ECONTECHMOD. AN INTERNATIONAL QUARTERLY JOURNAL – 2012, Vol. 01, No. 2, 03–07

Modelling of the kinetic energy loss in a vehicle on the basis of cumulative frequency of speed profile parameters

Z. Burski, H. Krasowska-Kołodziej***

* Department of Power Industry and Vehicles, University of Life Sciences in Lublin,
** University of Engineering and Economics in Rzeszów

Received March 20.2012: accepted April 15.2012

A b s t r a c t. This paper presents the modeling of energy intensity of vehicles in terms of loss of kinetic energy during driving on a motorway, dual carriageway and national road. The analysis was based on elements of mathematical statistics on the prevalence of sensitivity of the total speed and variation of its occurrence. The analysis was performed on a statistically significant number of vehicles using the envelope of oscillograms of the tachographic record of continuous motion.

K e y w o r d s : transport logistics, modeling, energy intensity of movement, tachographic record, mathematical statistics of oscillogram.

INTRODUCTION

Energy consumption of a vehicle movement is an essential component of the energy balance. It is the sum of energy expenditure to overcome the resistance to motion and gravity, inertia forces. The share of each component in the equation of motion depends on the realized velocity profile, which is largely determined by the acceleration phase parameters [12].

For longer journeys with variable speed a significant impact on energy consumption is the frequency of movement phases of acceleration and their intensity [1].

According to the previous research [13, 7] city driving has almost five times larger share of energy expenditure to overcome the inertia forces than road riding. Road riding has more than a double share of energy expended to overcome air resistance, due to higher average speed.

This is confirmed by studies of energy loss resulting from the difference between acceleration and deceleration phase of driving in urban infrastructure and road [4, 5, 9, 10, 11].

AIM OF RESEARCH

In the previously conducted studies, the energy intensity of vehicles has been largely boiled down to a theoretical analysis of the impact of balance sheet items of the vehicle energy dialogue, energy intensity of the basic phases of a movement or a complex profile of driving speed in the strictly defined so called Elementary Profiles [13].

These included successively: acceleration, constant speed driving and delayed traffic.

The operational, randomly variable conditions of real driving were included to a lesser extent. In this case the energy expended to travel the section of road is also dependent on the frequency and intensity of phase delay [3, 8].

The main direction of research concerned the speed limit in various communication infrastructure, with no apparent connection to its energy intensity and rather related with the safety of road users [6, 14, 16, 17].

Therefore, an important issue arising from the progressive geodelization of transport (Shapovalov, Nezhinsky 2010) proved to be an increased use of speed profile in the so called. tachografic record

This paper presents the results of the analysis of energy consumption at speeding up and slowing down with the method of mathematical analysis in the global count of losses occurring between these phases.

RESEARCH METHODOLOGY AND STATISTICAL CALCULATIONS

The assumed methodology used the tachographic records of vehicles statutorily required to use analogue and digital tachographs. The routes included the national and international roads (motorways and ways of fast motion). In order to find out the expended kinetic energy of velocity phase profile of the vehicle's motion, the computations were performed of the so called distribution of the empirical frequency of acceleration phase (F1) and delay phase (F2) in the corresponding section of the infrastructure of distance traveled.

As the basic statistical parameters of speed profile the frequency of occurrence of the mean value (x), median (Me), and dominant (Do) were assumed. To assess the variability of occurrence of individual driving phases in the global profile, the following values were calculated: (S2), standard deviation (s), and coefficient of variation (Wz) [15].

CALCULATION RESULTS AND ANALYSIS

1. EVALUATION OF THE BASIC PARAMETERS OF THE GLOBAL STATISTICAL PROFILE OF DRIVING SPEED

Tab. 1 shows the distribution of empirical numbering frequency of the arithmetic mean (x) of the upper (F1) and lower (F2) speed profile on the national road (1, 2), way of fast motion (3, 4) and motorway (5, 6). Analogous data have been presented for the empirical distribution of the median (Me) - Tab. 2 and the dominant (Do) - Tab. 3.

The maximum values of the median (Me) of acceleration phase (F1) are in the range 70-80 km / h and represent

Table. 1. Numbering the empirical distribution of the frequency of the upper (F1) and lower (F2) speed profile of the arithmetic mean (x) on the national road (1,2), way of fast motion (3.4), and motorway (5.6)

No	Velocity v	Arithmetic mean x					
		national road		way of fast motion		motorway	
		F1	F2	F1	F2	F1	F2
1.	10	-	-	-	-	-	-
2.	20	-	0,04	-	-	-	-
3.	30	-	0,12	-	-	-	-
4.	40	-	0,28	-	0,07	-	-
5.	50	0,15	0,60	0,02	0,23	-	0,06
6.	60	0,26	0,72	0,04	0,68	-	0,12
7.	70	0,69	0,84	0,20	0,95	-	0,45
8.	80	0,96	1,00	0,70	0,98	0,20	0,90
9.	90	1,00	-	0,97	1,00	0,82	1,00
10.	100	-	-	1,00	-	1,00	-
11.	110	-	-	-	-	-	-
12.	120	-	-	-	-	-	-
13.	130	-	-	-	-	-	-
14.	140	-	-	-	-	-	-
15.	150	-	-	-	-	-	-
16.	160	-	-	-	-	-	-
17.	170	-	-	-	-	-	-

Table. 2. Numbering the empirical distribution of the frequency of the upper (F1) and lower (F2) speed profile of median (Me) on the national road (1,2), way of fast motion (3.4), and motorway (5.6)

No.	Velocity v	Median					
		national road		way of fast motion		motorway	
		F1	F2	F1	F2	F1	F2
1.	10	-	-	-	-	-	-
2.	20	-	-	-	-	-	-
3.	30	-	0,03	-	0,06	-	-
4.	40	0,04	0,11	0,06	0,09	-	-
5.	50	0,08	0,38	0,09	0,13	0,02	-
6.	60	0,17	0,53	0,13	0,27	0,05	-
7.	70	0,30	0,57	0,27	0,59	0,05	0,03
8.	80	0,65	0,74	0,59	0,67	0,08	0,48
9.	90	0,91	0,96	0,65	0,74	0,66	0,87
10.	100	1,00	1,00	0,74	0,84	1,00	0,90
11.	110	-	-	0,84	0,88	-	0,97
12.	120	-	-	0,88	0,88	-	1,00
13.	130	-	-	0,93	0,93	-	-
14.	140	-	-	,093	0,93	-	-
15.	150	-	-	0,99	0,99	-	-
16.	160	-	-	1,00	1,00	-	-
17.	170	-	-	-	-	-	-

36.3% of the total number (Tab. 2). The corresponding values of the dominant (Tab. 3) are in the range (70-80) km / h (F1) and represent 33.3% of the total number, for (F2) - (50-60) km / h (44%).

For ways of fast motion the arithmetic mean (x) of the acceleration phase (F1) is in the range (70-80) km / h, which represents 50% of the total number. For the motion delay phase (F2) it represents 46%, in the range 50-60 km / h. The median (Me) values account for 41% of the number, in the range (80-90) km / h (F1), and for F2 - 36.5% in the range (60-70) km / h. The arithmetic mean (x) for the motorway is 61.5% of the number in the range (80-90) km / h (F1) and for (F2) - 78.8% of the number in the range of (60-80) km / h. The highest values of the number of incidence frequency of median (Me) for (F1) are in the range (80-100) km (90%), for (F2) - 84, 9%, in the range (70-90) km/h.

These figures are reflected in the course of accelerating the phase distribution function (F1) and deceleration speed (F2). The difference between them reflects the size of kinetic energy loss on the considered transport infrastructure routes (Table 1-3). The lowest energy loss occurs on the motorway. Loss of kinetic energy on the national road coincides with the motorway, regardless of the statistical parameter in question.

STATISTICAL EVALUATION OF VARIABILITY OF A GLOBAL PROFILE OF SPEED PARAMETERS

According to the obtained calculations (Table 4), the lowest standard deviation (s) obtained for the motorway was (5-20) km / h, then for the national road (10-30) km / h, and for the motorway (5-40) km / h. This is due to the frequency of its incidence. For the motorway 100% of its value is contained in the range from (0-20)%, while for the remaining infrastructure of F1 and F2 it stays in the range between (35-60)%.

According to the obtained calculations of variance (δ2) of the analyzed profiles F1 and F2 (Table 5), a significant variation in its value occurred within their increased volatility. This was especially observed for high speed road (3, 4).

Table. 3. Numbering the empirical distribution of the frequency of the upper (F1) and lower (F2) speed profile of dominant (Do) on the national road (1,2), way of fast motion (3.4), and motorway (5.6)

No.	Velocity v	Dominant					
		national road		way of fast motion		motorway	
		F1	F2	F1	F2	F1	F2
1.	30	-	-	0,04	0,04	-	-
2.	40	-	0,04	0,06	0,09	-	0,05
3.	50	0,11	0,20	0,13	0,25	0,12	0,11
4.	60	0,18	0,64	0,17	0,34	0,15	0,11
5.	70	0,25	0,82	0,32	0,53	0,20	0,14
6.	80	0,59	0,92	0,39	0,76	0,25	0,55
7.	90	0,74	1,00	0,71	0,86	0,67	0,88
8.	100	0,85	-	0,86	0,88	0,87	1,00
9.	110	0,92	-	0,95	0,97	0,97	-
10.	120	0,96	-	1,00	1,00	0,97	-
11.	130	1,00	-	-	-	1,00	-

Table. 4. Numbering the empirical distribution of total frequency of standard deviation incidence (s) of the upper (F1) and lower (F2) speed profile on the national road (1,2), way of fast motion (3,4) and motorway (5,6)

No	Value	Standard deviation					
		national road		way of fast motion		motorway	
		F1	F2	F1	F2	F1	F2
1.	5	0,03	-	0,02	0.02	0,21	0,03
2.	10	0,24	-	0,06	0.02	0,52	0,06
3.	15	0,61	0,03	0,49	0.06	0,74	0,39
4.	20	0,76	0,26	0,83	0.20	1,00	0,69
5.	25	1,00	0,65	0,98	0.47	-	0,93
6.	30	-	0,96	1,00	0.75	-	1,00
7.	35	-	1,00	-	0.93	-	-
8.	40	-	-	-	1.00	-	-

The coefficient of variation (Wz), is an important statistical parameter, which combines the characteristics of standard deviation (s) and mean value (x). According to the data in Tab. 6, for the motorway, 100% of the value contains the range of variation coefficient (0-30)%. Its highest value (40-60)% was obtained for the profile of traffic delay phase for the national road and way of fast motion.

CONCLUSIONS

Effect of acceleration and deceleration of the speed of vehicles on the kinetic energy losses due to its profile should be considered, depending on many factors: the transport infrastructure, road conditions, the management of its speed, psychological and physical features of drivers, etc. The study conducted on the statistically significant number of the vehicles involved in international freight transport, however, allowed for a global approach to this problem.

It was proved possible to determine the basic, dominant frequency ranges of statistical parameters of vehicle acceleration and deceleration phases. They express both the mean value distribution and the median and dominant distribution. While a greater variation of the summary value occurs in the case of the way of fast motion and the national road (40-60)%, for the motorway it is (85-90)% of the total.

The evaluation of the quoted results of calculation of the core statistical values of the global speed profile, in relation to the existing road testing studies of other authors (Gaca 2001, Szymanek 2001) allows for the following statements:

– Compared to the national road and way of fast motion, the motorway is characterized by large incidence clusters of both the analyzed phases in the speed range, thus there is a small area of energy loss between the empirical distribution functions;
– Motorway is a special case of frequency diversity of the analyzed parameters, resulting on one hand from a high speed limit, on the other hand from a need to reduce it due to the requirements of road safety.
– An example of this problem is introduction of collision-free traffic engineering solutions, e.g. the use of

Table. 5. Numbering the empirical distribution of total frequency of variance (δ2) of the upper (F1) and lower (F2) speed profile on the national road (1,2), way of fast motion (3,4) and motorway (5,6)

No	Value	Variance					
		national road		way of fast motion		motorway	
		F1	F2	F1	F2	F1	F2
1.	100	0,03	-	0,13	0,20	0,51	0,05
2.	200	0,22	0,03	0,20	0,04	0,69	0,25
3.	300	0,33	0,07	0,51	0,14	0,82	0,47
4.	400	0,63	0,15	0,82	0,21	0,97	0,67
5.	500	0,70	0,30	0,98	0,28	1,00	0,75
6.	600	0,78	0,53	0,97	0,52	-	0,91
7.	700	0,86	0,61	1,00	0,59	-	1,00
8.	800	1,00	0,84	-	0,69	-	-
9.	900	-	0,89	-	0,85	-	-
10.	1000	-	1,00	-	0,88	-	-
11.	1100	-	-	-	0,97	-	-
12.	1200	-	-	-	1,00	-	-

Table. 6. Numbering the empirical distribution of total frequency of variance factor (Wz) of the upper (F1) and lower (F2) speed profile on the national road (1,2), way of fast motion (3,4) and motorway (5,6)

No.	Value	Variance					
		national road		way of fast motion		motorway	
		F1	F2	F1	F2	F1	F2
1.	10	-	-	0,10	0,04	0,45	0,04
2.	20	0,20	0,08	0,21	0,04	0,78	0,54
3.	30	0,48	0,17	0,82	0,13	1,00	0,87
4.	40	0,80	0,34	0,95	0,27	-	0,96
5.	50	0,96	0,56	0,99	0,51	-	1,00
6.	60	1,00	0,87	0,99	0,83	-	-
7.	70	-	1,00	1,00	0,90	-	-
8.	80	-	-	-	0,95	-	-
9.	90	-	-	-	1,00	-	-
10.	100	-	-	-	-	-	-

small roundabouts significantly reducing the number of accidents (up to 70-90%) but at same time causing higher fuel losses when compared with the national roads with generally lower speed limits.
– The common choice by drivers in the globalization of international transport of the ways of fast motion rather than toll motorways may turn out significant in the overall costs of transport management.

Evaluation of variation in the incidence analyzed in global terms, can-tion, showed a considerable range of their occurrence. Calculations of variance, standard deviation and coefficient of variation in particular are the result of compliance with speed limits and driving bone psychological factors can affect the personality of drivers.

This is shown by their own research [2] and other authors (Humeniuk 2001). And in this case the highest values of the coefficient of variation museum and saw on the highway.

Especially in the case of highway Should Be Carried out refurbishment work on the „Unblocking" the improvement of physical resources to optimize for speed reduction, the kierochizacji with a division of functions Particular Between episodes. The date and Further work on research topics Presented Should allow the Development of the physical model of the kinetic energy loss in the actual operation of vehicles transport logistics contacts.

REFERENCES

1. **Burski Z. and Krasowski E. 2011.** Zastosowanie rozkładu prawdopodobieństwa amplitud prędkości jazdy w badaniach energochłonności pojazdu. Motrol, Wyd. PAN o/Lublin – UK Lwów (Dublany) T. 13D, Lublin-Dublany, 14–21.
2. **Burski Z., Krasowski E. and Kulewicz W. 2011.** Badania operatora agregatu maszynowego jako rolniczego systemu antropotechnicznego (SAT). Motrol Wyd. PAN o/ Lublin UK Lwów (Dublany) T 13D, Lublin-Dublany, 6–13.
3. **Burski Z., Krasowski E. and Kulewicz W. 2011.** Badania istotności statystycznych wybranych relacji rolniczego systemu antropotechnicznego (SAT). Motrol Wyd. PAN o/ Lublin UK Lwów (Dublany) T 13D, Lublin-Dublany, 6–13.
4. **Burski Z. and Mijalska-Szewczak I. 2008.** Ocena energochłonności pojazdu w międzynarodowej infrastrukturze komunikacyjnej UE. Teka KMRiL Wyd. PAN o/ Lublin, Tom 8A, Lublin, 10–15.
5. **Burski Z. and Mijalska-Szewczak I. 2009.** Analiza parametrów trakcyjnych jazdy pojazdu w infrastrukturze autostrady metodą statystyczną WPR. UE. Teka KMRiL Wyd. PAN o/Lublin, Tom 9, Lublin, 11–19.
6. **Gaca S. 2001.** Zarządzanie prędkością jako środek poprawy bezpieczeństwa ruchu drogowego. Mat. Konf. BRP. Lublin, s. 187–207.
7. **Humeniuk E. 2001.** Psychologiczne uwarunkowania zachowania się kierującego w ruchu drogowym. Mat. Konf. BRD Lublin, 131–152.
8. **Kostyro L. 2010.** The mechanizm of the stable development finansial strategy o fan enterprise: Methodology and Organization. Com. Of Mot. And Power Industry in Agriculture, PAAN o/Lublin DE UNU Lugansk, Ukraine, TEKA, vol. XA, 303–310.
9. **Mijalska-Szewczak I. 2010.** System Eco-Driving w teorii, eksperymencie I praktyce eksploatacyjnej pojazdu logistyki transportowej. Autobusy – Technika, eksploatacja, Systemy transportowe, Rzeszów, 40–47.
10. **Nachev G. and Luchko M. 2010.** The position of diagnostics and motor-service in transport-logistic system of the Ukraine. Com. Of Mot. And Power Industry in Agriculture, PAN o/Lublin DE UNU Lugansk, Ukraine, TEKA vol. 13, 65–71.
11. **Shapovalov V. and Nezhinskiy Y. 2010.** The evoluation technique of logistcs system Cargo transportation efficiency development. Com. Of Mot. And Power Industry in Agriculture, PAN o/Lublin DE UNU Lugansk, Ukraine, TEKA vol. 13, 162–170.
12. **Siłka W. 1997.** Energochłonność ruchu samochodu. Wyd. N-T. Warszawa
13. **Siłka W. 1998.** Analiza wpływu Parametrów cyklu jezdnego na energochłonność ruchu samochodu. Wyd. PAN o/Kraków, Zeszyt 14, Monografia 2, Kraków.
14. **Szymanek A. 2001.** Zarządzanie bezpieczeństwem ruchu drogowego od teorii do praktyki. Mat. Konf. BRP, Lublin, 201–228.
15. **Wesołowska-Janczarek M. and Mikos H. 1995.** Zbiór zadań ze statystyki matematycznej. Wyd. AR w Lublinie, Lublin.
16. **Wojciechowski A., Dąbrowska-Loranc M. and Leśniowska-Matusiak I. 2008.** Technika jazdy – ważny element bezpieczeństwa ruchu drogowego. Mat. Konf. BRD, Lublin, 67–76.
17. **Jamrozik A.** CFD modelling of combustion in HCCL engine using avl fire software: ECONTECHMOD. An International Quarterly Journal on Economics of Technology and Modelling Processes Vol. 1, No 1, 2012, 51–56.