Alignment of braking performance for truck and trailer as an important factor in road construction

Andrej Haring
Strakonická 122, 46008 Liberec, Czech Republic
andrej.haring@truckconsult.cz

Abstract. Alignment of braking performance of truck trailer is an important parameter that affects its braking stability. This shows particular in critical situations or during braking on a surface with reduced adhesion. Alignment of braking performance can be automatic, which is one of quality of electronical brake systems. Further on, can be forcible, which is being executed during service a diagnostic work. This contribution is focused on analysis alignment of braking performance. Describing technical conditions, internal and external factors which affect it. Due to magnitude of this problematics, is in this article evaluated the optimization of braking affects truck trailers in the start-up phase. The analysis of the process – start-up braking effect has justification from the reason, that has primary influence on the stability truck trailer during braking and this can be the cause of collision situations or also traffic accidents. The parameter of alignment of braking performance has a primary influence on the braking stability of the truck trailers, which significantly affects road safety and is also important for the economy of the truck trailers.

1. Introduction
The content of the paper is the issue of automatic optimization of the braking effect of the vehicle with the electronic control unit EBS of the tractor ie the issue of the so-called "automatic aligment of praking performance" of the vehicle. As part of the evaluation of the deceleration parameters of the truck and the semitrailer, the paper focuses on the phase of the onset of the braking effect. This phase significantly affects the stability of the combination during braking and especially in poor adhesion conditions or in critical driving situations. Therefore, within the analysis of the course of traffic accidents of combinations of vehicles, which are related to the issue of braking, it is important to evaluate the phase of onset of braking effects of the truck and trailer. The aim of the paper is to apply its conclusions, especially in expert and other professional practice.

2. Description of the issue
The content of the paper is an analysis of one of the parameters that has a significant effect on the stability of the truck and trailer during braking. This is aligment of braking performance, which is one of the functions of electronic brake systems. The paper is focuses on the analysis of alignment of braking performance in the phase of the onset of the braking effect. This braking phase has a significant effect on the stability of the truck and trailer during braking. The braking of the truck and trailer is affected by...
many factors. External include mainly the effects of the state of road. Internal factors include the effects of the design, configuration and technical condition of the truck and trailer brake systems. One of these effects is also the alignment of braking performance of the truck and trailer. This alignment of braking performance is regulated by an electronic control unit without the influence of the driver. The paper analyzes the harmonization of the braking effect of truck and trailer in onset of the braking effect phase. This parameter is one of the partial results of the measurement of the braking effect of the truck and trailer.

2.1. General about braking of the truck and trailer
The truck and trailer combination consists of two independent braking systems [1], [2]. However, these are communicatively connected. These are the braking system of the truck and the braking system of the trailer. Figure 1 shows a basic diagram of the communication of the brake systems of the truck and trailer. This communication is based on ECE Regulation No. 13.

The truck's braking system ensures the transmission of the braking request via a pneumatic signal and also via CAN (Controller Area Network) via the standardized ISO 7638 interface. In the case of electronically controlled systems, the mutual harmonization of the alignment of braking performance of the truck and the trailer is affected. Alignment of braking performance of the truck and trailer is an important parameter that affects the stability of the combination during braking. The braking process of truck and trailer is also influenced by other additional systems that increase driving comfort and safety. These systems are either part of the brake systems or are offered mainly as additional, optional vehicle equipment. These are mainly assistance systems that communicate with the brake system, which they also use for their function. In the case of truck and trailer, it is important to assess both the technical condition of the brake systems of the truck and trailer and also their mutual communication, which practically begins with the connection of electrical and pneumatic connections between the truck and trailer. Stabilization systems [3], which play a significant role in the braking process of the vehicle or combination of vehicles, especially in critical driving situations and when braking under degraded adhesion conditions, cannot be neglected. When assessing the technical condition of brake systems, in addition to the assessment of the technical condition of brake system components, it is also necessary to assess the parameter settings of conventional devices, electronically controlled modules (modulators) and also electronic control units. Although these are not typical failures of brake system components and these conditions are not listed by drivers as technical failures that would be the primary cause of accidents, these parameters quite significantly affect the braking process and the stability of vehicles and especially articulated brakes. The braking and stability of the truck and trailer is affected by a number of factors, both external and internal.
External factors are mainly related to the properties of the road surface and also, for example, to weather conditions. These external factors cannot be influenced, but the electronic control of the braking effect takes them into account when defining the braking parameters and checking them back.

Internal factors can be defined as the design and technical characteristics of the vehicles of the combination, i.e., the truck and the trailer, and their connection. The design characteristics of the truck and trailer of the combination are firmly defined by the vehicle manufacturer. It is the equipment of the vehicle with electronically controlled systems, their mutual interaction, which is related to their communication interface. The technical properties can be understood as the current technical properties or the current technical condition of the vehicles during braking. This is a relatively extensive issue, where within the solution of the problem it is necessary to thoroughly define the significant influences and quantities that are directly related to the problem and have an impact on it.

2.1.1 Alignment of braking performance of the truck and trailer. Automatic alignment of braking performance of the truck and trailer is one of the functions of the electronic braking system of the truck. When braking the combination, the electronic control unit of the truck's brake system processes and evaluates the parameters related to deceleration and optimal transmission of braking force. If the matching of the alignment of brake performance of the combination is not optimized, there are differences between the braking of the truck and the trailer. When the truck is "pushed", the trailer has a lower braking effect and the towing vehicle increases the slip when the braking force is transmitted from the tires to the road surface. Higher than optimal slip causes both a reduction in the braking effect of the truck and a reduction in the adhesion between the tires and the road surface. This condition results in the so-called "articulation of the combination", which practically means the overall uncontrollability of the combination and the emergence of a collision situation.

If there is a situation where the trailer has a higher braking effect than the truck, the truck is "towed". This condition results in an increase in the traction of the truck's wheels during braking and a deterioration in the steering and stability of the combination, which can lead to a critical driving situation.

In addition to these described conditions, which directly affect the safety of operation, there is also an increase in wear of the tires, the friction components of the wheel brake units and also the coupling device.

Proper matching of the braking effect is necessary mainly from the point of view of the safe operation of the truck and trailer. Therefore, this alignment of brake performance is one of the functions of the truck's braking system.

The condition for harmonizing or optimizing the braking effects of the truck and trailer is:
- Equipping the truck and trailer with an electronic brake system (EBS and TEBS) and ISO 7638 connection.
- Appropriate configuration of the brake system of the truck and trailer.
- Satisfactory and comparable technical condition of the braking systems of the truck and trailer.
- Appropriate configuration of braking parameters.
- Absence of external unprofessional interventions in braking parameters.

If these conditions are met, the electronic control unit of the truck's brake system regulates the control pressure in the control branch and its equivalent in the communication link via ISO 7638. It makes these changes during the first braking after starting the vehicle. If a match is made, the truck's electronic control unit EBS "remembers" the value of the braking correction and corrects the control pressure towards the trailer by this value during subsequent braking. However, this correction is checked during braking, after restarting the vehicle, the whole process is repeated. If the braking effect is not optimized
during the first braking, the correction process is repeated during several brakes. However, the correction of the control pressure parameters has a limitation, which is given by legislative requirements. If the above conditions are not met for optimum matching of the braking effect of the truck and trailer, at least a partial correction occurs.

2.1.2 Measurement. A vehicle was used to measure the braking parameters, in which the truck and the trailer were equipped with an electronic brake system, disc brakes and in a suitable technical condition. The vehicles were braked repeatedly and approximately the same input conditions as the initial braking speed and the level of depressing the brake pedal were observed. Repeated braking took place in one starting mode, so the ignition was not switched off during this test. The truck and trailer is shown in Figure 2. The trailer load was 15 000 kg. (table 1, 2)

| Table 1. Parameters of the truck MAN TGX 18.440 |
|-----------------------------------------------|
| Vehicle make | MAN TGX 18.440 |
| Type of vehicle | truck |
| Year of production | 2015 |
| Milage | 612162 km |
| Number of axles | 2 |
| Brake system specifications | EBS Electronic brake system |
| Manufacturer, type | KNORR-BREMSE, EBS 5 |
| Configuration | 4S/4M |
| Operating weight (kg) | 7 936 |
| Largest technically permissible weight (kg) | 20 000 |
| Technically permissible maximum axle weight (kg) | 7 500, 12 600 |
| Maximum technically permissible mass of the truck and trailer (kg) | 44 000 |

| Table 2. Parameters of the semitrailer KRONE SD PROFI LINER |
|-----------------------------------------------|
| Vehicle make | KRONE SD PROFI LINER |
| Type of vehicle | semitrailer |
| Year of production | 2015 |
| Milage | 627707 km |
| Number of axles | 3 |
| Lifting axle (number/specification) | 1, first |
| Brake system specifications | EBS Electronic brake system |
| Manufacturer, type | WABCO, TEBS E |
| Configuration | 4S/2M |
| Wheelbase (mm) | T 6 170/1 310/1 310 |
| Operating weight (kg) | 6 200 |
| Largest technically permissible weight (kg) | 39 000 |
| Technically permissible maximum axle weight (kg) | T 12 000, 9 000, 9 000, 9 000 |
Figure 2. View of the truck and trailer

Technical condition
Methods [4]:
• visual inspection
• diagnostics with a multi-brand diagnostic system BOSCH KTS TRUCK

Result
The truck and trailer are in a suitable technical condition, the technical inspection is valid.

Vehicle load: For measurement purposes, the semitrailer was loaded with a load of 15,000 kg, the load was evenly distributed.

Measuring point: Road Nr. č. 303, Náchod – Hronov

Measurement date: 14.4.2018
Conditions: sunny, temperature approx. 20 až 25° C

Road surface: dry asphalt
Measurement methods used:
The ÚSI RIO recording device was used to measure the deceleration of the truck and trailer.

Description of the ÚSI RIO recording device
The ÚSI RIO device is assembled using primary components from the company National Instruments™, which is able to record data simultaneously from 32 digital or analogy channels at once at a selectable data recording frequency (50 kHz sampling frequency was used for measurements with subsequent resampling to a lower frequency).
The required number of sensors can be connected to the device. The device can be controlled not only via a PC via a remote desktop, but also directly via the control panel on the front of the device.

The following sensors were used to measure the deceleration of the combination:
Semitrailer:
1 x GYRO L, 1 x DYT L - angular velocity and acceleration sensors located on the cross member of the frame approximately in the middle of the trailer

Truck:
1x PCB - acceleration sensor located on the tractor frame, approximately in the middle
1 x GYRO L, 1 x DYT L - acceleration sensors located in the driver's cab, approximately in the middle
1 x TAPE SW - sensor of continuous movement of the brake pedal
The ÚSI RIO recording device was located in the cab of the tractor, under the passenger seat. The locations of the sensors are shown in Figure 3. In Figure 4 shows the sensors located on the truck and on the trailer.

Used sensors:
- PCB Piezotronic - three-axis accelerometer with a range of 50 g
- Dytran - triaxial accelerometer with a range of 50 g
- Analog Devices ™ ADXRS 620 - angular velocity and acceleration sensor with a range of 300 ° / s
- Analog Devices ™ ADXRS 624 - angular velocity and acceleration sensor with a range of 50 ° / s

Outputs are published in accordance with SAE J1733.

**Figure 3.** The ÚSI RIO measuring device

**Figure 4.** sensors location

Measurement procedure:
Number of measurements: 8
Vehicle condition: no defects
Braking from initial speed: 60 to 85 km/h.

Figure 5 shows the results of the deceleration measurements of the three repeated brakes, which followed in the order a), b), c). This is the phase of the onset of the braking effect, where the correction of parameters is most pronounced.

Sufficient detail to allow the work to be reproduced. Methods already published should be indicated by a reference: only relevant modifications should be described. This section also may include theory, background, calculations which represent practical development from a theoretical basis.

The display of deceleration of the truck and trailer a) shows the first braking. When the driver depresses the brake pedal, the brake request is transferred from the truck to the trailer. After the onset of the braking effect of the truck and the semitrailer, the first optimization of the braking effect takes place after only 0.3 s, which is reflected in a higher deceleration and thus also a higher braking effect of the semitrailer. This is a time period of approximately 0.3 s to 0.7 s. Within 0.3 s, the deceleration of the truck is higher, which means that it is "pushed" by the trailer, to which the electronic control unit EBS of the truck increases by increasing the braking demand for the trailer braking system. Subsequently, after a time of 0.7 s, there is already a deceleration with the corrected parameters of the braking demand. Figure 5b) shows the second braking. Here it is visible that the deceleration curves of the truck and the trailer are relatively identical except for minor corrections. Figure 5c) shows the third braking, where the result of the correction of the parameters of the braking request of the phase of the onset of the braking effect is visible. The deceleration curves of the truck and the semitrailer have practically the same course, and it follows from this course that the electronic control unit EBS of the truck was able to optimize the deceleration parameters of the combination as a whole in the phase of the onset of the braking effect.

In the next phase of the full braking effect, corrections of the braking requirement also take place, which is also conditioned by the current adhesion conditions.

![Legend:](image)

Figure 5. The course of optimization of the braking effect of the truck and trailer (time - deceleration)
3. Conclusions
The content of the paper is the issue of automatic optimization of the braking effect of the vehicle with the electronic control unit EBS of the tractor ie the issue of the so-called "automatic alingment of braking performance" of the vehicle. As part of the evaluation of the deceleration parameters of the truck and the semitrailer, the paper focuses on the phase of the onset of the braking effect. This phase significantly affects the stability of the combination during braking and especially in poor adhesion conditions or in critical driving situations. Therefore, within the analysis of the course of traffic accidents of combinations of vehicles, which are related to the issue of braking, it is important to evaluate the phase of onset of braking effects of the truck and trailer.

The first part of the paper describes the factors that affect the automatic alingment of braking force of the truck and trailer and in the case of expert examination it is necessary to evaluate both the current technical parameters and technical condition of structural units of the vehicle that affect the onset of braking effect and adhesion conditions. This part of the paper focuses on the description of the most important and in practice the most common parameters and conditions that affect the automatic tuning of the onset of the braking effect of the truck and trailer.

The second part of the paper describes and evaluates the alingment of braking performance of the truck and trailer in the phase of the onset of the braking effect. This is an analysis of the results of a specific measurement of the deceleration of the truck and trailer, where the technical conditions, technical condition as well as design and configuration parameters enabled the alingment of braking performance alingment of braking performance of the truck and trailer [5], [6]. Another condition was one driving cycle, ie the ignition was not switched off during the measurement. This analysis shows that automatic alingment of braking performance occurs during the first braking. During repeated braking, the braking effect is further optimized. This optimization takes into account both technical influences, ie the effects of the properties of the braking systems and other structural units of the vehicles of the combination, as well as the external influences of the surroundings, which are mainly the properties of the road surface, ie adhesion conditions.

The aim of the paper is to apply its conclusions, especially in expert and other professional practice, but it can also be used in services that deal with the issue of the alingment of braking performance the truck and trailer.

References
[1] WABCO, EBS E - Elлектronically Controlled Brake System – TRAILER, training documentation Germany, 2010 – 2018.
[2] KNORR-BREMSE, Nutzfahrzeug – Bremssysteme, training documentation Germany, 2006 – 2015.
[3] KNORR-BREMSE, Training TEBS&RSP, training documentation, Germany, 2006.
[4] A. Bradáč, Soudní inženýrství. Akademické nakladatelství CERM, s.r.o., Brno, ISBN: 80-7204-057-X (in Cech).
[5] M. Semela, Systémové pojetí analýzy silničních nehod, Brno 2018 (in Czech).
[6] R. Kledus, Systémové pojetí oceňování majetku, Brno 2005 (in Czech).