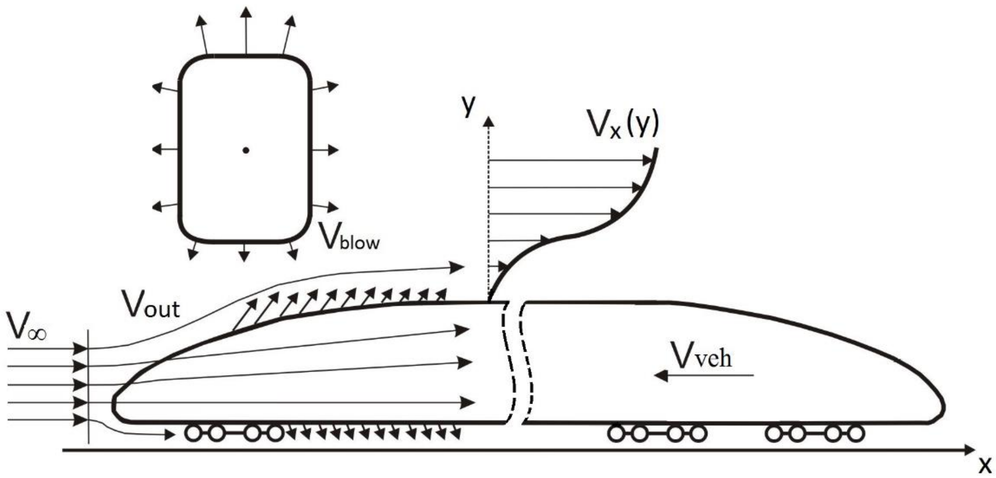

Fig. 1. Air flow structure around body of high-speed train, modified by non-uniform blowing

The closest analogue, which is essentially identical to the constructive design and therefore adopted as a prototype, is a device of realization of method of reducing the surface friction of an airplane or vessel by means of blowing some insignificant amount of air through a permeable streamlined surface perpendicular to it [2-4]. This method allows to control the velocity gradient of the external flow and reduce the roughness of the outer layer of the surface, thereby reducing surface friction. It is technically realized through the organization of porosity of the streamlined surface by array of micro-holes made in it, tools for supplying and distributing air to the permeable surface; device, intended to implement mentioned above method, contains a body which has a casing, a permeable shell, and interface air space zone, formed between the casing and the shell. The casing has surface with holes through which gas is supplied as well as means for transferring gas through the array of small holes.

The proposed engineering scheme is based on the task of creating an engineering solution aimed to change (decrease) the two main components of the total aerodynamic drag, namely, the surface friction drag R_f and the shape drag R_p in order to improve performance (increase speed) and reduce power consumption.

Numerous studies [1-8] give grounds to assert that already traditional for the aviation industry blowing technologies are perspective in in railway transport, especially for high-speed trains. The use of blowing technologies in the railway sector has several advantages:

– the proposed blowing technology does not affect the stability of the railway vehicle, since the direction of motion is determined by the fixed direction of the rails and under normal operating conditions (in the absence of a strong side wind) it does not cause dangerous flow separation modes;

– the application of blowing technologies is expedient, first of all, for high-speed trains, since it most effectively acts on friction drag R_f. The shape of the streamlined surface of the aircraft fuselage or the underwater part of the ship's hull, submarine or torpedo is very similar to the shape of the head part of the car, but the train is much more stretched and, accordingly, the aerodynamic drag to the movement of the high-speed train will be formed to the greatest extent due to the friction component, which determines the feasibility of using blowing exactly to minimize R_f;

– the effects associated with the effect of air compressibility, such as the appearance of shock waves and their strong interaction with the boundary layer, which are unavoidable in the flow around the outer surfaces of the most common transonic airplanes in civil transport aviation, are not relevant and should not be taken into account as factors that negatively affect the efficiency of blowing technology realization;

– for blowing the air can effectively be bled from the frontal part of the head car, and then to redistribute it along the streamlined surface. It allows to reduce the overpressure near the stagnation point and, in addition, to reduce the pressure drag R_p due to the centralized air bleeding required for blowing system operation, in the vicinity of the forward stagnation point.

Principal structure of the proposed engineering implementation of microblowing

The first key point of the proposal is a device of realization of the method for reducing the aerohydrodynamic drag of high-speed trains and other vehicles by means of mass transfer through a streamlined surface of a vehicle. This method consists in formation of a non-uniform blowing of a small (percentage share) quantity of a working fluid (gas or liquid) through the permeable streamlined surface of the vehicle, equipped with tools for supply and distribution of the working fluid, into its boundary layer (wall layer) for local reduction of wall friction drag. A new important aspect of this engineering solution is the fact that the non-uniformity of the blown stream of the working fluid is achieved by changing the flow rate of the working fluid while blowing along and across the streamlined surface 1, possible inconstancy of the angle of injection, as well as by intermittent sections of the permeable 2 and impermeable surfaces (fig. 2).

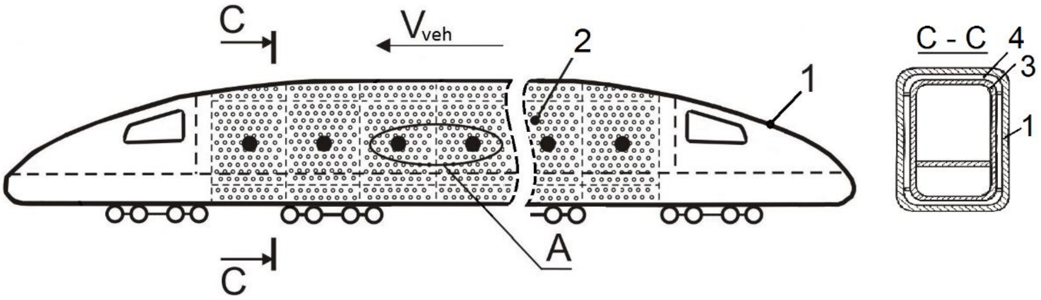

Fig. 2. Penetrable structure of high-speed train streamlined surface

The second key point of the proposal is the device for reducing the aerohydrodynamic drag of high-speed trains and other vehicles by mass transfer through a streamlined surface consisting of an outer streamlined surface 1, made of permeable (naturally or artificially) by micro-holes porous material 2, and an impermeable inner shell 3 that is separated from the outer shell by a certain gap (fig. 3).

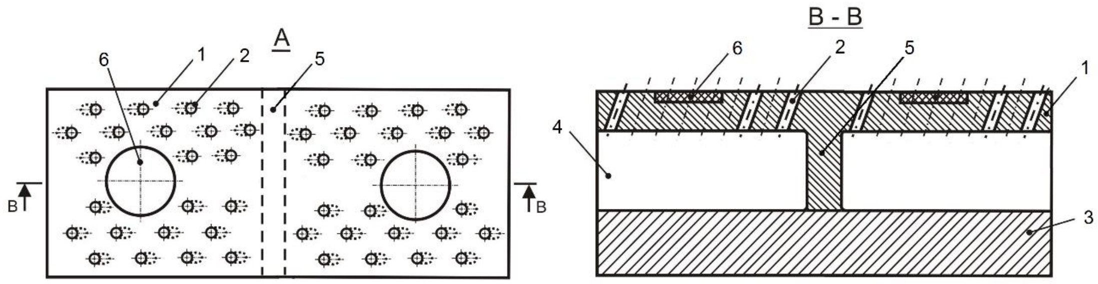

Fig. 3. Penetrable structure of high-speed train streamlined surface sections

Internal partitions 4 are located between the outer and inner shells, dividing the formed cavity into separated sections 5. Active control of turbulent flows over different sections is carried out by means of a closed control system. Internal partitions are made vertical, horizontal or intersecting, each of the sections formed by inner partitions is equipped with pressure sensor 6, connected to a switching computing device that regulates the independent supply of working fluid into each of the sections of the internal cavity by means of appropriate actuating throttling devices. A massively-parallel computing device should be used as the computing device to regulate the supply of the working fluid independently to each of the internal cavity sections in real time by means of appropriate actuators. Pressure sensors and corresponding actuators should be small enough and can be effectively based on micro- or nanoelectromechanical systems. One more principal aspect of this scheme is the fact that the permeable (perforated) sections formed by the inner partitions are disposed on the surface of the vehicle one by one in succession with impermeable sections of the outer shell. Besides, these permeable sections are located one near another with alternating sections with the angle of inclination of the blowing holes axes on the outer shell with respect to the direction of the working fluid flow around the surface which is less than 90° and more than 90°. Depending on the direction of movement of the vehicle, first or second are operated or both of them are functioned in different modes to generate in the wall area artificial longitudinal vortex systems, which regularize and regulate the wall turbulent exchange in order to additionally reduce the friction drag. The change in the operating mode of adjacent permeable sections is achieved by appropriate throttling with the control system. The supply of the working fluid (gas or liquid) to each of the sections formed in the cavity between the permeable (perforated) and impermeable shells is performed by means of intake device of the working fluid placed in the aerodynamic shroud of the frontal part. The distribution of the working fluid flow is carried out to each section through the internal pipelines of the vehicle.

Intake and air redistribution system is organized as follows: In the front part of the high-speed train (fig. 4) there is an air intake 7 with an air filter 8, connected to the internal pipeline 9. The installation of the air intake 7 in the aerodynamic shroud of the front section 10 of the high-speed train allows to reduce the pressure gradient in the direction of the longitudinal axis, which improves the air flow around the nose part and reduces the shape drag R_p. The internal pipeline 9 connects the air intake 7 to each of separate sections 11 and entering air flux is controlled by the corresponding valves 12.

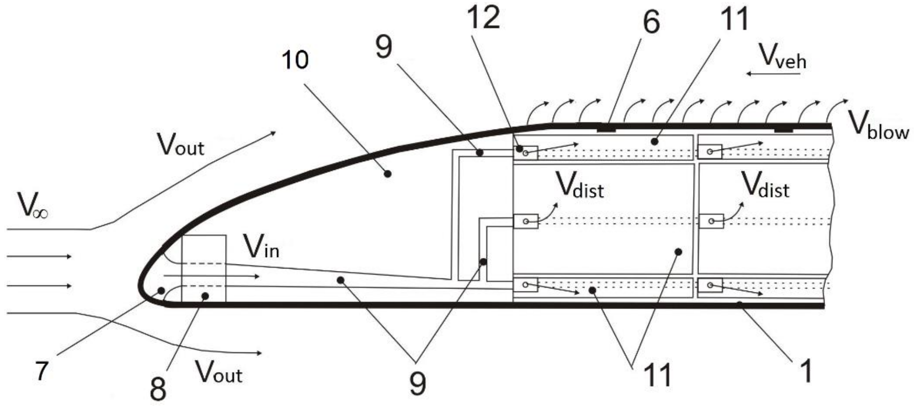

Fig. 4. A scheme of the intake and air redistribution system

In the advanced models of high-speed trains, the air intake system can optionally provide for the presence of an additional compressor that intensifies the intake of air, which will further contribute to the concomitant operation of the air injection system with the effect of reducing the shape drag R_p . In addition, in order to maintain its efficiency, the system must be equipped with air purification filters in order to prevent contamination of the injection holes.

Conclusions

The realistic engineering implementation of realization of the method for the aerohydrodynamic drag reduction of high-speed trains by means of microblowing through the streamlined surface is proposed.

Further research step will be associated with more detailed and optimal design of the above mentioned structural elements of this engineering implementation.

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