COEFFICIENT OF MOTOR VEHICLE TECHNICAL EFFICIENCY: MODELING AND CALCULATION

Goncharov, Oleg Yu., *College of the Institute of Service, Tourism and Design of North Caucasus Federal University (Pyatigorsk Branch), Pyatigorsk, Russia.*

ABSTRACT

The purpose of the research presented in the article is to refine the vehicle's technical efficiency coefficient and to estimate the range of its values in the proposed design model, taking into account the different variants of configuration of cars of the same brand and under different driving regimes. The modeling schemes used and the evaluation criteria are based on the data of the author's scientific analysis and are supported by practices.

Keywords: *vehicles, coefficient of efficiency, coefficient of technical efficiency, calculation methods, numerical modeling.*

Background. *Among theorists and practitioners dealing with vehicles, there is no single point of view on such indicators as «efficiency» and «coefficient of efficiency». Some consider them completely different (coefficient of efficiency characterizes the overall perfection of the car, and efficiency is its perfection as a purely transport machine [1]); others, on the contrary, identify them. In this case, everyone offers own way of determining the value of coefficient of efficiency [2], and therefore, brings own meaning into it. Although everyone has one thing in common: understanding of its need and importance for both theory and practice.*

A uniform for all vehicles dimensionless complex indicator such as «coefficient of efficiency» or «coefficient of technical efficiency» is extremely needed both at the design stage and during operation. But even more – in the conditions of strengthening the competition of producers in the relevant market segments: a single indicator facilitates all technical and economic calculations, including those related to the assessment of the competitiveness of manufactured cars, comparison with the best domestic and foreign analogues [3].

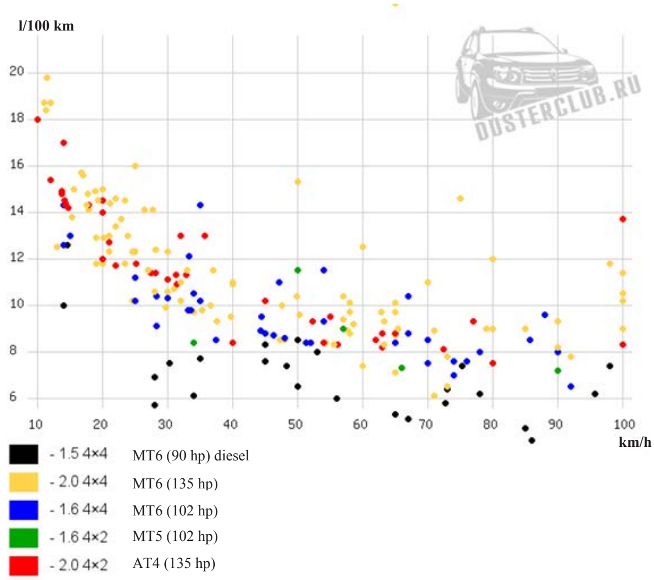
However, the interpretations of the «coefficient of efficiency of the car» and the formulas for its calculation proposed in recent years, accompanying their understanding of the problem, unfortunately, do not completely solve the problem. It is only possible to solve particular problems in assessing the economic efficiency of individual cars. But the economic evaluation will be different in different operating conditions, therefore, we must assume that it is first necessary to evaluate the technical efficiency of the car, and then give an economic assessment of the introduction of the model of the car in question.

Objective. *The objective of the author is to consider the coefficient of vehicle technical efficiency through its modeling and calculation.*

Methods. *The author uses general scientific and engineering methods, comparative analysis, graph construction, modeling, evaluation approach.*

Results. *There is a certain ambiguity in the interpretation of the concept of «car efficiency». After all, technical efficiency, according to the logics of some authors, is a component of the coefficient of efficiency of the car. This is indicated by D. V. Velikanov, Ya. E. Farobin, L. G. Trembovelsky [4].*

With this approach, the following necessary and simply determined characteristics and parameters can be adopted as physical quantities indicating the efficiency of the vehicle on any route: maximum engine torque, weight of the transported cargo, rolling radius of the driving wheels, average vehicle speed, gear ratio of main transmission, average density of a number of gear ratios, lower calorific value and mass (average) fuel consumption [5].



Pic. 1. Dependence of the fuel consumption on the average speed of the Renault Duster depending on configuration.

Table 1

Calculation of the coefficient of technical efficiency for various car configurations of Renault Duster (at a speed of 100 km/h)

Model	1,5 4x4 MT6 (90 hp) diesel	2,0 4x4 MT6 (135 hp)	1,6 4x4 MT6 (102 hp)	1,6 4x2 MT5 (102 hp)	2,0 4x2 AT4 (135 hp)
Type of engine	Diesel	Petrol-injector	Petrol-injector	Petrol-injector	Petrol-injector
Type of fuel	Diesel oil	Petrol	Petrol	Petrol	Petrol
Unladen weight, kg	1875	1877	1820	1850	1870
Cargo carrying capacity, kg (M_{cargo})	425	425	425	425	425
Average fuel consumption, l/100 km	7,5	10,4	10	7,9	8,4
Calorific power of fuel, kJ/kg	42400	43390	43390	43390	43390
Density, kg/l	0,85	0,75	0,75	0,75	0,75
Wheel track, m	1,822	1,822	1,822	1,822	1,822
Frontal area, m²	1,625	1,625	1,625	1,625	1,625
Coefficient of air resistance, k_a, N•c²/m⁴;	2,42	2,42	2,42	2,42	2,42
$M_{cargo}g\psi$, N	0,42	0,42	0,42	0,42	0,42
k_aFV^2, N	62,539	62,539	62,539	62,539	62,539
W_{use}, J	125,48	125,48	125,48	125,48	125,48
W, J	18801,9	18801,9	18801,9	18801,9	18801,9
Q_w, l/t•km	270300	338442	325425	257085,75	273357
ηe	0,176471	0,244706	0,235294	0,185882	0,197647

Table 2

Average fuel consumption of Renault Duster car configurations at various speeds

Model/ speed, km/h	1,5 4x4 MT6 (90 hp) diesel	2,0 4x4 MT6 (135 hp)	1,6 4x4 MT6 (102 hp)	1,6 4x2 MT5 (102 hp)	2,0 4x2 AT4 (135 hp)
15	10	12,5	12,7	14,2	15,4
30	7,5	11	10,5	9	11,2
40	8	10	9,5	10	8,5
50	7,2	10	8,5	11,5	9,3
60	6	9	8,5	9	8,4
70	5,5	6,2	8	7,5	8,1
80	6,2	9	8	7,2	7,5
90	5,9	8	8	7,2	8
100	7,5	10,4	10	7,9	8,4

N. Ya. Govorushchenko in his work in determining the efficiency of the car takes into account only the mechanical efficiency without aerodynamic losses [6].

In our opinion, from the outset, one should proceed from the fact that the main purpose of a vehicle is displacement of cargo and passengers. And then only that part of the work in the environment of the resistance forces, which depends on the cargo (passengers) being transported, can be considered useful. A. A. Tokarev [7] proposes, as an indicator of efficiency, to consider the ratio of the useful energy to the spent combustion energy of fuel:

$$\eta_e = \frac{W_{use}}{W}, \qquad (1)$$

where W_{use} – useful work spent on overcoming the forces of resistance to rolling, road and air conditions; W – total burning energy of the fuel.

$$W_{use} = S \cdot \left(mgf + k_a FV^2 + mg\sin\alpha \right), \qquad (2)$$

where m – mass of a vehicle; f – coefficient of rolling resistance; k_a – coefficient of air resistance; F – frontal area of a car; V – speed of a car; S – distance traveled.

$$W = H_i \cdot \rho \cdot Q_s, \qquad (3)$$

where H_i – net calorific value of fuel; ρ – density of fuel; $Q_s = f(V, \psi)$ – operating consumption of fuel.

When analyzing the formula (2), the question arises as to why the authors use the entire mass of the vehicle with the cargo, if we consider only the mass of the cargo being transported to be useful. It is equally obvious that an important factor will be the speed of the car, as well as fuel consumption, which is nonlinearly dependent on the speed of the car.

We propose to use the mass of cargo or passengers (payload weight, cargo carrying capacity) when calculating the coefficient of efficiency of a vehicle, then formula (2) takes a form:

$$W_{use} = S \cdot \left(m_{cargo} g \cdot \psi + k_a FV^2 \right), \qquad (4)$$

where m_{cargo} – mass of cargo or passengers; ψ – coefficient of road resistance.

An example of the criterion, in which the operational fuel consumption is combined with the

Table 3

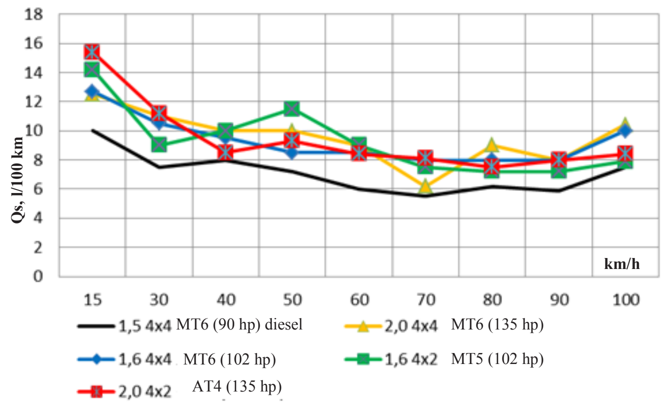
Coefficient of efficiency of configurations of Renault Duster cars at various speeds

Model/ speed, km/h	1,5 4x4 MT6 (90 hp) diesel	2,0 4x4 MT6 (135 hp)	1,6 4x4 MT6 (102 hp)	1,6 4x2 MT5 (102 hp)	2,0 4x2 AT4 (135 hp)
15	0,0223	0,0197	0,0194	0,0174	0,016
30	0,0492	0,0372	0,039	0,0455	0,0365
40	0,0652	0,0578	0,0608	0,0578	0,068
50	0,0725	0,0578	0,068	0,0502	0,0621
60	0,0869	0,0642	0,068	0,0642	0,0688
70	0,0949	0,0932	0,0722	0,077	0,0713
80	0,0841	0,0642	0,0722	0,0802	0,077
90	0,0884	0,0722	0,0722	0,0802	0,0722
100	0,0696	0,0556	0,0578	0,0731	0,0688

Table 4

Efficiency of fuel use of configurations of Renault Duster cars at various speeds

Model/ speed, km/h	1,5 4x4 MT6 (90 hp) diesel	2,0 4x4 MT6 (135 hp)	1,6 4x4 MT6 (102 hp)	1,6 4x2 MT5 (102 hp)	2,0 4x2 AT4 (135 hp)
15	0,235294	0,294118	0,298824	0,334118	0,362353
30	0,176471	0,258824	0,247059	0,211765	0,263529
40	0,188235	0,235294	0,223529	0,235294	0,2
50	0,169412	0,235294	0,2	0,270588	0,218824
60	0,141176	0,211765	0,2	0,211765	0,197647
70	0,129412	0,145882	0,188235	0,176471	0,190588
80	0,145882	0,211765	0,188235	0,169412	0,176471
90	0,138824	0,188235	0,188235	0,169412	0,188235
100	0,176471	0,244706	0,235294	0,185882	0,197647



Pic. 2. Dependence of fuel consumption on speed of a vehicle for various configurations of Renault Duster.

transport work, can be the fuel use efficiency indicator Q_w, which is derived by V. I. Erokhov [8]:

$$Q_w = \frac{Q_{op}}{100 \cdot W_{tr}}, \quad (5)$$

where Q_{op} – operational consumption of fuel, l/100 km; W_{tr} – transport work, t•km.

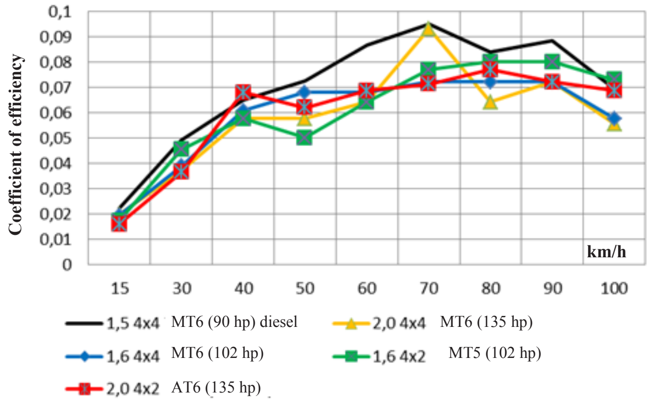
The efficiency indicator has long been used to assess the perfection of transportation and analysis of fuel consumption. A number of scientists offer similar evaluation criteria: D. P. Velikanov, Ya. E. Farobin [4], E. I. Narkevich [9].

We carried out a numerical modeling of the vehicle efficiency coefficient for a number of configurations of Renault Duster cars when driving at different speeds and full loads along a flat road (ψ = 0,015) of km. The results of the modeling are shown in Tables 1–4. The data on the real fuel consumption of Renault Duster cars at various driving regimes have been obtained experimentally and are shown in Pic. 1. Source – Duster Club Forum [10]. The curves of the modeling results are shown in Pic. 2–4. The distribution of the experimental data was averaged over the speed values for the modeling.

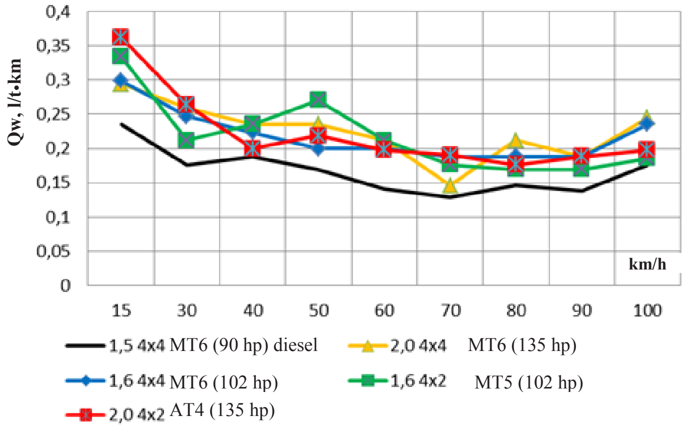
The purpose of all that has been done is to estimate the range of values of the proposed coefficient of vehicle efficiency for different variants of vehicle configurations of the same brand and at different speeds.

Having analyzed the graphs, we see an obvious dependence of the proposed efficiency coefficient on the engine type, cargo carrying capacity, vehicle motion modes.

In this particular example, we can conclude that the diesel version of Renault Duster is superior in its fuel-economic indicators. It is also legitimate to



Pic. 3. Dependence of coefficient of efficiency on speed for various configurations of Renault Duster.



Pic. 4. Dependence of the efficiency of fuel use on speed for various configurations of Renault Duster.

conclude that the most effective modes of movement for all configurations are speeds of 60–90 km/h. For the variant of the car with automatic transmission, the driving modes with low speeds (50–70 km/h) are more effective. These conclusions are fully confirmed by the results of the operation of the Renault Duster.

Conclusion. *Based on the results of the study, there is reason to speak of the consistency of the proposed methodology for constructing a coefficient of technical efficiency of a vehicle.*

REFERENCES

1. Lepeshkin, A. V. Evaluation criteria for energy efficiency of multi-wheeled vehicles [*Kriterii ocenki energojeffektivnosti mnogoprivodnyh kolesnyh mashin*]. *Avtomobil'naja promyshlennost'*, 2010, Iss. 10, pp. 19–23.

2. Karabtsev, V. S., Valeev, D. Kh. On efficiency and efficiency coefficient of a vehicle [*O KPD i koefficiente effektivnosti avtotransportnogo sredstva*]. *Avtomobil'naja promyshlennost'*, 2002, Iss. 10, pp. 16–19.

3. Karabtsev, V. S. Benefit can be counted [*Pol'zu mozhno soschitat'*]. *Korporativnyj zhurnal OAO «Kamaz»*, 2009, Iss. 1–2 [24], pp. 54–56.

4. Farobin, Ya. E., Shchuplyakov, B. S. Evaluation of operational properties for international transportation [*Ocenka ekspluatacionnyh svojstv dlja mezhdunarodnyh perevozok*]. Moscow, Transport publ., 1983, 200 p.

5. Pogosbekov, M. I. Once again about coefficient of Efficiency of a vehicle [*Eshhe raz o KPD avtomobilja*]. *Avtomobil'naja promyshlennost'*, 1996, Iss. 11, pp. 12–15.

6. Govorushchenko, N. Ya. Fuel saving and reduction of toxicity in road transport [*Ekonomija topliva i snizhenie toksichnosti na avtomobil'nom transporte*]. Moscow, Transport publ., 1990, 135 p.

7. Tokarev, A. A. Fuel economy and traction-speed properties of a car [*Toplivnaja ekonomichnost' i tjagovo-skorostnye kachestva avtomobilja*]. Moscow, Mashinostroenie publ., 1982, 224 p.

8. Erokhov, V. I. Economic operation of a car [*Ekonomicheskaja ekspluatacija avtomobilja*]. Moscow, DOSAAF publ., 1986, 186 p.

9. Narkevich, E. I. Determination of the average coefficient of efficiency of a car on a route [*Opredelenie srednego KPD avtomobilja na marshrute*]. *Avtomobil'naja promyshlennost'*, 1998, Iss. 10, pp. 20–23.

10. The Duster Club Forum. Topic: Dependence of fuel consumption on average speed of Renault Duster [*Forum Daster Klub. Tema: Zavisimost' rashoda topliva ot srednej skorosti Reno Daster*]. [Electronic resource]: http://forum.dusterclub.ru/showthread.php?page=7&t=1619. Last accessed 16.02.2017.

11. Evseev, P. P. Energy performance of a car on a route. Terms and «thorns» [*Energeticheskie pokazateli funkcionirovanija avtomobilja na marshrute. Terminy i «ternii»*]. *Avtomobil'naja promyshlennost'*, 1999, Iss. 2, pp. 15–17.

Information about the author:
Goncharov, Oleg Yu. – deputy director of the College of the Institute of Service, Tourism and Design of North Caucasus Federal University (Pyatigorsk branch), Pyatigorsk, Russia, smart30001@yandex.ru.

Article received 16.02.2017, accepted 14.06.2017.