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ANALYSIS OF THE FORCE DURING OVERCOMING THE ROADBLOCK – THE PRELIMINARY EXPERIMENTAL TESTS

Summary. The paper applies to the issue of preservation of passenger vehicles during overcoming the roadblocks on a dry asphalt surface with the constant speed. The study aimed to estimate the forces which are affecting the suspension of the vehicle during the contact between a tyre and roadblock. Using the video recording it is possible to calculate the values of the tyre deflection and forces acting in the system. The obtained deflections of the tyres were compared to earlier laboratory test results and load-deflection characteristics of the tyres with the same size. The roadblock with the defined geometry causes a dynamic deflection of the tyre. During the study a significant change in the geometry of the suspension has not occurred. The paper presents the characteristics of the vehicles research with a particular regard to model and type of tyres. The determination of the exact dimensions of the roadblocks and application of the ADIS 16385 system for acquisition and archiving the features of the kinematic motion of the vehicle allowed to determine the speed at the moment of collision with the roadblock.

ANALIZA SIŁ PODCZAS POKONYWANIA PRZESZKODY STAŁEJ – DOŚWIADCZALNE BADANIA PILOTAŻOWE

Streszczenie. Praca dotyczy problematyki zachowania pojazdów osobowych podczas pokonywania przeszkody stałej na suchej nawierzchni asfaltowej, z zadaną prędkością. Przeprowadzone badania miały na celu oszacowanie sił oddziałujących na zawieszenie pojazdu w momencie styku opony z przeszkodą. Wykorzystując nagranie wideo, możliwe były obliczenie proporcji ugięcia opony oraz teoretyczne wyznaczenie sił działających w układzie. Otrzymaną wartość ugięcia opony porównano z wcześniejszymi wynikami badań laboratoryjnych i charakterystykami obciążenie-ugięcie dla opon o tym samym rozmiarze. Przeszkoda o zdefiniowanej geometrii powodowała ugięcie dynamiczne opony. Podczas badań nie zaobserwowano istotnej zmiany geometrii zawieszenia. W artykule przedstawiono charakterystyki pojazdów badawczych, ze szczególnym uwzględnieniem modeli i rodzaju/typu opon. Opisano dokładne wymiary przeszkody, a wykorzystany układ ADIS 16385 do akwizycji i archiwizacji cech kinematyczny ruchu pojazdu umożliwił określenie prędkości w chwili najechania na przeszkodę.

1. INTRODUCTION

The economy is based mainly on road transport of goods and services. Intensively expanding road infrastructure makes it necessary to ensure the safety of all road vehicles. In many places there are tram tracks and crossings, which are fixed obstacles placed within the road [2, 4-6]. Additionally, especially in urban areas are islands bumps [3, 11], and curbs. Heavy use can lead to the formation of ruts faults, rifts and cracks. The resulting inequality can significantly affect the working of the tire and the road, which generates large peak forces acting on the tire and suspension of the vehicle. High acceleration values are not fully suppressed by the suspension and can be transferred to the car body and traveling.

Nowadays the highways do not consists of the road surfaces only, but are also equipped with the infrastructure. The highway infrastructure consists of the following elements: parking bays, bus stops, exits, median strips, street islands, railway crossings, viaducts, bridges and all elements surrounding the road. The surface contaminations can be divided into two groups. The first group results from using of the surface, i.e. ruts, humps, irregularities of surface and destroyed surfaces. The second group consists of the surface road contamination due to the road traffic and dirt which was carried from the shoulder. During the windy weather falling branches are a high risk for the road traffic. Weather conditions have a high influence on the road contamination and safety of the road traffic. Branches, stones, unequal road subgrades or road faults can be called as the roadblocks [10]. The paper presents the results of the experimental tests of overcoming the roadblock by the vehicle with the estimated speed [7-9].

2. THE METHODOLOGY AND COURSE OF EXPERIMENTAL TESTS

The aim of the tests was the assessment of the vehicle, tyres and suspension during overcoming the roadblock with the estimated velocity value of ca. 30 km/h. Two passenger cars were chosen for the investigations, i.e. Skoda Octavia and Volkswagen Passat (Fig. 1). Skoda Octavia estate car was produced in 2004. This vehicle was equipped with a front drive, six-speed manual gearbox and supercharged diesel engine with the capacity of 1896 cm3 and power of 96 kW. The second vehicle was Volkswagen Passat equipped with the same engine with power of 74 kW and five-speed manual gearbox. This car was produced in 2002.

Fig. 1. View of the examined vehicles, Skoda (left photo), Volkswagen (right photo)
Rys. 1. Widok badanych pojazdów, Skoda (po lewej), Volkswagen (po prawej)

Both vehicles were equipped with the tyres 195/65 R15 with the steel wheel bands. Skoda was equipped with Gislaved Euro Frost 3 tyres manufactured with symmetrical tread in 2011. The tyres were very used up – this fact can be seen for the measurement results of the tread depth which are presented in Table 1. Volkswagen Passat was equipped with summer tyres Dunlop Sport Bluresponse manufactured with asymmetrical tread in 2013. The tyres had a low wear (Tab. 2)

Table 1

Averaged measurements of the tread depth of the particular tyres for Skoda car

	FL	FR	RL	RR
external	3,90 mm	5,23 mm	3,36 mm	4,01 mm
centre	4,06 mm	4,54 mm	3,43 mm	3,90 mm
internal	3,92 mm	4,16 mm	3,46 mm	4,01 mm

Table 2

Averaged measurements of the tread depth of the particular tyres for Volkswagen car

	FL	FR	RL	RR
external	6,30 mm	5,98 mm	6,47 mm	6,30 mm
centre	6,17 mm	6,26 mm	7,02 mm	6,59 mm
internal	6,19 mm	6,25 mm	6,90 mm	6,74 mm

The vehicles were equipped with the measuring apparatus ADIS 16385 from the Analog Devices company. It consisted of three acceleration sensors and three piezogyroscopes which were integrated in one measuring system. During the road tests the measuring apparatus was fixed on the roof of the vehicles. Portable computer with the dedicated software was applied for acquisition and archiving the measurement data. The measuring apparatus was characterised by 2% measurement uncertainty [1].

3. THE CHARACTERISTICS OF THE ENVIRONMENTAL CONDITIONS AND ROAD SURFACE

The road tests have been done on the road with a small traffic flow along the embankment of the Głogowska Street near Komorniki in March 2014. This localization was chosen due to the security of the researchers and a lack of outsiders. The selected section of the road is characterised by a flat asphalt surface, lack of transverse inclination and longitudinal inclination of ca. 1%. During the tests the road surface was dry and clean. The road section had no defects or gaps, but inspection chambers were present in a regular interval. These inspection chambers did not have any influence on the measurement results (Fig. 2).

Fig. 2. View of the investigated road section
Rys. 2. Widok badanej drogi

During the road tests the environmental conditions were investigated before and after the examination of the kinematics of the vehicle motion which was overcoming the roadblock. The results of the environment research are presented in Tables 3 and 4.

Table 3

The measurement results of the environmental conditions before the kinematic features test of the vehicle motion

Ambient temperature	11,0 ^{o}C
Humidity	72,0%
Atmospheric pressure	1001,5 HPa
Temperature of saturation point	6,1 ^{o}C
Road surface temperature	15,4^{o}C

Table 4

The measurement results of the environmental conditions after the kinematic features test of the vehicle motion

Ambient temperature	12,0^{o}C
Humidity	70,3%
Atmospheric pressure	1001,3 HPa
Temperature of saturation point	6,5^{o}C
Road surface temperature	16,2^{o}C

4. THE MEASURMENT RESULTS

The road tests were performed from start until stop after overcoming the roadblock. The roadblock was placed in a distance of 30 m from the start line. The driver's task was to start, change the gear and overcome the roadblock with the velocity of 30 km/h. Next his task was to intensively apply brakes until full stop.

A wooden board was used as the roadblock (Fig. 3). It was undercut in order to run over the roadblock easily.

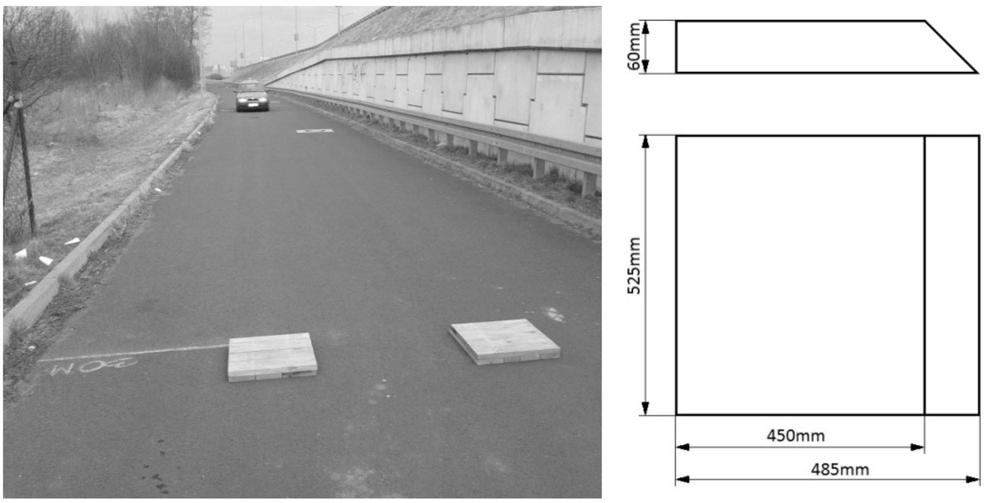

Fig. 3. View of the roadblock on the route (left photo), the dimensions of the roadblock (right picture)
Rys. 3. Widok przeszkody stałej na drodze (po lewej), wymiary przeszkody (po prawej)

Five runs over the roadblock for each vehicle were performed. The exemplary characteristics of the longitudinal acceleration in function of time are presented in Fig. 4.

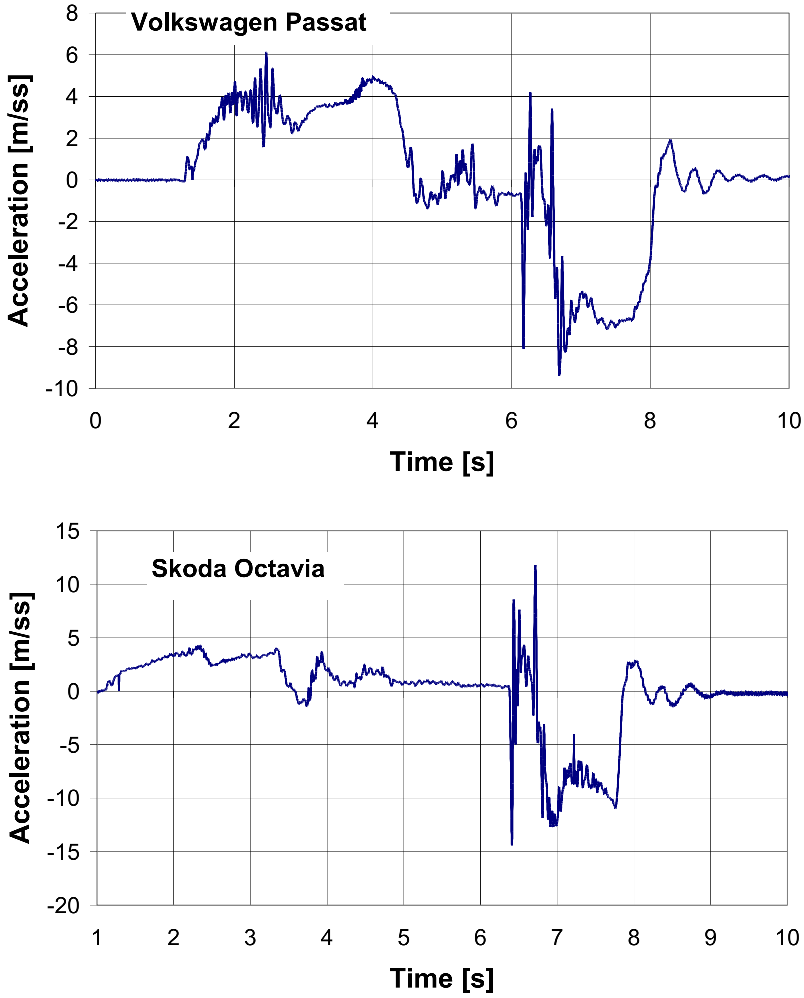

Fig. 4. Exemplary characteristics of the longitudinal acceleration with the visible impulse generated by the roadblock

Rys. 4. Przykładowe przebiegi przyspieszeń z widocznym impulsem siły generowanym przez przeszkodę

5. ANALYSIS OF THE MEASURMENT RESULTS

The measurement tests were done for one-way traffic with uphill drive. The inclination of the road surface was corrected in order to obtain the real values of the longitudinal accelerations. All tests were additionally recorded with a camera. This allowed us to analyse the deflection of the tyre and suspension (frame after the frame). On the basis of the video analysis with the application of the software for graphics processing we have stated that the real height of the roadblock, i.e. 60 mm, corresponds to 22 pixels in a picture. It was calculated that 1 pixel has a height of ca. 2,72 mm. The pixel segmentation of the frame allowed us to determine the deflection values of tyre and suspension during the contact between the tyre and the roadblock (Fig. 5). This fact is presented in Table 5. It was assumed that the tyre deflection during the motion on a flat surface with a constant velocity is equal to static deflection of the tyre which is resulting from the load intensity of the wheel.

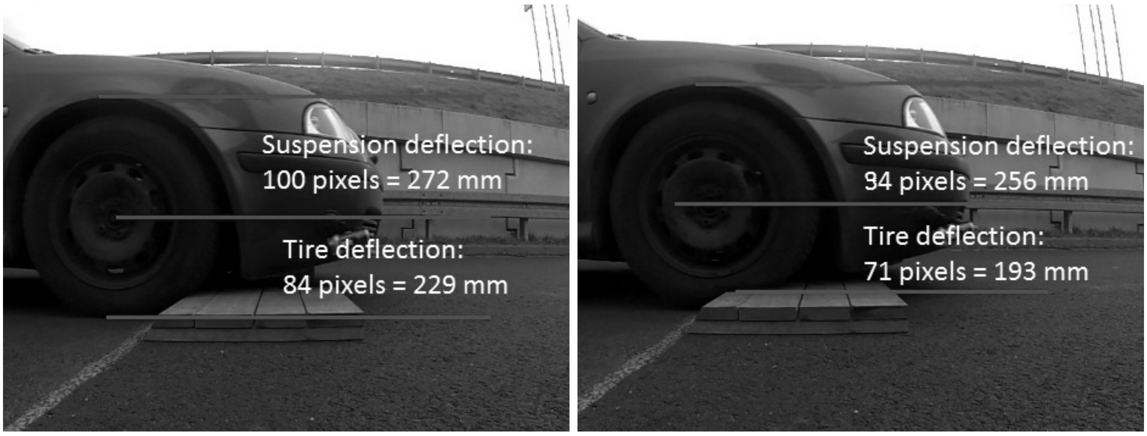

Fig. 5. View of Skoda car during overcoming the roadblock
Rys. 5. Widok samochodu Skoda podczas pokonywania przeszkody

To determine the theoretical value of the force which is generating the deflection during overcoming the roadblock, the laboratory tests of the relationship between the tyre deflection and loading for the tyre pressure of 0,2 MPa were performed (Fig. 6). After the measurements of the static unit pressure for the particular wheels of Skoda car, the value of the static deflection of the front right tyre was evaluated for loading with a static force - for the static force value of 4300 N the static deflection was equal to 26 mm. When we add together the value of the static deflection and the value of the deflection which was generated during overcoming the roadblock (36mm), then we get the total value of the deflection which was equal to ca. 62 mm. When we extrapolate data in accordance with the equation of the trend line (Fig. 6), then we get the value of the deflection force, i.e. 10266,7 N for the deflection value of 62 mm.

Table 5
The deflection values of the tyre and suspension calculated on the basis of the quantity of pixels for Skoda car

1 pixel = 2,72 mm							
Tyre deflection (distance between the wheel axis and road surface)				Suspension deflection (distance between the wheel axis and fixed element of the body of a car)			
Before overcoming the roadblock		During overcoming the roadblock		Before overcoming the roadblock		During overcoming the roadblock	
pixels	mm	pixels	mm	pixels	mm	pixels	mm
84	229	71	193	100	272	94	256
Tyre deflection caused by the roadblock: 13 pixels ≈ 36 mm				Suspension deflection caused by the roadblock: 6 pixels ≈ 16 mm			

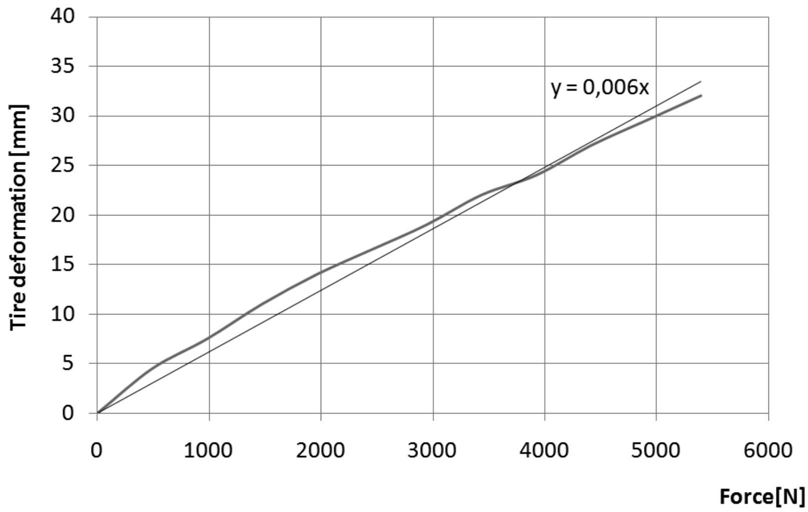

Fig. 6. The investigations of the deflection value of the winter tyre 195/65 R15 in function of loading for the tyre pressure of 0.2 MPa

Rys. 6. Badania wartości ugięcia opony zimowej o rozmiarze 195/65 R15 w funkcji obciążenia dla ciśnienia 0,2 MPa

6. CONCLUSIONS

On the basis of the analysis of the forces acting on the tyre and vehicle suspension system we can conclude that even a small roadblock which is overcome with a low speed can generate a high impulse of the force. We can also notice that the force which results from overcoming the roadblock is completely removed by the tyre and suspension deflection. Presented investigation shows in this article, that force impulse depends on type of the tyres and construction of the suspension. The influence of suspension construction is visible in acceleration characteristics (Fig. 4). There is second maximum (about $-9{,}3\,{}^{m}\!/_{s^2}$) after the first maximum of $-8{,}1\,{}^{m}\!/_{s^2}$ for Volkswagen Passat and $-14{,}4\,{}^{m}\!/_{s^2}$ for Skoda car. This fact has an effect on a drive comfort, the possibility of vehicle damage and safety of the road traffic.

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