

The impact of ABS system on the braking characteristics of the specified motorcycle on the dry road surface

J Ondruš¹ and E Kolla²

¹ Department of Road and Urban Transport, University of Zilina, Univerzitná 8251/1, 010 26 Zilina, Slovak Republic

² Institute of Forensic Research and Education of University of Zilina, Ulica 1. mája 32, 010 01 Zilina, Slovak Republic

E-mail: jan.ondrus@fpedas.uniza.sk

Abstract. This contribution deals with the braking process of the specified motorcycle with ABS system. The purpose of the measurement was to determine the braking performance of the motorcycle under the selected operating conditions, considering the riders' skills. It was necessary to perform the practical measurements of motorcycle braking characteristics on the dry road surface. To provide the most accurate results the measurements were performed on one selected motorcycle. We concentrated mainly on the specification of the full braking deceleration under individual operating conditions. The measuring device XL MeterTM Pro was used to perform the measurement. The collected data were processed in the programme XL Vision and evaluated by SW PC-Crash. The results of the performed measurements and their evaluation and comparison are presented in the final part of this contribution. The obtained results and data can be further processed in forensic engineering.

1. Introduction

Motorcycles represent an essential part of the road traffic. The annual growth of the number of road vehicles brings along a negative influence. The number of registered motorcycles in Slovakia growth annually by 6 to 7 ths. In the year 2017 the number of the registered motorcycles was already 133 452. The growth in the number of motorcycles causes also the higher risk of traffic accidents. The most common cause of the traffic accidents is speed. The motorcycle accidents, compared to car accidents, are more often fatal.

A high quality and a reliable braking system, which creates a basic component of an active motorcycle safety, is important for bringing the motorcycle to a safe stop. Another important factor is the rider's proper control of the brakes (correct driving technique), on which depends – contrary of the automobile braking system - the strength with which the front and the back brake shall brake. [1]

Intensive motorcycle braking is usually an essential and defensive rider's reaction in order to avoid an accident. Indeed, detection of the full braking deceleration value reached during the intensive braking is being one of the determining factors in accident action explication. [2]

2. Characteristics of the riders and description of the motorcycle

The measurement was carried out by two riders. The more experienced one (Tomáš) did not carry the measurement out using his own motorcycle, therefore he had to take a test ride of 30 km and 10 test brakings on the measured distance, in order to get acquainted with the braking characteristics of the



measured motorcycle. The test ride had to be undertaken in order to reach the best possible braking impact. The less experienced rider (Rado) took only 4 test brakings due to using his own motorcycle, and was therefore acquainted with the technical status and riding conditions of the respective motorcycle (table 1).

Table 1 Rider's characteristics

Rider	Age [years]	Height [m]	Weight [kg]	Skills	App. no. of kilometres driven	Motorcycle
Tomáš	32	1,80	80	App 17 years of motorcycles riding App 3 years – competes on enduro motorcycles	80 000	Honda Hornet CB600F
Rado	24	1,77	88	App 9 years of motorcycles riding App 3 years of road motorcycles riding	15 000	Honda Hornet CB600F

A motorcycle Honda Hornet CB600F was used as an experimental vehicle. To provide the most accurate results the measurements were performed on one selected motorcycle (figure 1), thus eliminating the differences among the tyres, the used braking system, motorcycle construction, technical condition, etc. The motorcycle belongs to the group of the „Naked bikes“ – bonnetless motorcycle. The motorcycle is used in the common traffic. The motorcycle and the braking system were in the technical conditions with no defects. The tyres were pumped as specified by the producer. The basic technical data of the motorcycle is shown in table 2.



Figure 1. The experimental motorcycle

Table 2. Technical data

Producer :	Honda	Transmission :	6 – speed manual
Model :	CB 600 F Hornet	Powertrain :	chain
Year :	2007	Front brakes :	ventilated double-discs
Category :	Naked bike	Diameter front :	296 mm
Engine type :	Inline, 4-cylinder, DOHC	Front tire :	120/70 - ZR17; 3,9 mm
Displacement :	599 ccm	Rear brakes :	ventilated disc
Max power :	102 HP (75 kw) at 12 000 rpm	Diameter rear :	240 mm
Max torque :	63 Nm at 10 500 rpm	Rear tire :	180/55 - ZR17; 4,2 mm
Compression ratio :	12:01	Weights :	173 kg
Bore x Stroke :	65,0 x 42,5 mm	Wheelbase :	1 435 mm
Fuel type :	Unleaded 95	Length :	2 090 mm
Cooling system :	Water cooling system	Width :	740 mm

3. Description of the measurement devices

Motorcycles represent an essential part of the road traffic. The annual growth of the number of road vehicles brings along a negative influence. The number of registered motorcycles in Slovakia growth annually by 6 to 7 ths. In the year 2017 the number of the registered motorcycles was already 133 452. The growth in the number of motorcycles causes also the higher risk of traffic accidents. The most common cause of the traffic accidents is speed. The motorcycle accidents, compared to car accidents, are more often fatal.

3.1. *Decelograph XL MeterTM Pro*

Measurement device XL MeterTM Pro of the 3rd generation was used for measuring (figure 2). It is a universal accelero/decelometer with the alphanumeric LCD display. It serves to measure and evaluate vehicle acceleration and the state of its service brakes; it's easy to operate as it uses only 3 buttons placed at the top of the device box, each of them being of a different colour (black, green, red) and therefore of a different function. [3]

The device is powered by a battery but it can also be connected via an external source. From the technical point of view, it consists of three main parts: electronics, a vacuum suction cupule and an articulated arm which allows customizable mounting. XL MeterTM Pro is easy to attach to the desired location on the surface of the vehicle windshield or any other smooth surface and it can be fixed to the surface by turning the lever of the vacuum suction cupule. The device is built-in into an aluminium box which is purpose-designed to provide easy controllability and installation. The articulated arm allows zero point calibration while being installed on the vehicle windshield by means of the vacuum suction cupule.

There are two slots at the back panel; nine-pin D-SUB connector RS-232 allows connection with the computer and it may also be used to connect the brake pedal sensor as well as output signal control and the round slot is used to power the device from the external source (CC-in adapter). [3] The 14-bit measuring technology has been improved in the process of new XL MeterTM Pro development. Thanks to its increased storage capacity it is now possible to realise 8 measurements without the necessity to transfer data directly into a computer. The new functions of synchronisation and remote control enable easier and more comfortable usage. The modular architecture makes XL MeterTM Pro the ultimate device either for speed-up or brake performance tests. The electronic system of the device continuously records values of output signal voltage during the measurement, with the sampling rate of 200 Hz, i.e. the values are measured and recorded every 5 ms. There is an automatic off position recognition built-in in the device, so the precise zero point setting is not that necessary. The device records the course of acceleration within a span of 40 seconds from the moment of being turned on. [4]

3.2. *XL MeterTM Pro console*

Taking into account that there is no windshield or other screen on the motorcycle, it was necessary to figure out how and where the XL MeterTM Pro shall be fixed, so that the measurement can be carried out correctly. Therefore we had to develop a console on which the XL MeterTM Pro could be fixed, and which could at the same time be fixed on the motorcycle.

We fixed the measuring device on the bottom part of the front fork of the motorcycle due to the assembly simplicity and also to prevent the measuring device from including the influence of the shock absorbtion into the results. Also the console had not to constrain the rider and the riding conditions of the motorcycle. (figure 2 - left).

3.3. *Auxiliary wheels*

During performing the motorcycle braking characteristics measurements the riders' safety was our number one priority. The measurements were carried out at a high speed, with the ABS system turned off. Therefore we decided to fabricate an auxiliary wheels which prevented the rider from falling off of the motorcycle. The wheels were placed at the rear fork in such a way, that the spring influence did not have any effect on the steering control of the motorcycle. The wheels height setting was solved through

a precisely drilled holes and openings for the regulation bolt. These settings ensured the controllability required for the measurement purposes (figure 2 – right).



Figure 2. Fixing the console with the XL Meter™ Pro and the auxiliary wheels

The decelerograph was fixed by means of the vacuum suction cupule, on the „simulated windshield“, during the measurement. The device was positioned in such a way, that its measuring axis was parallel to the riding direction and that its controls were within the reach of operation. The device switches into calibration mode after being switched on and successful completion of the automatic system control. The mode then displays current value of measured acceleration. If a motorcycle stands still on the horizontal surface, the displayed value should be 0 m.s^{-2} . Any deviation can be corrected by adjusting the devices' butt hinge in such a way that its measuring axis is in the closest possible to the horizontal position.

4. Measuring methodology

The purpose of the measurement was to determine the braking performance of the motorcycle under the selected operating conditions (with or without activated ABS system), considering the riders' skills on the dry road surface. Each rider performed 16 measured rides, which presents 32 measurements in total, for both riders. We concentrated mainly on the specification of the full braking deceleration, braking distance and braking time under individual operating conditions.

The experiment was carried out on March 25, 2017 on the road III/2184. This road connects the villages Rakša and Turčiansky Michal, in the district of Turčianske Teplice, region of Zilina (figure 3). The surface conditions were: dry asphalt runway with the estimated adhesion factor of range 0.8 - 0.90 and the runway temperature of 8°C . The temperature of ambient air 12°C with very low speed wind, therefore its impact on the measurement can be ignored. Prior to the experiment we carried out calibration and test measurements to determine the necessary measurement characteristics (location of the braking manoeuvre, installation and calibration of the system, etc.).

The green track pictured on the figure 3 was used for the acceleration and bringing the motorcycle to the required speed. The length of the experimental green track was of approximately 100 m. The red track served for motorcycle braking and the measuring of braking distance. This track was approximately 30 m long. The surface was cleaned from the rough rubbish.



Figure 3. The experimental track

The target process to be observed was braking on the point of the swerving (on the dry road surface), with fully applied service brakes and with the ABS system turned on. The rider set the motorcycle in motion to the desired speed. Then at the moment of the desired steady speed the rider violently pushed the front and rear brake handle simultaneously. Intensive braking was being conducted until the vehicle reached the zero speed.

It was necessary to stop data recording by pushing the off button, when the motorcycle reached the zero speed. All these data were being recorded and were available in a complete data file at the end of the experiment. The experiment measurement was repeated after a short break. For reaching the best possible results the calibration was performed prior to every measurement. In order to reach more precise results the measurements were performed on each selected velocity twice.

The next measurement was performed with a deactivated ABS system. The measuring equipment control as well as the measuring procedure was identical with the previous measurement. ABS was deactivated by removing the safety plug from the system. Both riders undertook an identical measuring methodology.

5. Processing of measured data

For processing of results acquired from the measuring device XL Meter™ Pro the programme XL Vision™ and PC Crash 10.9 were used (figure 4). For the necessary tables and graphs MS Excel was used.

All data measured by XL Meter™ Pro can be saved and evaluated later offline. Individual data are stored in the permanent memory so they are accessible even after the device is off but only until being rewritten. Communication and transfer of the measured data between a PC and the XL Meter™ Pro device and its sequential processing is provided by the freeware XL Vision™.

In the XL Vision™ programme it is possible to display and save the measured data as the measurement process diagrams. These files with the measured data had to be saved in the programme XL Vision™ as a file PC Crash (*.asc), so that they can be opened in the programme PC Crash 10.9, where the data can be precisely processed and evaluated.

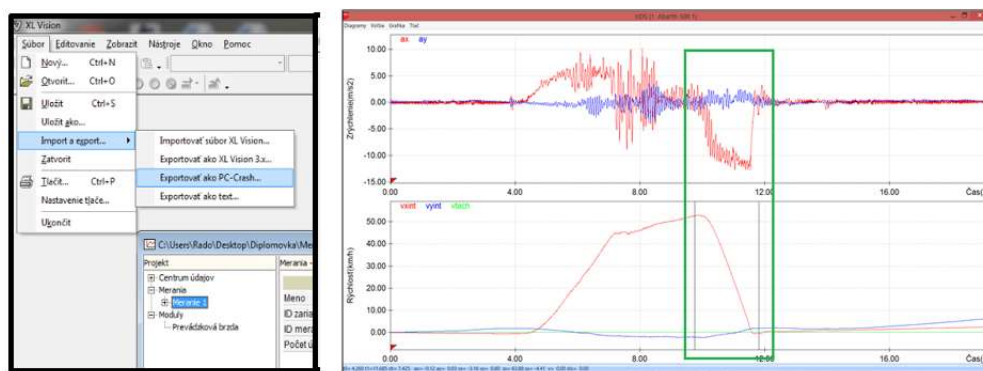


Figure 4. The view of SW XL Vision™ and PC Crash 10.9 [5]

6. Measured data evaluation

Values obtained from the braking characteristics measurement are stated in tables 3 and 4 considering the riders' skills and ABS functionality. All data were evaluated using the programme PC – Crash 10.9. We processed the data of the velocities at the beginning of full braking deceleration, calculated average values for full braking deceleration, time and distance data that the motorcycle has passed over this section.

The results show that the more experienced rider, Tomáš, reached better results due to higher average of the total braking deceleration.

Table 3. Evaluation of the measured data on the dry road surface with ABS system on

Riders	Trial	Velocity at the beginning of full braking deceleration (km/h)	Braking distance (m)	Braking time (s)	Full braking deceleration (m/s²)	Average full braking deceleration during individual velocities (m/s²)	Average braking deceleration of individual riders (m/s²)	Average full braking deceleration (m/s²)
Rado	1.	29,61	5,04	1,147	6,71	6,645	8,099	8,308
	2.	30,44	5,43	1,24	6,58			
	3	46,9	9,86	1,456	8,61	8,470		
	4	48,49	10,89	1,546	8,33			
	5	59,11	17,64	2,114	7,64	8,380		
	6	57,37	13,92	1,685	9,12			
	7	62,68	17,3	1,916	8,76	8,900		
	8	64,56	17,79	1,917	9,04			
Tomáš	1.	28,68	4,56	1,124	6,96	6,960	8,516	8,308
	2.	x	x	x	x			
	3	46,72	9,08	1,37	9,27	8,900		
	4	47,22	10,09	1,444	8,53			
	5	53,44	12,16	1,566	9,06	9,355		
	6	56,83	12,91	1,608	9,65			
	7	71,41	22,02	2,16	8,93	8,850		
	8	64,52	18,31	1,946	8,77			

x - incorrect measurement

Results of full braking deceleration measurement are:

Counted values

- maximum full braking deceleration: 9,65 m.s⁻² (trial 6, rider Tomáš),
- minimum full braking deceleration: 6,58 m.s⁻² (trial 2, rider Rado),
- average magnitude of full braking deceleration: 8,308 m.s⁻² (both riders),
- standard deviation of full braking deceleration (rider Rado): 0,944 m.s⁻²,
- standard deviation of full braking deceleration (rider Tomáš): 0,798 m.s⁻²,
- standard deviation of full braking deceleration (both riders): 0,935 m.s⁻².

The next table 4 shows the calculated values of measured braking characteristics on the dry surface, with the ABS system turned off. As in the previous table 3, a significant difference between individual riders' full braking deceleration can be noticed.

Table 4. Evaluation of the measured data on the dry road surface without ABS system off

Riders	Trial	Velocity at the beginning of full braking deceleration (km/h)	Braking distance (m)	Braking time (s)	Full braking deceleration (m/s²)	Average full braking deceleration during individual velocities (m/s²)	Average braking deceleration of individual riders (m/s²)	Average full braking deceleration (m/s²)
Rado	1.	27,4	3,91	0,998	7,41	7,820	7,986	8,549
	2.	26,7	3,49	0,898	8,23			
	3	47,37	10,46	1,494	8,28	8,135		
	4	46,38	10,39	1,575	7,99			
	5	53,46	13,93	1,841	7,92	7,910		
	6	53,9	14,19	1,704	7,9			
	7	61,06	18,44	2,097	7,8	8,080		
	8	62,66	18,12	1,912	8,36			
Tomáš	1.	29,72	4,25	1,082	8,01	7,965	9,113	
	2.	28,84	4,05	0,958	7,92			
	3	51,75	7,34	1,218	9,15	9,550		
	4	47,32	8,68	1,256	9,95			
	5	55,68	12,33	1,487	9,7	9,355		
	6	56,78	13,81	1,727	9,01			
	7	64,15	16,92	1,797	9,38	9,580		
	8	68,02	18,25	1,859	9,78			

Results of full braking deceleration measurement are:

Counted values

- maximum full braking deceleration: $9,95 \text{ m.s}^{-2}$ (trial 4, rider Tomáš),
- minimum full braking deceleration: $7,41 \text{ m.s}^{-2}$ (trial 1, rider Rado),
- average magnitude of full full braking deceleration: $8,549 \text{ m.s}^{-2}$ (both riders),
- standard deviation of full braking deceleration (rider Rado): $0,288 \text{ m.s}^{-2}$,
- standard deviation of full braking deceleration (rider Tomáš): $0,726 \text{ m.s}^{-2}$,
- standard deviation of full braking deceleration (both riders): $0,788 \text{ m.s}^{-2}$.

6.1. Full braking deceleration comparison

The highest average full braking deceleration $8,549 \text{ m.s}^{-2}$ was reached on the dry surface with the ABS system turned off. In this case a high grow of the braking deceleration was registered for the more skilled rider -Tomas – from the value $8,516 \text{ m.s}^{-2}$ to $9,113 \text{ m.s}^{-2}$ (table 5). Rider Tomáš reached the grow of the full braking deceleration by $0,597 \text{ m.s}^{-2}$ when braking with the ABS system turned off, as oppose to braking with the ABS system on. Thus the total average braking deceleration grew as well (table 4).

It was confirmed, that by correctly performed braking on the point of swerving it is possible to reach higher value of the full braking deceleration and thus a shorter braking distance than with the ABS turned on. In this case also the statement from the expert literature was confirmed, stating that the ABS does not always secure shortening of braking distance. The main contribution of the system is securing the constant controlability of the motorcycle throughout the braking process. [6]

On the dry surface and with the ABS system on the average full braking deceleration reached a value of $8,308 \text{ m.s}^{-2}$ (table 3).

The less experienced rider, Rado, reached slightly better results of the full braking deceleration with the ABS system on, but there was no significant difference. There results show that using ABS is, in this case, more convenient for the less experienced rider. Comparison of the influence of using the ABS on the braking characteristics for the individual riders show that the biggest difference in braking deceleration between the riders was $1,127 \text{ m.s}^{-2}$, with the ABS system turned off (table 5).

Table 5. Full braking deceleration for individual riders on the dry road surface

Riders	Full braking deceleration with ABS system on (m/s^2)	Full braking deceleration without ABS system off (m/s^2)
Tomáš	8,516	9,113
Rado	8,099	7,986

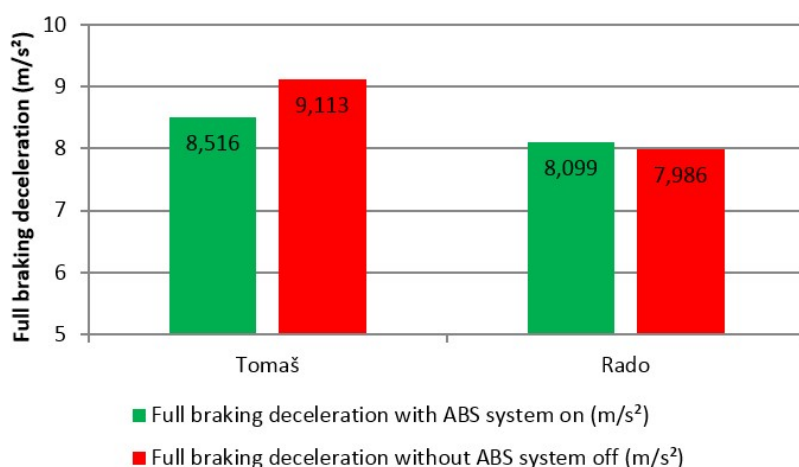


Figure 5. Comparison of the full braking deceleration for individual riders on the dry road surface

6.2. Dependence of the braking distance on the velocity at the beginning of full braking deceleration on the dry road surface

From the obtained data stated in tables 3 and 4, the dependence of the braking distance on the velocity at the beginning of the full braking deceleration both with and without the ABS system activated, shall be compared (figure 6).

The figure proves that braking distance is strongly dependant on the velocity. The green curve consists of 15 points and shows the continuance of the results stated in table 3 (dry surface, ABS system on). The red curve consists of 16 points and shows the results stated in table 4 (dry surface, ABS system off). These points combine both riders into one joint polynomic curve with and without the ABS system.

The polynomic trend line was set through individual points and a regression formula stated in the figure and a reliability value R^2 were used. In both cases a very high reliability values R^2 were reached. The polynomic curve with the ABS system on reached the value $R^2 = 0,9817$; with the ABS system off $R^2 = 0,9328$ (figure 6). Reaching such a high reliability value (coming near to 1) we can declare that an appropriate regression type was used. Both curves are almost of the same course which proves both methods are suitable to be used.

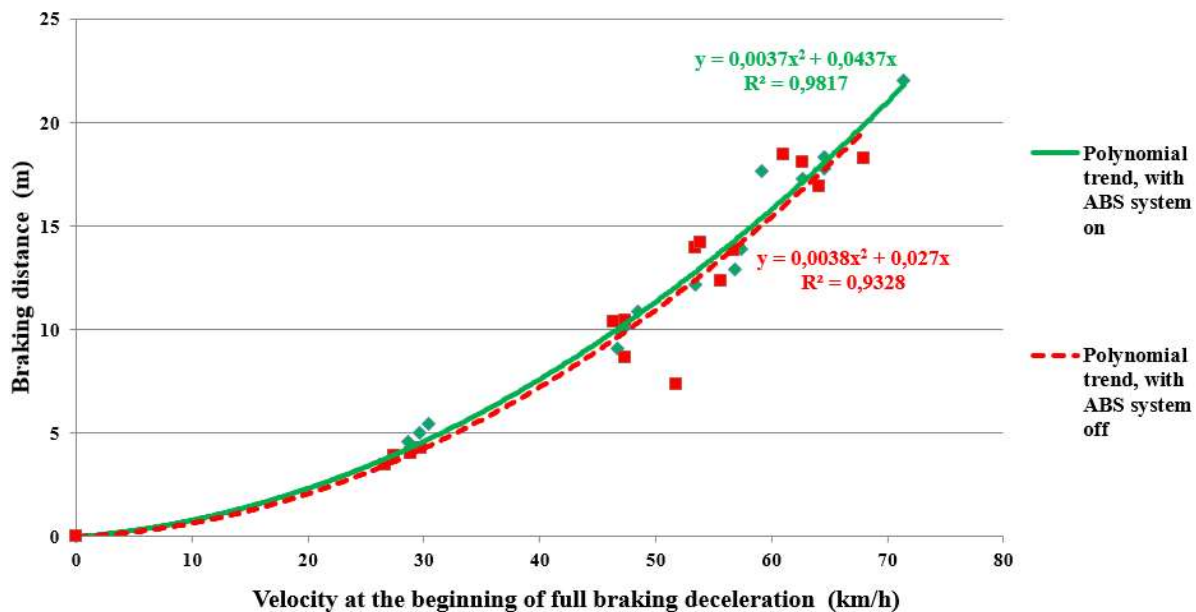


Figure 6. Comparison of the braking distance on the velocity at the beginning of full braking deceleration on the dry road surface

7. Conclusion

The measuring device XL Meter™ Pro was used to take the measurements. Our experiment consisted of 32 deceleration measurements on the dry asphalt with the sampling rate of 200 data per second. Decelograf XL Meter™ Pro is a professional device for analysis of acceleration and deceleration of different vehicles such as motorcycles, passenger cars, busses, commercial vehicles, trucks, etc.

An important contribution of this experiment is the practical measurement of the braking behaviour of the motorcycle under the selected operating conditions (with or without activated ABS system), considering the riders' skills. To provide the most accurate results the measurements were performed on one selected motorcycle. We focused mainly on the specification of the braking distance and full braking deceleration. This presents a very important indicator on which the braking distance is strongly dependant. This value is also very important for the Road Traffic Experts when elaborating the Forensic Expert's Reports of traffic accidents, where it represents the core entry value of braking behaviour of the respective vehicle; or alternatively in other areas, where the measured results can help to achieve the solution.

Out of the obtained data we can conclude that the ABS system does not always shorten the braking distance. It was confirmed, that by correctly performed braking on the point of swerving it is possible to reach higher value of the full braking deceleration and thus a shorter braking distance than with the ABS turned on. This effect can be expressively seen with the more experienced rider, Tomáš.

Also the experience of the riders effected the process. The less experienced rider, Rado, reached lower values of the average full braking deceleration under the same conditions as the rider Tomáš. For better results and more precise evaluation more measurements would have to be performed.

Acknowledgements

This contribution is the result of the project implementation:

2/KCMD/2018

Centre of excellence for systems and services of intelligent transport II, ITMS 26220120050 supported by the Research & Development Operational Programme funded by the ERDF.

References

- [1] Hockicko P and Trpišová B 2013 Are students' conceptions about automobile braking distances

- correct? *Proc. Int. Conf. 41st SEFI Engineering Education* (Belgium: Leuven, SEFI)
- [2] Hockicko P and Ondruš J 2012 Analysis of vehicle stopping distances *Proc. Int. Conf. New trends in physics NTF 2012* (Brno: University of Technology) pp 214-217
- [3] Handbook of XL Meter™ Pro
- [4] Vrábel J, Jagelčák J, Rievaj V and Caban J 2014 The quality of the brake components and its impact on the basic parameters of braking *Machines, technologies, materials: international virtual journal* Vol **8** no **6** pp 6-8
- [5] SW XL Vision™ and SW PC Crash 10.9
- [6] Kasanický G and Kohút P 2003 *Analysis of single-track vehicle accidents* (Zilina: University of Zilina, EDIS) pp 488