UDC 629.3
DOI: 10.15587/1729-4061.2025.320494

JUSTIFICATION OF CHOOSING A REASONABLE DISTANCE BETWEEN THE DRIVER'S CABIN AND THE SEMI-TRAILER TO REDUCE THE AERODYNAMIC RESISTANCE OF THE VEHICLE

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The object of the study is the aerodynamic resistance of a main road train and its influence on the efficiency of the transportation process.

Reducing the aerodynamic resistance of road trains is an important problem, since fuel consumption and transportation efficiency depend on it. A 2 % reduction in aerodynamic drag reduces fuel consumption by 1 %. Reduction of aerodynamic resistance is achieved by using special aerodynamic devices. But their use creates a number of problems – an increase in the weight of the road train and its overall dimensions, etc.

It is assumed that by choosing a rational distance between the cab and the semi-trailer of the road train, it is possible to significantly reduce fuel consumption.

The obtained results show that the total aerodynamic resistance of the road train significantly depends on the distance between the driver's cabin and the semi-trailer. This is explained by the fact that in the space between the cabin and the semi-trailer, vortices of the air flow occur, which leads to an increase in aerodynamic resistance. The resulting dependence of excess pressure in the space between the cabin and the semi-trailer on the distance between them makes it possible to determine two ranges of distances where this pressure will be minimal. In contrast to known studies, the results of the modeling make it possible to establish a rational distance between the cab and the semi-trailer of the road train from the point of view of obtaining the minimum total aerodynamic resistance. However, changing the distance between the cab and the semi-trailer can affect the controllability and stability of the road train.

The obtained results can be used in the development of semi-trailer structures, which will ensure a reduction of the total aerodynamic resistance of road trains. And this will lead to a decrease in fuel consumption for the transportation process

Keywords: air resistance, aerodynamics of highway trains, CFD modeling of train aerodynamics, fuel consumption, aerodynamic resistance, influence of the distance between the cabin and the body on aerodynamics

Received 01.10.2024
Received in revised form 03.12.2024
Accepted 13.12.2024
Published 05.02.2025

How to Cite: *Beherskyi, D., Vitiuk, I., Koval, A., Golubovskyi, A., Perehuda, M. (2025). Justification of choosing a reasonable distance between the driver's cabin and the semi-trailer to reduce the aerodynamic resistance of the vehicle. Eastern-European Journal of Enterprise Technologies, 1 (1 (133)), 44–51. https://doi.org/10.15587/1729-4061.2025.320494*

1. Introduction

Aerodynamic drag is the force that opposes the movement of a vehicle. When a vehicle moves, it cuts through the air, and the larger the frontal surface area and the less streamlined its shape, the greater the aerodynamic drag. To overcome this drag, the vehicle's engine has to consume more energy, which results in higher fuel consumption. It is known that the force of aerodynamic drag has a quadratic relationship with the speed of movement [1], which puts engineers in a tight spot to achieve a balance between the speed of transportation and the cost of overcoming aerodynamic drag. In order to optimize existing rolling stock without total rework, an effective solution is to use additional aerodynamic elements such as spoilers, aerodynamic fairings, etc. [2]. The most problematic area that aerodynamic elements usually cover is the gap between the rear wall of the driver's cab and the front wall of the semi-trailer (Fig. 1).

Fig. 1. Example of aerodynamic body elements

Based on the above, it can be concluded that research related to improving the aerodynamic characteristics of mainline road trains is relevant.

2. Literature review and problem statement

Paper [2] presents general approaches to computer modelling of the aerodynamics of mainline road trains. It is noted that the use of computer modelling methods has a number of advantages, including reducing the time and cost of research. However, this article considers the improvement of road trains aerodynamics only by using special aerodynamic elements. The models considered in this article are based on existing combinations of tractors and semi-trailers, which does not allow to judge the effect of the distance between the cab and the semi-trailer in a wide range of its values. It should be noted that [1] presents the results of modelling the effect of the distance between the driver's cab and the semi-trailer on the overpressure arising in this space due to air turbulence. However, these data were obtained for a narrow range of speeds and therefore require further refinement and generalization.

In [3], it is proposed to study the parameters of aerodynamic drag by numerical modelling using the ANSYS-FLUENT software product. Also, this paper proposes a method of reducing the aerodynamic drag of a semi-trailer by modifying its external surfaces. Despite the fact that the modelling results have been confirmed experimentally, the proposed modification of the outer surfaces of the body gives a very small reduction in aerodynamic drag. It should also be noted that the presented model does not reflect all the important properties of the road train and is very simplified. Therefore, it can be concluded that the information provided in this article does not answer the question of the effect of the distance between the cab and the semi-trailer on the total aerodynamic drag of the road train.

Paper [4] presents a device that can be installed on a semi-trailer to reduce aerodynamic drag by 10 %. However, the installation of the proposed device increases the overall height and total weight of the road train. The effectiveness of the proposed device was studied by physical modelling in a wind tunnel. As will be shown below, this method has a number of significant disadvantages, the main ones being high cost and low variability of model parameters. As in [2, 3], this paper considers the issues of reducing the aerodynamic drag of a road train by using special aerodynamic devices. However, their use leads to an increase in the weight and overall dimensions of the road train, which negatively affects the efficiency of the transportation process. Therefore, works [2–4] do not provide answers to the question of the influence of the distance between the cab and the semi-trailer on the aerodynamic drag of a road train. However, these works indicate that it is the geometric features of the road train that are of key importance in reducing aerodynamic drag.

Paper [5] presents an analysis of research related to the study of the peculiarities of the formation of air resistance force during the movement of mainline road trains. It is shown that the distances between the elements of a road train significantly affect the aerodynamic drag of the road train. It is emphasized that this study does not take into account the magnitude of these values, but only emphasizes the relevance of the study. From the materials presented in this paper, it follows that it does not provide an answer to the key research question, namely, the choice of a rational distance between the driver's cab and the semi-trailer in terms of obtaining the minimum total aerodynamic drag of a road train.

Paper [1] found that every 2 % reduction in the aerodynamic drag of a vehicle improves fuel efficiency by 1 %. It is noted that there is a difference in approaches between the design of cars and trucks, which is that the main task of road trains is to transport goods, and therefore the body should be much higher compared to cars, and this implies a completely different approach to reducing aerodynamic drag. Based on the power balance, it is concluded that a significant proportion of engine power is spent on overcoming aerodynamic drag forces. It is noted that there is a quadratic relationship between speed and aerodynamic drag. However, the results obtained by the authors do not allow to generalize the information obtained for all possible conditions of road trains.

Paper [6] investigated the effect of the area between the driver's cab and the semi-trailer on the aerodynamics of a road train. A configuration was found in which the aerodynamic drag was reduced by 1.8 %. It is noted that the gap between the cab and the semi-trailer is of the greatest importance for reducing aerodynamic drag, since it is in this area that the strongest airflow turbulence is created. Particular attention was paid to the discrepancy between the results of simulations and road tests, which is due to the fact that other factors such as wheel rotation, suspension operation, wind direction, etc. also occur when a real road train is moving. At the same time, given the described discrepancy in the results obtained by different methods, it is difficult to judge the adequacy of the models used and their completeness in terms of taking into account important features of road trains.

Paper [7] presents a comparative analysis of the study of road train aerodynamics by physical modelling in a wind tunnel and computer modelling methods using CFD (Computational Fluid Dynamics) algorithms. It is noted that both approaches have a number of advantages and disadvantages, and the best results are obtained by combining these methods. However, this work is devoted to comparing the results of studying the aerodynamics of a road train using different methods, rather than to studying the influence of specific factors on the aerodynamic drag of a road train. Therefore, it is of interest from the point of view of planning research and analyzing its results.

Paper [8] is devoted to numerical modelling of reducing the aerodynamic drag of racing cars. It is noted here that a significant reduction in aerodynamic drag can be achieved by using aerodynamic devices. However, this article does not address issues related to the aerodynamic drag of road trains. The article is interesting because of the approaches to computer modelling of vehicle aerodynamics presented in it.

Paper [9] presents basic approaches to creating a virtual wind tunnel. These data make it possible to combine the advantages of numerical modelling and physical modelling in a wind tunnel when studying the aerodynamics of cars in a virtual environment.

In [10], attention is paid to the study of the influence of air flow characteristics on the aerodynamic properties of tractors. It is noted that the swirling of the air flow behind the cab has a significant impact on the total aerodynamic drag of the tractor. Obviously, the use of a semi-trailer increases this effect. However, since the article considers the aerodynamics of a tractor, not a road train consisting of a tractor and a semi-trailer, it does not answer the question of the effect of the distance between the cab and the semi-trailer on the total aerodynamic drag of the road train.

Thus, based on the analysis of known literature sources [1–6, 10], it can be concluded that the issue of the influence of the distance between the rear wall of the driver's cab and the front wall of the semi-trailer of a mainline road train on its aerodynamic properties requires further study. This is due to the fact that airflow turbulence is formed in this area, which significantly affects the total aerodynamic drag of the road train. However, previous studies do not provide a definitive answer to the question of choosing a rational distance between the tractor cab and semi-trailer in terms of improving the aerodynamic characteristics of a road train.

3. The aim and objectives of the study

The aim of the study is to improve the aerodynamic characteristics of mainline road trains by finding a rational distance between the tractor cab and the semi-trailer to increase the fuel efficiency of road trains. This will make it possible to increase the efficiency of the transportation process, improve the safety and reliability of road trains, and increase their environmental friendliness.

To achieve this goal, the following tasks need to be completed:

– to analyze the influence of aerodynamic drag of a road train on its fuel consumption during the transportation process;

– to establish the dependence of the aerodynamic drag of a road train on the distance between the driver's cab and the semi-trailer.

4. Materials and methods of the study

The object of study is the aerodynamic drag of a mainline road train and its impact on the efficiency of the transportation process.

Based on previous studies, it can be hypothesized that it is possible to improve the aerodynamic characteristics of road trains by choosing a rational distance between the rear wall of the driver's cab and the front wall of the semi-trailer. In turn, improving the aerodynamic characteristics of a road train will lead to a reduction in fuel consumption, which will reduce the cost of transportation and, therefore, increase the efficiency of the transportation process.

Thus, it can be assumed that there is a relationship between fuel consumption and the distance between the driver's cab and the semi-trailer. Then, as will be shown below, the problem of finding rational values of this distance is reduced to finding the form of the function that describes the dependence of the aerodynamic drag force on it and finding its extremes.

To choose a method for studying the aerodynamic drag of road trains, the existing methods for studying the aerodynamics of road trains were considered and the advantages and disadvantages of each of them were determined. The factors that influence the differences in research results are determined.

There are several approaches to studying the aerodynamic characteristics of road trains, each of which has its own advantages and disadvantages, which will be discussed below.

The main methods for determining the aerodynamic characteristics of a road train can be considered [7]:

– method of physical modelling in a wind tunnel;

– numerical modelling method (Computational Fluid Dynamics, CFD) [2, 8];

– field tests;

– experimental methods based on laser technology and interactive visualizations.

The main disadvantages of full-scale and physical modelling methods, as well as the latest experimental methods, are their cost, which, in turn, is compensated by the high accuracy of the results. At the same time, the paper focuses on wind tunnel modelling and numerical simulation, as these methods are the most accessible and provide sufficient accuracy of the results.

Numerical modelling (Computational Fluid Dynamics, CFD) is based on the application of the finite element method. It uses numerical methods and algorithms to analyze the movement of gas flows in a particular environment [10].

The main algorithms and methods used in CFD modelling include the following:

– finite volume method (FVM);

– finite element method (FEM);

– finite difference method (FDM);

– large eddy simulation (LES);

– Reynolds method averaged by Navier-Stokes (RANS);

– volume of fluid (VOF);

– particle methods;

– adaptive mesh refinement (AMR);

– algorithms for linearization and solving systems of equations, etc.

These methods and algorithms are key to performing a wide range of CFD modelling tasks.

The advantages of numerical modelling include:

– relatively low costs compared to wind tunnel testing;

– the ability to quickly test different object configurations;

– high accuracy and detail of results;

– no restrictions on the size of the objects under investigation.

However, there are also certain disadvantages:

– the need for high-performance computers, which can be quite expensive;

– the need to create extremely accurate models to achieve high accuracy of results.

Based on the analysis, it was decided to study the aerodynamic drag of a road train by numerical modelling using the ANSYS software (United States of America), which implements CFD algorithms for modelling the flow of liquids and gases. Also, based on the analysis of the differences in the results obtained by different methods, a number of model simplifications were adopted. Namely, that the rotation of the wheels does not create additional aerodynamic drag, and the influence of internal aerodynamic drag is excluded from consideration. The modelling results were compared with those obtained by physical modelling in a wind tunnel.

5. Results of research on improving the aerodynamics of road trains by establishing a rational distance between the cab and the semi-trailer

5. 1. Analysis of the influence of aerodynamic resistance of a road train on its fuel consumption during the transportation process

The aerodynamic drag force (F_d) is the force that results from the interaction of the vehicle body with the air flow while driving. It acts in the opposite direction to the vehicle's movement and prevents it from moving forward and is described by formula (1):

$$F_d = \frac{1}{2} \cdot \rho \cdot V^2 \cdot C_d \cdot A, \quad (1)$$

where ρ – air density; V – speed of movement; C_d – aerodynamic drag coefficient; A – frontal surface area.

The dependence of the aerodynamic drag force on the speed of movement is non-linear and is described by a quadratic law. This means that the aerodynamic drag force increases in proportion to the square of the speed (Fig. 2).

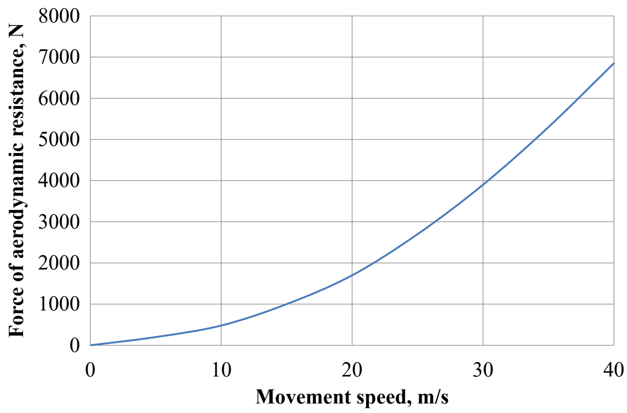


Fig. 2. Dependence of aerodynamic drag force on the speed of movement

In order to gain and maintain speed, some power (P_d) is required to overcome drag forces, including aerodynamic drag. The power required to overcome aerodynamic drag is a key factor in determining the energy consumption of a vehicle while driving. This power is determined by the amount of energy the engine must provide to overcome air resistance (Fig. 3). The power required to overcome aerodynamic drag is calculated using formula (2):

$$P_d = F_d \cdot V = \frac{1}{2} \cdot \rho \cdot V^3 \cdot C_d \cdot A. \quad (2)$$

According to these formulas, it is possible to assume that fuel consumption (Q) is directly related to aerodynamic drag. This is because to overcome this drag, more energy is required than the engine receives by burning fuel.

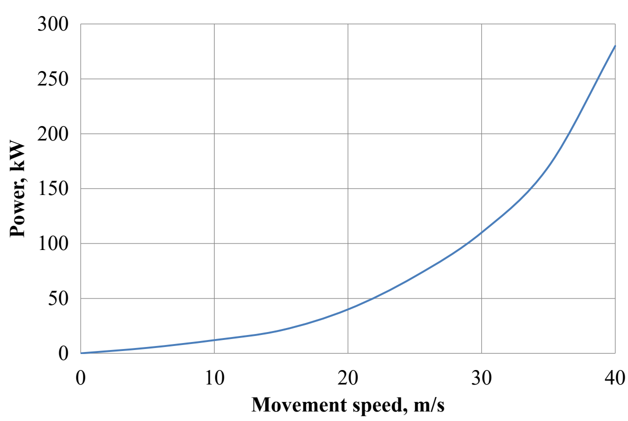


Fig. 3. Dependence of power on driving speed

The dependence of fuel consumption on the aerodynamic drag force (F_d) is determined by formula (3):

$$Q = \frac{F_d}{\eta \cdot H}, \quad (3)$$

where η – engine efficiency; H – heat of combustion of fuel.

Fig. 4 shows the dependence of fuel consumption (Q) on the speed of the road train (V).

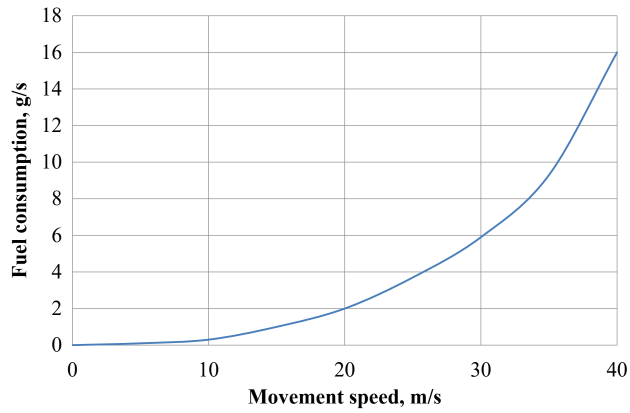


Fig. 4. Dependence of fuel consumption on driving speed

From the above, it follows that fuel consumption depends on aerodynamic drag, and aerodynamic drag, in turn, is determined by the geometric parameters of the road train and, in particular, the distance between the driver's cab and the semi-trailer. The dependence of the aerodynamic drag force on the distance between the driver's cab and the semi-trailer can be represented by formula (4):

$$F_d(d) = f(d). \quad (4)$$

Then the problem of determining the rational distance between the driver's cab and the semi-trailer can be presented as a search for the appropriate values of this distance at which function (4) will have minima, for which it is necessary to establish the general form of the presented function.

5. 2. Determination of the dependence of the aerodynamic drag of a road train on the distance between the driver's cab and the semi-trailer

One of the most popular aerodynamics software products is Ansys Fluent. This software has the most advanced algorithms and provides highly accurate results.

The calculation process usually involves the following steps:
- creation of a solid model (Fig. 5);
- building a finite element mesh;
- adding a model to the calculation module;
- setting input conditions for the calculation;
- processing of the results obtained.

It is known that the accuracy of results and calculation speed largely depend on the quality of the finite element mesh. Therefore, in order to determine the size of the finite elements that ensure sufficient accuracy and calculation speed, a mesh independence study was conducted. To do this, the type of finite element mesh was first selected. Since the model of a road train contains a significant number of elements of nonlinear geometry, an irregular finite element mesh was chosen (Fig. 6, *a*). Then, under the same conditions (speed and distance between the cab and the semi-trailer), a number of calculations were performed for different sizes of finite elements. Based on the results of the calculations, the pressure in the space between the cab and the semi-trailer was plotted against the size of the finite element (Fig. 6, *b*).

Fig. 6, *b* shows that when the size of the finite elements is increased beyond 4 cm, the pressure values in the space between the cab and the semi-trailer change dramatically. This indicates that the size of the finite element of 4 cm is the limit at which the independence of the mesh is preserved. However, with a finite element size of 2.5 cm, it is possible to obtain more accurate results without significantly increasing the calculation time. Therefore, a mesh with a finite element size of 2.5 cm was chosen for further research.

The paper considers the dependence of aerodynamic characteristics on the geometric parameters of a road train, namely the distance between the rear wall of the tractor and the front wall of the semi-trailer. For this purpose, the air flow rate and the parameters of its interaction with the road train surfaces were set. The list of set conditions is shown in Fig. 7, *a*. Then, under the same other conditions, the distance between the cab and the semi-trailer was changed. Each time this distance was changed, a simulation was performed and the overpressure in the space between the driver's cab and the semi-trailer was determined. An example of the results of such a simulation is shown in Fig. 7, *b*.

The distance between the rear wall of the tractor cab and the front wall of the semi-trailer was changed in increments of 20 centimeters in the range from 0 to 2 meters. The result was a graph of the influence of the distance from the cab to the semi-trailer on the value of the total aerodynamic forces of resistance to the movement of the road train (Fig. 8).

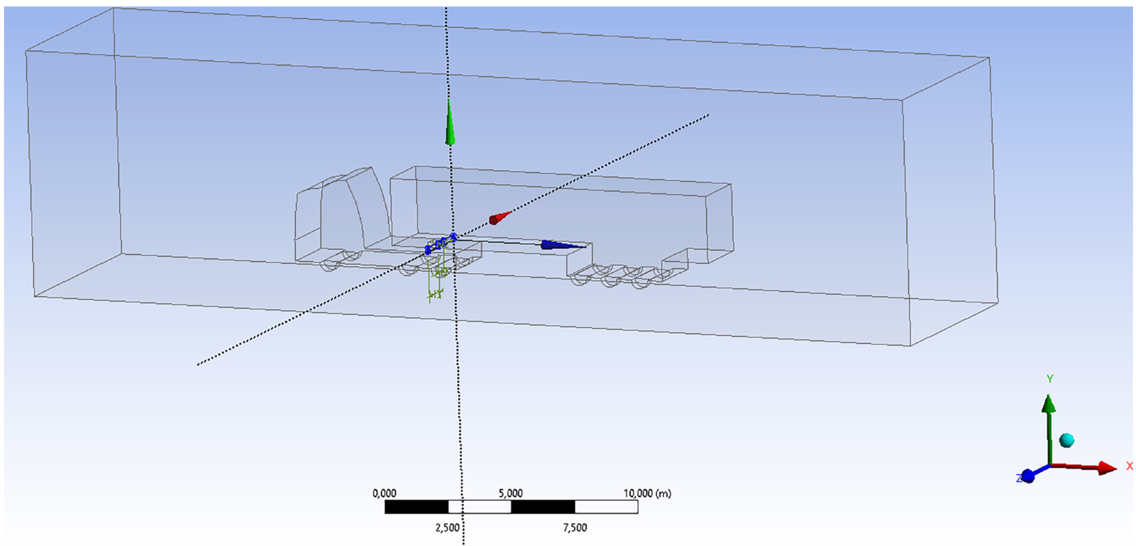
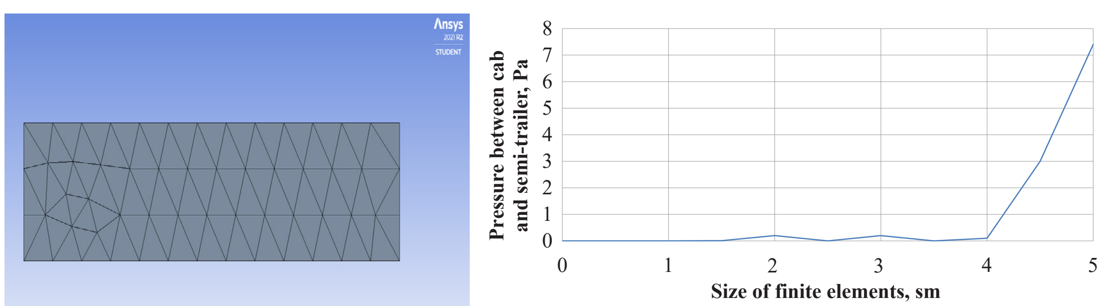
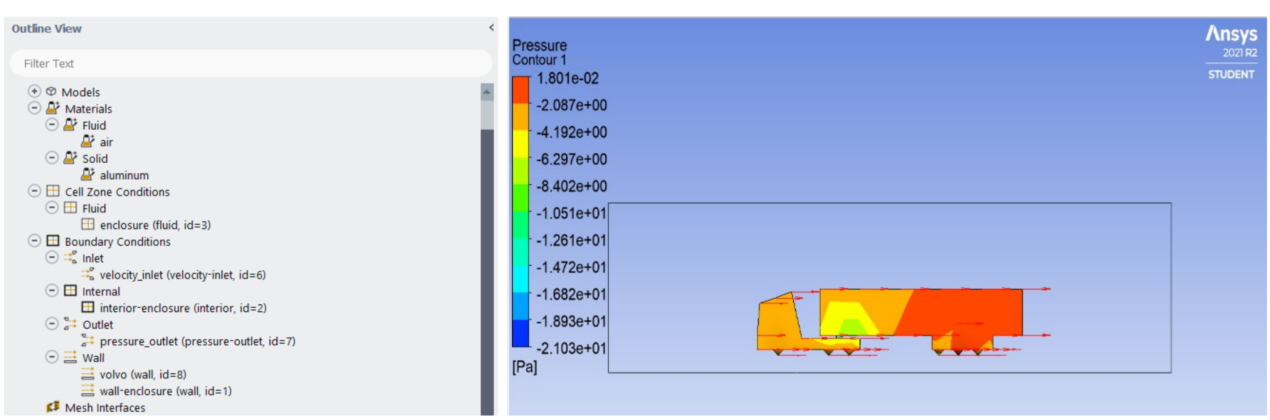


Fig. 5. Model of a road train in Ansys Fluent



a *b*

Fig. 6. Finite element mesh parameters of the model:
a – appearance of the finite elements; *b* – results of the mesh independence study



a *b*

Fig. 7. Conditions and results of simulations: *a* – conditions of interaction of air flow with the surfaces of a road train;
b – an example of displaying the pressure distribution over the surface of a road train

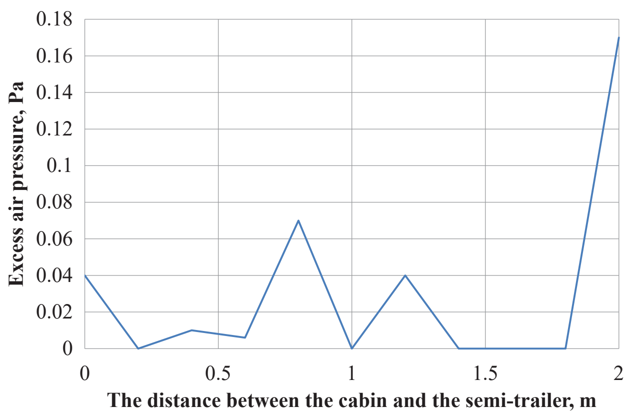


Fig. 8. Dependence of air pressure in the space between the cab and semi-trailer on the distance between them

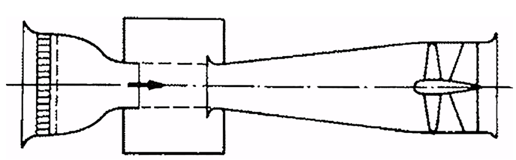
Fig. 8 shows that the relationship between the distance between the cab and the semi-trailer and the pressure is indirect, so additional research with different configurations of road conditions is needed to determine the rational value of the distance.

To confirm the modelling results, the results of experimental studies presented in [5] were used.

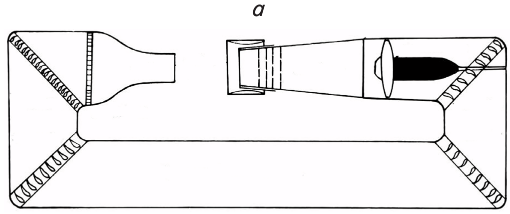
The design of wind tunnels and stands can vary. In particular, fan tubes are one of the most common types due to their simplicity. They are used to determine the aerodynamic characteristics of bodies in gas flows moving at a much lower speed than the speed of sound.

Wind tunnels are divided into two main types of construction according to the method of air supply: closed and open (Fig. 9). The closed type generally requires less power to drive the fan compared to the open type, which saves energy. In addition, a closed system allows for climate control by adjusting the temperature and humidity. However, such a system has high equipment costs. The open type of construction reduces construction costs, but requires more fan power, which increases operating costs. In addition, outdoor installation exposes the system to atmospheric conditions, which affects its efficiency [5].

Before starting the modelling, the characteristics of the wind tunnel, the flow rate, and the nature of the air jets were determined. Based on this, the geometric characteristics of the model were determined, the prototype of which was a MAZ-6310 car in a scale of 1:25. Paper [5] investigated the effect of gaps between the elements of a road train by physical modelling (Fig. 10).



a



b

Fig. 9. Wind tunnel design [5]: *a* — closed type (Eiffel design); *b* — open type (Göttingen design)

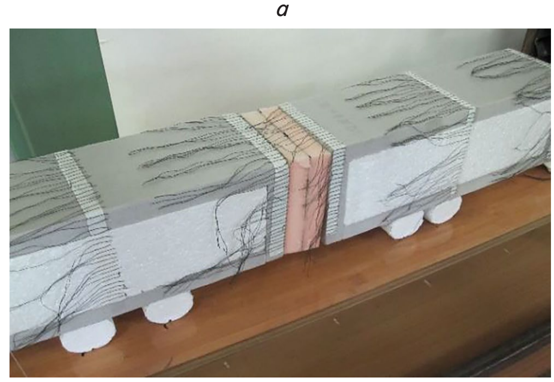
Fig. 10. General view of the pilot plant [1]

In the proposed experimental setup (Fig. 10), the total aerodynamic drag of a road train was estimated by the value of the deflection angle of the suspended moving platform on which the model of the road train was installed. However, this method does not allow for an accurate numerical assessment of the value of the total aerodynamic drag. In addition, the accuracy of determining the air resistance force is also affected by the presence of the platform, since it is also affected by air flow. The imperfection of the road train model, namely the materials from which it was made, also introduces a significant error in the measurement.

However, during the experiment, it was found that in the area between the bodies of the tractor and trailers, the air flow forms a vortex, which decreases to minimum values when the distances between the elements decrease (Fig. 11, *a*, *b*).

The results of this study showed that reducing the gaps between the elements of a road train results in a decrease in turbulence, and as a result, a decrease in aerodynamic drag in general.

a



b

Fig. 11. Character of air flow [5]: *a* — with gaps between the trailed links; *b* — without gaps between the trailed links

Therefore, the results obtained here provide only a general idea of the effect of the distance between the cab and the semi-trailer on the total aerodynamic drag of the road train. And, although these results do not allow to confirm or refute the results obtained by numerical modelling, they show, as well as the modelling results, that the accepted hypothesis about the significant influence of the distance between the cab and the semi-trailer on the total aerodynamic drag of the road train is correct. It is obvious that the experimental setup and the physical model of the road train itself need to be improved.

6. Discussion of the results of the study of the influence of the distance between the cab and the semi-trailer on the aerodynamics of road trains

The analysis of the dependence of fuel consumption on the aerodynamic drag of a road train makes it possible to present the air resistance force as a function of the distance between the cab and the semi-trailer (4). Then, the search for a rational distance between the cab and the semi-trailer can be reduced to finding the form of this function and its extremes.

An analysis of the known methods for studying the aerodynamic characteristics of road trains has shown that mathematical and computer modelling methods have an advantage in terms of cost and speed of research compared to physical modelling methods in a wind tunnel. In terms of the problems of this research, this is expressed in the possibility of quickly changing the distance from the cab to the semi-trailer in the computer model (Fig. 5), while to change this distance during the wind tunnel study (Fig. 10, 11), it is necessary to create a new model of the road train.

The results of computer modelling of the influence of the distance between the cab and the semi-trailer (Fig. 8) on the overpressure in the space between them show the presence of minima at certain values of this distance. This indicates that the total aerodynamic drag forces will have a similar pattern of dependence on the distance between the cab and the semi-trailer. In accordance with formulas (2)–(4), a change in total aerodynamic drag will lead to a decrease in fuel consumption. Based on the results of the analysis of the obtained dependence of the overpressure in the space between the cab and the semi-trailer on the distance between them (Fig. 8), it can be concluded that there are two ranges of distances with minimal overpressure, namely from 0.2 to 0.6 m and from 1.4 to 1.8 m. However, these conclusions require further research in terms of ensuring the controllability and stability of a road train with such parameters. The reduction of overpressure in the space between the cab and the semi-trailer, based on the modelling results, is up to 10 %. If to assume that the change in total aerodynamic drag is proportional to the reduction in overpressure in the space between the cab and the semi-trailer, and that every 2 % reduction in aerodynamic drag leads to a 1 % fuel saving, it is obvious that the savings can be quite significant. However, it is too early to draw conclusions about the real values of fuel economy. To do so, additional research is needed to take into account the actual change in total aerodynamic drag, rather than its components.

In contrast to [5], where the effect of the distance between two trailers on the aerodynamics of a road train was studied by wind tunnel modelling, this paper investigates the effect of the distance between the cab and the semi-trailer by computer simulation. This approach allows obtaining results in a wider range of different parameters, such as the distance between the cab and the semi-trailer, the relative speed of the road train and the air flow, the presence of aerodynamic panels and other devices, and others. In addition, as noted above, the results presented in [5] give only a general idea of the change in the total aerodynamic drag of a road train with the distance between its elements and do not allow for a numerical determination of this dependence. At the same time, the results of this study provide a numerical estimate of the effect of the distance between the cab and the semi-trailer on the aerodynamic drag of a road train. Also, unlike the materials in [4], the article proposes approaches that make it possible to reduce the cost of research by using a computer model compared to research by physical modelling methods.

In contrast to the results of work [10], where the aerodynamic characteristics of the tractor were considered, this article considers the aerodynamic properties of a road train with a semi-trailer. Therefore, the obtained results provide an opportunity to optimize not only the tractor, but also the road train as a whole. In this aspect, it can be argued that the obtained results are useful, since the transportation process is carried out by road trains, and not by individual tractors. Therefore, it makes sense to consider the tractor as part of a road train.

Considering the small number of studies on the effect of the distance between the cabin and the semi-trailer on the aerodynamics of the road train, it can be stated that the obtained results allow to determine its rational values for reducing aerodynamic resistance and, accordingly, fuel consumption. However, the standardization of road train designs makes it difficult to adjust the parameters that affect the maneuverability and traction-dynamic characteristics of road trains. One of the reasons for such conservatism is the need to ensure stable operation of the road train in various operating conditions, such as traffic on the highway or in urban conditions. On highways, the road train reaches high speeds, where the reduction of aerodynamic drag is most important, but at the same time acceptable maneuvering characteristics must also be maintained, which often requires a compromise.

It is obvious that changing the distance between the cab and the semi-trailer must have certain limitations in terms of impact on the controllability of the road train. Therefore, the question of changing the distance between the cabin and the semi-trailer requires further research from the point of view of the influence of this distance on such operational properties of the road train as maneuverability and controllability. These questions will be considered in the following works.

At this stage of the study, only the influence of the distance between the cabin and the semi-trailer on the aerodynamic resistance and fuel consumption of the road train was considered, and the influence of this distance on its other operational properties, for example, controllability, stability, was not considered. Since the handling and stability of a road train affect its safety, the effect of the distance between the cab and the semi-trailer on these properties needs to be carefully studied. A significant deterioration of these properties may lead to the impossibility or impracticality of using the obtained results.

One of the ways to solve the problem can be the creation of devices that will automatically change the distance between the cabin and the semi-trailer depending on the mode of operation of the road train. For example, reducing this distance when driving on highways where there is no need to maneuver and increasing it when it is necessary to perform certain maneuvers. The distance between the cabin and the semi-trailer will vary depending on the speed of the road train. However, these issues require additional research, especially regarding the impact on traffic safety.

The disadvantages of these studies are that at this stage it is not clear the ratio of advantages that will provide the establishment of a rational distance between the driver's cabin and the semi-trailer of the road train and the risks associated with the impact of changing this distance on controllability. This is due to the fact that at this stage, the permissible limits for the change of the distance between the cabin and the semi-trailer have not been established, which makes such a comparison impossible. However, this issue will be discussed in the following articles.

7. Conclusions

1. Based on the analysis of the influence of the aerodynamic resistance of the road train on its fuel consumption during the transportation process, the dependence of power and fuel consumption on the speed of the road train was established. Taking into account the dependence of the aerodynamic resistance force on the speed of the road train, it is shown that the task of finding a rational distance between the driver's cabin and the semi-trailer is reduced to establishing the type of function that describes the dependence of the air resistance force on this distance and finding its extremes.

2. On the basis of the study, an indirect dependence of the distance between the driver's cabin and the semi-trailer and the total aerodynamic resistance of the road train was established. Based on the analysis of the dependence obtained by the method of numerical modeling, it can be stated that the change in the distance between the cab and the semi-trailer can significantly affect the aerodynamic resistance, and it, in turn, affects the fuel consumption. Through CFD modeling, the relationship between the amount of excess pressure in the space between the cabin and the semi-trailer and the distance between them was established. From the analysis of the obtained dependence, it can be seen that under the given modeling conditions, two ranges of distances between the cabin and the semi-trailer are possible, in which the minimum values of excess pressure are observed – from 0.2 to 0.6 m and from 1.4 to 1.8 m. However, it should be noted that setting such values of the distance between the cabin and the semi-trailer can have a negative effect on the controllability and stability parameters of the road train.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this study, including financial, personal, authorship, or any other, that could affect the study and its results presented in this article.

Financing

The study was conducted without financial support.

Availability of data

The manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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