

## Influence of Ambient Air Temperature on the Fuel Efficiency of Vehicles

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**Abstract:** The article evaluates the adaptation of commercial vehicles to the ambient air temperature by the fuel consumption at carriage of cargoes. The provided methodology allows to adjust fuel allowances at operation of commercial vehicles on a case-to-case basis, which will allow to improve the efficiency of motor transport usage.

**Key words:** Transport • Fuel consumption • Motion speed • Air temperature • Increase ratio • Mathematical model

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### INTRODUCTION

To achieve the objective of commercial vehicles operating efficiency improvement, it is necessary to implement new methods oriented to improvement of the transportation process performance [1-6]. Considerable improvement of the motor transport performance in various variable operating conditions is achieved by accounting for the adaptability of the transport to these conditions. At considerable seasonal variation of the operating conditions, the existing methods of planning and arranging the technological process of cargo carriage do not allow to apply in full the potential quality of vehicles that was designed in them during their development and production [7]. Therefore, the achievement of the objective to improve the commercial vehicles performance in various variable operating conditions requires accounting for the adaptability of the transport to these conditions. A typical feature of motor transport is the excessive versatility of operating conditions, wide range of values of many environmental factors, such as the road, climatic and other factors. However, at determination of the fuel allowances, the different adaptivenesses of various models of commercial vehicles to certain operating conditions are not accounted for. The insufficient attention to the adaptiveness of operated vehicles results in extra transportation costs. Great differences and the variable nature of many factors of the environment are typical of vehicle operating

conditions [8]; therefore, special interest is attracted by the research of the ambient air temperature influence on the fuel consumption of various models of vehicles during cargo carriage. The considered problem becomes the more topical, the greater deviations of the operating conditions from the standard ones exist and the worse the vehicles are adapted to these deviations.

**The objective of the research** is the determination of regularities of the change of the values of fuel consumption by commercial vehicles depending on the ambient air temperature.

In order to achieve this objective, the following problems need to be solved:

- To determine the type of the mathematical model of ambient air temperature influence on the fuel consumption of commercial vehicles;
- To develop the indexes of vehicles' adaptiveness to the ambient air temperature by fuel consumption;
- To determine experimentally the numerical values of the mathematical model parameters for the KAMAZ-55102, KAMAZ-45143 and KAMAZ-65115 vehicles.

**Objects and Methods of the Research:** To determine the fuel consumption at various ambient air temperatures, we carried out experimental studies of the operation of the KAMAZ-55102 vehicle with the ODAZ-9770 semitrailer, the KAMAZ-45143 vehicle with the ODAZ-

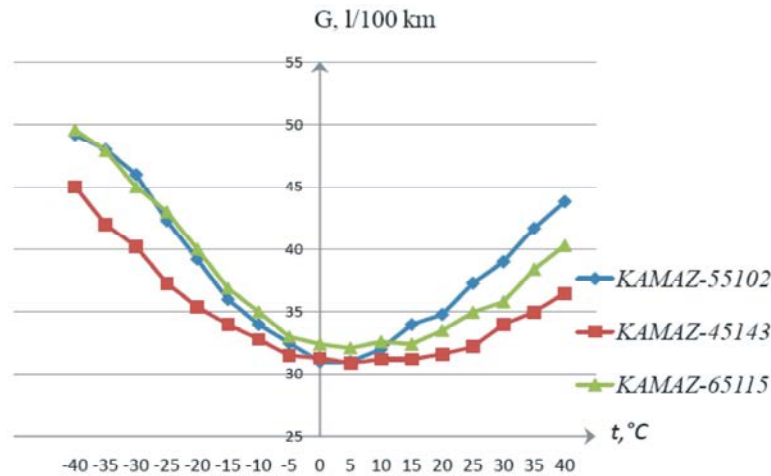


Fig. 1: The dependence of the fuel consumption of the KAMAZ-55102, KAMAZ-45143 and KAMAZ-65115 vehicles on the ambient air temperature

9770 semitrailer and the KAMAZ-65115 vehicle with the ODAZ-9770 semitrailer at carriage of agricultural products weighing 20 tons to the distance of 60 km by asphalt roads. Measurement of the fuel consumption was carried out using the GLONASS navigation system and the GPS transport monitoring system at the speed rate of  $(65 \pm 2)$  km/h [9, 10].

The dependences of fuel consumption on the ambient air temperature were built within this research (Figure 1).

Based on the experimental statistical average data (Figure 1), we determined the analytical models of the fuel consumption  $G$  dependence on the ambient air temperature. According to the experiment data, the dependencies  $G=f(t)$  do not have U-type symmetry; therefore it is reasonable to divide the temperature range into two ranges:  $(-40^\circ\text{C}; t_0)$  and  $(t_0; 40^\circ\text{C})$ . The research showed that within the considered temperature ranges, the ambient air temperature influence on the fuel consumption of commercial vehicles could be described with the exponential model:

$$G = G_0 e^{k(t-t_0)} \quad (1)$$

where  $G$  is the fuel consumption rate, l/100 km;  $G_0$  is the lowest value of fuel consumption, l/100km;  $k$  is the increase ratio  $1/^\circ\text{C}$ ;  $t$  is the ambient air temperature,  $^\circ\text{C}$ ;  $t_0$  is the optimal ambient air temperature,  $^\circ\text{C}$  at the lowest fuel consumption rate.

Let us find the physical meaning of the increase ratio  $k$ . Let us designate the temperature interval, at which the fuel consumption increases in  $e$  times, as  $\Delta t$ , then

$$\frac{G}{G_0} = e^{k\Delta t} = e^1 \rightarrow k\Delta t = 1 \rightarrow k = \frac{1}{\Delta t} \quad (2)$$

Consequently, the increase ratio  $k$  is a physical value, reciprocal to the temperature interval, within which the fuel consumption increases in  $e$  times.

To assess the adequacy of the suggested one-factor mathematical model, we will carry out calculations using statistically average experimental data for the KAMAZ-55102 vehicle.

For the suggested one-factor mathematical model within the temperature interval of  $(5^\circ\text{C}; 40^\circ\text{C})$ , the approximation validity is equal to 0.97 and within the interval of  $(-40^\circ\text{C}; 0^\circ\text{C})$ , it is equal to 0.96 (Figure 2). Consequently, for modeling the influence of the ambient air temperature on the fuel consumption of the KAMAZ-55102 vehicle, we recommend to apply the following equations:

- Within the temperature interval of  $(5^\circ\text{C}; 40^\circ\text{C})$

$$G = 31e^{0.00925(t-5)}; \quad (3)$$

- Within the temperature interval of  $(-40^\circ\text{C}; 0^\circ\text{C})$

$$G = 31e^{0.0124(t-0)}. \quad (4)$$

Similarly, using the average statistical experimental data, we obtained the dependencies of the fuel consumption on the ambient air temperature for the

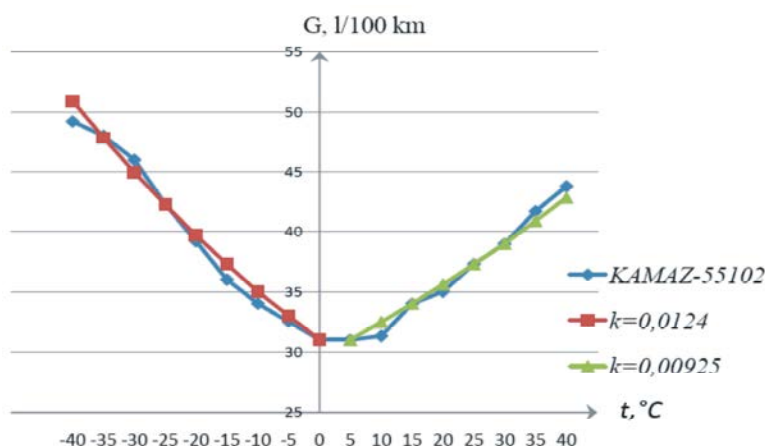


Fig. 2: Evaluation of modeling the influence of the ambient air temperature on the fuel consumption of the KAMAZ-55102 vehicle

Table 1: Mathematical modeling of the ambient air temperature influence on the fuel consumption

Vehicle	Temperature interval	One-factor mathematical model	Approximation validity
KAMAZ-55102	(5°C; 40 °C)	$G = 31e^{0.00925(t-5)}$	0.97
	(-40 °C; 0 °C)	$G = 31e^{0.01242(t-0)}$	0.96
KAMAZ-45143	(5°C; 40 °C)	$G = 30.9e^{0.0021(t-5)}$	0.96
	(-40 °C; 0 °C)	$G = 30.9e^{0.00752(t-0)}$	0.98
KAMAZ-65115	(5°C; 40 °C)	$G = 31e^{0.00428(t-5)}$	0.97
	(-40 °C; 0 °C)	$G = 31e^{0.0114(t-0)}$	0.96

KAMAZ-45143 and KAMAZ-65115 vehicles within the considered temperature ranges. The results of calculations are provided in Table 1.

**Summary:** Having provided the comparison of the fuel consumption values at low and high ambient air temperatures, we can notice the following: during operation of the commercial vehicles in the circumstances of the Amur region, the low temperatures of the environment result in considerable increase of fuel consumption for the KAMAZ-55102 and KAMAZ-65115, rather than for KAMAZ-45143 at all other conditions equal. This can be explained by the increase of the oil viscosity in the gearbox, the additional consumption of power required for maintaining the temperature mode of the car, the change of the tires' operational parameters. At high temperatures, the least gain in fuel consumption is observed with respect to the KAMAZ-45143 vehicle and the maximum gain is observed for KAMAZ-55102, which is evidenced by the variation of the adaptiveness model parameters.

Application of the obtained results of the research when scheduling cargo delivery makes it possible to state precisely the methods of energetic costs cutting [11], which would allow to decrease the transportation costs and, as a consequence, to improve the efficiency of using vehicles in the companies.

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