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car effectiveness; action as a criterion; operating parameters; road car tests

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ACTION AS A CRITERION OF THE CAR OPERATING EFFECTIVENES

Summary. Currently used criteria for determining car operating efficiency in road traffic are, among others, emission of harmful substances, consumption of engine driving fuels, technical service and reliability of operation, safety of use. The operational characteristics of the car in terms of engine driving fuel consumption data is usually recognised as so-called road specific fuel consumption. An important deficiency of this approach is the failure to take into account the influence of the time on the journey's effectiveness and the final result of the entire project. To obtain a new solution in this range in the analysis, a quantity called "action", which at last will be treated as the criterion of the car operating effectiveness, was used. The quantity of action is the product of the performed work and its realisation time. Many phenomena and processes in nature take place according to the principle of "minimum of action" – this criterion can be applied in the analysis of the car's operating efficiency taking place in road traffic. An approach of this issue is presented in this article, wherein the basic data for analysis were obtained in the framework of the car tests performed at the real traffic conditions.

DZIAŁANIE JAKO KRYTERIUM OCENY EFEKTYWNOŚCI EKSPLOATACJI SAMOCHODU

Streszczenie. Kryteriami efektywności eksploatacji samochodów aktualnie stosowanymi są m.in. te dotyczące: emisji substancji szkodliwych, zużycia materiałów pędnych, obsługi technicznej i niezawodności eksploatacji, komfortu oraz bezpieczeństwa użytkowania. Charakterystyka eksploatacyjna samochodu w zakresie wielkości zużycia materiałów pędnych (benzyna, olej napędowy, LPG) ujmowana jest zwykle jako tzw. drogowe (objętościowe, masowe) zużycie paliwa. Istotnym niedostatkiem takiego podejścia jest fakt nieuwzględniania w analizie wpływu czasu realizacji podróży na wynik całego przedsięwzięcia. W tym celu wykorzystano wielkość zwaną „działaniem". Wiele zjawisk i procesów zachodzi według zasady „minimum działania", dlatego też kryterium to może znaleźć zastosowanie w analizie efektywności ruchu drogowego. Takie ujęcie zagadnienia przedstawiono w artykule, przy czym podstawowe dane do analizy pozyskano w ramach testów zrealizowanych w warunkach ruchu drogowego.

1. INTRODUCTION

Currently, the criteria used for determining the car's operating effectiveness are among other criteria relating to pollutants and amount of harmful emissions, fuels and performance of driving materials consumption, technical service and operation reliability, comfort and safety in use [4, 5].

In the framework of the driver training courses, and especially during the current car use, there should be close attention to the efficiency of their operations, including the correctness of the vehicle driving, mainly in the selection of the gear ratio used, being achieved acceleration and the temporary as well as the average speed of the vehicle at the existing road condition [3, 6, 9].

This issue is generally referred to as "eco-driving".

The operational characteristics of the car in terms of fuel consumption data (gasoline, diesel, LPG) is usually recognized by the so-called “road fuel consumption” (expressed as volume, d_V, $m^3/100\ km$, or sometimes as mass, d_m , $kg/100\ km$). This parameter is very often treated as a major, often the only, or the most important criterion for assessing the operating effectiveness of an automobile [7].

A significant shortage of this approach is the lack of the duration time of the whole journey on the impact and quantitative analysis outcomes of the entire project [2, 4].

In this aspect in the paper, the additional variable quantities called “action” have been used [1, 2].

Many phenomena and processes observed in nature take place according to the principle of "minimum of the action"—so consequently it was considered that this criterion can and should be applied by evaluating and analysing the efficiency of the traffic and road transport [2, 8].

For practical reasons, it is proposed to complement the existing information presented by the onboard computer of the car with additional indications (in addition to the traditional, e.g. road fuel consumption) for the current and the average values of the criterion of action [4, 10].

The description of this issue has been presented in the paper, wherein the basic data required for use in quantitative analysis of the posed problem were obtained under the road tests carried out [8].

2. CONDITIONS AND THE CHARACTERISTICS OF THE ISSUE

The commonly used criteria for evaluating the effectiveness of car exploitation are four basic groups of criteria relating to [5, 7, 10]:

a. emissions (quantity and quality of the combustion products),
b. consumption of exploitation materials (fuel, oils and lubricants consumption),
c. operation reliability (technical service, wear processes of the driving system),
d. comfort and safety (convenient to use, statistics of accidents and collisions in road traffic).

The criterion of harmful emissions is an important emissions indicator of identified harmful components (CO, NO_x , C_mH_n , PM) of exhaust gases, determined basically relative to the distance travelled by the vehicle; usually expressed as e_i, g/km; for each case valid are emission standards (→ EURO 6).

Currently, a significant (the greenhouse effect) is given as an indicator referring to carbon dioxide emissions of CO_2 amounting to an average of about $(120 \div 180)$ g/km, and which indirectly let us know the amount of the said road fuel consumption (d_V , d_m; this quantity is also a measure of the efficiency of the chemical energy consumption of the motor fuel used).

Running over any stretch of road S, km, depending on the attained current speed of the car $w(x)$, is done in time period t_s:

$$S = \int_0^{t_S} w(t) \cdot dt \tag{1}$$

and also: $$S = w_S \cdot t_S \ , \qquad w_S = \frac{1}{t_S} \cdot \int_0^{t_S} w(t) \cdot dt \ , \tag{2}$$

whereby: w_S , m/s - the average speed of the vehicle over the distance S of the travelled road.

The operational characteristics of the car in terms of fuel consumption (gasoline, diesel, LPG) is usually described as “road fuel consumption” (expressed as volume, d_V, $m^3/100\ km$, or sometimes as mass fuel consumption, d_m, $kg/100\ km$); related as:

$$d_m = \rho_p \cdot d_V \ , \qquad d_m = \left(\frac{100}{S}\right) \cdot m_{p,S} \, , \qquad d_m = \left(\frac{100}{w_S}\right) \cdot \dot{m}_{p,S} \ , \tag{3}$$

whereby: ρ_p, kg/dm^3 - density of the engine fuel (equals about: 0,75 ÷ 0,82 kg/dm^3), $m_{p,S}$, kg - mass of the fuel consumed on the travelled road S, w_S, km/h - average speed of the vehicle on the road S, $\dot{m}_{p,S}$, kg/h - average stream of the fuel consumed on the road S.

The analysed journey and vehicle parameters are schematically illustrated in the Fig. 1.

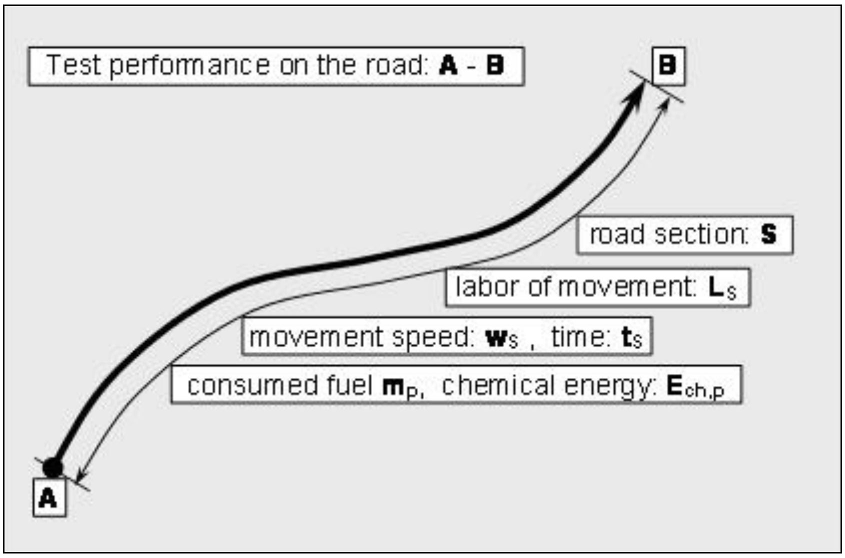

Fig. 1. Performance parameters of the vehicle during the road drive
Rys. 1. Parametry ruchu pojazdu podczas przejazdu odcinka drogi

The road fuel consumption is a very important parameter of the vehicle operational characteristics, determining, inter alia, the total fuel consumption and so incurred operating costs because if the total distance to be travelled is S km (i.e. $0 \le x \le S$), then on this way the car consumes m_p, kg of fuel:

$$m_p = \int_0^S d_m \cdot dx = \rho_p \cdot \int_0^S d_V \cdot dx \, . \tag{4}$$

The efficiency of the vehicle exploitation, including the current value of road fuel consumption d_V, $dm^3/100\ km$, depends on many factors and the driving conditions, and above all from [6, 8, 9]:

- current speed of the car $w_s(x)$, (*driving style influences the resistance of the surrounding air*);
- used gearbox ratios (*selection of the workplace in the work-field of combustion engine)*;
- rolling resistance (*landform and road surface quality*);
- weather and atmospheric conditions (*precipitations, wind*).

The main task of conditioning the use of the internal combustion engine is the conversion of the chemical energy of the fuel supplied to the system, until mechanical work is obtained, next conducted from the system through the crankshaft—in the form of the torque $M_{o,\,e}$, Nm/rad, correctly understood as the mechanical work transported per 1 radian of the crankshaft rotation.

To overcome the stretch of road, S (Fig. 1) is required for the performance of mechanical work L_S, kJ:

$$L_S = L_{e,E} \cdot \eta_N \ , \tag{5}$$

where: $L_{e,E}$, kJ - effective IC engine shaft work performed by driving the vehicle on the way S,
η_N , - - energy transfer efficiency of the vehicle driving system.

Production of the work by the IC combustion engine driving the car takes place according to the relation:

$$L_{e,E} = m_p \cdot H_{d,p} \cdot \eta_e \ , \qquad L_{e,E} > L_S \ , \tag{6}$$

where: η_e - effective energy efficiency of the IC engine, m_p, kg - mass of the fuel consumed on the overcome way S, $L_{e,E}$, kJ - effective work performed by the engine driving the car, $H_{d,p}$, kJ/kg - low caloric value of the fuel used on the way (about 44 MJ/kg).

After substituting the relation (6) into eq. (5) will be achieved:

$$L_S = m_p \cdot H_{d,p} \cdot \boldsymbol{\eta}_e \cdot \boldsymbol{\eta}_N \ , \tag{7}$$

and next after taking into account the relationship (4) is obtained on the route S performed work L_S, which finally can be noted as:

$$L_S = d_{V,S} \cdot S \cdot H_{d,p} \cdot \boldsymbol{\eta}_e \cdot \boldsymbol{\eta}_N \cdot \boldsymbol{\rho}_p \ , \tag{8}$$

whereby:

$$d_{V,S} = \frac{1}{S} \cdot \int_0^S d_V \cdot dx \tag{9}$$

where: $d_{V,S}$, $m^3/100\ km$ - overage value for the way S of the road fuel consumption.

The internal combustion engine as a drive unit of the vehicle is a complex eco-energy object, shown illustratively in Fig. 2.

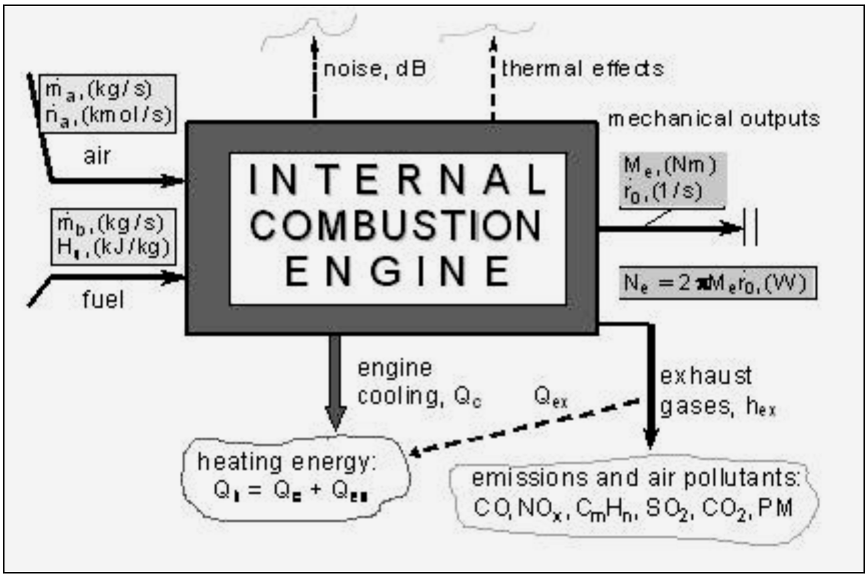

Fig. 2. Classic IC engine system and its parameters
Rys. 2. Klasyczny układ silnika spalinowego i jego parametry

The range of possible operating states of the IC engine (includes subsequent values from the lowest torque to the outer characteristics of the engine load) is performed usually at constant speed ($\dot{r}_o$ = idem) of the crankshaft and gearbox ratio, which corresponds to different traffic burdens (*different torque, corresponding to him engine power*) even at the assumed traffic speed *w(.)* of the car on the route.

According to formulas (7), (8) - particular attention should be paid to the formation of energy-efficiency η_e of the combustion engine driving the vehicle.

Effective energy efficiency η_e of the internal combustion engine takes different values in the engine operating field; these characteristics are pictorially shown in Fig. 3.

The operating characteristics of the IC engine (Fig. 3) expresses the functional dependence [3, 6, 7]:

$$\boldsymbol{\eta}_e = F(M_{o,e}, \dot{r}_0) \tag{10}$$

or relatively:

$$\boldsymbol{\eta}_e = F(N_e, \dot{r}_0), \tag{11}$$

whereby: $$M_{o,e} = \frac{N_e}{2 \cdot \pi \cdot \dot{r}_o} , \qquad (12)$$

where: $\dot{r}_0$, *rev/s*, - the rotational speed of the crankshaft, $M_{o,e}$, *Nm/rad* - the effective engine torque, N_e, *kW* - effective power of the IC engine, - also included in the operation area (shown in Fig. 3) of the IC engine.

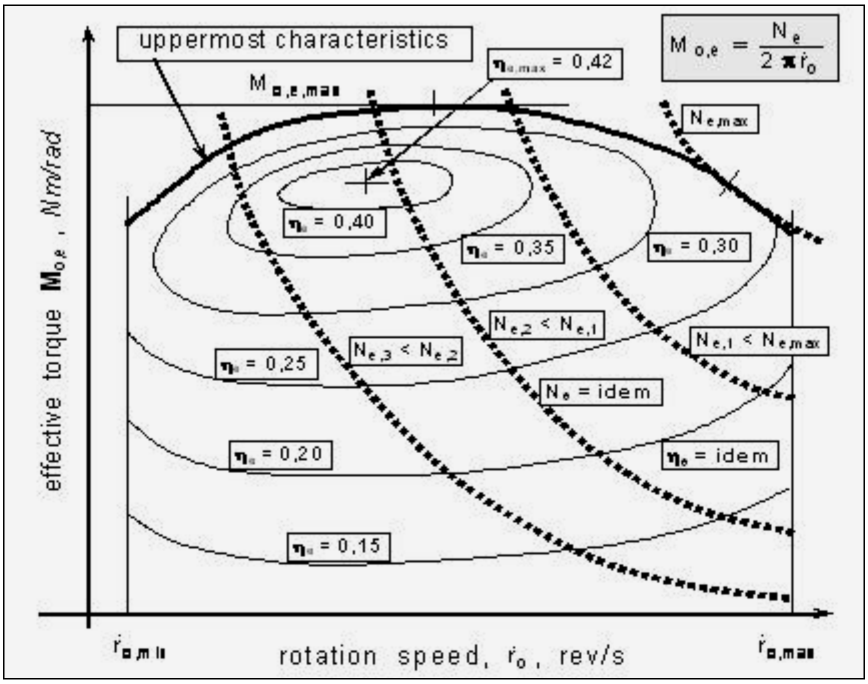

Fig. 3. Performance characteristic of the internal combustion engine
Rys. 3. Charakterystyka eksploatacyjna silnika spalinowego

If the work of the internal combustion engine is characterized by its power $N_{e,E}$, *kW*, then as equivalent of the equation (8) it will be the average driving power N_S on the route *S*, in the form of relationship:

$$N_S = d_{V,S} \cdot w_S \cdot H_{d,p} \cdot \eta_{e,E} \cdot \eta_N \cdot \rho_p , \qquad (13)$$

where: $d_{V,S}$, $m^3/100\ km$ - the average value of road fuel consumption on the road stretch *S*, w_S, *km/h* - average speed of the vehicle on the test road *S*.

It is similarly worth noting that the same average ground speed w_S on a given stretch of road *S* can be achieved using various ratios (i.e. gears) in the gearbox; so this parameter should also be taken into account because it determines the value of the engine rotation speed $\dot{r}_0$ and so the actual energy efficiency $\eta_{e,E}$ of the combustion engine driving the vehicle.

3. IMPORTANCE AND USEFULNESS OF DIFFERENT CRITERIA IN THE CAR EFFECTIVENESS ANALYSIS

Unambiguously, an objective assessment of the exploitation of the car can be made on the basis of correctly defined criteria that should be used in their analysis.

Very often in the analyses (e.g. in different cases of individual drivers) it is assumed: the criterion of minimum demand of the chemical energy of consumed fuel ($E_{ch,p} \rightarrow E_{ch,p,min}$), and, therefore, also minimum amount of fuel ($m_p \rightarrow m_{p,min}$) to overcome the stretch of road *S*, which consequently corresponds to achieving minimum road fuel consumption ($d_V \rightarrow d_{V,min}$), and it follows directly from the relations (3), (9).

Acceptance of the criterion of a minimum amount of road fuel consumption ($m_p \rightarrow m_{p,min}$) to overcome a given stretch S of the road is equivalent to exploring the minimum value of the road fuel consumption ($d_{V,S,min}$ or alternatively $d_{m,S,min} = \rho_p \cdot d_{V,S,min}$, $kg/100\ km$) – commonly accounted, for example, depending on the average speed w_S of traffic on the stretch S of road.

A significant shortcoming of this approach is disregard of the journey time t_S on the assessment and the final test result of the whole road project:

(time - *as the proverb says* - is money)

e.g. personal labour costs of the executors are also important.

It is, therefore, necessary to define more general and universal criteria for assessing the operational effectiveness of the car, taking into account also this aspect of that research. For this purpose, it is proposed to take into account and use in the analysis the quantity [1] - called "action - D".

In the simplest approach, "action - D" is the product of the value of performed labour L and the exercise time t thereof; and, therefore, in relation to the analysed issues of traffic and operating efficiency of the car, the action - D can be calculated using the relationship [2, 4, 8]:

$$D_S = L_S \cdot t_S \quad . \tag{14}$$

This relationship can be expressed also in the form:

$$D_S = N_S \cdot t_S^2 \qquad \text{relatively:} \qquad D_S = N_{e,E} \cdot t_S^2 \cdot \eta_N \quad . \tag{15}$$

After taking into account the relations (2) and (9) in the definition (14), this expression can be obtained:

$$D_S = \left(\frac{d_{V,S}}{w_S} \right) \cdot S^2 \cdot H_{d,p} \cdot \boldsymbol{\eta}_{e,E} \cdot \boldsymbol{\eta}_N \cdot \boldsymbol{\rho}_p \qquad , \tag{16}$$

which can be used for determining of the achieved values D_S and next used in the complex analysis of the action at given road operating conditions, both in terms of instantaneous and next averaged for the selected road section.

For the calculated action amount of D_S, it is advisable to define and adopt a reference state $)_0$, for example, will be determined by the contractual parameters:

$$D_{S,0} = \left(\frac{d_{V,S}}{w_S} \right)_0 \cdot S_0^2 \cdot H_{d,p} \cdot \boldsymbol{\eta}_{E,0} \cdot \boldsymbol{\eta}_{N,0} \cdot \boldsymbol{\rho}_p \tag{17}$$

and then the relative (dimensionless) value Ω actions can be defined as:

$$\boldsymbol{\Omega} \stackrel{df}{=} \left(\frac{D_S}{D_{S,0}} \right) \quad . \tag{18}$$

Relative value Ω of the criterion of action results finally as:

$$\boldsymbol{\Omega} = \frac{\left(\frac{d_{V,S}}{w_S} \right)}{\left(\frac{d_{V,S}}{w_S} \right)_0} \cdot \left(\frac{S}{S_0} \right)^2 \cdot \left(\frac{\boldsymbol{\eta}_E}{\boldsymbol{\eta}_{E,0}} \right) \cdot \left(\frac{\boldsymbol{\eta}_N}{\boldsymbol{\eta}_{N,0}} \right) \quad , \tag{19}$$

whereby the issue can be analysed for any selected road section S; also of course for $S = S_0$; both instantaneous and averaged for a fixed road section.

According to formula (19), the relative value of the criterion of action can be recorded as:

$$\boldsymbol{\Omega} = \frac{\left(\frac{d_{V,S}}{w_S} \right)}{\left(\frac{d_{V,S}}{w_S} \right)_0} \cdot K \tag{20}$$

whereby the parameter K: $$K = \left(\frac{S}{S_0}\right) \cdot \left(\frac{\eta_E}{\eta_{E,0}}\right) \cdot \left(\frac{\eta_N}{\eta_{N,0}}\right) \quad . \tag{21}$$

For a simple approximation of traffic conditions (according to driver assistant) can be assumed:

$$\left(\frac{S}{S_0}\right) \approx idem\,, \quad \left(\frac{\eta_E}{\eta_{E,0}}\right) \approx idem, \quad \left(\frac{\eta_N}{\eta_{N,0}}\right) \approx idem\,, \tag{22}$$

then usual: $$K = \left(\frac{S}{S_0}\right) \cdot \left(\frac{\eta_E}{\eta_{E,0}}\right) \cdot \left(\frac{\eta_N}{\eta_{N,0}}\right) = idem, \quad or\ even: \ K \approx 1\,. \tag{23}$$

It will be important to search for a minimum of the adopted criterion of action at the various engine loads on the road (different torque and the corresponding power of IC engine) and at the assumed traffic speed of the exploited car.

Many phenomena and processes commonly found in nature (e.g. different cases of motion in the gravitational field, the passage of light rays by the centres with different optical properties) take place in accordance with the natural principle of "minimum action"; therefore, this criterion can and also should be used in the analysis of the efficiency of vehicles involved in road traffic.

4. SELECTED ROAD TESTS

In the framework of the road test prepared program, it was determined that there is need to travel the same selected road route length S_0 = 62,5 *km*, and with the selected unchangeable route speed w_i of the moving car. In subsequent steps of realized tests, the car speed was chosen from the range of 40 to 130 *km/h*. The investigations were performed on the selected three-band section of the motorway A-1, length of S_0 = 62,5 *km*; a Peugeot 307 was used in the test cycles while maintaining suggested for the given test speed of the car's optimal gear ratio [3, 4, 9].

According to the conditions of the i-th variant test (different travelling speed w_i, i = 1, 2, 3,..., 7) recorded were the travel time ti, and amount V_p of the fuel consumed on the road S_0.

The data obtained in the tests allowed first determination of the specific road fuel consumption $d_{V,i}$, then the index ($d_{V,i}/w_i$) and finally the achieved values of the relative action Ω - using the formula (20).

The main chosen results of the road tests are presented in Table 1.

Table 1

Results of the car road investigations

Series number	Speed of the car w_i, *km/h*	Travel time on the route t_i, *min.*	Total fuel consumed $V_{p,i}$, *dm³*	Road fuel consumption $d_{V,i}$, *cm³/km*	Index of action ($d_{V,i}/w_i$), *cm·s*	Relative action **Ω**, -
1.	40	93,8	3,76	60,16	$0{,}5414\cdot10^{-6}$	1,6988
2.	50	75,0	3,43	54,88	$0{,}3951\cdot10^{-6}$	1,2397
3.	*60*	*62,5*	*3,32*	*53,12*	$0{,}3187\cdot10^{-6}$	*1,0000*
4.	70	53,6	3,41	54,56	$0{,}2806\cdot10^{-6}$	0,8805
5.	90	41,7	3,86	64,76	$0{,}2470\cdot10^{-6}$	0,7750
6.	110	34,1	5,42	86,72	$0{,}2838\cdot10^{-6}$	0,8530
7.	130	28,8	7,26	116,16	$0{,}3217\cdot10^{-6}$	1,0320

The basic function of the traffic volume road fuel consumption d_V obtained in performed tests is illustrated in Fig. 4. Analysed function (Fig. 4) reaches a minimum with an approximate value of $d_{V,min}$ = 53,4 cm^3/km, achieved at the speed of about 61,1 *km/h*, which is often a very important and useful information for a selected group of car drivers.

A characteristic feature of the function course (Fig. 4) of the analysed traffic fuel consumption volume d_V is the most significant increase of its values in the range of the movement speed above (on right) the reached minimum value $w_{S,min}$; whereas in this area the travel times ti of the given road distance are getting shorter.

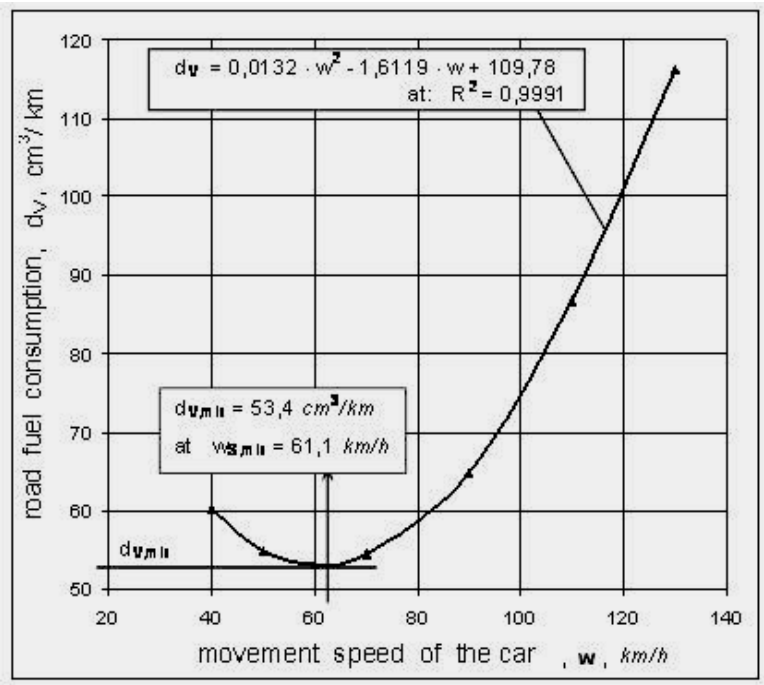

Fig. 4. Road fuel consumption of the vehicle at different velocities
Rys. 4. Drogowe zużycie paliwa przy różnych prędkościach pojazdu

Determined in this manner, the function of the road fuel consumption $d_V(w)$ can be described by a suitable approximation, for example, in the form of a second degree polynomial:

$$d_V = A \cdot w^2 + B \cdot w + C \tag{24}$$

The coefficients *A, B, C* should be determined using the collected experimental data (Table 1).

For the analysed case of realized research, the dependence (24) takes the form:

$$d_V = 0{,}0132 \cdot w^2 - 1{,}6119 \cdot w + 109{,}78 \tag{25}$$

i.e.: $A = 0{,}0132\ (h^2 \cdot cm^3)/km^3$, $B = -1{,}6119\ (h \cdot cm^3)/km^2$, $C = 109{,}78\ cm^3/km$,

with the regression coefficient: $R^2 = 0{,}9991$.

A minimum of the function (24), (25) describing the fuel road consumption occurs at the speed:

$$w_{S,\min} = -\frac{B}{2 \cdot A} = \frac{1{,}6119}{2 \cdot 0{,}0132} = 61{,}1 \quad km/h\ , \tag{26}$$

and the value of the road fuel consumption at this point is: $d_{V,min} = 53{,}42\ cm^3/km$.

Another look at this issue is achieved by using the criterion "action - Ω" defined by formula (17) or its dimensionless form (18), (19) and (20).

Thanks to the completed road tests (Table 1) for successive values $w_{S,i}$ of the motion speed, first was determined the factor (16) of action indicator ($d_{V,S,i}/w_{S,i}$), next according to formula (17) the base value of action indicator ($d_{V,S,0}/w_{S,0}$), and finally using equations (20), (21) approximate values Ω of the relative action.

Using equations (16) and (24) describing the road fuel consumption, the equation describing the relative action can be appointed, for this purpose, the first base relationship:

$$D=\left(\frac{d_V}{w}\right)=A\cdot w+B+\frac{C}{w} \quad . \tag{27}$$

Namely, using the approximation (25) we obtained:

$$D_S=\left(\frac{d_V}{w}\right)=0{,}0132\cdot w+\frac{109{,}78}{w}-1{,}6119 \ . \tag{28}$$

Determined in this way, the relative values Ω of the action are illustrated in the Fig. 5.

As the reference speed was adopted the value: $w_0 = 60$ *km/h*, which according to formula (17) allows us to determine the reference value of the action criterion: $D_{S,0} = 0{,}3187\cdot 10^{-6}$ *cm·s*; it is also included in Table 1.

The action function (27) reaches a minimum at the point:

$$w_{\Omega,\min}=\sqrt{\frac{C}{A}} \quad , \tag{29}$$

while the sought minimum value of the action is:

$$D_{S,\min}=\left(\frac{d_V}{w}\right)_{\Omega,\min}=2\cdot\sqrt{A\cdot C}+B. \tag{30}$$

Based on the equations (25) and (29) we obtained:

$$w_{\Omega,\min}=\sqrt{\frac{109{,}78}{0{,}0132}}=91{,}2, \quad km/h \tag{31}$$

and then according to (28) and (30) we obtained: $D_{S,min} = 0{,}7957$ *(h·cm³)/km²*.

Analysed function of the relative action (Fig. 5) reaches a minimum value $\Omega_{min} = 0{,}782$, at the vehicle speed of about $w_{\Omega,min} = 91{,}2$ *km/h*.

A characteristic feature of the course of action function (Fig. 5) is that the most significant increase of its values present in the range below (on the left) the characteristic (31) movement speed $w_{\Omega,min}$.

This happens among others due to a systematic increase in the travel time t_S in this area.

Based on the achieved results, it can be assumed that an indication that ultimately favours the values of the cruising speed can be selected from the designated range:

$$w_{S,min} \le w(t) \le w_{\Omega,min} \ .$$

In this manner, at the same case, we can partly satisfy the criterion of a minimum road fuel consumption and also the importance of the duration time of the trip.

For practical reasons, it is proposed to supplement the current information saved and presented by the car's on-board computer for additional indications (beyond the traditional; for example, road fuel consumption) concerning current (19) and the average criterion values of the action Ω.

5. CONCLUSIONS

Commonly used criteria for the effectiveness of car exploitation, including m. In. criteria: emissions and consumption of fuel should be extended to take into account the criterion of system operation time associated with performing of the task.

The operating characteristics of the car in terms of fuel consumption data determines mainly the cost of fuel, resulting from the manner of the car exploitation.

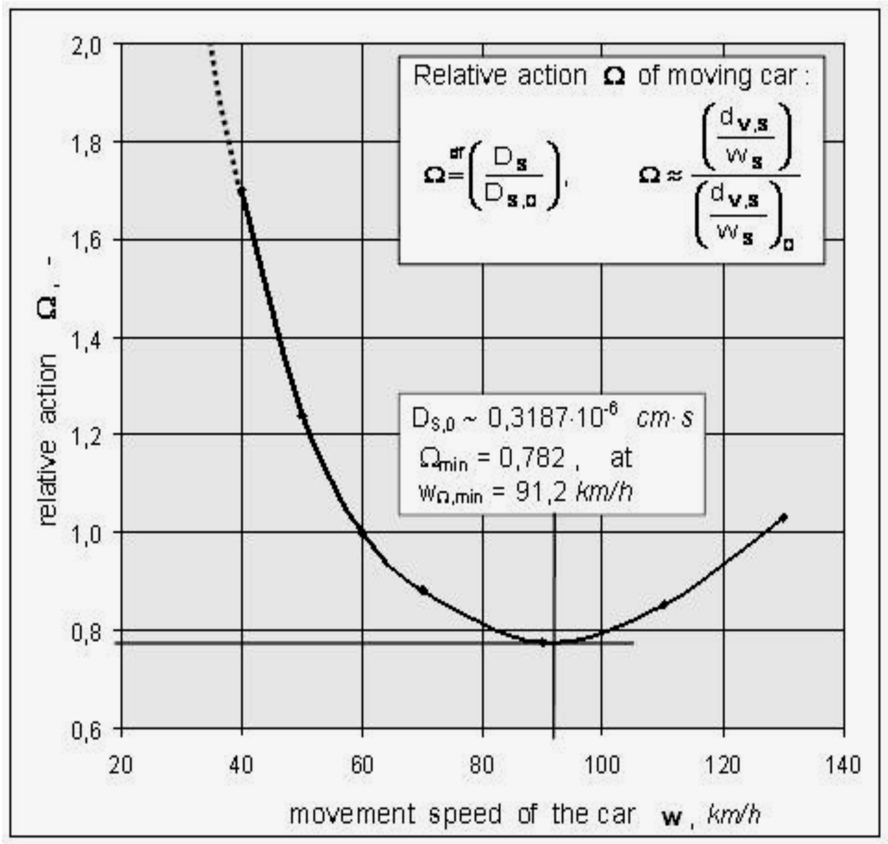

Fig. 5. Relative action of the vehicle drive at different velocities of the car
Rys. 5. Względne kryterium działania przy różnych prędkościach pojazdu

A significant shortage of this approach is the lack of the time taken into account, its impact on the journey parameters and on the effective outcomes of the entire project.

To complement this, it is proposed to use a quantity called "action", which as a criterion can be used in the analysis of the efficiency of the car's operation on the road.

General approach to the problem based on the criterion "action" was elaborated and presented in the paper additionally illustrated by the results obtained within the framework of car driving examinations carried out on the road.

Based on the results of road tests, it was found that the most preferred range of the cruising speed should be lying rather in the immediate vicinity of the characteristic speed $w_{\Omega,min}$, resulting from eq. (29), (31), whereby its value: $w_{\Omega,min} > w_{S,min}$, and according to the equation (29) this car speed $w_{S,min}$ allows us to achieve only the minimum of the road fuel consumption.

In this manner it makes itself satisfied with the criterion of minimum road fuel consumption and the optimum of required duration of the trip. The new information from the range of the optimal driving problem displayed on the screen can suggest and indicate to the driver the selection of drive parameters (gear ratio, speed of movement) and the manner and overall style of vehicle driving.

The obtained results of the performed road tests confirm the practical usefulness of the proposed solution of the optimal driving problem.

Nomenclature

$M_{e,0}$ - effective torque, *Nm/rad*

$\eta_{e,0}$ - effective efficiency, -

$N_{e,0}$ - effective power output, *kW*
$\dot{r}_0$ - revolution number (engine speed), *rev/s*
d_V - the average value of road fuel consumption, *m³/100 km*
$L_{e,E}$ - effective work performed by the engine driving the vehicle, *kJ*
L_S - mechanical work of transportation on the road, *kJ*
η_N - energy transfer efficiency of the vehicle driving system, -
m_p - mass of the fuel consumed on the road, *kg*
t - duration of the travel, *s*
H_u - lover heating value, *kJ/kg,*
w - speed of the vehicle on the test road, *km/h*
D - index of action criterion*, J·s*
Ω - value of relative action, -

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