Article citation info:
Caban A, Kidawski A, Włodarczyk A. Synchronization of the braking of heavy tractor-trailer and tractor-semitrailer units: operational problems. The Archives of Automotive Engineering - Archiwum Motoryzacji. 2017; 77(3): 17-29, http://dx.doi.org/10.14669/AM.VOL77.ART2

SYNCHRONIZATION OF THE BRAKING OF HEAVY TRACTOR-TRAILER AND TRACTOR-SEMITRAILER UNITS: OPERATIONAL PROBLEMS

SYNCHRONIZACJA HAMOWANIA ZESPOŁÓW POJAZDÓW CIĘŻKICH – PROBLEMY EKSPLOATACYJNE

ANDRZEJ CABAN[1], ANTONI KIDAWSKI[2], ANDRZEJ WŁODARCZYK[3]
Automotive Industry Institute (PIMOT)

Summary

The safety on roads depends, to a significant degree, on the technical condition of the vehicles that participate in road traffic, especially of their braking systems, whose adequate operation is a matter of critical importance. This particularly applies to the heaviest vehicles moving with high speeds, chiefly tractor-trailer and tractor-semitrailer units. Apart from correct functioning of the braking system of each of the vehicles being components of such units, the synchronization of braking of the vehicles plays a fundamental role in the braking process. The synchronization does not have to be checked during the mandatory periodical inspections of such vehicles being in service. This article deals with the problem mentioned above, especially if encountered in the case of older vehicles, as well as with the related adverse effects and possibilities of making appropriate corrections when any faults or malfunctions are detected. Thanks to technological progress, more and more vehicles are now

[1] PIMOT (Automotive Industry Institute), Braking Systems Laboratory, ul. St. Dubois 110, 93-465 Łódź, Poland; e-mail: a.caban@pimot.eu

[2] PIMOT (Automotive Industry Institute), Braking Systems Laboratory, ul. St. Dubois 110, 93-465 Łódź, Poland; e-mail: a.kidawski@pimot.eu

[3] PIMOT (Automotive Industry Institute), Braking Systems Laboratory, ul. St. Dubois 110, 93-465 Łódź, Poland; e-mail: a.wlodarczyk@pimot.eu

provided with advanced electronic braking systems (EBS), where the problem of synchronization of the braking of vehicle combinations has already been solved to a considerable degree. Nevertheless, there are many situations that some minor adjustments might be recommendable even in this case. It is worth emphasizing, however, that for an appropriate correction to be made, adequate equipment and, above all, high professional knowledge and skill of the servicing personnel is indispensable.

Keywords: braking, vehicle combination, compatibility, performance, wear

Streszczenie

Bezpieczeństwo na drogach, w dużym stopniu, uzależnione jest od stanu technicznego uczestniczących w ruchu pojazdów, dla których poprawność działania układów hamulcowych odgrywa kluczową rolę. Ma to szczególne znaczenie w przypadku najcięższych, szybko poruszających się pojazdów, a zwłaszcza zespołów: pojazd ciągnący i przyczepa lub naczepa. Oprócz prawidłowego działania układu hamulcowego każdego ze składników takiego zespołu, ważną rolę odgrywa również właściwa synchronizacja ich hamowania. Obowiązujące przepisy nie wymagają jej kontroli, podczas okresowych badań technicznych eksploatowanych pojazdów. W niniejszym opracowaniu opisano powyższy problem dotyczący zwłaszcza pojazdów starszych, negatywne zjawiska z nim związane oraz możliwości dokonywania odpowiednich korekt, w przypadku stwierdzenia nieprawidłowości. W wyniku postępu technicznego, coraz więcej pojazdów wyposażonych jest obecnie w zaawansowane układy hamulcowe EBS (Electronic Braking System), dla których problem synchronizacji hamowania zespołów pojazdów został w dużym stopniu rozwiązany. Często jednak niewielkie regulacje, także w tym przypadku, bywają wskazane. Warte jest jednak podkreślenia, że dla wykonania odpowiedniej korekty konieczne jest profesjonalne oprzyrządowanie, a przede wszystkim fachowa wiedza pracowników obsługi technicznej.

Słowa kluczowe: hamowanie, zestaw, synchronizacja, skuteczność, zużycie

1. Introduction

One of the main factors that are decisive for the safety of road traffic is adequate technical condition of vehicles, especially the serviceability of their braking systems. Particularly big hazards may be caused by incorrect functioning of brakes of the heaviest vehicles, which move nowadays with high speeds, especially tractor-trailer or tractor-semitrailer units. Pursuant to the regulations in force, every vehicle participating in road traffic should pass mandatory periodical inspections, in result of which it should be accepted as fit for further safe use on the roads. A statement made by an authorized diagnostician that the towing or towed vehicle is "roadworthy", i.e. in conformity with current legal requirements, confirmed by an appropriate diagnostician's annotation in vehicle documents, has the meaning of an official permit for further operation of the specific vehicle. However, it does not guarantee that the braking systems of the tractor and the trailer or semitrailer will correctly cooperate with each other because of the problem of synchronization between the functioning of brakes of the two vehicles combined together. There are no regulations at present that would require the diagnosticians at Vehicle Testing Stations to check the said synchronization. Simultaneously, the examination of the actual synchronization between specific vehicles combined together, possibly resulting in an adjustment of brake pressures, would not be sufficiently effective in the case of, quite frequent, interchangeability

of vehicles in vehicle combinations, as every exchange of the vehicles would have to be followed by re-examination and re-adjustment of the new combination. Ideally, therefore, only specifically predefined and technically tested vehicle combinations should be given roadworthiness certificates.

2. Examination of the braking performance of vehicles combined in a tractor-trailer or tractor-semitrailer unit

During mandatory periodical inspections of brakes of the towing vehicle, chiefly the service brake performance is checked. Pursuant to the regulations currently effective (Dz. U. (*Polish Journal of Laws*) of 2016, item 2022: Announcement of the Minister of Infrastructure and Construction of 27 October 2016 on the publication of a consolidated text of the Regulation of the Minister of Infrastructure on the technical requirements for vehicles and on the scope of the necessary vehicle equipment), applicable to the vehicles registered for the first time after 28 July 2010, the "braking rate"[4] (also referred to as "braking efficiency" or "braking force ratio"), defined as the ratio of the sum of the retarding forces developed by each braked wheel to the Gross Vehicle Weight (GVW), determined by the Maximum Authorised Mass (MAM) of the vehicle, i.e. $z_M = T_M/P_M$ (see Fig. 1), should be at least 0.5 (i.e. 50 %). In the case of very efficient brakes, this efficiency may be achieved at relatively low brake actuator pressures, much lower in comparison with those available when the brake pedal is fully depressed.

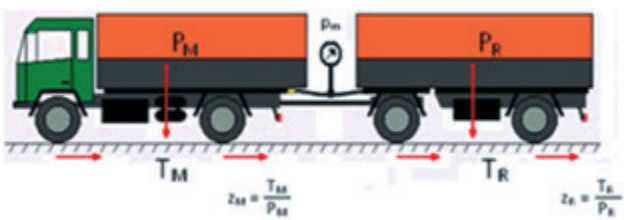

Fig. 1. Braking rate values for individual vehicles in a vehicle combination

For towed vehicles, the braking force ratios $z_R = T_R/P_R$ are required to be not less than 50 % for trailers and 45 % for semitrailers. During the tests of a towed vehicle having relatively less efficient brakes, the required braking efficiency z_R may also be achieved, but at much higher pressures, although still available, being applied to brake actuators. Such a trailer or semitrailer will also be fully approved as "roadworthy" by an authorized diagnostician. However, if the vehicles as described above are combined together, the towed vehicle will overrun the tractor, pushing it with a force depending on such factors as braking intensity and difference in the values of braking efficiency of each vehicle. Pursuant to the regulations in force

[4] Not to be confused with "braking ratio", which is defined as the distribution of braking effort between the front and rear wheels. Translator's note.

(Dz. U. of 2015, item 776: Announcement of the Minister of Infrastructure and Development of 21 April 2015 on the publication of a consolidated text of the Regulation of the Minister of Transport, Construction, and Maritime Economy on the scope and method of carrying out mandatory motor vehicle inspections and on the standard forms of documents used at such inspections), an authorized diagnostician should check the brake actuator pressure at which the braking efficiency required is attained. However, the acceptability limits of such pressures have not been specified. In practice, the pressure measurement as mentioned above is exclusively aimed at the calculation of the maximum braking efficiency available if the efficiency measured is found unsatisfactory due to wheel slippage on the brake tester rollers at a brake actuator pressure considerably below the available maximum. Fig. 2 shows example $z_M = f(p_m)$ and $z_R = f(p_m)$ characteristic curves illustrating this problem, plotted for a motor truck and a trailer, fully laden, in a vehicle combination (the symbol "p_m" denotes the pressure in the trailer brake control line).

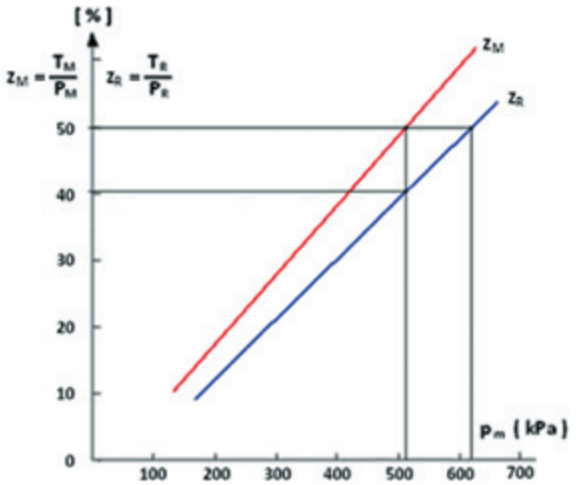

Fig. 2. Example of incorrect synchronization between tractor and trailer brakes

The curves indicate that the braking force ratios ("braking efficiency values") achieved by both vehicles are correct, i.e. in conformity with the regulations in force (the "z" values exceed 50 % in both cases). For the towing vehicle, z_M = 50 % when the pressure in its trailer brake control line is $p_m \approx 510$ kPa. For the same braking force ratio z_R to be achieved by the trailer, the latter must receive, through its brake control line, a pressure of $p_m \approx 620$ kPa. An analysis of these curves also shows that if the combination brakes were applied with an intensity at which the pressure in the trailer brake control line would be $p_m \approx 510$ kPa then the tractor would achieve a braking efficiency of $z_M = 50$ % while the trailer's braking efficiency would merely be $z_R = 40$ %. In such a vehicle combination, any application of brakes would cause the tractor to be undesirably pushed by the trailer because of relatively weaker brakes of the latter. In the case as above ($p_m \approx 510$ kPa), the force applied by the trailer to the tractor would be equal to about 10 % of trailer's weight. So high a force pushing the towing vehicle would deteriorate the stability of the vehicle combination during

the braking process; in extreme cases, this may result in a dangerous effect of folding of a tractor-trailer unit. As it can be seen from the above, dangerous problems may come up in spite of good, legally acceptable, technical condition of each of the vehicles treated separately. In practice, such problems may only be detected by vehicle drivers based on their subjective feelings. It is easier to detect the fact that the towed vehicle overruns the tractor, especially during hard braking. In contrast, the relatively more efficient braking of the towed vehicle, offering better driving comfort, especially when the difference in the braking efficiency is not very big, is often detected only when the wear of brake liners of both vehicles are analysed. If incorrect synchronization of brakes of combined vehicles is detected, it may be refined; however, this cannot be done without adequate equipment and, above all, high professional knowledge and skill of the servicing personnel. Among the mistakes often made by servicing mechanics, we should highlight the attempts to "fit" the brakes of both vehicles to each other without prior analysing the braking efficiency of each of them to identify the one that is accountable for the problem. The adjustment of this kind improves the synchronization, but only in a specific vehicle combination. The interchanging of individual vehicles in vehicle combinations, sometimes very frequent, may result in even greater asymmetry in the tractor-trailer units thus formed. It is impracticable to re-synchronize every vehicle combination having been formed anew. Since the problem of compatibility of brakes of individual vehicles in vehicle combinations is very important, it has been included in the standard procedure of type-approval testing of new vehicles checked for conformity with the requirements of UN ECE Regulation No. 13 "Uniform provisions concerning the approval of vehicles of categories M, N and O with regard to braking", where a requirement has been provided that the braking characteristics $z_M = f(p_m)$ and $z_R = f(p_m)$ of the towing and towed vehicle, respectively, both laden and unladen, should be within prescribed tolerance zones referred to as "compatibility bands" or "compatibility corridors".

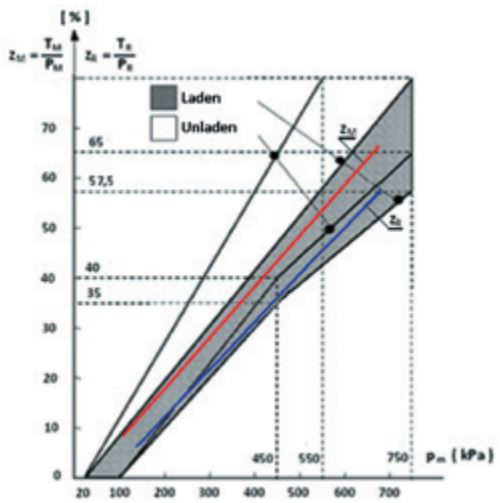

Fig. 3. Tolerance zones for braking characteristics of the towing and towed vehicle, according to UN ECE Regulation No. 13.

Fig. 3 shows the "compatibility bands" for a motor truck and a trailer (identical for such vehicles) with the example braking characteristics from Fig. 2 having been plotted. Both the characteristic curves are within the tolerance zones, i.e. they are in conformity with the type-approval requirements in force. In spite of this correctness, the braking of such a vehicle combination cannot be declared as optimally safe. For the braking synchronization to be improved, the braking characteristics should be changed to be as close to each other as possible or, ideally, identical. The incompatibility of the braking characteristics in a used vehicle combination may also be caused by operational wear or defects of braking system components. When any existing problems are rectified, the braking systems may be synchronized with the use of appropriately modified methods employed at type-approval tests according to the provisions of UN ECE Regulation No. 13.

3. Synchronization of the braking of vehicle combinations without EBS

In vehicle combinations with air-operated brakes without an electronic braking system (EBS), the synchronization problems may be rectified in two ways. The first one consists in changing the pressure in the trailer brake control line (p_m) without changing the tractor braking pressure, accomplished by means of a valve installed on the tractor (Fig. 4). In the other method, the towed vehicle braking pressure is changed in relation to the trailer brake control line pressure (p_m) by means of a valve installed on the trailer or semitrailer. In both cases, quite a wide adjustment range is available. As an example, if both valves are appropriately set (and braking force regulators are not used to correct the pressures) then, in the case of both vehicles being fully laden, a pressure in the trailer brake actuators exceeding the braking pressure in the tractor even by more than 200 kPa can be achieved. So much room for manoeuvre enables effective synchronization but also poses some threats. Inadequate knowledge of the servicing mechanic or insufficiently advanced equipment used for this work may cause problems that would result in deterioration in braking safety and accelerated wear of, or even damage to, brake components. The mechanic that is to synchronize the brakes of a vehicle combination because the trailer or semitrailer overruns the tractor must make a decision which of the valves mentioned above should be adjusted. If the valve situated on the tractor is used for the adjustment, the trailer brake control line pressure (p_m) will be raised without changing the braking pressure (braking efficiency) of the tractor. In consequence, the tractor braking characteristic curve $z_M = f(p_m)$ will be shifted to the right (Fig. 4). In turn, the adjustment carried out with the use of the valve installed on the trailer or semitrailer will increase the braking efficiency of the towed vehicle without a change in the pm pressure, in result of which the braking characteristic curve of the towed vehicle, i.e. $z_R = f(p_m)$, will be moved upwards.

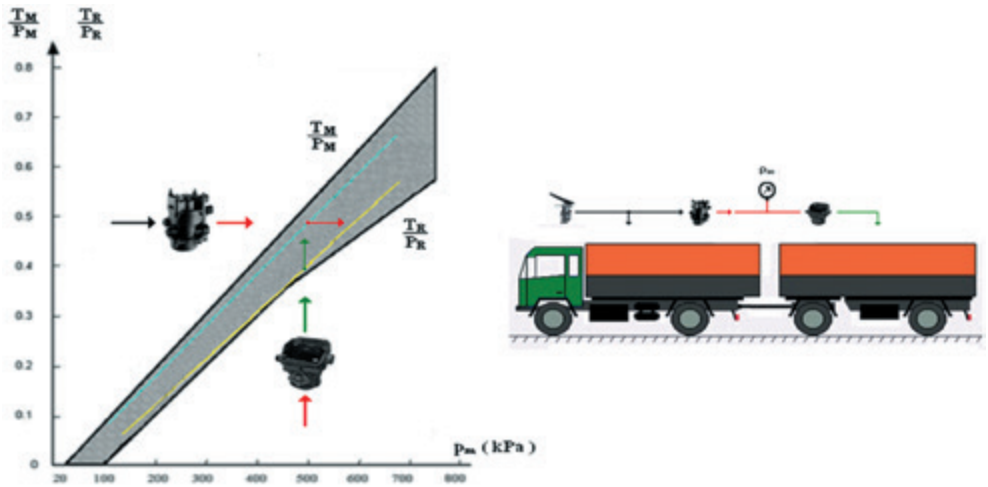

Fig. 4. Possible methods of the synchronization of braking of a vehicle combination

In the case under consideration, each of the above methods would cause the characteristic curves to come closer to each other and, in consequence, the braking synchronization to be improved. For a correct decision to be made which of the valves should be adjusted, first the braking characteristics of both vehicles must be determined. This can be done with the use of a roller brake tester, by successively applying brakes of all the axles of the tractor and the towed vehicle at predetermined values of the trailer brake control line pressure (p_m), read out from a pressure gauge connected to the said brake control line. The total braking force on all the wheels of a specific vehicle divided by the vehicle weight defines the braking efficiency value attained at a specific p_m value and a specific vehicle weight. The values thus determined are coordinates of each of the successive points of the braking efficiency curves plotted for the tractor and towed vehicle:

$$z_M = T_M/P_M = f(p_m) \text{ and } z_R = T_R/P_R = f(p_m)$$

When the measurements and subsequent simple calculations have been carried out, the characteristic curves should be superimposed on the "compatibility bands" defined by the regulations in force. Thus, the driver's feelings may be objectively verified, the specific adjustable valve to be used for the correction may be identified, and the necessary correction range may be determined. If the braking characteristic curve of any of the vehicles involved were not fully within the prescribed tolerance zone, the adjustment should, first of all, rectify this non-conformity with the regulations. If both of the curves were within the "compatibility band", they should be as close as possible to the central position in the tolerance zone for the synchronization to be considered optimum. Such an adjustment would result, *inter alia*, in higher probability of correct cooperation of brakes of both vehicles of the combination, without the need of additional re-adjustment, if interchangeability

of the vehicles were to be taken into account. The analysis should be carried out for both extreme load states, but it is often limited to the fully laden vehicles because this case is more dangerous.

4. Synchronization of the braking of vehicle combinations with EBS

Thanks to advanced electronics introduced to heavy vehicles, the optimal solution of the synchronization of brakes in vehicle combinations has become possible. The most obvious solution seems to be the use of a "dynamometer coupling device", which would measure the force in the device used to couple the vehicles with each other and would communicate with an electronic activator of towed vehicle's brakes in order to ensure the optimal harmony of braking of the vehicle combination. However, a solution like this has not become popular, chiefly for economic reasons. The braking process in vehicle combinations of this kind is optimized in another way. A specific depression of the brake pedal in the towing vehicle, activating a "brake signal transmitter", is read as a demand for a corresponding vehicle deceleration, which translates into a desired braking efficiency. An electronic control unit (ECU), receiving the signals from the transmitter, executes the braking with an intensity as required by the driver. In the electronic braking system, trailer brakes are operated from the tractor, via a special electrical connector, with the use of CAN (Controller Area Network) signals sent by the ECU, which also controls the pressure (p_m) of the pneumatic signal that is sent to the trailer via the brake control line and is to produce a trailer braking efficiency corresponding to the braking efficiency of the tractor. The values of the above control signals are so selected by the ECU that the tractor braking characteristic curve $z_M = f(p_m)$ falls in the central part of the "compatibility band" shown in Fig. 3. If the characteristic curve of the towed vehicle is similarly situated, the vehicle combination braking may be considered as optimal. Should the braking characteristic curve of the trailer or semitrailer deviate from the central position in the tolerance zone, the ECU on the tractor will be capable of detecting such a situation and correcting it by changing the braking intensity of the towing vehicle. As an example: thanks to the exchange of information between the controllers on the tractor and towed vehicle provided with the Knorr EBS 5 system, even a detected difference exceeding 1 % in the tyre slip between the wheels of both vehicles induces corrective actions, according to data published by the Knorr-Bremse Company. This shows that in such systems, the braking synchronization is practically correct during the entire process of "fully developed" braking of a vehicle combination.

The situation is somewhat different when a tractor with EBS is coupled with a towed vehicle without EBS, i.e. without a CAN connector. In such a case, the trailer brakes may only be controlled by the pneumatic signal sent by the tractor, at which an optimum tractor braking characteristic curve $z_M = f(p_m)$ is simultaneously ensured. If the brakes of the towed vehicle are compatible with the tractor brakes, no readjustment is needed. If the braking efficiency of the vehicle combination, corresponding to the current brake pedal effort, is lower than expected (attainable for the tractor moving without a trailer attached) due to relatively weaker brakes of the towed vehicle then the air pressure in the trailer control line is raised, with an objective to attain the deceleration required. The vehicle combination

braking process is thus improved, although it is not always brought to the optimum because of the existing acceptable adjustment limits. The inadequate braking efficiency of the vehicle combination is always interpreted by the ECU of the tractor EBS as incorrect operation of the trailer brakes. A possible in-service deterioration in the functioning of tractor brakes may result in undesirable overloading of brakes of the towed vehicle.

If the brakes of a trailer or semitrailer with EBS are operated by a tractor without EBS, the pressure in the trailer brake control line (p_m) cannot be automatically adjusted for correct braking efficiency of the vehicle combination to be attained when the vehicles are moving. The pressure (p_m), supplied to the towed vehicle via the control line, is in accordance with the braking characteristic curve $z_M = f(p_m)$, predefined for the tractor and remaining unchanged in the tolerance zone appropriate for the tractor during the braking process. In this case, the electronic braking system of the towed vehicle only receives a pneumatic control signal (there is no CAN signal) and transforms it into an electric signal, thanks to which the ECU on the trailer or semitrailer can execute a braking process in accordance with the braking characteristic curve in the "compatibility band" as saved in the ECU memory.

It can be seen from the above that in vehicle combinations with EBS, the synchronization of brakes is automatically optimized when the vehicles are moving. In the case of doubts about correct performance of this function, the effect cannot be verified in static tests carried out on a diagnostic brake tester, as it is done for vehicles without EBS, due to dynamic nature of the adjustment process. This may be roughly estimated by comparing the temperatures of the friction surfaces of braking mechanisms, after the brakes have been applied for a number of times according to a predefined test procedure. The characteristics of functioning of the EBS-controlled vehicle brakes are saved by vehicle manufacturers in the electronic controllers (ECU) installed on the vehicles. However, there is a possibility of making some small corrections, if necessary, in the pre-programmed parameter sets. The above description of the automatic synchronization of brakes in vehicle combinations when in motion is applicable to the "fully developed" braking, with higher values of the brake actuator pressures. An important problem, related to safety, but also and above all, to the vehicle operation costs, arises from the consequences of unfavourable characteristic curves occurring when the vehicle combination is braked with low pressure values. It is known from the research works carried out that low pressures are used in an overwhelming majority of the cases of braking; in as many as about 90 % of such cases, the air pressure in brake actuators does not exceed 150 kPa (1.5 bar), according to some sources. The braking mechanisms used in heavy vehicles often differ from each other in the "brake actuation threshold", i.e. the pressure at which the mechanism begins to brake the wheel connected with it. This may arise from the type of the braking mechanism used (drum or disc brake) and its current technical condition; it may also result in vehicle operation problems. If the case of soft braking (e.g. in urban traffic) of a tractor with a high value of the brake actuation threshold combined with a trailer where the value of this threshold is low, chiefly the trailer brakes will be loaded and, in consequence, the wear of friction liners in the trailer will be significantly accelerated. An opposite case, where the delayed operation of brakes of the towed vehicle causes overloading of the tractor brakes, is also very frequent.

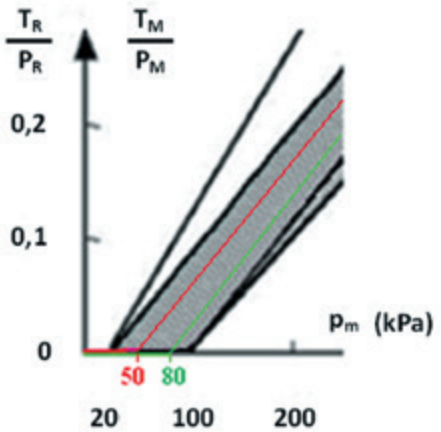

Fig. 5. Lower range of braking characteristics of the towing and towed vehicle

Fig. 5 shows an example of braking characteristics $z_M = f(p_m)$ of the towing vehicle (red curve) and $z_R = f(p_m)$ of the towed vehicle (green curve) within the range of soft braking or snubbing. In this range, the braking force and deceleration values are not very high; hence, the pushing force that might be applied by the towed vehicle to the tractor is insignificant, too. Therefore, any incompatibilities of the braking characteristics are hardly noticeable for the driver, if the opinion is only based of his/her feelings, especially if the vehicle combination is operated in a "soft" manner. Thus, the problem will not be detected before it forces premature replacement of brake liners in the tractor. For an incompatibility of the braking characteristics in the range of low braking pressures to be detected, a simple procedure may be run, feasible for a vehicle service station and consisting in the obtaining of simultaneous start of braking the tractor and towed vehicle. At the first stage, the brake actuation threshold pressures should be measured for all the braking mechanisms in the vehicle combination as functions of the values of pressure p_m in the trailer brake control line, at the full load of the vehicles being simulated. An example of the threshold pressure values measured has been presented in Fig. 6.

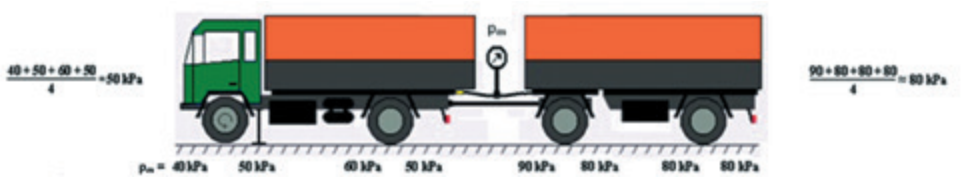

Fig. 6. Measurement of the brake actuation threshold pressures

The measurements should be carried out for each wheel of the vehicle combination in succession, by lifting the wheel involved so that it can freely rotate and afterwards, by gradually applying compressed air to the related brake actuator. The arithmetic mean calculated from individual threshold pressure values will be then taken as a basis for comparisons. The difference between the average threshold pressures for the tractor and trailer in the example under consideration is 30 kPa (0.3 bar). The measurement results as presented above show that for pressures p_m in the trailer brake control line of up to about 80 kPa, only the tractor brakes will be applied during the vehicle combination braking process. The measurement procedure as described above makes it also possible to detect possible malfunctions of individual braking mechanisms, manifesting themselves in a gross difference in the threshold pressure values.

Another method of determining the threshold pressure values, less labour-consuming but simultaneously less accurate, may be the applying of vehicle brakes on a roller brake tester with the use of low braking pressures, with recording the pressure values p_m corresponding to the appearance of braking force readouts for individual wheels. In the case under analysis, the trailer braking pressure should be raised in relation to the pressure in the trailer brake control line so that the tractor and trailer brakes are activated at the same time. In a vehicle combination with electronic braking systems (EBS), the pressure correction permitted by the manufacturers of such systems should not exceed 20 kPa (0.2 bar). In the case that a necessity of pressure correction considerably exceeding this limit is revealed in result of tests carried out, the brakes usually have to be restored to adequate technical condition and the tests should be repeated. If no satisfactory improvement were thus obtained, the problem should be reported to the vehicle manufacturer. A repeating defect like this, found to occur in a few vehicles of the same type, should result in a vehicle manufacturer's request for the EBS manufacturer to recalculate the braking system parameters. A readjustment may only be carried out with the use of appropriate diagnostic programs. For the parameters saved in the memory of the electronic brake controllers to be modified, prescribed PIN codes must be available. This means that the corrections may exclusively be made by authorized and appropriately trained personnel. In the case of the vehicle combination presented in the example above, the optimal modification would consist in raising the tractor braking pressure by 30 kPa in relation to the pm value. At most service stations, the pressure would be raised in this case by the permitted value of 20 kPa, which would be a correct but technically insufficient step towards an improvement in the uniformity of wear of vehicle friction liners. For some EBS controllers, made by specific manufacturers, a correction by a higher value is impossible; however, there are also controllers for which such a correction is practically possible, although not recommended. In many cases, servicing mechanics readjust the braking pressure of trailers or semitrailers merely based on information obtained from vehicle drivers, without prior checks of the actuation threshold pressures for individual braking mechanisms. It also happens that readjustments by values exceeding the manufacturer-permitted limits are made. The actions of this kind may cause deterioration in the compatibility of braking systems in vehicle combinations and, in consequence, they may adversely affect the safety of vehicle operation and result in non-uniform wear of friction liners.

5. Recapitulation

The problem of synchronization of brakes in heavy tractor-trailer and tractor-semitrailer units may be counted among important issues concerning road traffic safety. The correct synchronization is not, and practically cannot be, required during mandatory periodical inspections of tractors, trailers, and semitrailers because of the interchangeability of individual vehicles in vehicle combinations. In the case of older vehicles, provided with conventional compressed-air braking systems, without electronic control (EBS), good cooperation of brakes in vehicle combinations is a manufacturer's responsibility. The tractors, trailers, and semitrailers whose brakes are in conformity with the type approved ensure that their braking characteristics are kept within the requirements of UN ECE Regulation No. 13. If individual towing and towed vehicles are coupled to form vehicle combinations, the standardization prevents the building-up of excessive forces in the vehicle coupling devices. For the vehicle brakes to be optimally synchronized, corrections in the braking systems can be made both in the towing and towed vehicles. Before any readjustment, the vehicle where a correction should be made must be identified and the adjustment range must be determined by carrying out appropriate tests. A correction improperly carried out, especially when variations in the vehicle combination setting-up are possible, may result in serious consequences, both concerning the vehicle operation and safety. The application of electronics to the braking systems of heavy vehicles has significantly reduced the hazards that might result from incorrect synchronization of the braking of vehicle combinations. The braking system controllers installed on the tractor and trailer or semitrailer and communicating with each other govern the process of braking each of the vehicles in a way that ensures the attaining of not only the braking efficiency required but also the optimum synchronization of the braking systems. Therefore, no additional corrections are needed for the "fully developed" braking. The electronic EBS controllers on the towing and towed vehicles operate vehicle brakes in a way pre-programmed by the manufacturers, in accordance with the requirements of UN ECE Regulation No. 13, which cover, *inter alia*, the harmony of braking of vehicle combinations. Since braking mechanisms characterized by different brake actuation threshold pressures are used in individual vehicles, the controllers enable some small braking pressure corrections aimed at simultaneous activation of brakes of all the vehicle wheels and additionally improving e.g. the uniformity of wear of friction liners. The technological progress in the field of braking systems of heavy vehicles has resulted in significant improvement in the cooperation of brakes of vehicle combinations. The fixed synchronization attained by appropriate adjustment of pneumatic valves incorporated in the braking system of the towing or towed vehicle has been superseded by electronic synchronization, capable of making corrections automatically during the braking process. Nevertheless, professional technical servicing is still indispensable to supervise the operation of both older and newly manufactured vehicles; however, the servicing will only be effective if advanced technical equipment is used for this purpose.

The full text of the article is available in Polish online on the website
http://archiwummotoryzacji.pl

Tekst artykułu w polskiej wersji językowej dostępny jest na stronie
http://archiwummotoryzacji.pl

References

[1] UN ECE Regulation No. 13: "Uniform provisions concerning the approval of vehicles of categories M, N and O with regard to braking".

[2] Dz. U. of 2016, item 2022: Announcement of the Minister of Infrastructure and Construction of 27 October 2016 on the publication of a consolidated text of the Regulation of the Minister of Infrastructure on the technical requirements for vehicles and on the scope of the necessary vehicle equipment.

[3] Dz. U. of 2015, item 776: Announcement of the Minister of Infrastructure and Development of 21 April 2015 on the publication of a consolidated text of the Regulation of the Minister of Transport, Construction, and Maritime Economy on the scope and method of carrying out mandatory motor vehicle inspections and on the standard forms of documents used at such inspections.

[4] Knorr-Bremse: Educational materials on EBS – Motor vehicles and TEBS G2.

[5] WABCO: 815 020 093.3 / 01.2017 TEBS E Versionen E0 bis E5 Systembeschreibung.