Measurement and analysis of pressure forces on pedals at driver's workplace

Paweł Bachman*, Marcin Chciuk*, Ján Pavlovkin**

*University of Zielona Góra, Poland, **University of Matej Bel, Banská Bystrica, Slovakia

Abstract: This paper describes a method for measuring the pressure forces on the pedals in the bus. Shows the results and the analysis of the measurements, in terms of using them to determine the level of fatigue of the driver and his driving style.

Keywords: measurement pressure forces on pedals in a car

1. Introduction

One of the important parameters of a driver's workplace are forces that he needs to drive. The main attention should be paid to turning the wheel and pressing the accelerator and brake pedals, because these operations are carried out most of the working time of a driver. Knowledge of these forces is important, because exceeding any of these limits may discredit some employees to work as a driver. Motivation to do these measurements was the necessity to check, whether women can drive a buses Jelcz 120MM, which are part of the Public Transportation Company fleet. According to the Council of Ministers of 10 September 1996. on the list of works forbidden for women (Journal of Laws No. 114, item 1996. 544 and 545 [5]) it is emphasized, that it is forbidden for women to perform work where the use of foot forces exceeds 120 N at permanent work and 200 N at casual work – up to 4 times per hour during one shift work. Therefore, in the article it has been decided to examine the possibility of measurement of forces on the pedals, make a post of force test on accelerator and brake pedals and perform measurements. The main emphasis will be put on performance of measurement analysis in order to verify whether standards are not exceeded. Collected measurements will be also used to investigate whether by measuring force on pedals one can detect driver fatigue and also to determine the "temperament" of the driver.

2. Measurements of pressure force on pedals

On the market there are several devices for measuring pressure force on the pedals. One of them is suitable for the measurement of force on a vehicles brake pedal sensor CL23 (fig. 1). It can be mounted both on the brake pedal and the foot of a driver. Fixing takes place by a magnet (the pedal) or with elastic bands (the soles of the shoe). It is on the basis of the tensometer 1 kN built [3].

Fig. 1. Pressure force on pedals sensor
Rys. 1. Czujnik siły nacisku na pedał

Another device is decelerometers AMX520 that provides verifying the effectiveness of brakes of cars or motorcycles (fig. 2). The main purpose of the instrument is to measure the negative longitudinal acceleration of the vehicle (delays) that occur in the process of braking. In addition to the vehicle's longitudinal delay, the instrument can also measure the pressure force on a brake pedal. This measurement is carried out by using high-precision tensometer [4].

Fig. 2. Decelerometers [4]
Rys. 2. Miernik opóźnienia

In scientific literature one can also find examples of measurements of braking forces. They were made in the context of testing the effectiveness of brakes, but they can serve as comparative data for studies conducted in the context of this article. In the article [1] the authors also set forth to Regulation No. 13 EKG ONZ (EKG ONZ No. 13.09 from 27 April 1998) for the braking system. Its important record is that the measurements do not exceed maximum pressure on brake pedal (with hydraulic brake systems) 500 N for cars and 700 N for trucks. Summary of test result is shown in table 1.

Tab. 1. Pressure force on the car's brake pedal [1]
Tab. 1. Siły nacisku na pedał hamulca w samochodzie

Pressure force on pedal [N]
61.7
68.2
68.2
71.5
84.5
179
179
231
211
205

3. Construction of a stand to examine the force of driver's foot pressure on pedals in a bus

Due to the fact that the trials had to be carried out in conditions similar to road traffic, for safety the sensors are mounted on steel by means of screws, directly to the accelerator and brake pedals (fig. 2). The use of sensors on two pedals at the same time is a novelty and can give time for additional testing of driver's legs displacement from one pedal to the other which can be helpful in determining the driver's reaction time, such as during long routes and fatigue.

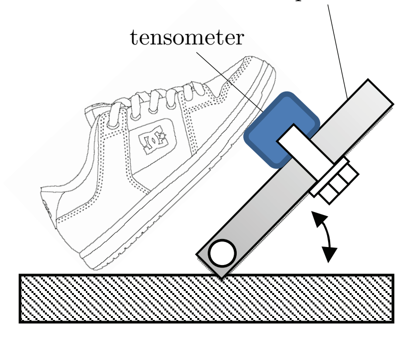

Fig. 3. Assembly of tensometers
Rys. 3. Montaż tensometrów

View of the measuring apparatus is shown in fig. 3. The whole of it was powered from the slot 24 V bus voltage by the inverter. For measuring KMM30 tensometers were applied. From tensometers the signal was given to the measuring amplifier system built on the circuit INA128. The amplified signal was fed to the analog inputs of the recorder PCS10.

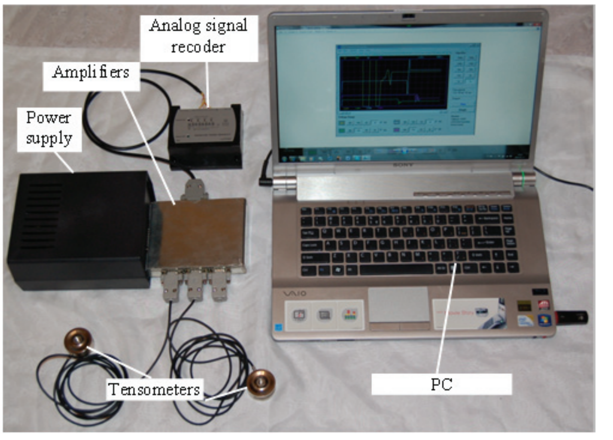

Fig. 4. Measuring apparatus to test pressure on pedals
Rys. 4. Widok aparatury pomiarowej

4. The results of measurements of the maximum pressure force on pedals

Measurements were made in the following situations:

1) Measurement of braking force when the vehicle is halted (fig. 5). The driver was asked to press the pedal with enough force that he usually uses for mild braking. Then he was asked to press the pedal with such force that he would use at the time of emergency braking.

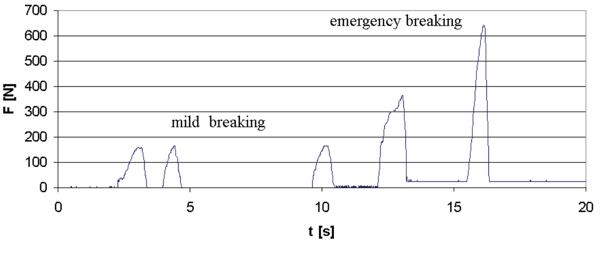

Fig. 5. Measurement of braking force during the vehicle is halted
Rys. 5. Pomiar siły hamowania podczas postoju pojazdu

2) Measurement of pressure force during regular driving in a city (fig. 6). The driver drove a part of a city route stopping at bus stop as a participant in the traffic

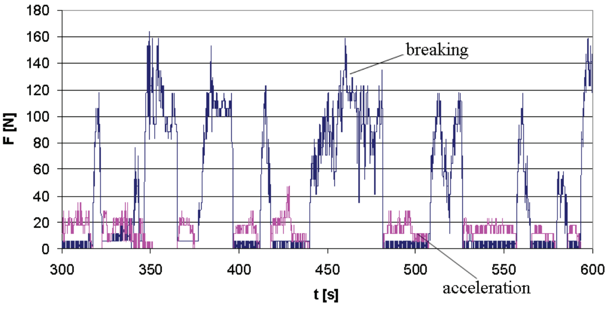

Fig. 6. Measurement of pressure force during regular city driving
Rys. 6. Pomiar siły hamowania podczas jazdy miejskiej

3) Measurement of pressure force made during braking while driving in the depot (fig. 7)

Fig. 7. Measurement of pressure force made during mild and emergency braking while driving in the depot
Rys. 7. Pomiar siły hamowania podczas jazdy w zajezdni

4.1. Conclusion of measurement

On the basis of measurements it has been found out that forces acceptable according to standards are only exceeded at the emergency deceleration. Normal braking force varies from 80 N to 160 N. These results are similar to those described in chapter 2. Pressure on the gas pedal does not exceed 40 N. Therefore, the position of the test does not exceed the standard and there are no counterindications for women to drive a bus Jelcz 120MM.

5. Analysis dynamics of the driving

Using the collected data it has been tried to make analysis whether in this position dynamics of pushing the pedals can be measured and how a driver's fatigue affects the dynamics of pushing the pedals in a vehicle. Three values have been taken into account:

1) The time lapsing between moving a foot from the acceleration pedal to moving it on the brake pedal (t_1 in fig. 8) also called reaction time (by the author).
2) The maximum braking force F_{max} (assuming that only cases of braking during regular driving are analyzed, except for emergency braking).

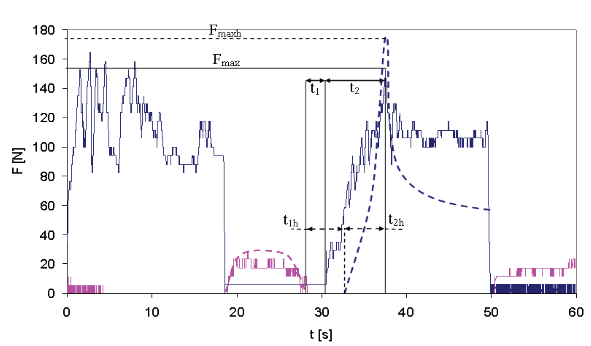

Fig. 8. Real and hypothetical characteristics of maximum braking force, reaction and braking time for the rested and tired driver
Rys. 8. Rzeczywiste i hipotetyczne wartości maksymalnej siły hamowania, czasu reakcji i hamowania dla kierowcy wypoczętego i zmęczonego

3) The time lapsing from the moment of moving a foot on the brake pedal to the moment of achieving maximum braking force t_2 in fig. 8 (a similar assumption as in section 2) hereinafter referred to as a braking time (by the author).

Hypothetical time values t_{1h}, t_{2h} and force F_{maxh} for tired drivers are plotted dotted line in fig. 8.

Measurements have been made for two different parts of the route and two different driving styles (easy and dynamic) and placed in tab. 2. Extreme measurements have been rejected.

Tab. 2. Data summary – maximum force, reaction and braking time
Tab. 2. Zestawienie pomiarów maksymalnej siły hamowania, czasu reakcji I hamowania

	F[N]	t_1[s]	t_2[s]
easy drive	135	12.14-11.35 0.79	16.13-12.14 3.99
	~~82.5~~	59.18-58.84 0.34	64.45-59.18 ~~6.27~~
	123.5	196.43-193.59 ~~2.84~~	200.79-196.43 4.36
	111.5	242.64-242.13 0.51	244.89-242.64 2.25
	106	284.04-283.1 0.94	287.02-284.04 2.98
dynamic drive	117.5	317.54-317.12 0.42	321.01-317.54 3.74
	164.5	346.55-345.74 0.81	349.44-346.55 2.89
	153	377.31-375 ~~2.31~~	384.21-377.31 ~~6.9~~
	158.5	439.99-439.47 0.52	460.16-439.99 ~~20.17~~
	117.5	557.07-556.54 0.53	560.68-557.07 3.61
	~~58.5~~	579.36-578.86 0.5	581.23-579.36 1.87
	158.5	593.35-592.64 0.71	597.32-593.35 3.97
average	**131.888**	**0.616**	**3.295**

6. Conclusion

On the basis of the results, after removed extreme measurements (deletion on fig. 9), it can be stated that for different driving styles most of the measurements fits to a determined range. This result allows us to use the data for further analysis. Knowing the reaction time of a rested driver and comparing it with the measured time while driving, it can be determined whether the driver is tired.

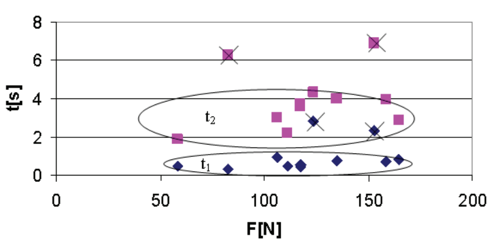

Fig. 9. Characteristics of reaction t_1 and braking time t_2
Rys. 9. Charakterystyki czasu reakcji i hamowania

By analyzing more samples (in this study only the samples from a 10-minutes' drive – about 12 braking situations have been collected) the characteristics of the driver's driving style can be also determined. Knowing how the driver drives may be useful, for example, to assess hiss efficiency. Acceleration time has a big impact on fuel consumption and engine abrasion, and braking force affects the frequency of replacement of brake components. Thanks to the using a stand described in this work and thanks to analysis of test results errors in the driver's driving technique can be detected and eliminated, for example during additional training on simulators.

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Pomiar i analiza sił nacisku na pedały na stanowisku kierowcy

Streszczenie: W artykule opisano metodę pomiaru sił nacisku na pedały w autobusie. Pokazano wyniki oraz przeprowadzono analizę pomiarów, pod kątem wykorzystania ich do określenia stopnia zmęczenia kierowcy oraz jego stylu jazdy.

Słowa kluczowe: pomiar siły nacisku na pedały w samochodzie

Marcin Chciuk, MSc
Assistant at the Institute of Education Technology and Computer Science, Faculty of Mechanical Engineering, University of Zielona Góra. Interests: mechatronics and control systems.

e-mail: M.Chciuk@eti.uz.zgora.pl

Paweł Bachman, MSc
Assistant at the Institute of Education Technology and Computer Science, Faculty of Mechanical Engineering, University of Zielona Góra. Interests: mechatronics and control systems. Scholarship in Sub-measure 8.2.2 "Regional Innovation Strategies", Measure 8.2 "Transfer of Knowledge", Priority VIII "HR Regional Economy" Operational Programme Human Resources co-funded by the European Social Fund, the European Union and the state budget.
e-mail: P.Bachman@eti.uz.zgora.pl

Ján Pavlovkin, PhD Eng
Department of Techniques and Technologies, Faculty of Natural Science, Matej Bel University Banská Bystrica. Interests: automation, robotics, mechatronics and control systems.

e-mail: Jan.Pavlovkin@umb.sk