EXPLORATION OF THE SHOCK-ABSORBER DAMAGE INFLUENCE ON THE STEERABILITY AND STABILITY OF THE CAR MOTION

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Abstract

The condition of shock-absorbers is one of factors influencing the in active-safety technology which help drivers to control of their vehicles in the motion. It stuck in the drivers' consciousness, that the damage of the shock-absorber causes the elongation the braking path and the lowering of the drive comfort. The remaining consequences of the worse conditions of shock-absorbers they are not known for the drivers' generality. This impinges on the vehicle motion parameters, its steerability and directional stability.

The results of investigations and the analyses of the inefficient shock-absorber influence on vibration damping and the motion of the car were introduced in the presented work. The damping coefficients of the shock-absorber and their change during the exploitation were defined on the basis of test-bed investigations. Road tests were carrying over, on the basis which, try to catch the influence of fault on steerability and the directional stability of the vehicle motion. Road tests were carry over on the A class car.

There was compared behaviour of the efficient vehicle and with the worn out shock-absorber. To comparison coefficients various tests are proposed. The road tests were carrying out on A class car with the 4WD driving system, equipped with the drive stability system. Results from individual tests were introduced on graphs.

Keywords: *shockabsorber, suspension damping coefficient, road tests, the vehicle stability, road safety*

1. Introduction

Contemporary vehicles together with the construction development and upgrowth of the net of roads, can achieve higher driving speeds. The quantity of vehicles riding on roads increases. These two factors directly influence on the road motion safety and on grow up requirements of cars suspension and driving systems.

The constructors of vehicles introduce new solutions, being characterizing the larger safety of the use of the vehicles. Under the influence of the working of the friction force, follows wearing away individual units what influences the increase of clearances and the change of the parameters of the work of the vehicle suspensions in the real car. Shock-absorbers are one of the units whose wear out directly influences on the road motion safety. The inefficient shock-absorber will generate the serial change of loads on the road and in the effect the pulsation the values of forces transferred on the point of contact of the wheel with the road. In the border case, it can follow disconnection the wheel from the road.

Because of this, that the wear is this process stretched in the time, the driver clearly feels the bad condition of the shock-absorber just near the total absence of damping. This is not clearly perceptible in the conditions of the partial wear.

In the paper author try introduce both the change of characteristic quantity for the shock-absorber as also their influence on behaviour oneself the vehicle on the road.

2. The investigation of the character of the shock-absorber on the measuring stand

The measurement of the effectiveness of damping on the test stand was executed to confirmation of the damage of the shock-absorber [5, 6]. The progress of the damping force

changes in the function of the deflection for the efficient and inefficient shock-absorber for various road frequencies were showed on graphs (Fig. 1).

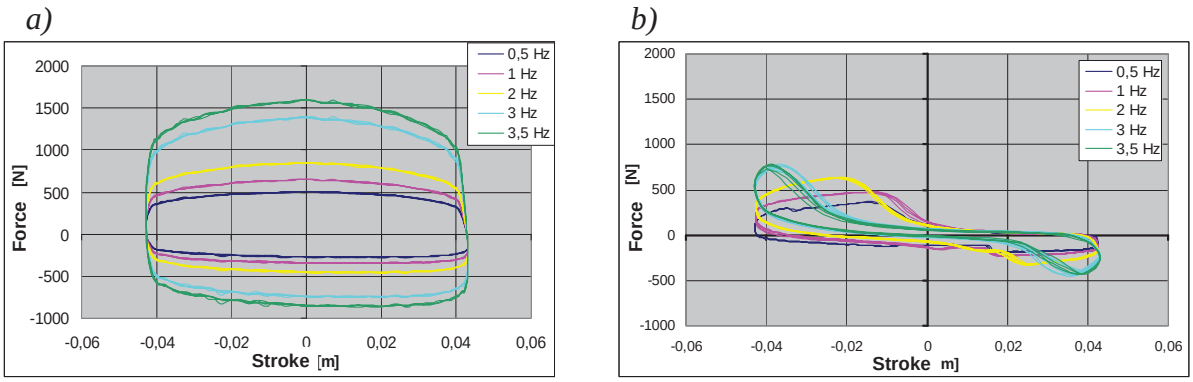

Fig. 1. The damping force in the efficient and inefficient shock-absorber in dependence from the oscillations frequency (deflection 84 mm, measurement on the test stand) a) efficient, b) inefficient

As it was showed on graphs, the efficient shock-absorber generates damping force about the similar value in the whole range of the piston stroke. The growth of damping force steps out only in the case of the larger values of the stroke, after the change of the direction of the motion of piston which means that damping will step out only in the initial stage of the piston motion in the case of the inefficient shock-absorber. It is this causes the small content of oil in the shock-absorber, which near the higher speeds of the motion piston, will not manage to flow down and set in the motion of valvelets in the piston of the shock-absorber. Conducted measurements allowed to delimitation of the coefficients of damping.

3. Change of the damping coefficient appear from the damage of the shock-absorber

The shock-absorber has been removed from the vehicle. The damping coefficients were marked of for the maximum values of force acting on the shock-absorber on the test stand. The largest values of the coefficient are presented near the low frequencies of vibration. Stabilizing the value of the coefficient on the uniform level together with follows with the growth of the frequency.

The value of the damping coefficients of the shock-absorber for the compression (jounce) and expansion the (rebound) was presented on graphs.

From graphs we can see results that the damping coefficient is considerably lower in the case of the inefficient shock-absorber. In the phase of the rebound, for the wear out shock-absorber, the coefficient gets smaller 60 to 65% and in phase of jounce about 35 to 50%.

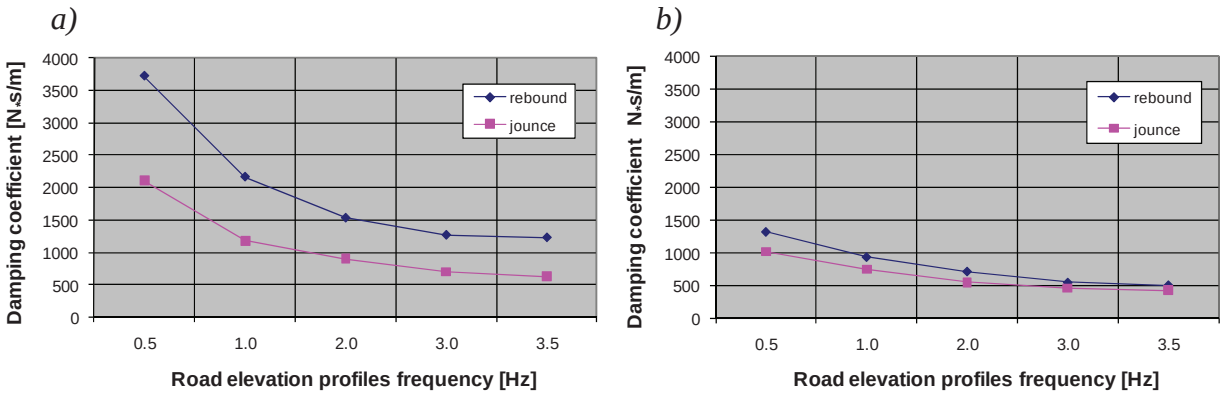

Fig. 2 The damping coefficients of the efficient and inefficient shock-absorber in the function of the road elevation profiles frequency a) efficient, b) inefficient

It results that the damage of the shock-absorber will produce the lowering the damping of the perpendicular vibration of wheels from above mentioned considerations (what will be in certain rate transferred on the vibration of the vehicle body). It will be different flexibility of the suspension and the period of vibration. This one will also join with larger force transferred on the body, the larger inclination angles of vehicle while executing the turn manoeuvres and „worse" passing on force on the point of contact of the wheel with the road.

The change of the border values of force transferred from wheels on the surface of the road will also influence on the motion of vehicle, his steerability and stability. To confirm these road tests had been carry over.

4. Traction test of the vehicle

The series of road testing was carry out in this aim of proof of the influence of the unefficiency of the shock-absorber on behaviour the vehicle on the road [1, 2]. Several tests imitating behaviour were chosen oneself vehicles while executing various manoeuvres. Road tests depends on braking on the straight section of the road, braking on turn and drive on the circular track. Tests were executed the comparative method, first for the efficient vehicle and then for the vehicle with the damaged shock-absorber installed in the right front suspension. Tracks used during road tests were schematically introduced on figures.

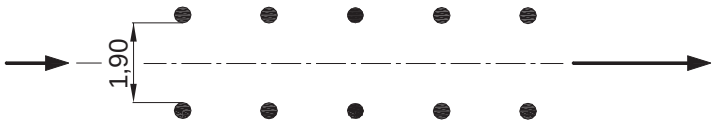

Fig. 3a. The measuring track to test of braking on straight section of road (test 1)

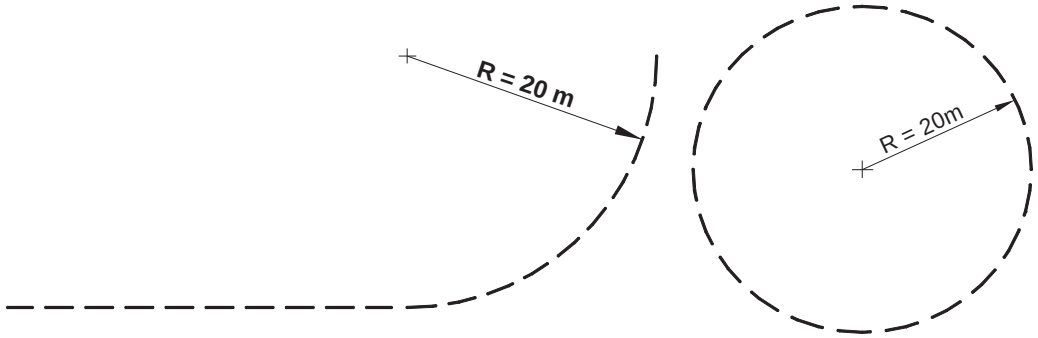

Fig. 3b. The measuring track of braking on curve of road (test 2) The measuring track of driving on circle (test 3)

For the valuation of behaviour the vehicle was gone to the number of coefficients got from the measurements of the motion of the vehicle. There was compared behaviour of the efficient vehicle and with the worn out shock-absorber. To comparisons coefficients were proposed various tests.

The road tests were carrying out on car class A with the 4WD driving system, equipped with the drive stability system [3, 4]. Results got from individual tests were introduced on graphs below.

Test 1 „braking on the straight section of the road"

Braking on the straight section of the road was carrying out for the driving car with the initial velocity ~80 km / h. There was compared: yaw from the straight direction of the track, the intensity of braking and the courses of pressure in the brake circuits of individual wheels.

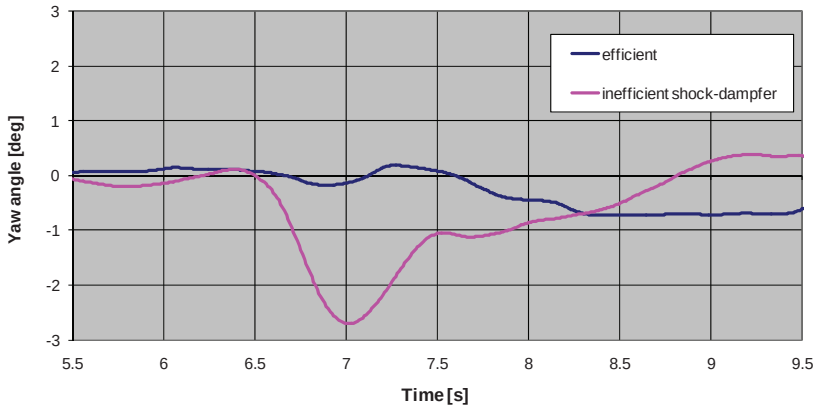

Fig. 4 Yaw angle from the straight direction of the track

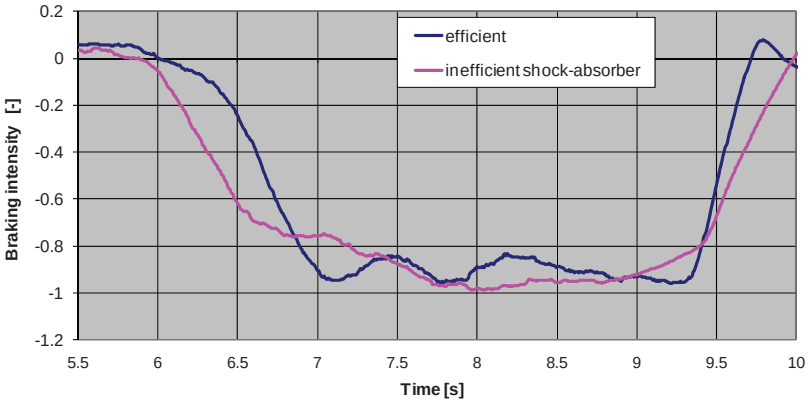

Fig. 5 Braking intensity

The stopping distance in the case of the damaged shock-absorber extended what resulted from the yaw on the straight direction of the track about 1 m (and it extorted the correction of the direction of the track by the driver) as one can observe from graphs. The intensity of braking in the initial part is clearly smaller and approaches to the curve for the efficient vehicle near the end of braking.

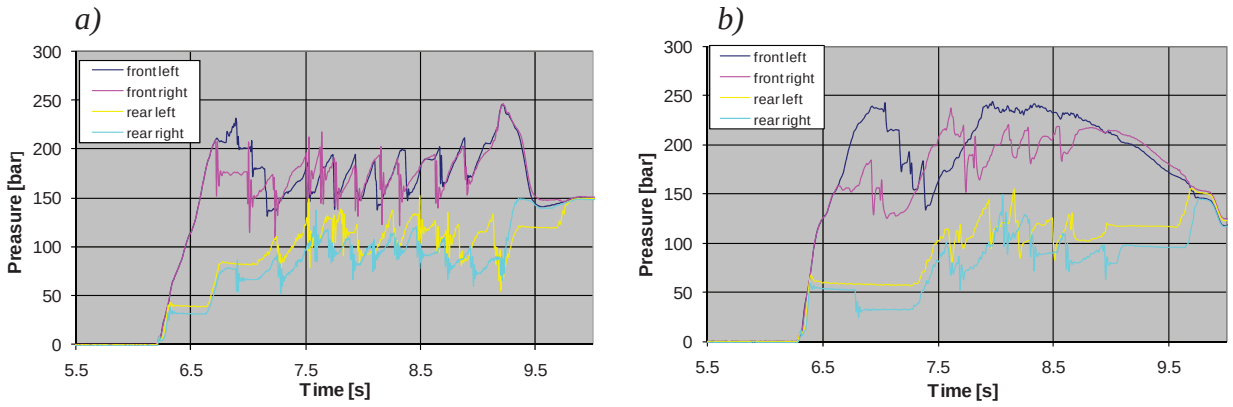

Fig. 6. The courses of pressure in the brakes of wheel a) the efficient car b) the damaged shock-absorber.

The efficient car shows the symmetry of the acting of the brakes of right and left wheels. The asymmetrical acting of the brake system called out visible is the temporary unloading and uploading of the wheel in the car with the damaged shock-absorber. This influences the acting of the brakes of remaining wheels.

Test 2 „braking on the curve of the road"

Test braking on the curve of the road was carrying out for the derived car with the initial speed ~55 km/h. The car move on the curve of the road with ray ~30 m and after the conquest ~20 m began the manoeuvre of braking. It was compared: total accelerations: longitudinal and side, change understeer of the vehicle expressed by the difference the slip angles of the wheels of individual anises, the angle of the inclination of the body, the velocity of yaw and the courses of pressure in the brakes system for individual wheels.

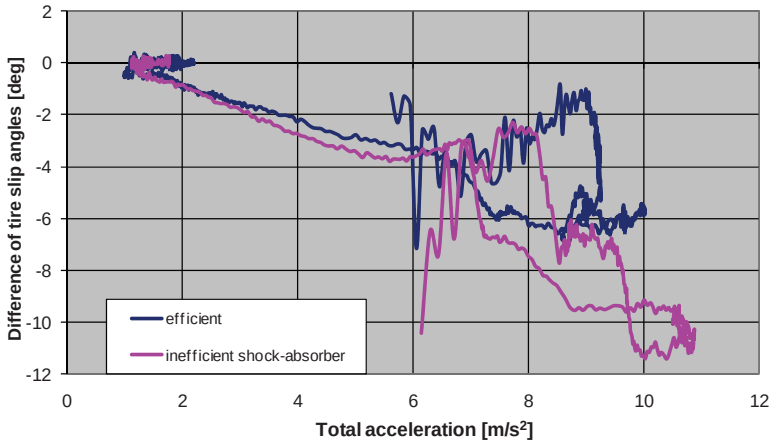

Fig. 7. Difference of the tire slips angles of the wheels from front and rear axis

You can see from the graph of accelerations that efficient car is characterizes lower total accelerations: side and longitudinal during the manoeuvre of braking on the road curve. The difference of the tire slip angles of the wheels of the front and rear axis is considerably particularly larger in the range of large total accelerations in the car with the inefficient shock-absorber. The difference of the angles of the tire slip of wheels set on this same level in the final phase of a system of braking (on the low velocities of the drive). The unefficiency of the shock-absorber influences the side inclination of the vehicle which increases from 6 to 8 degree. Yaw velocity of for inefficient car is particularly larger in the range of large side accelerations, what causes enlargement of the ray on which the vehicle drives. The damage of the shock-absorber calls out the change of pressure on the sides of the vehicle caused upload of right wheels (the larger inclination of the body) and particularly front right wheel. The rear left wheel is so as much unloaded, that he does not transfer braking forces. In the final phase of braking the pressure get equal (Fig. 8).

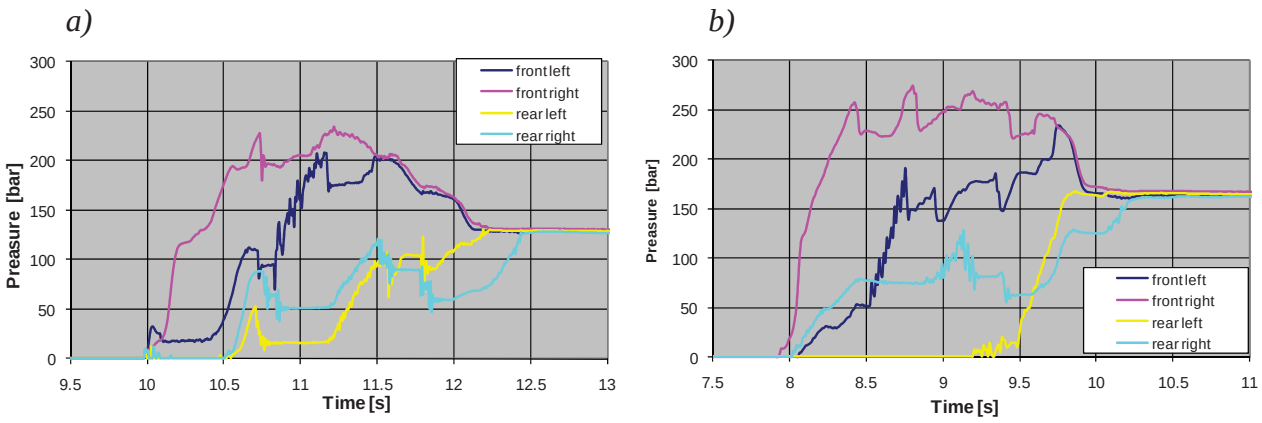

Fig. 8 The courses of pressure in the brakes of wheels a) the efficient car b) the damaged shock-absorber.

The test 3 „drive on the circle”

The test consisted on the drive on the circle with the quasi-static enlarged velocity as much as till the moment of the loss of drive transmitting. The vehicle moved with the steady angle of the turn of the steering wheel. The initial ray the circle on which the car moved carried out 17.5 m. It was compared: the understeer change of the vehicle showed by the difference of the tire slip angles of the respective anises wheels, angle of the sideslip β, the standardized angle of yaw ψ and the track of the vehicle.

The car with the inefficient shock-absorber is characterizes the larger difference of the tire slip angles of front and rear wheels and larger understeer. These perceptible differences are in the range from low to high side accelerations.

The standardized yaw angle of ψ/δ_H shows, that the inefficient vehicle periodically increases and decreases the yaw angle uniform setting of the steering wheel. The motion of this vehicle shows the lower angles of yaw and lower side accelerations, what joins with the change of the ray on which the vehicle moves.

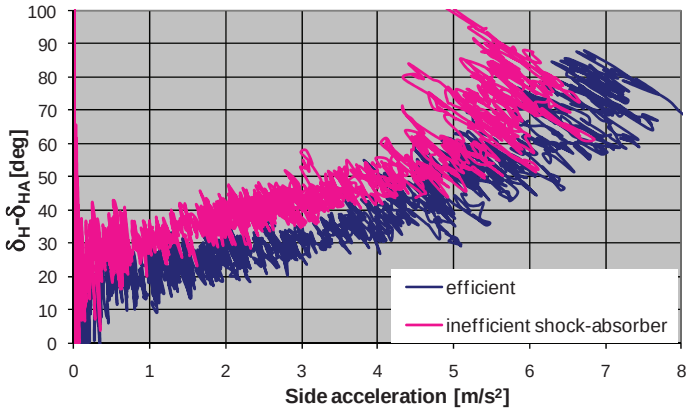

Fig. 9. The steerability characteristics (the difference of the steering wheel angle and Ackermann angle)

The difference of the steering wheel angle and Ackermann angle shows clear enlargement of understeer the vehicle in the whole range of side accelerations.

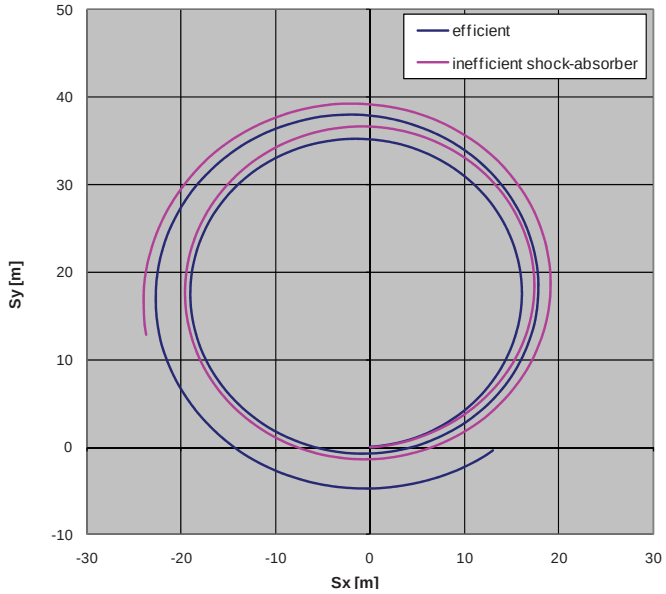

Fig. 10 The track of the movement of the vehicle

The track the motion, on which the efficient vehicle moves, is characterizes the smaller ray in the whole range of the test (in the whole range of the drive velocity).

5. Recapitulation

The wear of the shock-absorber influences the change of characteristics of suppression particularly while rebound. Decrease of the coefficient of damping is almost 3 times in these conditions. While jounce the coefficient of damping gets smaller only about ~ 30%. It causes this decrease suppression force of the shock-absorber about ~ 50% during the compression and expansion. The results of this state are also visible while executing various manoeuvres by driving the car.

The compared parameters of the motion of the vehicle allow to following thesis relating to the car with the damaged shock-absorber:

- The damage of the shock-absorber causes the yaw from the track of the movement while braking on the straight section of the road. This joins with elongation stopping distance of braking and the automatic correction of the individual wheels braking force.
- The unefficiency of the shock-absorber causes enlargement of the ray of the track of the motion of the vehicle what is effective clear enlargement of undesteer, speed and the angle of yaw, the larger side inclination of the body. You can also see this on the pressure distribution in the individual wheels circuits of the brakes.
- During the drive on the circle vehicle is characterizes clearly larger understeer what guides to the enlargement of the ray of the circle after which the car moves.

6. Conclusions

One can appear following conclusions on the basis of introduced measurements and road tests:

1. The damage of the shock-absorber guides to the decrease of the damping both: during the movement of the compression and expansion of the shock-absorber. This joins with the clear decrease of damping forces in the suspension.
2. The damage of the shock-absorber causes the change of the profile steerability of the vehicle - increases car understeering.
3. The damage of the shock-absorber influences elongation of stopping distance of braking.
4. The damage of the shock-absorber causes occurrence of the yaw from the track, exacting corrections by the driver in the case of braking on the straight track. The tested car was equipped in the steering system with electric power assistance, from here the growth the moment acts on steering wheel is comparatively little perceptible.
5. The unefficiency of the shock-absorber causes disconnect off the wheels from substrate, particularly during the requiring manoeuvres of the quick turn of the steering wheel. This meanwhile inefficiency influences worsening of the steerability of the vehicle.
6. You should notice that this tests were carried out on the dry and fine surface. The change of the surface called out the acting of atmospheric factors on the surface with the smaller coefficient of friction (e.g. wet, snow-covered surface or icy) it will guide to enlargement of the reaction of the car on inefficiency. From this regard, the small reaction of vehicle on the good friction conditions can mark considerably larger reactions of the vehicle during the motion of vehicle on roads with the lowered friction coefficient.

References

[1] Andrzejewski, R., *Dynamika pneumatycznego koła jezdnego*, WNT, Warszawa 2010.
[2] Lozia, Z., Guzek, M., *Przegląd metod badań stateczności i kierowalności pojazdów samochodowych*, Zeszyty Naukowe Instytutu Pojazdów, Nr 2(14), Warszawa 1995.

[3] Parczewski, K., Wnęk, H., *Wpływ wybranych niesprawności na zachowanie pojazdu na drodze*, Autoprogres-KONMOT, Zakopane 2006.
[4] Parczewski, K., Wnęk, H., *Wpływ niesprawności zawieszeń na stateczność ruchu pojazdu – porównanie badań symulacyjnych i pomiarów*, Archiwum Motoryzacji – The Archives of Automotive Engineering, Nr 2, s. 159-169, 2006.
[5] Reński, A., *Bezpieczeństwo czynne samochodu, Zawieszenia oraz układy hamulcowe i kierownicze*, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2011.
[6] Sikorski, J., *Amortyzatory pojazdów samochodowych, budowa, badania, naprawa*, WKŁ, Warszawa 1984.