Influence of measurement conditions on results of a wheel geometry check

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Abstract. Wheel alignment effects on vehicle's stability and steerability, so it has a significant influence on, so called, active safety of a car. That's why it is important to regularly check and properly adjust the wheel geometry. The measurements should be performed according to specific requirements. The influence of measurements conditions on results of a wheel geometry check is analysed in this paper. The results of measurements of wheel alignment of three cars with different suspension types are presented and the influence of measurements condition on the obtained results is discussed.

1. Introduction

During the design process of a vehicle, the special emphasis is put on its safety. The engineers and researchers constantly do their work to improve safety of the vehicles and to make them more efficient and natural environment friendly or to develop better diagnostics methods [1-4]. Recently, a significant part of research works are a numerical simulations, what allows for costs reduction of the implementation of new solutions [5-8]. Regardless of the computer simulations, the test bench and road test are also conducted [9-12].

A crucial role in the active safety of a car plays its suspension and steering system. That's why the purpose of many works is the optimization and development of these systems [5,13-15]. The modern cars are usually equipped with an independent suspensions in both axles or the independent suspension in front axle and semi-independent in the rear [16]. Regardless of the type of suspension, its proper maintenance is very important. Wheel alignment should be checked and, if needed, adjusted regularly, to ensure appropriate vehicle handling and even tires wear.

The correct measurement of the wheel alignment must be carried out in accordance with a specific requirements, such as: right tires pressure, load of the car in accordance with a manufacturer's requirements, a vehicle should stand on a flat surface and mustn't have any slacks or damages of steering and suspension systems.

The aim of this work is an analysis of an influence of improper measurement conditions on the results of the wheel alignment check. Two cases were studied: the measurement conducted without slip plates under rear wheels (so a car was inclined during the tests) and the measurement with a driver of about 100 kg sitting on a driver's seat.

2. Measurements

Three different cars were used for measurements: Opel Insignia A 2.0 Turbo AWD, the second generation Toyota Prius (XW20) and fifth generation Volkswagen Passat Variant (B5). Each of them were tested few times, the first measurement was carried out according to the requirements for the wheel alignment measurements. The following tests were conducted without a slip plates under rear wheels and with a driver in a driver's seat. The aim of the work was the evaluation of an influence of improper measurement conditions on the results of wheel alignment measurement. The measurements were conducted on a flat test bench surface using four-head device with a CCD cameras. The suspensions and steering systems of the tested cars were in a good technical conditions, the tire pressure was correct and during the correct measurement, the cars were loaded only with their curb weight– according to the manufacturer's requirements. Before each test, the runout compensation of individual wheel was performed.

2.1. Tested cars

The tested cars were equipped with different types of suspension. The different kinds of suspensions allowed for an additional analysis of the influence of type of suspension on the obtained results. The basic parameters of cars used in measurements are presented in table 1.

Table 1. The basic technical parameters and dimensions of tested vehicles.

	Opel Insignia AWD	Toyota Prius XW20	VW Passat Variant B5
Engine	2.0 T	1.5	1.9 TDi
Drive wheels	AWD	Front	Front
Front suspension	MacPherson	MacPherson	Multi-link
Rear suspension	Multi-link	Twist-beam	Twist-beam
Length [mm]	4830	4450	4675
Wheelbase [mm]	2737	2700	2705
Track front/rear [mm]	1585/1587	1505/1480	1515/1515
Curb weight [kg]	1503	1317	1445
GVM [kg]	2020	1725	2010

Figure 1 shows one of the tested cars, on a test bench, during the preparation for the measurements of wheel alignment.

Figure 1. One of the tested cars (Opel Insignia AWD) during the preparation for the measurements

2.2. Measuring equipment

CUSTOR HWA G58 wheel alignment device was used for measurements [17]. The device consists of four active heads with CCD cameras. The heads are mounted to the wheels using the special wheel clamps and connects with a main unit via wireless connection.

The technical specification of the device is presented in the table 2.

Table 2. The technical specification of CUSTOR HWA G58 wheel alignment device.

	Parameter	Range	Accuracy
Front axle	Toe	± 24°	± 1’
	Camber	± 10°	± 1’
	Caster	± 20°	± 2’
	SAI	± 20°	± 2’
	Setback	± 10°	± 1’
Rear axle	Toe	± 24°	± 1’
	Camber	± 10°	± 1’
	Setback	± 10°	± 1’
	Thrust angle	± 10°	± 1’

An overview of the main unit of the wheel alignment device used during the measurements and one of its heads is presented in figure 2 and 3.

Figure 2. An overview of the main unit of the CUSTOR HWA G58 device. Two of four heads with CCD cameras and the wheel clamps are visible

Figure 3. A close-up view of a front right head of the CUSTOR HWA G58 device mounted on a wheel of the tested car

3. The sample results

The sample results of measurements are presented in figures 4 to 9. The differences between the values of wheel alignment parameters obtained during the actual and the correct measurement were presented in yellow in all charts.

The sample results are also shown in tables 3 to 5. The percentage differences between the obtained values, given in the tables, were calculated using equation (1).

$$D = \left|\frac{C-P}{C}\right| \cdot 100\% \qquad (1)$$

where:

C– the value obtained during the correct measurement,
P– the value obtained during the particular measurement.

3.1. Opel Insignia

Table 3. The sample results of the measurements of wheel alignment of Opel Insignia.

	Front left wheel camber angle [°]	Difference, front left wheel camber angle [%]	Front left wheel caster angle [°]	Difference, front left wheel caster angle [%]
Correct measurement	0.28	———	3.08	———
Without slip plates	0.33	17.9	4.20	36.4
With a driver	0.42	50.0	3.15	2.3

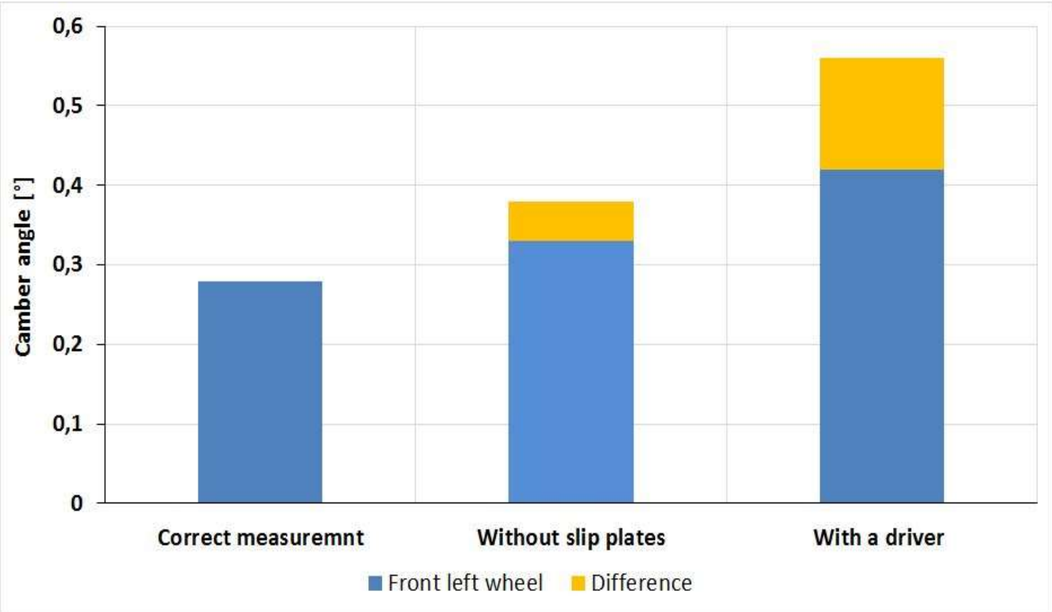

Figure 4. The results of the measurements of the front left wheel camber angle of Opel Insignia

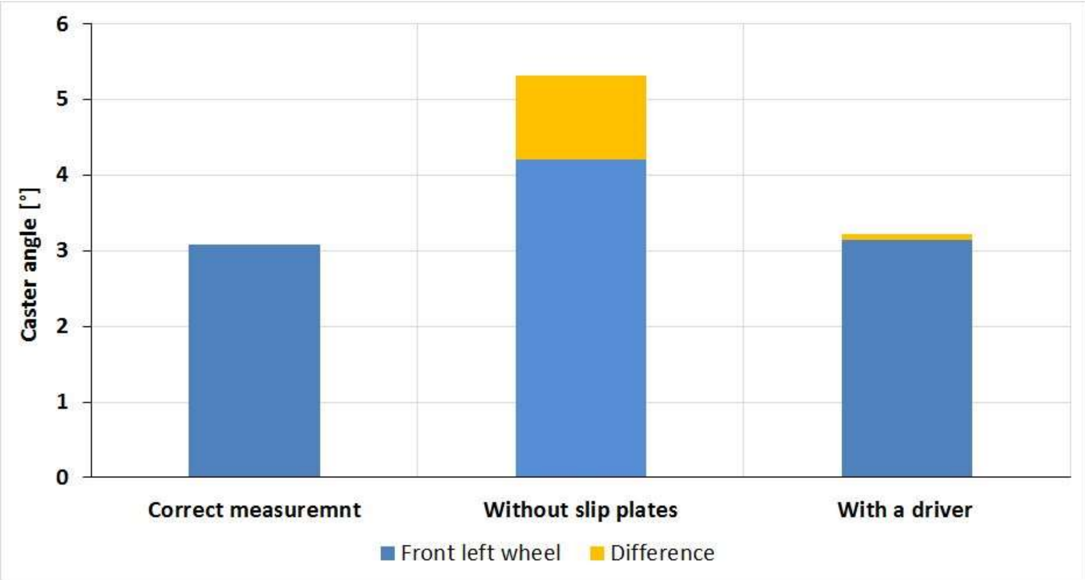

Figure 5. The results of the measurements of the front left wheel caster angle of Opel Insignia.

3.2. Volkswagen Passat B5

Table 4. The sample results of the measurements of wheel alignment of VW Passat B5.

	Front left wheel camber angle [°]	Difference, front left wheel camber angle [%]	Front wheels toe [°]	Difference, front wheels toe [%]
Correct measurement	-0.78	———	0.17	———
Without slip plates	-0.82	5.1	0.23	35.3
With a driver	-0.73	6.4	0.22	29.4

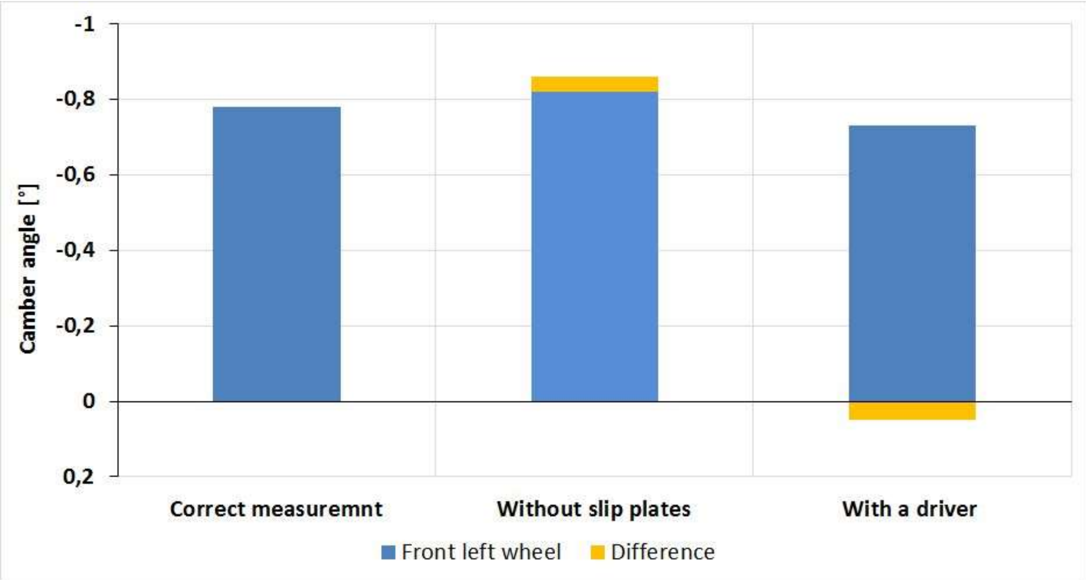

Figure 6. The results of the measurements of the front left wheel camber angle of VW Passat B5.

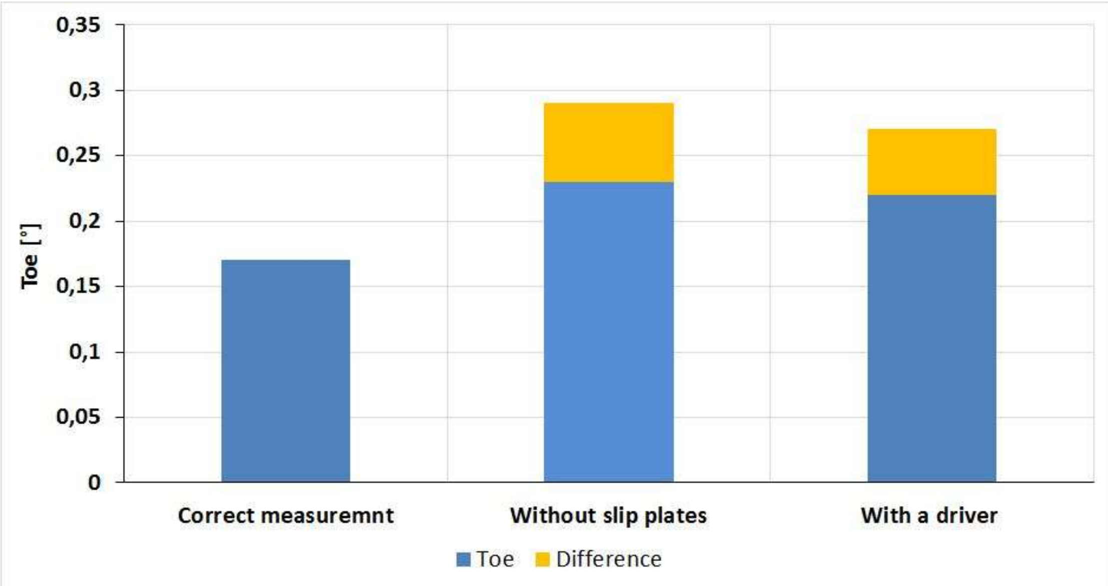

Figure 7. The results of the measurements of the front wheels toe of VW Passat B5.

3.3. Toyota Prius XW20

Table 5. The sample results of the measurements of wheel alignment of Toyota Prius.

	Rear right wheel camber angle [°]	Difference, rear right wheel camber angle [%]	Front right wheel caster angle [°]	Difference, front right wheel caster angle [%]
Correct measurement	-1.43	— — —	3.23	— — —
Without slip plates	-1.42	0.7	4.32	33.8
With a driver	-1.52	6.3	3.03	4.6

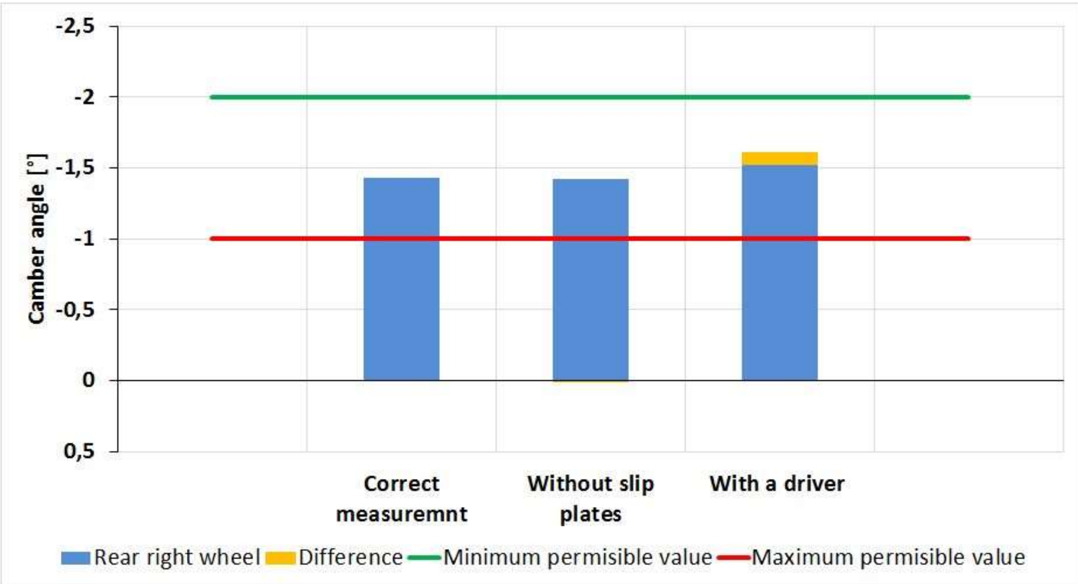

Figure 8. The results of the measurements of the rear right wheel camber angle of Toyota Prius.

Figure 9. The results of the measurements of the front right wheel caster angle of Toyota Prius.

4. Summary

The correct wheel alignment has an important influence on vehicle handling and regular tires wear.

Before the measurement car should be properly prepared, moreover the appropriate measurement conditions are required.

In the work, the sample results of wheel alignment measurement, conducted without proper conditions are presented.

An analysis of the results indicates the differences between the results of obtained measurements. It is noticeable that the absence of a slip plates under rear axle wheels has greater influence on achieved results than the presence of a driver in the car during the measurements. It is especially visible in the obtained caster angle values, which is caused by the inclination of the vehicle on the test bench. The achieved differences reached above 30%. The improper measurements conditions influenced also on front wheels toe, which is particularly noticeable in case of the multi-link front wheels suspension.

In most cases, even relatively large differences between the obtained results, did not caused exceeding the measured parameter's value above the permissible tolerance given by the manufacturer of the car. On the other hand, the values of measured parameters were often different on the left and right side of tested car– especially in case of measurement conducted with a driver on a driver's seat. Such inequalities can inappropriately effect on vehicle handling.

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