Tests of lateral acceleration during a controlled skid - various types of vehicles

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Abstract: This article presents the values of lateral acceleration during controlled slip for a passenger vehicle and a city bus. Skidding is one of the most dangerous road situations that can occur while driving a vehicle. They can happen to anyone, without exception whether someone has experience or is a young driver. The lateral accelerations during the controlled skidding presented in the article showed higher values for a passenger vehicle. The article refers to drawing attention to the lateral accelerations acting on the vehicle during the slip. It depends on the driving system of the driver whether he will be able to make the correct choice in a dangerous situation. Therefore, improving driving techniques, especially in a skidding situation, should be generally available to drivers.

Keywords: road accidents, controlled skid, automotive safety

1. Introduction

One of the scariest things that can happen while driving is losing control of your vehicle due to skidding. Skidding is the result of a loss of grip between the vehicle tires and the road surface [1-4]. This is usually because the driver accelerates too rapidly, brakes too hard, changes direction abruptly at too high a speed. Front wheel skid occurs when a vehicle's front wheels lose traction. Front-wheel drive vehicles (front-wheel drive) suffer from this problem more often than rear-wheel drive vehicle [5-8].

This is mainly due to the fact that the front wheels drive the vehicle and require more grip than the rear tires [6-7]. Front wheel slippage usually occurs when braking hard, when the front wheels lock up, or when trying to corner too fast for road conditions. Front wheel skid is also known as understeer because the vehicle is going straight no matter how much pressure on the steering wheel [9-11]. Rear wheel skid occurs when the rear wheels lose traction. It happens either during heavy braking, especially in the case of failure of the rear brakes, or more frequently, when the corner is taken too quickly [10-11]. In this respect, vehicles with rear wheels suffer more often from slippage of the rear wheels than vehicles with front-wheel drive because the rear wheels drive the vehicle and thus place additional demands on the tires [12-13].

It should be noted that one of the main causes of vehicles accidents is the speed not being adjusted to the road conditions [14-16]. This means that slippery ground or poor visibility is a serious hazard. Experts argue that sharp turning of the steering wheel will be useless if we skid while driving or we have to avoid an obstacle, e.g. a pedestrian who suddenly appeared on the road [16-19].

2. Research methodology

The research was carried out on the training and training track located 20 km south of Radom in the Jastrząb commune. The research used a skid-in-run plate (100x20m), equipped with a dynamic plate of the "jerking devices" type. The plate allows the vehicle to skid at speeds above 40 km/h. Figure 1 shows
a skid-and-overrun plate with a dynamic plate of the shredder type. When the rear axle of the vehicle travel the plate of the controlled skid station, the hydraulic vehicle axle jerking device will dynamically move the entire plate of the device in the transverse direction to the specified direction of travel. The surface of the plate with a high coefficient of adhesion causes the rear axle of the vehicle to deviate from its previous direction of travel, simultaneously causing it to skid. After reaching the extreme position, the device quickly returns to its initial position. In order to reduce the adhesion of the vehicle to the surface, the skid-run plate was covered with a layer of water throughout the entire duration of the tests.

![Figure 1](image1.png)

**Figure 1.** The skid-on-ramp plate with the dynamic plate of the jerking devices type

The initial speed of the vehicle, for which the horizontal acceleration values were determined, was 40 km/h and 50 km/h. The tests were carried out at an ambient temperature of about 20°C. During a series of tests, the dynamic plate was set to random mode, thanks to which the driver approaching the plate was not able to predict which side the plate would be dislocated. An Audi A6 passenger vehicle and a city bus were used in the research. Each time, a series of 5 measurements was performed. During the tests, the vehicles were loaded with the driver, measuring equipment (about 20 kg) and the person carrying out the measurement. To register the traffic parameters of the tested vehicles, specialized measuring equipment was used, including:

- TAA Datron® triaxial linear acceleration sensor and TANS Datron® linear and angular acceleration
- uEEP-12 Datron® data acquisition stations with ARMS® data analysis software,
- S-350 Aqua Datron® optoelectronic sensor for measuring longitudinal speeds.

The first vehicle to be tested was the Audi A6 passenger vehicle. Its curb mass was 1,920 kg (permissible mass 2,475 kg). The vehicle is equipped with a power unit with a capacity of 2,967 cm$^3$ and a power of 176 kW. The second research vehicle was a city bus capable of carrying 54 passengers. During the controlled skidding, the vehicles accelerated to the assumed speed, and then ran onto a dynamic plate. Depending on the position of the plate, the rear axle of the vehicle moved to the left or right side. The driver's task was to get the vehicle out of a controlled skid, while keeping the vehicle on a skid plate. Figure 2 shows a city bus during a controlled skid test. On the other hand, in Figure 3 of the Audi A6 passenger vehicles, during a controlled skid test.
3. Analysis of the results
Figures 4-7 show examples of the transverse velocity of the tested vehicles during a controlled skid. The lateral speed of the Audi A6, during a controlled skid at 50 km/h, recorded the lowest values. The duration of the controlled skidding in the Audi A6 was 5 seconds, while in the city bus it was 9 seconds.

**Figure 2.** City bus during a controlled skid test

**Figure 3.** Audi A6 passenger vehicle during a controlled skid test

**Figure 4.** Transverse velocity of the Audi A6 during a controlled skid from 40 km/h

**Figure 5.** Transverse velocity of the City bus during a controlled skid from 40 km/h
Figure 6. Transverse velocity of the Audi A6 during a controlled skid from 50 km/h

Figure 7. Transverse velocity of the City bus during a controlled skid from 50 km/h

Figures 8 and 11 show examples of the characteristics of lateral acceleration for the Audi A6. On the other hand, in Figures 16 and 17, examples of the characteristics of lateral acceleration for a city bus.

Figure 8. Characteristics of lateral accelerations of the Audi A6 during a controlled skid at a speed of 40 km/h

Figure 9. Characteristics of lateral accelerations of the City bus during a controlled skid at a speed of 40 km/h

Figure 10. Characteristics of lateral accelerations of the Audi A6 during a controlled skid at a speed of 50 km/h

Figure 11. Characteristics of lateral accelerations of the City bus during a controlled skid at a speed of 50 km/h
Table 1 presents the maximum values of deceleration during the controlled skid of the tested vehicles. The highest value of deceleration during a controlled skidding was 11.79 m/s² for the Audi A6 vehicles traveling at 40 km/h. In the case of the city bus, the greatest deceleration value was 6.82 m/s² during the test at 50 km/h.

Table 1. Deceleration values during a controlled skid from a speed of 40 km/h

| Ip | Speed 40 km/h Deceleration, m/s² | Speed 50 km/h Deceleration, m/s² |
|----|---------------------------------|---------------------------------|
|    | Audi A6 | City bus | Audi A6 | City bus |
| 1  | 11.79   | 5.61     | 10.26   | 6.54     |
| 2  | 11.39   | 4.98     | 7.78    | 5.68     |
| 3  | 10.20   | 6.18     | 8.71    | 5.94     |
| 4  | 9.74    | 5.39     | 8.26    | 6.82     |
| 5  | 10.59   | 5.51     | 8.77    | 6.71     |
| Mean | 9.94    | 5.53     | 8.76    | 6.34     |
| SD  | 1.44    | 0.39     | 0.83    | 0.45     |

4. Conclusions

Staying alert while driving is critical because being aware of a problem and resolving it in seconds can mean the difference between causing an accident and solving the situation safely. Slippage cannot always be avoided. Every skid is different and involves many factors related to driver activities, road conditions and hazards. The research showed that the Audi A6 passenger vehicle had a much shorter duration of controlled skidding than in the case of the city bus. Skidding can happen to anyone, and the more someone drives, the more likely it is. For our own safety, we should be able to deal with such unexpected behavior of the vehicle, preferably under control conditions. Improving the driving techniques of the driver contributes to increasing the safety of the driver and other road users.

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References

[1] Zhao L., Wang H., Yang Y., Sun L., Liu J., 2013, Dynamic modeling and drift control of high-speed wheel mobile robot, Control Conference (CCC) 2013 32nd Chinese, 5827-5832.
[2] Jian Z., Shuang-shuang W., Hua L. Bin L., 2012, The sliding mode control based on extended state observer for skid steering of 4-wheel-drive electric vehicle, 2012 2nd International Conference on Consumer Electronics, Communications and Networks (CECNet), 2195-2200, doi: 10.1109/CECNet.2012.6201445.
[3] Yang Y., Wang X., Zhang Y., 2021, Study on Mechanism Analysis of Skidding Prediction for Electric Vehicle Based on Time-Delay Effect of Force Transmission. World Electr. Veh. J, 12, 171, https://doi.org/ 10.3390/wevj12040171
[4] Sekour M., Hartani K., Abdelkader M., 2017, Electric Vehicle Longitudinal Stability Control Based on a New Multimachine Nonlinear Model Predictive Direct Torque Control, Journal of Advanced Transportation, 4125384.
[5] Fawzy N., Habib HF., Mokhtari S., 2021, Performance Evaluation of Electric Vehicle Model under Skid Control Technique. World Electr. Veh. J, 12, 83.
[6] Austin L., Morrey D., 2000, Recent advances in antilock braking systems and traction control systems, Proc. Inst. Mech.Eng. Part D, 214, 625–638.
Based on analysis of road accidents in 2002–2018, pp. 1–8, doi: 10.1109/AUTOMOTIVE SAFETY.2018.8373297

[10] Martinez MC., Heucke M., Wang FY., Gao B., Cao D., 2018, Driving Style Recognition for Intelligent Vehicle Control and Advanced Driver Assistance: A Survey, in IEEE Transactions on Intelligent Transportation Systems, 19, 3, 666-676, doi: 10.1109/TITS.2017.2706978.

[11] Shi B., et al., 2015, Evaluating Driving Styles by Normalizing Driving Behavior Based on Personalized Driver Modeling, in IEEE Transactions on Systems, Man, and Cybernetics: Systems, 45, 12, 1502-1508, doi: 10.1109/TSMC.2015.2417837.

[12] Choi JK., Kwon YJ., Kim K., Jeon J., Jang B., 2019, Driver Behavior Analysis and Warning System for Digital Cockpit Based on Driving Data, 2019 International Conference on Information and Communication Technology Convergence (ICTC), 1397-1399, doi: 10.1109/ICTC46691.2019.8939875.

[13] Wang WY., Li IH., Chen MC., Su SF., Hsu SB., 2009, Dynamic Slip-Ratio Estimation and Control of Antilock Braking Systems Using an Observer-Based Direct Adaptive Fuzzy–Neural Controller, in IEEE Transactions on Industrial Electronics, 56, 5, 1746-1756, doi: 10.1109/TIE.2008.2090439.

[14] Szumska E, Frej D, Grabski P., 2020, Analysis of the Causes of Vehicle Accidents in Poland in 2009-2019, LOGI – Scientific Journal on Transport and Logistics, 11, 2, 76-87. https://doi.org/10.2478/logi-2020-0017

[15] Jurecki R.S., 2020, Analysis of Road Safety in Poland after Accession to the European Union. Communications - Scientific Letters of the University of Zilina, 22, 2, 60-67, https://doi.org/10.26552/com.C.2020.2.60-67

[16] Jaśkiewicz M., Jaskolski J., 2017, Wypadkowe dane statystyczne na polskich drogach w latach 2001-2016. Autobusy : technika, eksploatacja, systemy transportowe, 18, 20–23.

[17] Frej DP, Ludwinek K., 2020, Analysis of road accidents in 2002–2019 on the example of Poland. The Archives of Automotive Engineering – Archiwum Motoryzacji, 89, 3, 5-18. doi:10.14669/AM.VOL89.ART1.

[18] Lozia Z., 2020, Can anything optimistic be found in the statistics of road accidents in Poland in 1975-2018?, 2020 XII International Science-Technical Conference AUTOMOTIVE SAFETY, 2020, 1-4, doi: 10.1109/AUTOMOTIVESAFETY47494.2020.9293513.

[19] Prochowski, L., Kochanek, H., Gidlewski, M., Pusty, T., 2018 Analysis of the seasonal and regional variations in the accident hazard in Poland. WIT Transactions on the Built Environment, 176, 441–452, doi: 10.2495/UT170381.

[20] Prochowski, L., Gidlewski, M., Dabrowski, F., 2018, Analysis of changes in the accident hazard for the elderly in road traffic compared to demographic changes and possibilities of supporting the elderly mobility. XI International Science-Technical Conference AUTOMOTIVE SAFETY, 2018, pp. 1–8, doi: 10.1109/AUTOSAFE.2018.8373297