THE EFFECT OF THE DRIVER AND CONSTRUCTION CHANGES IN VEHICLE SUSPENSION SYSTEMS ON THE ABILITY TO PERFORM SUDDEN MANOEUVRES ON THE ROAD ON THE BASIS OF TESTS CARRIED OUT ON POLICE CARS

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Abstract

Police cars are very often driven as priority vehicles, reaching high speed in the open road traffic. That is why the parameters related to vehicle stability and steerability should be very high. This paper is an attempt to answer the question to what extent a typical driver can feel, and what is more important – take advantage of technical changes in the chassis in order to increase the speed in the performance of a test, or to enhance the safety of the drive. In this paper the authors attempt to assess to what extent the results of measurements of vehicle dynamics are affected by the driver and to what extent by particular technical solutions. The work was carried out under research and development project no. OR00000911 "Determination of the technical requirements and the equipment necessary in police cars on the basis of tests on model demonstrators" and previous results obtained in tests carried out in the Military Institute of Armored and Automotive Technology (WITPiS).The tests were carried out on the basis of a KIA CEED, currently one of the models most frequently used by the Police.

Keywords: *steerability, stability, police cars, effect of the human factor*

1. Introduction

Functionality and ergonomics should not be the only characteristics of police cars. It is true that the comfort of policemen's work, often during many hours of service, depends largely on those features, but the overriding goal should be to introduce such cars to police service which will guarantee safety of the officers, but also of the outsiders.

Police cars are very often driven as priority vehicles, reaching high speed in the open road traffic. That is why the parameters related to vehicle stability and steerability should be very high. The vehicles should also be adapted for driving through urban and natural obstacles that can be encountered during pursuits on paved and dirt roads.

At present, despite the increasingly more modern fleet, a straight majority of police cars does not differ much from basic cars in terms of construction and equipment. They are passenger cars which are only indirectly adapted for pursuits, driving in difficult road conditions or action in urban areas.

The question should be posed, however, to what extent an average driver can feel, and what is more important – take advantage of technical modifications in the chassis in order to increase the speed in the performance of a test, or to enhance the safety of the drive. In this paper the authors attempt to assess to what extent the results of measurement of vehicle dynamics are affected by the driver and to what extent by particular technical solutions. The work was carried out under research and development project no. OR00000911, "Determination of the technical requirements and the equipment necessary in police cars on the basis of tests on model demonstrators", carried out by WITPiS (Military Institute of Armored and Automotive Technology) in cooperation with AMZ Kutno.

2. Police cars characteristics

Currently, we can find several makes of cars in the police fleet. The group consists of various models with different types of engines and equipment. Altogether it comes up to tens of different kinds of vehicles, which does not only render fleet management more difficult, but also results in the lack of uniformity of vehicles in terms of specifications and technical properties.

The most numerous passenger car is KIA CEED (Fig. 1). This is the effect of bidding procedures carried out in the recent years. In August 2008 there were 5 open competitive bidding procedures for the supply of marked cars for 19 Police Headquarters. In total, the basic order covered 2515 estate cars. This car model was also selected for tests under the project and prepared at AMZ Kutno.

Fig. 1. View of KIA CEED Police Car

The two-litre engine of a KIA CEED with 140 HP ensures good performance results with relatively low fuel consumption. All cars supplied to the police are silver and their standard equipment includes: ABS, air bags for the driver, the passenger, side air bags and curtains, air conditioning, electric front and back windows and electrically steered and heated external mirrors. Additionally, all KIA CEED cars are marked. They are fitted with radio communication systems and priority marking.

Although the cars are characterised by relatively good equipment and high quality of workmanship, it must be emphasised that the braking system, the engine power as well as the characteristics of shock absorbers and springs are identical for the basic and the police cars. However, due to the nature of performed tasks, especially in road traffic service, a police car should be characterised by particularly good driving properties. Since the tests under the project are at an initial stage, as of now only preliminary tests were carried out on a car fitted with a modified suspension. At a further stage of the project, technical modifications will be introduced to the braking system, the internal combustion engine and the chassis protection against the effect of driving on a bumpy road.

When it comes to selection of the suspension rigidity, it is commonly believed that a rigid suspension enhances the ability of fast driving. The belief is confirmed by the results of a survey conducted among policemen (Fig. 2).

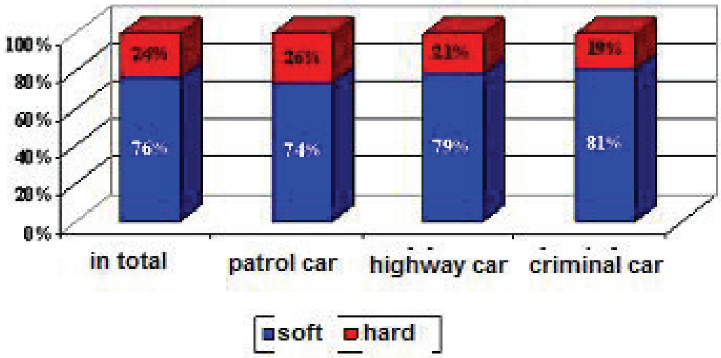


Fig. 2. What kind of suspension would you consider most appropriate for your professional work? (kind of service) – the result of a survey among policemen (source – Internet, unknown author)

It must be remembered, however, that a rigid suspension reduces steerability of the vehicle on uneven surfaces and worn-out roads. Moreover, it causes shifting of higher accelerations onto passengers, which can be tiring during a long drive.

While the selection of adequate suspension rigidity in police cars is a difficult and debatable matter, the suspension itself should unquestionably be resistant to damage resulting from road obstructions. The part that can be replaced in the suspension without interfering with the basic construction of the vehicle is the absorber. In the standard version, the cars are fitted with dual tube dampers. They are characterised with a relatively small diameter of the piston rod. An absorber of such a construction has low ability of shifting the bending moment, which causes its damage while driving through typical urban obstructions, such as kerbs. A much better solution to be applied in police cars is a single tube absorber (Fig. 4), which is characterised by a bigger diameter of the piston rod.

3. Test Results

The initial tests of the effect of the suspension rigidity on steerability and stability were performed on a racetrack in Poznan. The car used in drivers' efficiency tests was a Ford Focus 2.0, fitted with bucket seats, a 4-point harness and a very rigid Bilstein suspension. The changes were to improve the functionalities while driving and to ensure the optimum driver's position for fast driving (Fig. 3).

Fig. 3. A view of a Ford Focus on the track and the interior after modifications

Another car was a Kia Ceed, a twin vehicle of those currently used by the police. The vehicle was fitted with two kinds of suspensions: the original one mounted at the plant and a suspension made by Intrax, a Dutch manufacturer, with adjustable height and damping characteristics. Due to the good condition of the track surface, damping was set at high values in order to minimise car-body tilting (Fig. 4).

Fig. 4. A view of a Kia Ceed and a single tube absorber (thickness of the piston rod)

The tests were carried out both on the main loop of the track and a so called go-kart loop. Due to the good condition of the surface, the differences in the registered parameters for the serial (soft) suspension and the high-performance (rigid) one were minimum and often within the margin of error. This refers to speed on the bends and lateral accelerations. A change in the body tilting during fast driving was noticeable. The hardened suspension reduced the car-body tilting by 3 on average as compared to the serial suspension. Obviously, the results of such tests will differ for a flat surface, as on the track, and an uneven surface, whether with small potholes or bigger ruts. This kind of comparisons will be carried out at a further stage of the project.

The effect of modifications in the suspension system, however, was minimum in relation to the differences generated by the selected drivers both in the total lap time and in speeds on certain bends. Table no. 1 illustrates the total times obtained by the drivers on 3 go-kart track laps (the total of 4.2 km).

Tab. 1. Total time of the drivers in 3 go-kart track laps

Driver	Time [s]	Difference [s]	Difference [%]
1	219	0	0
2	223	4	2
3	231	12	5
4	242	23	11
5	248	29	13
6	263	44	20

It must be emphasised that the tests were carried out on the small, so called go-kart loop of the Poznan Track. Momentary speeds did not exceed 120km/h and the average speed was about 60 km/h, i.e. it was similar to the speed of a priority car going through a city centre.

Although the drivers selected for the tests were young, 20-30 years of age, holding a driving licence for at least a few years and characterised by "dynamic driving", the differences in obtained times and speeds on bends were very big. The difference between the best and the worst driver was 44 seconds on the distance of a bit over 4 km. Although the drivers were not stressed by any danger (secured track, relatively low speed), the differences in speeds on bends were also substantial (Fig. 5).

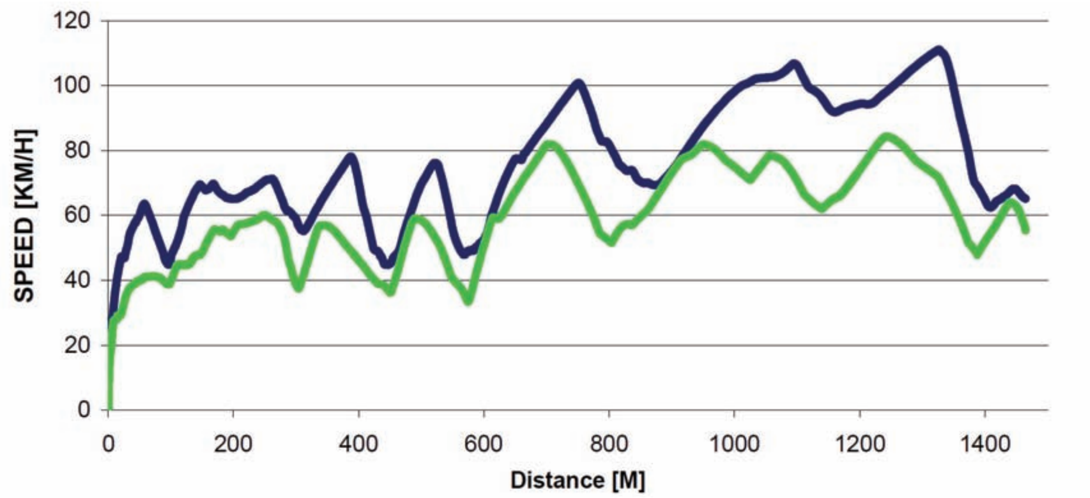


Fig. 5. Characteristics of speed in the function of the path, for the fastest and slowest driver in the test (blue fast driver, green slow)

Particularly, considerable differences occurred on the faster part of the track. Errors in the driving path, gas and break operations and wrong reactions often made the difference in speed reach even 40 km/h. It should be emphasized that it was a slow test for drivers, with the maximum speed of up to 120 km/h, while most participants only slightly exceeded 100 km/h at the fastest point. The briefly discussed tests of the suspension of a KIA CEED were taken on the main loop, only with one selected driver, and the speed obtained during the tests exceeded 180 km/h on the straight and 140 km/h on the bends. Due to the other drivers' lack of experience in driving with such speeds, the remaining drivers did not take that test, but it could be expected that the differences would be even bigger.

The lateral acceleration affecting the car (Fig. 6) shows that all the drivers drove aggressively and to the limits of their ability and the capabilities of the car. Even the slower driver obtained relatively high lateral accelerations, brought the car to slides, even too frequently, especially on the slow part of the track (the track characteristics, registered in the RT3002 system, is presented on Fig. 7). The detailed analysis allows to define the moments when the drivers committed errors.

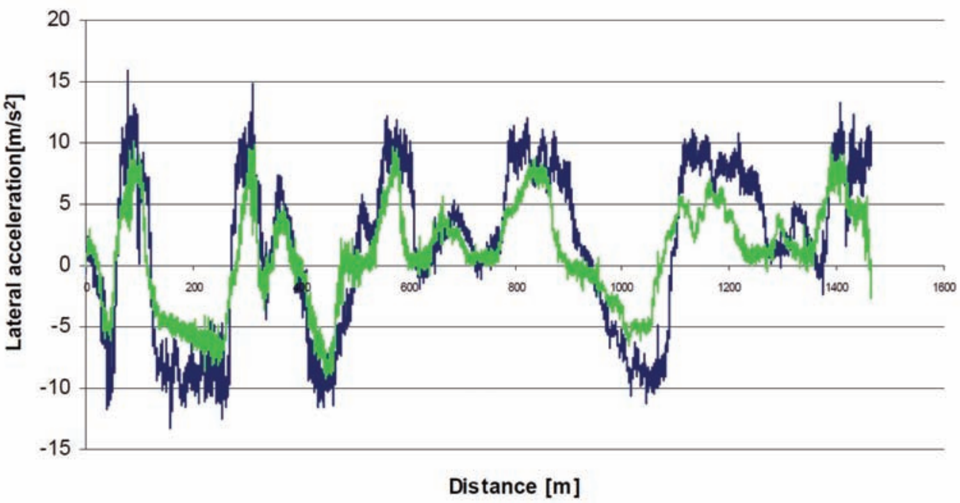


Fig. 6. Characteristics of lateral acceleration affecting the car in the function of the path for the fastest and slowest driver in the test (blue fast driver, green slow)

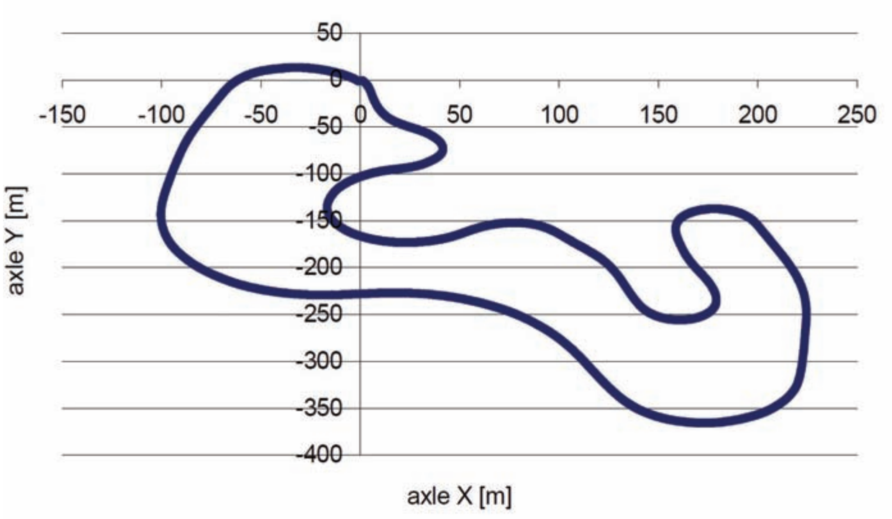


Fig. 7. Geometry characteristics of the go-kart loop on the Poznan Track in the square coordinates of the measurement system

4. Results of Previous Tests Conducted by WITPiS

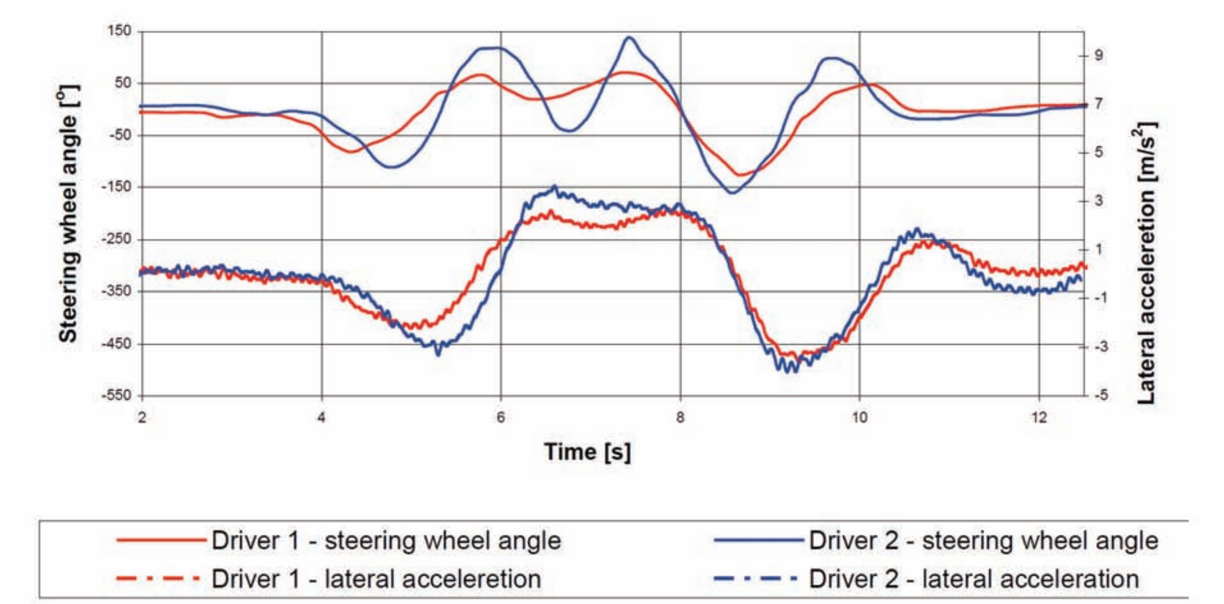
The observations included in the previous section confirm the results of previous tests carried out by the authors at the Military Institute of Armament Technology.

Figures 8-10 illustrate the diagrams of parameters recorded for two drivers driving an armoured vehicle on the test track with the speed of 80 km/h.

An analysis of the results obtained during the drives (diagrams 8-10) shows that both the behaviour of the vehicle and the forces affecting the personnel carrier may differ considerably, depending on the style of driving (calm driving – driver 1, dynamic driving – driver 2) with the same speed.

For instance, the gentler operation of the steering wheel translated in the results of the first driver to a nearly 30% smaller sideslip angle. The above example illustrates best that the difference in the driving style between two drivers can be bigger by over an order of magnitude from inaccuracy of the devices.

Similar differences were observed in the analysis of the heel angle during the test drive and the lateral acceleration affecting the personnel carrier. The differences range from over ten to 25%. An analysis of the diagrams of the steering wheel angle also shows that the drivers needed to adjust their path with the steering wheel to a different degree in order to control the vehicle while driving.



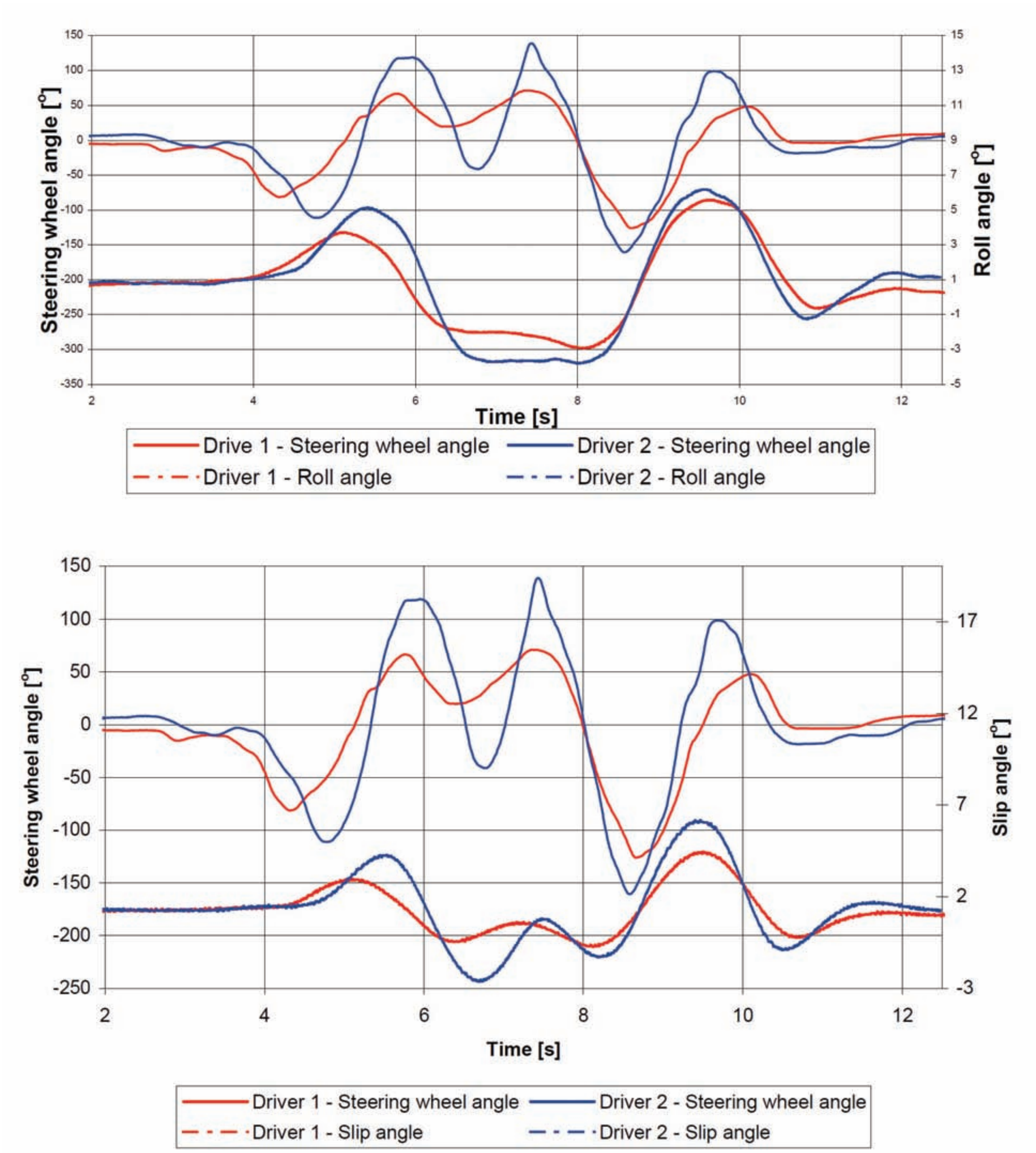


Fig. 8-10. Characteristics of the steering wheel angle along with: lateral acceleration, angle of slip and drift in the function of time for the two drivers

5. Summary

As the authors point out in the paper, the driver has the biggest effect on stability and steerability of the vehicle. Due to inadequate training and wrong reactions, the driver can obtain different characteristics with the same vehicle. The threat is less significant if the errors only lead to obtaining lower driving parameters (speed, time). It is worse when due to the errors the driver loses control of the vehicle and causes an accident, in which apart from the police car also civilian cars in the open road traffic may participate. Therefore, constructional modifications in the suspensions should be carried out simultaneously with adequate training for the users.

Some of the policemen are already taking part in supplementary training courses. However, the publicly available courses of so called "Safe Driving" are insufficient and they are not targeted at the needs of the police. Such training should be provided for all drivers of priority vehicles, it should be dedicated to the specific service and follow a cyclical pattern.

References

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