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SIMULATION ANALYSIS OF TRANSPORT ENERGY EFFICIENCY OF ROAD TRAINS AND INTERNATIONAL MOTOR TRANSPORTATIONS

The object of the study is the production and technological processes of international road transport (PTP IRT) according to the innovative approach and the conceptual idea of technical and technological energy saving in motor transport. Predictive assumptions about the development of the object of study – the realization of the possibilities of operational-simulation and technical-evolutionary method of complex analysis of transport energy efficiency of road trains and production and technological processes of international road transport in the practice of international road transport.

In the course of the research the operational-simulation and technical-evolutionary method of complex analysis of transport energy efficiency of road trains and production-technological processes of international road transportations was considered. As an example, the influence of changes in such a design parameter of the road train as the gear ratio of the main transmission of the tractor on its transport energy efficiency, as well as fuel and energy consumption of the road train DAF FT95.360 (Netherlands) in the test trunk operation (at $\alpha_g=0$). It is established that when the value of the gear ratio of the main transmission (U_o) increases, the value of the energy efficiency indicator (P_e) varies from 0.55 to 0.58. The greatest value of energy efficiency is at $U_o=2.846$. It is determined that when the value of the gear ratio of the main transmission (U_o) increases, the value of the energy consumption indicator (A_c) increases, and the minimum value of 3.2 MJ acquires the value of the gear ratio of the main transmission – 2.846. It was found that when the value of the gear ratio of the main gear (U_o) increases the fuel consumption (Q_c) increases and acquires a maximum value of 3496.84 g with the value of the gear ratio of the main gear – 4.39. The minimum value of fuel consumption of 1684.2 g is achieved when the value of the gear ratio of the main transmission 2.846.

The results of the study can be used to implement systemic and conceptual innovation management in the field of international road transport.

Keywords: *conceptual idea, simulation analysis, road transport of international road transport, structure of motor transport, design and road factors.*

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1. Introduction

Road trains that are used for international freight transport today represent a wide range of automotive equipment, which is constantly updated and which has a number of requirements (resource conservation, environmental friendliness, fuel efficiency, etc.). When substantiating the renewal of the fleet of road trains, it is necessary to take into account the great variety of their design parameters and a wide range of road conditions. In addition, a very capital-intensive, science-intensive process of renewal of the park should correspond to the conceptual idea of innovative and operational-technological energy and resource saving (IIOTERS) on vehicles [1, 2]. Currently, the existing methods of efficiency analysis and rolling stock selection have a number of shortcomings for solving the problems of organizing international road transport. They do not provide technological and innovative projects of transport processes and do not correspond to the concept of IIOTERS. The reason is that they are based on the calculation schemes of virtual transportation of goods and passengers [3, 4]. In addition, these schemes take into account intangible meters of transportation results – ton-kilometer or passenger-kilometer [5]. In general, the question of energy efficiency in transport is actual. Thus, in [6, 7] energy efficiency in maritime transport is considered, while in [8, 9] the authors emphasize the great potential for improving energy efficiency.

In works [1, 10] under road transport technology (RTT) is understood operationally expedient, formalized set of material-creative and machine-energy ways of creation of a qualitative product of motor transport. This takes into account the production requirements for the transport operation, traffic conditions and a set of properties of the car as a carrier of technical resources. It follows that in the conceptual substantiation of international road trains it is necessary to use their technologically significant indicators of transport energy efficiency and take into account the models of analysis of the main components of RTT:

- ways to create a product;
- set of resource and technical properties of the road train;
- traffic conditions and physical product of the vehicle.

In addition, the method of selection of road trains account the evolution of design parameters of vehicles shall be taken into account and variety of transportation conditions.

Analysis of research and publications in the direction of domestic and international road transport shows that they use known indicators of RV performance and transportation costs, which are based on axioms and calculation schemes of virtual and non-technological movement of cars. These schemes do not take into account: the processes of energy conversion of technological resources into a product of motor transport, procedures and processes of transport technologies, the effects of structural and technical, road and transport and operational factors. In works [11–13] the essentially new and actual method of technological and innovative increase of transport energy efficiency of automobile transportations at updating of a rolling stock is considered.

Thus, the practical implementation of the conceptual idea of innovative and operational-technological energy and resource saving on motor transport is relevant IIOTERS and the use of adapted mathematical models of the theory of energy efficiency of cars and methods of their simulation and reference-comparative analysis. Thus, *the object of research* is the production and technological processes of international road transport (PTP IRT) according to the innovative approach and the conceptual idea of technical and technological energy saving in motor transport. And *the purpose of the work* is to present the results of operational-simulation and technical-evolutionary method of complex analysis of transport energy efficiency of road trains and PTP IRT.

2. Methods of research

This paper focuses on improving the energy efficiency of international road trains. Therefore, a conceptual method of scientific analysis and substantiation of road train renewal is proposed. And also the mathematical models of the theory of energy resource efficiency of the car of the generalized type and technological processes of automobile transportations (TERECGTTPAT) are used [1, 10]. This method was developed at the Department of Transport Technologies of the National Transport University (Kyiv, Ukraine).

To ensure the controllability of the processes of development of transportation equipment and technologies according to the conceptual idea of IOTERS, the methods of increasing TERECGTTPAT must be implemented taking into account the functional structure of motor transport as a sphere of material production of motor transport services.

In [1] this structure is presented a set of three functional components of motor transport:

1) control superstructure of transport (CST), which includes capital owners, managers, organizers, transport engineers, economists and marketers;

2) resource-technological base (RTB) is a set of all technological (technical, energy, labor) resources of motor transport, models and methods of analysis of transport technologies, as well as rules for transport and terminal operations of transportation processes;

3) transport-technological processes (TTP), which are based on schemes of energy transformation of technological resources into a physical product of motor transport.

The strategic task of CST is to mutually coordinate and harmonize the implementation of the conceptual idea of IOTERS in all three of the above stated components of transport for long-term conceptual and innovative management of the development of RTB and TTP [1]. The operational tasks of CST are to organize the delivery of goods and passengers in the current state of RTB and TTP.

The paper presents as an example the results of modeling the functioning of a road train as a resource-technical means of production using the method of simulation-test analysis [10]. The influence of the change in the value of the gear ratio of the main transmission (*Uo*) on the indicators of transport energy efficiency of the road train DAF FT95.360 (Netherlands) is considered. Based on such results, it is possible to predict the suitability of different variants of the DAF road train for energy-saving technologies.

The work was performed in the following stages:

a) selection of calculation schemes of transport operations;

b) adaptation of mathematical models of energy efficiency indicators to the movement of road trains according to the concept of IIOTERS [1, 10, 14]; modeling and analysis of the influence of such design parameters as engine power and radius of the driving wheel of the truck tractor on the energy efficiency index.

3. Research results and discussion

In works [1, 10, 14] it is established that for formation of a technique of conceptual substantiation of cars with technical novelty it is necessary to provide:

a) use of the new DDT principle (developed and described technology), instead of existing in theories of economy and the organization of transport FUT (freezing undescribed technology) process;

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b) to maximize the value of transport energy efficiency indicators of new cars;

c) step-by-step (by investment planning periods) increase of energy-technological efficiency of transportation projects;

d) long-term planning of high-tech resource- and energy-saving production of motor transport services.

The above problems cannot be solved using known indicators of RV productivity and transportation costs [3–5].

Mathematical models of these indicators are unsuitable for improving transport technologies, so in [14, 15] it was found that the idea improvement of transport technologies is a gradual increase in the value of energy efficiency ρ_e (in some cases – resource efficiency ρ_R) of transportation. To implement this idea, a dimensionless indicator of transport energy efficiency of RV is used to substantiate new rolling stock. The corresponding formulas are derived in [10, 14]. In these formulas, the indicators of the dimensionless coefficient of the average speed of the RV on the calculation route and the dimensionless fuel coefficient of the RV on the calculation route are two functional dependencies on the set of design parameters of the road train, which can be displayed as follows:

$$k_{vp}=f_1(N_m, R_k, U_{ki}, U_o,...),\ \ k_{ep}=f_2(N_m, R_k, U_{ki}, U_o,...),$$

where N_m is the maximum engine power of the road train; R_k is the radius of the driving wheel of the tractor; U_{ki} and U_o are the gear ratios of the gearbox and the main gear. According to these dependences, the influence of design parameters on the transport energy efficiency of a road train is considered.

As an example, the influence of changes in such a design parameter of the road train as the gear ratio of the main gear of the tractor on its transport energy efficiency, as well as fuel and energy consumption of the road train DAF FT95.360 in the test trunk operation (at $\alpha_g=0$). The structure of the operation includes the phases of the road train with different constant speeds (3–22 m/s), the acceleration phases of the road train at a fixed position of the fuel pedal 85 % in different gears, braking phases, the coefficient of road resistance is $\psi=0.03$. Based on the calculated data, graphs of changes in the indicators P_e of energy efficiency of the road train, energy consumption A_c and fuel Q_c from the change in the value of the gear ratio of the main transmission are constructed. Such graphs are presented in Fig. 1–3.

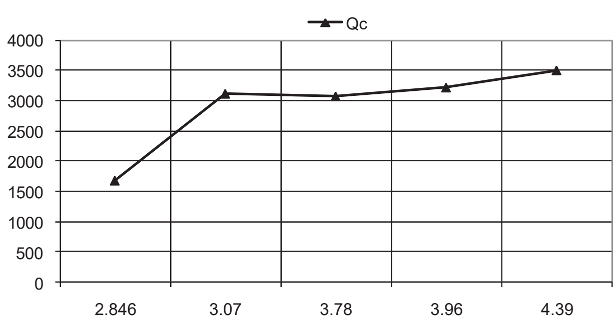

Fig. 1. The schedule of change of an indicator of energy efficiency of a road train on a settlement route (at $\alpha_g=0$) from change of value of a transfer number of the main transfer

Based on the calculation on the example of the road train DAF FT95.360 it is established that when increasing the value of the gear ratio of the main transmission (U_o), the value of the energy efficiency indicator (P_e) varies from 0.55 to 0.58. The greatest value of energy efficiency is at $U_o=2.846$. That is, when increasing the value of the gear ratio of the main transmission, the energy efficiency decreases by 24 %, and after reaching the value of 4.39, there is an increase in energy efficiency.

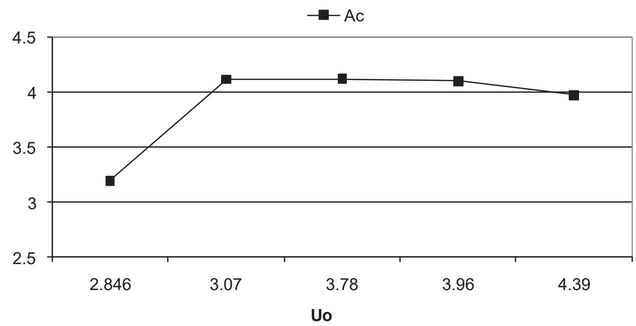

Fig. 2. The schedule of change of an indicator of expenses of energy A_c (MJ) of a road train in test main operation from change of value of a transfer number of the main transfer

Fig. 2 shows that with increasing the value of the gear ratio of the main transmission (U_o) the value of the energy consumption indicator (A_c) increases, and the minimum value of 3.2 MJ acquires the value of the gear ratio of the main transmission – 2.846. At the same time at a value of 3.07 acquires a maximum value of 4.12 MJ, after which it is possible to observe a further decline in the value of energy consumption.

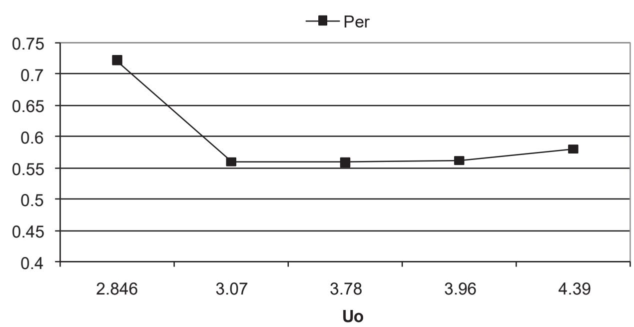

Fig. 3. The schedule of change of an indicator of fuel consumption *Qc* (g) of a road train in test main operation from change of value of a transfer number of the main transfer

It was found that when the value of the gear ratio of the main gear (U_o) increases the fuel consumption rate (Q_c) increases and acquires a maximum value of 3496.84 g with the value of the gear ratio of the main gear – 4.39. The minimum value of fuel consumption of 1684.2 g is achieved when the value of the gear ratio of the main transmission 2.846.

This research can be used in the design of new road trains, as well as carriers, mainly in justifying the technological and innovative choice of new road trains, which may have different factors of technical novelty:

– new car engine (change of maximum power);
– new gearbox (change of gear ratios and efficiency);
– new rear axles (change of gear ratio of the main gear and efficiency), wheel radius, etc.

Taking into account these factors, the carrier accepts a reasonable solutions for technical and technological innovations, and also has the ability to take into account changes in road conditions (road profile, road surface condition), and various operational factors (load class, different batch sizes, axial loads, modes of adaptive-discrete traffic, etc.). The development of the study is to introduce the conceptual idea of IOTERS and the use of adapted mathematical models of the theory of energy efficiency of cars. As well as the method of their simulation and reference-comparative analysis and taking into account its impact on the cost of transportation and the development of international road transport in general.

4. Conclusions

It is revealed that to solve the problems of operational analysis of transport energy efficiency of road trains it is necessary to use mathematical models of the theory of energy efficiency of cars adapted to the structure of road train and methods of their simulation and reference-comparative analysis.

According to the results of operational-simulation modeling, sufficient sensitivity of mathematical models to the problems of comparative analysis of road train variants with technical novelty is shown. Quantitative characteristics of the impact of changes in such a design parameter of the DAF FT95.360 road train as a change in the value of the gear ratio of the main transmission on the indicators of its transport energy efficiency, fuel consumption and energy. It is established that with increasing the value of the gear ratio of the main transmission (U_o) the value of the energy efficiency indicator (P_e) varies from 0.55 to 0.58. The greatest value of energy efficiency is at U_o=2.846. It is determined that when the value of the gear ratio of the main transmission (U_o) increases, the value of the energy consumption indicator (A_c) increases, and the minimum value of 3.2 MJ acquires the value of the gear ratio of the main transmission – 2.846. It was found that when the value of the gear ratio of the main gear (U_o) increases the fuel consumption rate (Q_c) increases and acquires a maximum value of 3496.84 g with the value of the gear ratio of the main gear – 4.39. The minimum value of fuel consumption of 1684.2 g is achieved when the value of the gear ratio of the main transmission in 2.846.

The results of the research can be implemented in international transport companies engaged in the transportation of goods, as well as companies engaged in the construction of road trains.

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