Rafał JURECKI[1], Krzysztof LUDWINEK[2]

Kielce University of Technology, Department of Vehicles and Transport (1)
Kielce University of Technology, Department of Electrical Machines and Mechatronic Systems (2)

The control system of mock-ups in the study drivers' behaviour in case of emergency situations

Streszczenie. *W artykule przedstawiono wyniki badań dotyczące wyznaczania czasów reakcji kierowców w symulowanych sytuacjach zagrożenia wypadkowego. Przedstawiono zbudowany układ umożliwiający sterowanie niezależnym ruchem dwóch makiet pieszych, symulujących wtargnięcie na jezdnię. Układ sterowania zbudowano przy pomocy dwóch trójfazowych silników indukcyjnych klatkowych z przekładnią zębatą i pasową, dwóch falowników napięcia oraz sterownika PLC. Porównano wyniki badań eksperymentalnych uzyskane przy użyciu zbudowanego układu sterowania i układu bez elementów programowalnych (**Układ sterowania makiet w badaniach zachowania kierowców w sytuacjach wypadkowych**).*

Abstract. *This paper presents the results of the determination of reaction times of drivers in simulated situations with accident risk. Authors presented a built system capable of control of independent movement of two pedestrian mock-ups, which simulate the intrusion onto the road. The control system was built using two three-phase cage induction motors with gear and belt drive, two voltage inverters and PLC controller. The results of experimental tests obtained from the use of built control system and a simple system built without programmable elements have been compared.*

Słowa kluczowe: układ sterowania, czas reakcji kierowców, badania eksperymentalne, stanowisko badawcze.
Keywords: control system, driver's reaction time, experimental research, test–bed.

Introduction

The activities of experts carrying out various reconstruction and analysis of traffic accidents is now assisted by computer systems for traffic simulation and reconstruction of their movement. One of the characteristics of most of these systems is that they allow the computer animation of the reconstructed accident situation, so that an expert has the opportunity to present the result of their work. The result is presented not as complicated, unclear to a wider range of audiences calculations, but in the form of an animated film. The fact that a result is reliable is more important than a presentation of a reconstruction as it affects the final result of legal proceedings relating to an accident. The credibility of the reconstruction carried out by an expert depends on many parameters, which at the time of its preparation and use, an expert must enter into a computer programme. Not all parameters are known to an expert, some of them are estimated and some are selected based on the literature, e.g. [1]. Hence, there is a great deal of uncertainty in these reconstructions.

Among input data, one of the fundamental (used in the calculations carried out in the course of the reconstruction of an accident) is "driver's reaction time." This is the time that elapses from the moment accident risk occurs, till a driver starts influencing the vehicle control mechanisms; steering wheel, pedals and levers. Reaction time is also used in modelling driver's behaviour, as one of the coefficients - driver model parameters [2, 3, 4, 5, 6]. Driver model completed by vehicle model [7, 8] may allow computer simulation of a driven vehicle.

The values of this time is usually obtained on the basis of the driver's reactions to various stimuli. In a study on a simple stimulus, a driver has to act on one of the vehicle controls (brake pedal, hand brake lever, steering wheel). Examples of the results of the study are known and still widely used reaction time values determined by Burckhardt and Burg [9]. Their experiment involved two vehicles. Tested driver (driving the second vehicle) reacted to brake lights of the car in front. A series of tests of one of the drivers was approximately 1 hour. During this time, approximately 100 reaction times values were recorded. Reaction times determined by this method [10] were widely used in Germany in the 80's and 90's, quoted in major publications, books on dynamics of braking for example [11], the reconstruction of road traffic accidents [1]. A similar method was also used later in the research conducted by Nishida [12].

Another way to carry out research on reaction time on a simple single stimulus is presented in [13], in which a driver responded to the sound of the bell. Paper [14] described a study in which a driver responded to a light pulse stimulator stuck on the windscreen.

Much research carried out in a relatively simple way is realised to determine the various factors on reaction time of a driver. These factors considered in [15] include a mobile phone call (with or without a hands-free kit), listening to the radio in the car, talking to a passenger. These studies have been carried out in such a way that a red lamp of 50mm diameter was placed at the distance of 2m from the eyes of a driver. Such an examination was carried out in the laboratory to simulate the actual situation on the road, when the brake lights light up (with a diameter of 300 mm) of a preceding vehicle at a distance of 12 m [15]. The experiment measured the reaction time between the activation of red light, the beginning of releasing a pedal and start pressing the brake pedal.

These test methods have, however, a significant drawback, because a driver has a reaction to a simple stimulus. It is important to realize that in real road situations, a driver reacts especially to complex stimuli. In order to avoid an accident he or she carries out manoeuvres: braking and avoidance. Paper [16] described reaction tests to a complex stimulus, in which the stimulator used a lamp stuck on the inside of the windscreen. The driver had to react in these studies, both on colour and layout of lighted lamps (light colour and arrangement meet the defined manoeuvre).

Such studies are conducted in projects aimed at building accident avoid assistant systems. In such studies, in recent years, the use of inflatable thick foil balloon mock-ups, with the actual shapes and dimensions of the vehicle, has become popular. Electronic system is installed in the car to avoid a collision with inflatable mock-ups placed on the road and made of thick foil having real shapes and dimensions of the vehicle barriers. They can be used to achieve two research scenarios, referred to as "hard braking" and "violent avoidance".

Research conducted on the behaviour of drivers of special measuring beds may also apply to reaction time of drivers with disabilities or after diseases, operations. They can be carried out to determine the suitability of such people on the road and the progress of their recovery. Such tests were carried out including people after orthopaedic surgery such as total replacement of the knee ligament [17]. Testing also includes the reaction time of drivers [18] in the state of fatigue, sleepiness.

In recent years, research on roads or tracks increasingly rely on the execution of certain selected accident scenarios. An example can be research described in [19], which simulated an a perpendicular intrusion of a vehicle to the crossroads.

Another example can be research for the reaction to pushed out (from behind parked cars in the right lane) small pedal bike [20] or a cardboard box thrown on driving track [21].

In a study conducted by [19] the behaviour of drivers in both the simulator and on the track were tested. In the simulator, the beginning of an emergency vehicle was a photo in 1:1 scale of an obstacle projected on the screen, in the case of track, a foam mock-up of equal dimensions, which had an image (photo) of an obstacle car. The number of available literature of this type of study is relatively small and only some special cases are discussed.

The authors of this study in the research conducted in 2004 - 2005 [7, 22, 23] have used a mock-up (barrier/obstacle) manually triggered and made of expanded polystyrene (Fig. 1). The aim of this study was to determine the parameters of driver model which includes both a brake manoeuvres W_1, W_2, W_3 - equation (1) and turn –parameters W_4, W_5, equation - (2) [7, 24]. Brake τ_b reaction time and τ_s steering reaction time were determined among the values of model parameters.

$$b_b(t) + W_1 \dot{b}_b(t) = W_2\left(y_{lat}(t-\tau_b) - y_s(t-\tau_b)\right) + W_3\left(\frac{1}{t_r}\right) \tag{1}$$

where: b_b- brake deceleration, y_{lat} - lateral obstacle displacement, y_s -lateral displacement of the centre of vehicle mass, τ_b – driver's reaction time (braking), t_r – current risk time, describing road situation, W_1, W_2, W_3 - parameters of driver braking model

$$\delta_s(t) + W_4\dot{\delta}_s(t) = W_5(y_{pop}(t-\tau_s) - y_s(t-\tau_s)) \tag{2}$$

where: δ_s- steering angle, δ'_s - steering speed, W_4, W_5, parameters of steering driver model, τ_t – driver's reaction time (steering)

The characteristics of steering and delay determined in the study allowed the identification of the model parameters of driver behaviour in case of emergency situations - $W_1 \div W_5$ and reaction times of drivers τ_b and τ_s. These parameters were necessary to carry out a computer simulation [22]. Braking model parameters: W_1, W_2, W_3 are related to: delay escalation, position of vehicle mass centre in relation to the lateral displacement of the obstacle and risk time characterising a risk situation.

W_4, W_5 model parameters characterise a steering model. They are connected with: speed of steering angle and the position of vehicle mass centre in relation to the lateral displacement of the obstacle.

A mock-up of a passenger car was lowered (within the road it fell under the influence of its own mass) at the time of achieving proper distance S of a test vehicle from an obstacle.

The study was conducted at a simulated crossroads of two two-lane, two-way roads, with reduced visibility in both the left and right sides. In all studies, certain actions were not imposed on drivers, and the driver himself decided about which defensive manoeuvre to apply (braking only, solely avoidance of an obstacle, or both of these actions at the same time) [25]. The behaviour of the driver was recorded using equipment installed in the test vehicle.

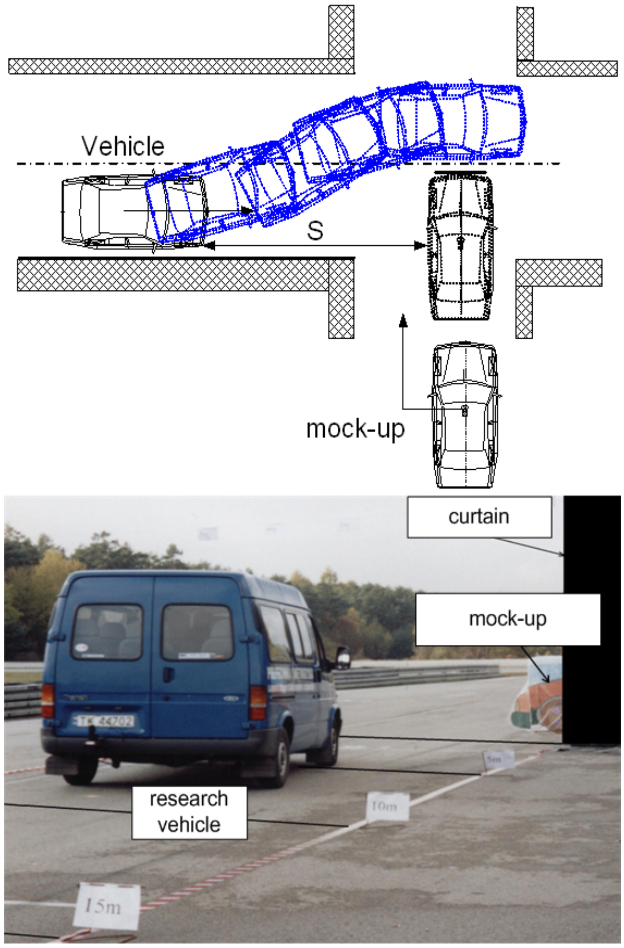


Fig. 1 View of a research vehicle during testing and simplified diagram of vehicle traffic (research and mock-up)

The continuation of this study was to realisation of research in 2006-2010, which included three new cases of accidents [26, 27]:
- scenario I: a car entering the intersection at right sides from the right, while another car is moving on the left lane from the opposite direction, in the direction of the test vehicle (Fig. 2a);
- scenario II: pedestrian, an adult entering perpendicular to the road (the right lane) (Fig. 2b);
- scenario III: a truck passing perpendicularly through the crossroads with a 2-lane road so that both lanes are blocked (Fig. 2c).

In addition to the significantly different scenarios during testing a new (patented) test stand/bed [30] was used shown in Figure 3, and a mock-ups of obstacles: pedestrians [31], a car and a truck (also patented).

The test bed consisted of a column carrier (A), where, at a height of more than 2,3m above, the grid (B) was mounted. The movement in the position of mock-ups took place in a specially made grill suspended for (B) I-beam rails made of (4) with bogies (3), which are connected to opposite sides of the drive cable (5). The movement of rope drive was carried out by means of a drive unit (6) made of the pulley, engine and transmission. Three-phase cage induction motor was powered from network with a frequency converter (inverter) and operated remotely using photocells and radio lines (Figure 4). Research/test car (1) travelling on tested section passing the reflector (2) resulted in the release of Datron photocell (light barrier) (3), which turned on a transmitter radio line (4).

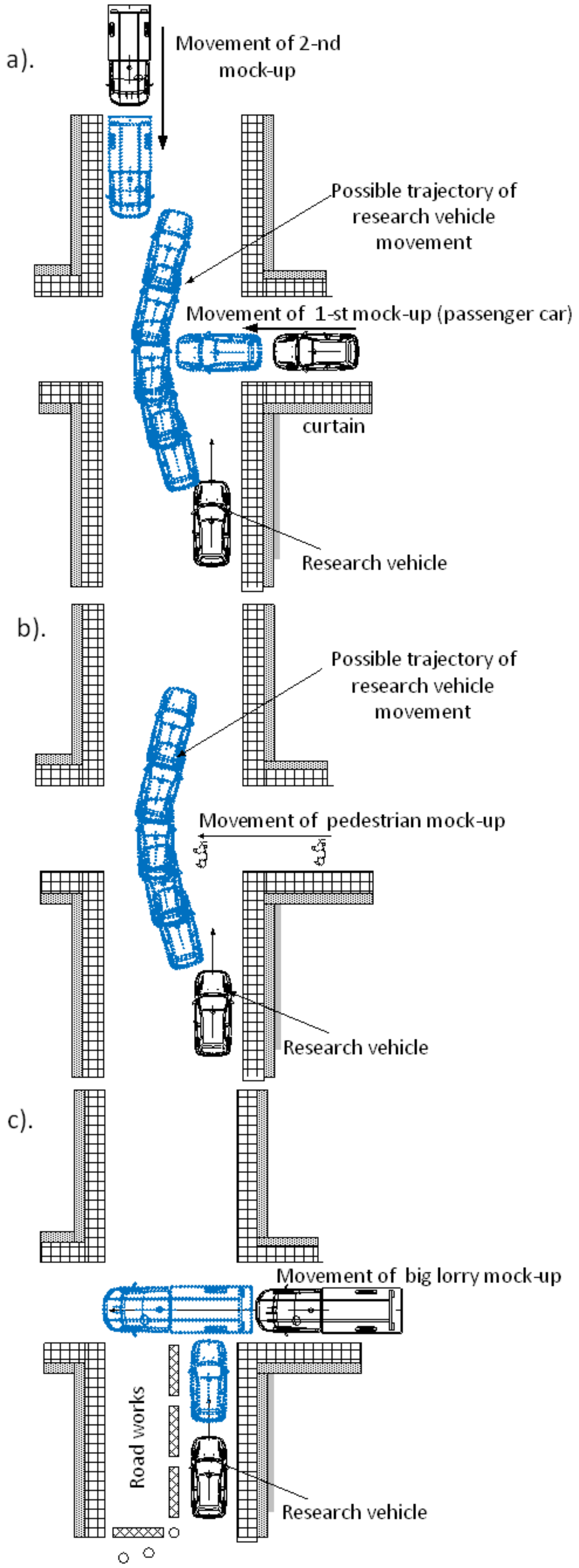


Fig. 2 Scenarios carried out during research in the years 2006-2010 a). scenario I, b). scenario II, c). scenario III

Photocell (light barrier) signal (9) was received by the receiver (5), which resulted in activation of the drive to work (6) of frequency switch. Induction cage motor triggered a vehicle mock-up motion (8), whose stop occurred in a place where an end switch war marked (7).

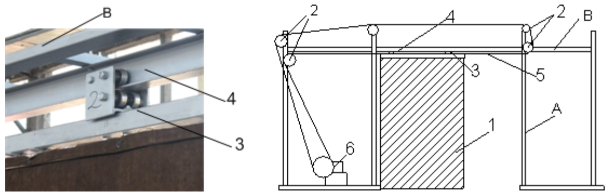


Fig. 3 Diagram of a test stand; 1 - mock-up, 2 - recurrent and supporting rollers, 3 - carriages, 4-runner, 5 - line drive, 6-drive unit

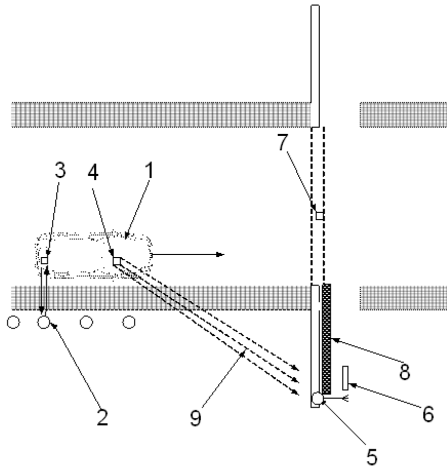


Fig. 4. Diagram of a measuring unit

The test stand/bed allowed to conduct research on complex stimulus, in the form of emerging models (mock-up), which, however, can appear only on the right side.

Modern test-bed

The study, which was carried out in the framework of research in 2012, were considered two further scenarios in which an obstacle can arise from both the left and right side - Figure 5.

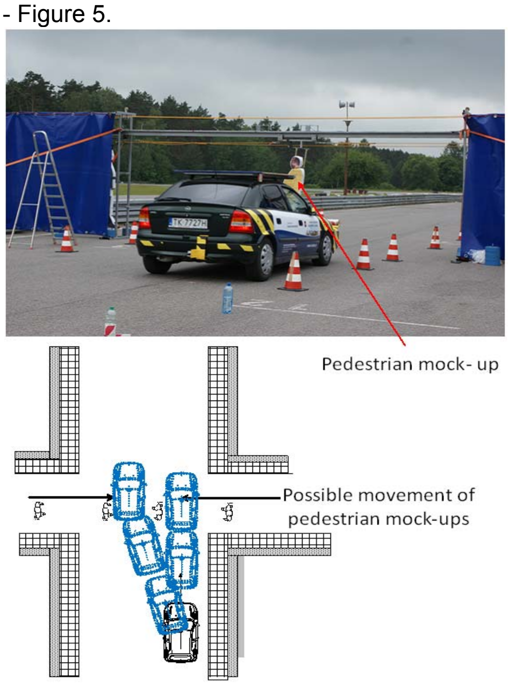


Fig. 5. Diagram of a test and a picture the scenario

Starting implementing the research, the authors wanted to confirm, noticed in previous studies, the attribute of drivers that they devote much more attention to the left side of the road [32]. Opel Astra II research vehicle, which has no front bumper and was equipped with

special piping and caps to protect the vehicle against the effects of possible collisions with a mock-up (patent-based solution [30]) (Fig. 6). is equipped with the appropriate test equipment. Both the movement of mock-ups and measurements were remotely activated by Datron photocell (light barrier), mounted on a test vehicle (Fig. 6).
Measurement track comprised of:
• μEEP-12 data acquisition station - Corrsys - Datron (Kistler) with software and tablet control (Fig. 7),
• S-350 Corrsys - Datron 2-axis contactless optoelectronic sensor designed for direct, slip free measurement of longitudinal and transversal vehicle dynamics (vehicle velocity range of 0,5÷250km/h and sideslip angle range ±40^{o}) (Fig. 8a),
• 3 directional linear acceleration sensor with +/- 2g (Fig. 8b) to determine the acceleration of the longitudinal and transverse of car body,
• wire potentiometer sensors to measure displacement control pedals: accelerator, brake and clutch, in order to determine each pedal stroke - the driver's reaction (Fig. 8c),
• Corrsys - Datron measuring steering wheel allows for non-contact measurement of steering moment, steering angle and steering speed. (Fig. 8d).

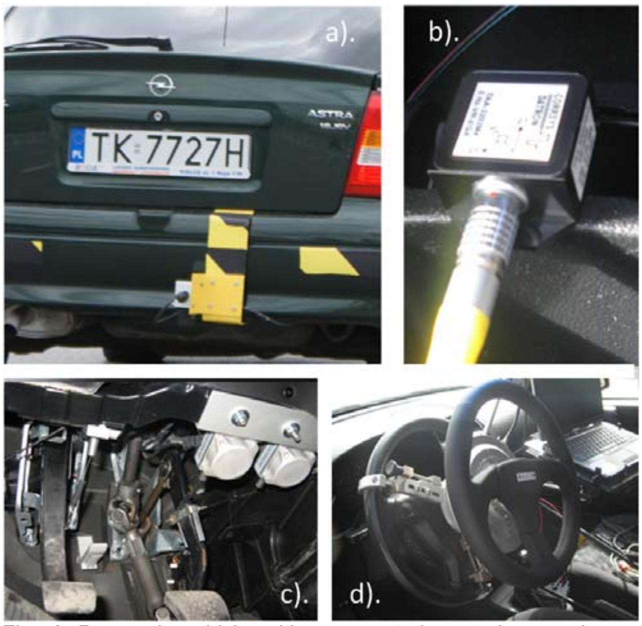


Fig. 8 Research vehicle with a mounted control-measuring equipment

Fig. 6. Opel Astra research vehicle with attached front tubing and a photocell (light barrier)

Fig.7 Data acquisition station with a tablet and ARMS software installed

Test beds used in previous studies have been thoroughly modernized. In order to allow independent movement of both pedestrian mock-ups guides using double I-beam placed across the width of the test and double-drive systems that uses ropes independently driven models left and right (Figure 9).

To ensure the highest possible repeatability of measurements, (the same tests were carried out by a number of drivers) a special, programmable motion control system of mock-ups was built and triggered as in previous studies by radio. Programmable control system was built using Omron PLC controller [33, 34, 35], which enabled rapid modification of acceleration mock-up times, programme and time to change the direction of movement of mock-ups, and automation of measurements.

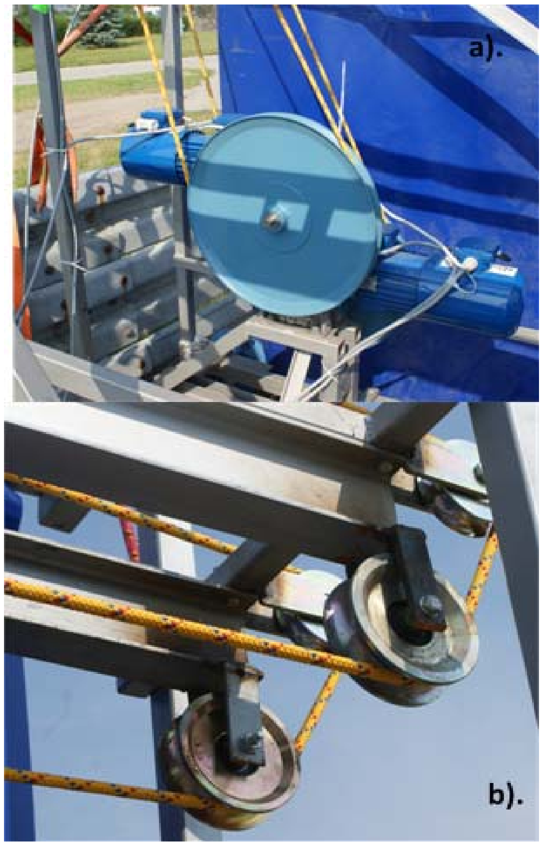


Fig. 9. Some details of the construction of a test stand a) a drive wheel with reducer, b) ropes system to allow the movement of mock-ups

The experience gained by the authors in the construction of control systems in the Kielce University of Technology [36, 37, 38] made it possible to build such a control system which enables automatic triggering, programming, direction of movement, stopping (intrusion walking on the road) and mock-ups reverse back to the starting position. At the trigger moment it was possible to register immediately in a graphical environment, which allows a large amount of research carried out by one person, even without leaving your car every time you move mock-ups. Figure 10 shows a view of the programmable control of the direction of the mock-ups.

Experimental research

Experimental studies were carried out on the test track using the test bed equipped with a motion control system made of mock-ups. Figure 11 shows the diagram of traffic control of mock-ups with a general view of the position sensors and the key components of the drive system. The test bed consists of:

- two A1000 voltage inverters, programmed to control operation of the magnetic field vector in an open loop control with RS422/485 and digital multifunction I/O (NPN/PNP).
- drive system that allows the movement of mock-ups by the rope, which consists of two three-phase induction motors with a capacity of 1.5 kW, which by regulators (mechanical transmission) and transmission belt, the drive is transferred to the mock-ups,
  Besel Skh90-4L cage induction motor
  - general purpose motors,
  - continuous work S1(duty S1),
  - U_N =230V/400V (∆/Y),
  - f_N = 50 Hz,
  - p_b = 2, n=1500 rpm
  XC-63-7 reducer with shift -7.5, output rotations – 187, output moment 67Nm was connected to a cage induction motor
- performed mock-up movement control system (fig. 11) with electronic part supply system,
- FM 7001 R - generation set consist of synchronous generator rated data P_N = 5.8 kW, U_N = 230 V, I_N = 25.2 V, f_N = 50 Hz, petrol-powered MITSUBISHI GM401PN motor. The FM 7001 R - generation set is the power supply control system that allows and enables regardless of access to power to carry out research in any place (racetrack).
- programmable PLC controller CP1L-M30DT1 - type that has digital inputs and outputs of 24V which are supplied control signals from the sensors from A1000 two inverters with multifunction digital inputs.
- Power supply unit S8VM-03024CD for PLC controller, P = 30 W and 24VDC,
- operator panel (control) (Fig. 11), allowing:
  - turning on and off of mock-ups (inverters),
  - selection of mock-up 1 movement, mock-up 2 and both mock-ups simultaneously,
  - possibility to choose independent speed for each mock-up movement.
- M18KS08-WP-B1 2M E2A-inductive sensors, working as limit switches to determine the initial and final positions of each of the mock-ups, facilitating to control the mock-ups automatically and in manual mode.

Fig.10. View of programmable system controlling the movement of mock-ups

Both A1000 inverters were software configured with a modern and highly practical DriveWizard Yaskawa Industrial environment, which is available on the website of Yaskawa as free-ware. This software allows you to perform many complete useful settings:

- „Signal Monitor" for a selected inverter such as: rotor frequency, current and voltage, output power and current, etc.
- „Trend Recorder"- it is an option that allows to monitor up to six different variables at the same time with the possibility to present their values in a graph,
- „Auto-tuning" - is an option that allows the identification of the parameters of induction or synchronous motor connected to the inverter. The parameters of the engine are in group "E: Motor Parameter",
- „Energy Saving Tuning" is an option that allows the selection of such an driver of an inverter as the motor operating point was chosen optimally while maintaining the selected output parameters.

Configuration of the A1000 inverters is very clear and up to eight steps (8 tabs) that you can choose any of the tabs or sequentially:

Step 1 The choice of steering method between U/f=const and vector.

Step 2 Setting basic motor parameters: rated current, rated frequency and maximum output frequency (the exact

parameters for rated current may be obtained by performing „Auto-tuning" in DriveWizard Yaskawa Industrial environment).
Step 3. Selection the method to set output frequency (Fig. 12b), by:

- main inverter panel,
- analogue inputs (for example, using a potentiometer, voltage, current),
- communication through a terminal,
- network card.

Step 4 Select how to set Start/Stop commands through (as in Step 3).
Step 5 Selection:

- of the method to stop the engine in operation (freewheel or through pre-set braking time),
- permit the engine to operate with recurrence,
- acceleration time,
- breaking time.

Step 6 Determination of output frequencies of the engine by Multi-Function Input Terminals.
Step 7. Assigning Multi-Function Input and Output Terminals possibilities to perform different functions set by a user (if the Inputs and Outputs are used).
Step 8 Determination of the inverter reaction in emergency states after a restart or the drive getting stuck.
Figure 12a shows a general view on DriveWizard Yaskawa Industrial program window, which has a possiblity to select any tab to configure the inverter. Figure 12a shows an example of third step of configuration of the inverter which includes determination on how to set a rotation speed during the configuration of the inverter: from the main panel to the inverter analogue input (A1 - AC - voltage signal control) or A2 - AC - current signal control) via the RS 422/485 or via built-in network card.

Results of experimental research

As a result of experimental research, (reaction times of drivers) were registered. Based on the results of measurements time performance of control pedals displacement and angle of steering wheel rotation were determined, showing the behaviour of the driver in an accident situation.

Figure 14 shows the displacement of vehicle traffic controls such as pedals: accelerator, brake, clutch and the angle of (steering) wheel rotation. Based on analysis of these runs, it was possible to determine reaction times, that is a driver's behaviour in an accidents situation

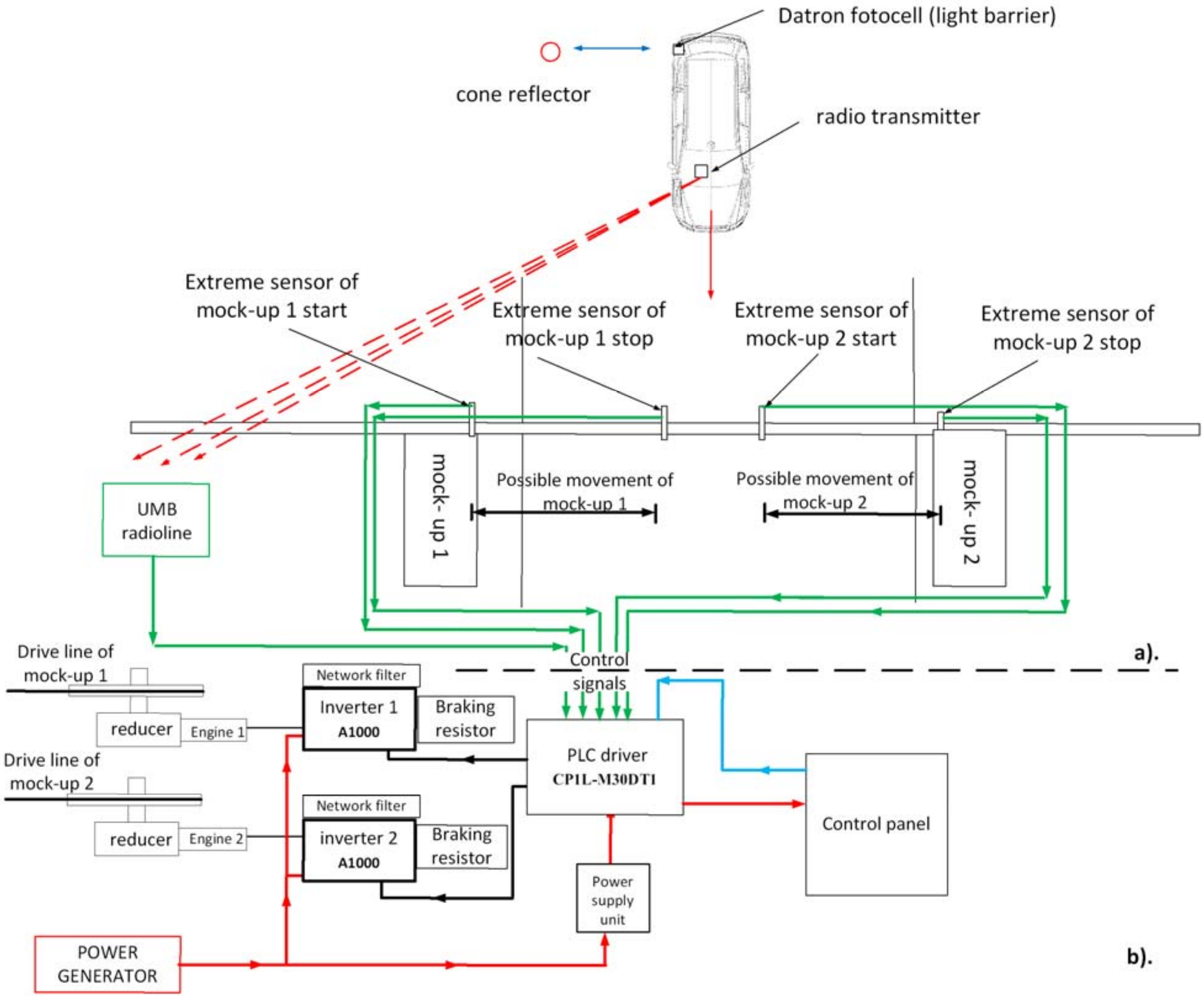
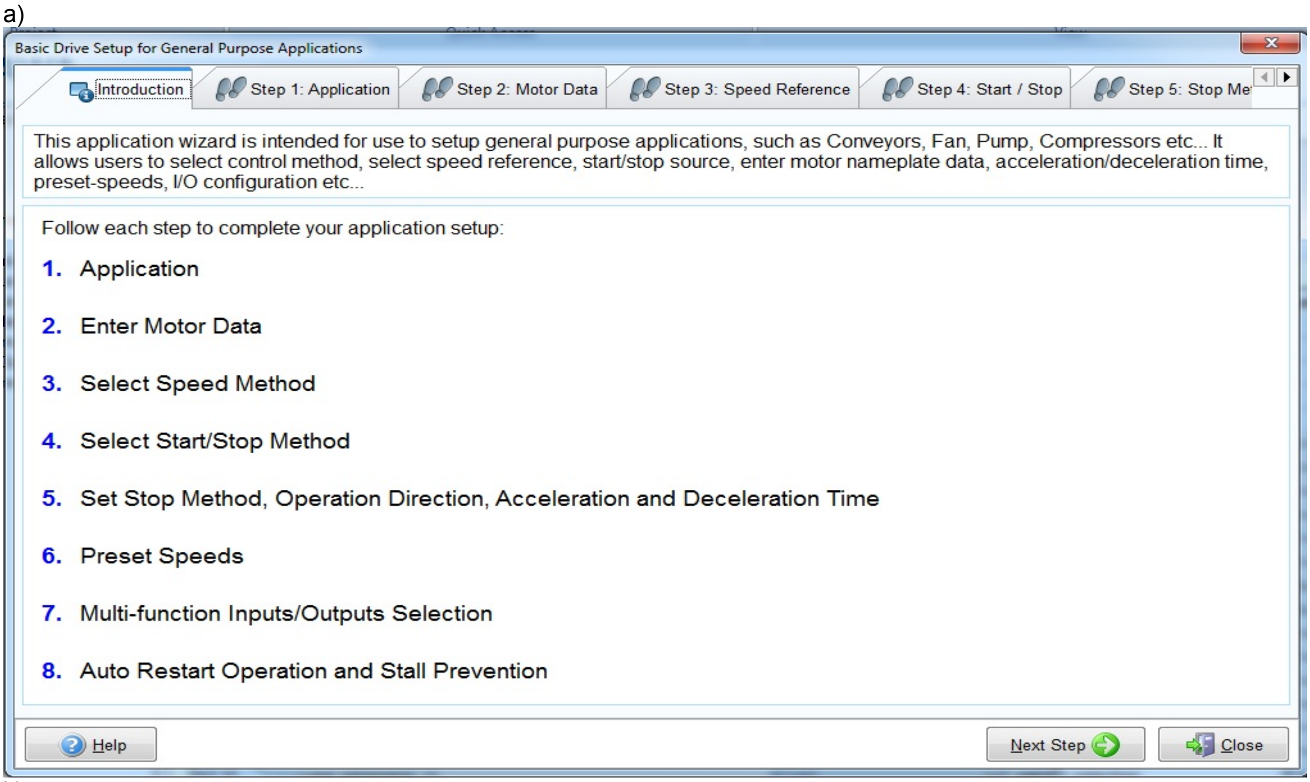


Fig. 11. Diagram of mock-up control unit: a) a general view of the location of sensors and mock-ups, b) the key elements of the propulsion and control system

a)



b)

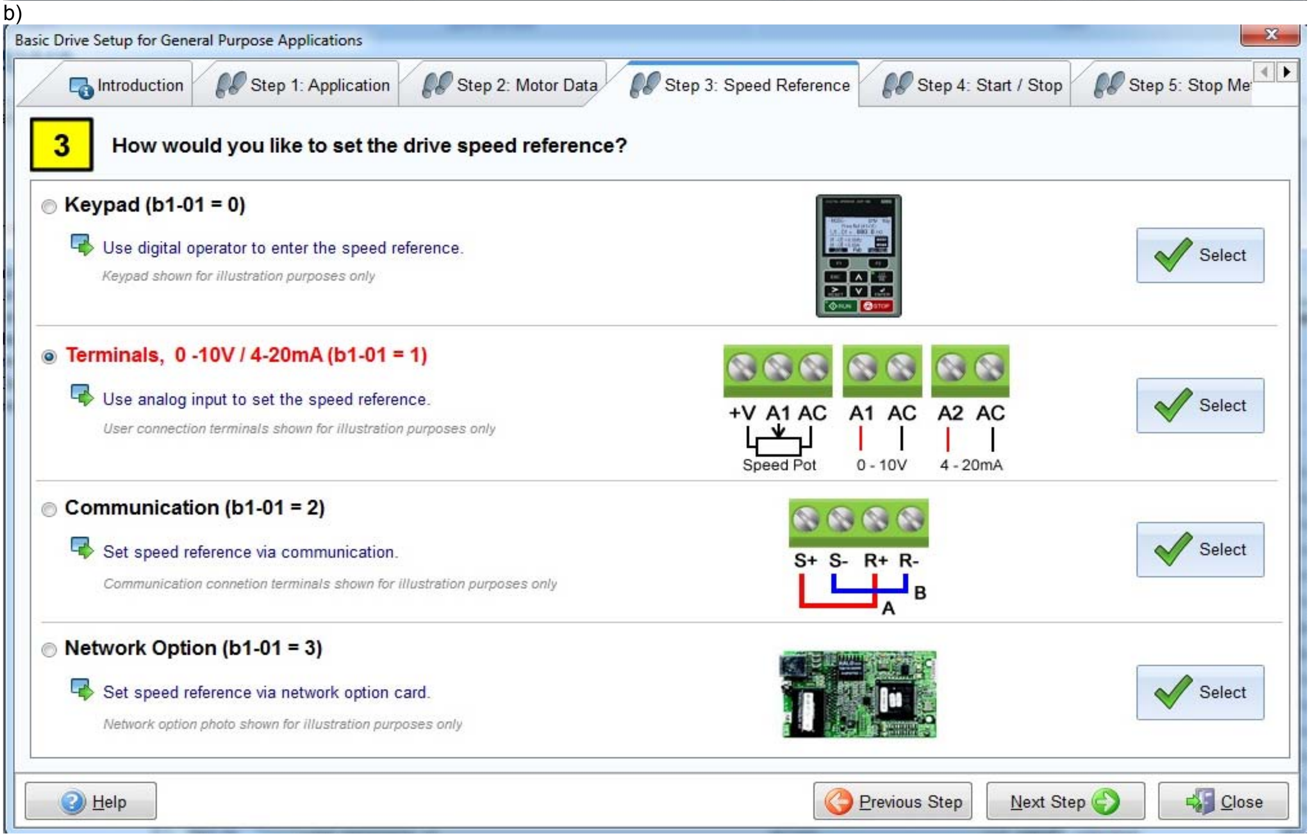


Fig. 12. *Yaskawa Industrial DriveWizard* Steps during inverter configuration; a) general view of a selection tab particular configuration steps, b) Step 3 - inverter configuration using *Yaskawa Industrial DriveWizard* environment

.

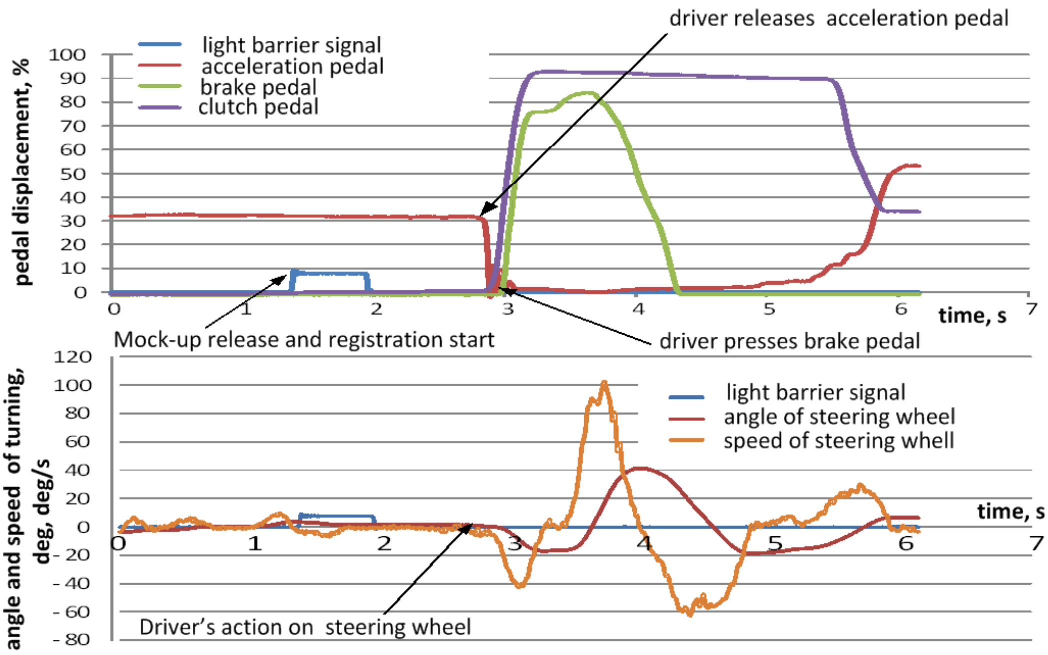


Fig. 14 Timing characteristics showing driver's behaviour in an accident situation

Figure 15 shows the results of measurements of the reaction time of drivers for the brake pedal (speed reduction achieved by pressing brake) in a risk time function (i.e. the relation of the distance of the vehicle from the obstacle to the its speed). The chart, apart from the average values of reaction time, presented the standard deviation. It is worth noting that each of the value has been determined as the average for 30 drivers. Average reaction time values determined in a risk time function - Figure 15, show an upward trend.

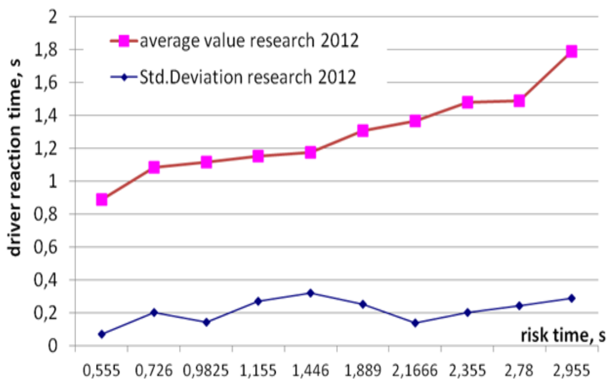


Fig. 15. Reaction time measurement results on the brake pedal

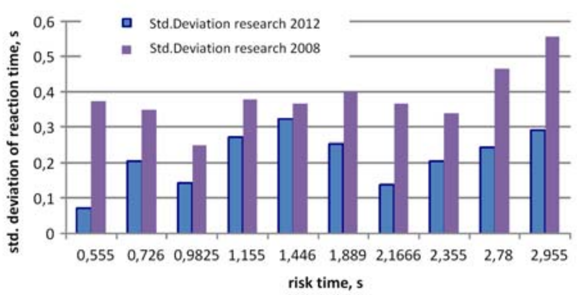


Fig. 16. Comparison of the standard deviation value of driver reaction time on brake pedal (S.D.) for research conducted in 2008 and 2012

Average reaction time of drivers on an accident situation is not constant and is in the range 0,9-1,8s. The standard deviations showing scattered results are small and contained within the limits of 0,17-0,35s.

In comparison to previous researches [28], which were carried out in 2008, it can be seen by analysing Figure 16 that the standard deviation is lower throughout the whole range of risk times.

Conclusions

This paper presents the results of the determination of reaction times of drivers in a simulated emergency accident situations with the use of a motor vehicle, the driver and controlled pedestrian mock-ups intruding the road. The research was made possible by built programmable unit that allows independent control of two pedestrian mock-ups. The article compared the experimental results obtained from the use of the built control system and a simple built system without the programmable elements.

The mock-up control system developed by the authors, through the use of a programmable logical controllers connected to two inverters enables:

- significantly simplify the trigger system of mock-ups,
- quick modification of mock-up motion parameters (acceleration, speed, direction of movement, stopping on the road, etc.),
  - much more repeatable reaction time results,
  - tests conducted by one person,
  - recording a number of events simultaneously in a risk time function.

Project N N509 549 040 financed by the National Science Centre.

REFERENCES

[1] Wypadki drogowe. Vademecum biegłego sądowego. Praca zbiorowa. Wyd. IES Kraków 2002.

[2] Bułka D., Wolak St., Walczak St.: Antycypacyjny model kierowcy zastosowany w programie do symulacji ruchu i zderzeń pojazdów V-Sim, *Zeszyty Naukowe Politechniki Świętokrzyskiej*, Mechanika 79 (2006), 147-157

[3] Bułka D., Walczak S., Wolak S.: Uncertainty of modelling of typical defensive manoeuvres discussed for models used in road accident reconstruction as

example, *European Association for Accident Research and Accident Analysis. Proceedings Institute of Forensic Research Publishers*, Kraków 2007, 313-324.
[4] Guo K., Guan H.: Modelling of Driver/Vehicle Directional Control System, *Vehicle System Dynamics International Journal of Vehicle Mechanics and Mobility* 22(1993), pp. 141-184
[5] Sharp R.S., Casanova D., Symonds P.: Mathematical Model for Driver Steering Control, with Design, Tuning and Performance Results, *Vehicle System Dynamics: International Journal of Vehicle Mechanics and Mobility* 2000, Vol. 33, Issue 5, 289-326
[6] Ungoren A.Y. and Peng H.: Adaptive Lateral Preview Driver Model, *Vehicle System Dynamics: International Journal of Vehicle Mechanics and Mobility*, Vol. 43, Issue 4, 2005, 245-259
[7] Jurecki R. S.: Modelowanie zachowania kierowcy w sytuacjach przedwypadkowych. *Rozprawa doktorska. Politechniki Świętokrzyska, Wydział Mechatroniki i Budowy Maszyn*, Kielce 2005r.
[8] Więckowski D., Stańczyk T. L.: Model samochodu dla symulacyjnego badania wybranych (typowych) manewrów. *Teka Komisji Motoryzacji PAN Oddz. w Krakowie*, nr 29-30. 2005.
[9] Burckhardt M., Burg H.: Die Brems-Reaktionsdauer von Pkw-Fahrer. *Der Ferkehrsunfall* 1981, N.12: 224-235.
[10] Dannert G.: Grundprobleme der Reaktionzeit des Kraftfahrers. *Ferkehrsunfall und Fahrzeugtechnik* 1998, N. 12: 328-334.
[11] Burckhardt M.: Fahrwerktechnik: Bremsdynamik und Pkw-Bremsanlagen. Vogel Verl., Würzburg, 1991.
[12] Nishida Y.: Driving characteristics of the elderly: risk compensation of the elderly driver from the viewpoint of reaction behavior. *JSAE Review* 1999, 20, 375-380.
[13] Törnros J.: Effect of driving speed on reaction time during motorway driving. *Accident Analysis and Prevention* 1995,(4) 27: 435-442.
[14] Fröming R.: Assesment of Integrated Pedestrian Protection System. PhD thesis. Fortschritt-Berichte VDI, Reihe 12, *Verkehrstechnik/Fahrzeugtechnik*, 681, 2008.
[15] Consiglio W., Driscoll P., Witte M., Berg W. P.: Effect of cellular telephone conversations and other potential interference on reaction time in a braking response *Accident Analysis and Prevention* 35 (2003), 495–500
[16] Magister T., Krogulec R., Batista M., Bogdanović L.: The driver reaction time measurement experiences. Innovative Automotive Technology – IAT'05, Bled,21st-22nd April 2005.
[17] Spalding T.J.W., Kiss J., Kyberd P., Turner-Smith A., Simpson A. H.: Driver reaction time after total knee replacement, *The Journal of Bone & Join Surgery*, 8/1994 vol.76-B, 754-756
[18] Baulk S.D., Reyner L.A., Home J.A.: Drive Sleepines – Evaluation of Reaction Time Measurement as a Secondary Task, *Sleep*, vol. 24, No.6 2001, 695-698
[19] McGehee D.V., Mazzae E.N., Baldwin G.H.S.: Driver reaction time in crash avoidance research: validation of a driving simulator study on a test track. *Proceedings of the 14th Triennial Congress of the International Ergonomics Association and the 44th Annual Meeting of the Human Factors and Ergonomics Society (IEA 2000),* San Diego/USA, (6) 2000.
[20] Krause R, de Vries N, Friebel W.-Ch.: Mensch und Bremse in Notbremssituationen mit Pkw – neue Erkenntnise zu Prozesszeiten beim Bremsen. Teil 1. *Ferkehrsunfall und Fahrzeugtechnik* 2007, 6: 164-171.
[21] Hillenbrand J.: Fahrerassistenz zur Kollisionsvermeidung. PhD thesis. Fortschritt-Berichte VDI, Reihe 12, *Verkehrstechnik/Fahrzeugtechnik* 2008, 669.
[22] Jurecki R., Stańczyk T.L.: Driver model for the analysis of pre-accident situations. *Vehicle System Dynamics* 2009.(5) 47: 589-612.
[23] Stańczyk T. L, Jurecki R.: Fahrereaktionszeiten in Unfallrisikositationen – neue Fahrbahn- und Fahrsimulatorversuche, *Verkehrsunfall und Fahrzeugtechnik* 2008, 07-08: 235 – 246.
[24] Jurecki R., Stańczyk T. L.: Model matematyczny sposobu reagowania kierowcy w sytuacjach przedwypadkowych, *Zeszyty Naukowe Instytutu Pojazdów Politechniki Warszawskiej*, Nr. 4(67)/2007, 5-23,
[25] Jurecki R.S, Stańczyk T.L.: The test metod and the reaction time of drivers, Metody badań a czas reakcji kierowców, *Eksploatacja i Niezawodność - Maintenance and Reliability*, 2011, 3, 84-90.
[26] Stańczyk T. L, Lozia Z, Pieniążek W, Jurecki R.: Badania reakcji kierowców w symulowanych sytuacjach zagrożenia, *Zeszyty Naukowe Instytutu Pojazdów Politechniki Warszawskiej* 2010, 1(77), 27-52
[27] Stańczyk T. L, Lozia Z., Pieniążek W., Jurecki R. S.: Research Studies on Driver's Studies on Drivers' Reactions for Incoming Vehicle from Righ-Hand Side, *Kongress EVU*, Praga 14-16 October, Proceedings 2010, 41-53.
[28] Stańczyk T. L., Jurecki R., Jaśkiewicz M., Walczak S., Janczur R.: Badania poligonowe reakcji kierowcy na pieszego wkraczającego na jezdnię z prawej strony zza przeszkody, *Journal of Kones*, vol. 18 (1), 615-622
[29] Stańczyk T. L., Jurecki R., Zuska A., Walczak S., Maniowski M.: On the track researches of driver's reaction time to the big lorry entering the crossroad from the right side with limited visibility, *Monographs of the maintenance System Unit Problems of maintenance of sustainable technological systems, Volume IV Automotive Engineering and vehicle safety engineering*, Kielce 2012, 140-151
[30] Stańczyk T.L., Jurecki R., Jaśkiewicz M., Karendał M., Zuska A.: Stanowisko do badania zachowań kierowców w warunkach symulowanych sytuacji wypadkowych, PL390414 patent, decyzja z dnia 2012-03-02
[31] Stańczyk T.L., Jurecki R., Jaśkiewicz M., Karendał M.: Makieta do symulacji szybkiego ruchu pieszego, decyzja na patent z dnia 14.08.2012 PL390397
[32] Jurecki S.: Badanie postrzegania przeszkody przez kierowcę, *Zeszyty Naukowe Politechniki Świętokrzyskiej, Seria Budowa i Eksploatacja Maszyn* 2008, 8: 209-218
[33] Ludwinek K.: Adresowanie modułów cyfrowych wejść i wyjść w obszarze pamięci sterowników PLC. *Elektro-Info*, Nr 3, 2010. ss. 38 - 43.
[34] Ludwinek K., Chrzan K.: Konfiguracja modułów A/D i D/A sterowników PLC do pomiarów i sterowania. *Napędy i sterowanie*, Nr 9, 2009, 46-52.
[35] Ludwinek K., Chrzan K.: Programowanie modułów A/D i D/A sterowników PLC do pomiarów i sterowania. *Napędy i sterowanie*, Nr 10, 2009 , 70-75.
[36] Jaśkiewicz M., Ludwinek K.: Stanowisko do pomiaru wielkości fizycznych występujących podczas zderzenia z przeszkodą. IX - Konferencja Nowe Kierunki Rozwoju Mechaniki - Hucisko, 17-19 marca 2011, 23-33.
[37] Jaśkiewicz M., Ludwinek K., Staszak J., Suliga T.: Possibilities of graphical environment application for determining parameters of the mechanical system. *Journal of KONES Powertrain and Transport*, Vol.18, No. 4, 2011,151-164
[38] Ludwinek K., Jaśkiewicz M., Więckowski D.: Układ do pomiaru wielkości fizycznych podczas badań bezwładnościowych. decyzja 2011-08-16. PL 210632 B1.

Autorzy: *dr inż. Rafał Jurecki, dr inż. Krzysztof Ludwinek, Politechnika Świętokrzyska, Al. Tysiąclecia PP. 7, 25–314 Kielce, e–mail: rjurecki@tu.kielce.pl; k.ludwinek@tu.kielce.pl*