Technical and Technological Means to Ensure the Development of Interoperable Transportation Between Ukraine and the EU

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Summary
The article discusses realistic development trends for effective international railway transportation between Ukraine and the EU countries based on the introduction of results of scientific and technical research on technical support for freight transportation in accordance with the transshipment-free technologies. In particular, there is a brief description of experience with European Automatic Gauge Changeover Systems (AGCS). This article presents information on scientific and technical projects for ensuring intermodal transportation based on technologies that involve the use of AGCS-technology. The prospects of development and practical application of similar systems with a view to accession of Ukraine to the railway transportation network of the European Union are discussed.

Keywords: combined transport, rolling stock, gauge change

1. Introduction

One of the fundamental technical and technological problems of ensuring the effective intermodal transportation between Europe and Asia, including the New Silk Road, is the difference between the track gauge at the junction of the Trans-European Transport Network (TEN-T) and railways of neighboring partner countries. The urgent need for deepening economic and social relations between the EU and Ukraine determines the priority of effective international rail traffic. A key technical issue that remains open is if Ukraine will use an automatic change of gauge, taking off the real limit to interoperability, or continue to use the current schemes of reloading cargoes on the border with the EU. Obviously, the transportation market, both present and forecasted, should be taken into account to choose the best AGCS technological solution for railway transportation of goods between Ukraine and the EU.

In recent years, systems of automatic track gauge changeover increasingly attracts researchers' attention in the field of transport communication between the countries whose railways differ in structures and design of tracks. Numerous works like the following [1, 12, 15] are dedicated to the presentation of such systems. The problems of the rolling stock transition through the breaks-of-gauge of 1435 and 1520 mm tracks are particularly important because of the development of international combined transportation [8].

The prospects of wide implementation of AGCS is associated with the development of international transport corridors. The following directions should be considered as the first priority: the Baltic Sea – Black Sea (part of the project „Baltic-Black Sea axis"); Ukraine – Poland – Germany; Ukraine – Hungary – Slovenia – Italy; Ukraine – Slovakia – Austria / the Czech Republic. On the part of Ukraine, the last two corridors are the natural extension of corridors of the trans-European Transport Network TEN-T, namely the Rhine-Danube Corridor and the Mediterranean Corridor.

The positive experience in using the SUW2000 system of automatic track gauge changeover for passenger transportations between Poland and Ukraine was obtained due to a long and fruitful cooperation of Ukrainian and Polish experts.

The example of effective implementation of AGCS-technology is the project of passenger railway transportation service on the route Baku – Tbilisi – Istanbul with the use of DBAG Rafil type V system of automatic track gauge changeover. However, the prospects for further development of freight transportation based on the existing AGCS systems remain uncertain.

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2. Technologies for the rolling stock transition through the breaks-of-gauge of 1520/1435 mm tracks

International railway transportation services between Ukraine and EU countries are related to the need to perform transitions from 1520 mm tracks to 1435 mm tracks and vice versa. Transition points for Ukrainian and EU countries railways located mainly at the Lviv railway (See Table 1).

Table 1

Transition points at the breaks-of-gauge of 1520/1435 mm tracks

Transitional points	Bordering states
Yagodyn – Dorohusk	Poland
Mostiska 2 – Medyka	Poland
Chop – Chiyerna nad Tisou	Slovakia
Uzhhorod – Matovtse	Slovakia
Batiovo – Epereshke	Hungary
Chop – Záhony	Hungary
Vadul Siret – Dornești	Romania
Djakovo – Halmeu	Romania

2.1. Transportation with the use of bogie exchange and transshipment

Until now, traditional technologies based on the change of running gears are used to provide direct and transshipment-free railway transportation service between 1520 mm and 1435 mm tracks. There are appropriate technical facilities at the points of cars rearrangement (PCR) which are located at border stations. Except for PCR with enclosed space at Yagodyn station, all other points perform works outdoors, which creates inconveniences in case of unfavorable weather conditions. Production procedures connected with cars rearrangement include shunting operations on placement of cars to the bays and rolling stock forming after bogies exchange, lifting and lowering of cars on jacks, withdrawal of one type of bogies and supply of another type of bogies. This operation includes low usage of automation and mechanical equipment in works related to traffic safety and hoisting. Technical and economic weaknesses of the system of cars rearrangement include the need for availability of spare bogies pool corresponding to the number of cars crossing the border. In the context of passenger transportations, cars rearrangement makes passengers feel uncomfortable due to the need to carry out these production operations. Some of these operations, such as lifting and lowering of cars with passengers on jacks, are potentially dangerous. Works with cars on production areas of PCR are carried out in conditions of high noise impact on passengers. The duration of operations on cars rearrangement leads to violations of sanitary and hygienic conditions, and it is not compatible with comfort requirements. It is obvious that the use of technology of cars rearrangement with bogies exchange does not meet modern requirements for passenger transportation and does not contribute to the attractiveness of international travel by the railway transport.

There is an occasional use of points of freight cars rearrangement. This is largely a result of restricted admission of 1520 mm track cars to the railways with 1435 mm track due to non-compliance with requirements for dimensions and low dynamic characteristics that significantly reduce permitted speed.

Today's transportation in „East-West" directions is performed mainly using transshipment technology. This can be transfusion (pumping) of liquid cargo (liquefied gas, oil products, chemicals, etc.), transloading from one car into another, car unloading at designated areas (storage units, boxes, bins, containers, etc.). Transshipment technologies require significant time and labor expenditures and energy resources. There are problems with the preservation of cargoes and the rolling stock. Furthermore, at the transshipment of hazardous cargo there is a potential threat of technological disasters.

The analysis of technical condition of freight rolling stock involved in the international transportation with transshipment shows that in recent years there is sufficiently high level of cars' damages caused during transshipment. There are mass damages of 1520 mm track cars at the foreign transshipment points. Losses of railway companies associated with the restoration of damaged cars are not covered by penalty payments of parties guilty of the damage caused.

Traditional technology of transportation with the transshipment based on outdated technical solutions and limited to temporary commercial considerations meets views of carriers but, in essence, it constrains the development of scientific and technological progress in international railway transportation with different standards of track. The continued widespread use of transshipment technologies is the direction associated with the loss of cargo, damage to rolling stock, and in the case of hazardous cargo it also causes environmental problems and operational safety threat. Therefore, the development and implementation of advanced technologies based on the use of technics for transshipment-free transportation is of vital importance.

2.2. Transshipment-free transportation

Previous studies of technical and technological provision of international railway transportation services showed that there is no alternative for technologies based on automated systems for the rolling stock transition through the breaks-of-gauge of 1520/1435 mm tracks for passenger transportation [7]. The technology of international passenger transportations associated with the use of variable gauge wheelsets (VGW) is winning, since it substantially reduces the time for crossing borders with EU countries and eliminates the need for storage of exchangeable bogies at the point of car arrangement. It should be noted that systems of variable gauge wheelsets are a subject of EU Regulation 1302/2014 (TSI LOC&PAS) and also that new EN standard is prepared.

However, the practical application of the system of automatic transition through the breaks-of-gauge of tracks of different standards requires the implementation of a set of measures to ensure safe operation of running gears with VGW. Automated systems of the rolling stock transition through the breaks-of-gauge of tracks with different gauge are becoming more widespread. European systems of automatic rolling stock transition through the breaks-of-gauge of tracks with different gauge realized in metal includes: Spanish systems TALGO and BRAVA, Bulgarian system BT, Polish system SUW2000 and German system DB AG/Rafil.

TALGO and BRAVA systems

TALGO system is the most practically developed automatic track gauge changeover system [1, 9, 10]. Since the late 60s of the last century, TALGO RD trains provide direct transportation between Spain, Switzerland and France. Moreover, this type of trains performs domestic passenger transportation by means of change of track gauge from 1668 mm to 1435 mm and vice versa.

Articulated TALGO trains are distinguished by their features of automatic track gauge changeover. Furthermore, TALGO system cars are equipped with passive system of body tilt (in curves). Running gears of TALGO system are two-wheeled bogies which support two adjacent cars in the rolling stock (Fig. 1). Wheels of such bogies run independently of each other. Such bogies are equipped with systems of radial wheel mounting on semi-axis.

The reorganization of running gears of TALGO system for the desired track gauge is made by means of special gauge changeover devices (GCD). In the process of changing the distance between the wheels the load from the body is transferred to the elements of track changeover devices with the help of the sliding wheelsets. To reduce the coefficient of sliding friction water is delivered to the friction wheelsets. At low temperatures it is necessary to heat the water. At the same time, delivery of heated water is accompanied by icing of running gears.

Technical solutions, which are implemented in TALGO system and have been long-tested at passenger rolling stocks with 180–350 km/h speed, are used in the designs of variable gauge wheelsets for freight cars. However, the first version of the bogie with such VGW could not stand the test set, and the search for rational design continues.

Fig. 1. TALGO system bogie

In 1999 CAF company developed new system of automatic track gauge changeover BRAVA [1]. This system is designed for both non-motorized and traction rolling stock, and this enables uninterrupted transition through GCD with the speed up to 40 km/h. The maximum speed of trains equipped with BRAVA system running gears is 250 km/h. During the certification tests the speed of 293 km/h was achieved, which is a world record for this type of trains.

The technologies developed by TALGO and CAF are based on the same principles but are not geometrically compatible. Gauge changeover devices of TALGO and BRAVA systems are somewhat different. At the same time, there is the project on which these devices can be compatible. State-owned company ADIF as Administrator of Railway Infrastructures has integrated both technologies in a unique installation called dual changeover facility, in use for commercial passenger trains.

BT variable gauge wheelset

In Bulgaria, engineer Nikola Haydarov proposed the design of variable gauge wheelset. Wheels in variable gauge wheelset run independently relative to the fixed axis. Just like in TALGO and BRAVA systems, the reorganization of wheels for the required track is made with unloaded wheels. Standard bogies of Y25 type for freight cars with some design changes (Y25 Lsd-2M type) were equipped with wheelsets of Haydarov system. Table-type GCDs are used for track changeover of such bogies. The maximum speed of the cars on the section of track with gauge changeover device can reach 30 km/h.

To test the possibility of using VGW of Bulgarian production Lviv Railway bought 10 bogies of Y25 Lsd-2M type in 1994. The refrigerator car was equipped with these bogies. It was subjected to dynamic and running tests. Monitoring of variable gauge wheelsets during dynamic tests did not reveal any defects in their work. The efficiency of the mechanism of automatic change of position of wheels according to the track gauge was tested on changeover device at Batievo station on Lviv railway. The results of running dynamic tests showed a number of shortcomings of Y25 Lsd-2M-type bogies due to which they were not allowed to be used on the railways of Ukraine. The main reason for this conclusion was the unsuitability of the design of bogies for 1435 mm track to the work on the railways with 1520 mm track.

SUW2000 system

Options of variable gauge wheelsets for passenger and freight cars were first proposed by famous Polish designer and researcher Ryszard Maria Suwalski [11, 13, 14]. His system named SUW2000 got a practical application. Wheelsets of SUW2000 system are used for equipping bogies of both passenger and freight cars. Fig. 2 shows 25AN/S-type bogie for passenger cars that meets the requirements of Technical Specifications for Interoperability.

Fig. 2. 25AN/S-type bogie

6RS/N-type bogie for freight cars was developed within the framework of the international project INTERGAUGE [2] (Fig. 3).

The first (presentation) run of the train with cars with VGW of SUW2000 system was in April, 2000 [3]. Then, after the transition from 1435 mm track to 1520 mm track at Zamost station of LHS line the said train arrived at Kovel station on Lviv railway. This run marked the beginning of works on studying the possibility of admission of cars with VGW of SUW2000 system to the operation on railways with 1520 mm track.

Fig. 3. 6RS/N-type bogie

According to the joint decision of UZ and PKP, Ukrainian-Polish group of experts for studying the conditions of joint operation of cars with VGW of SUW2000 system was created. According to the agreed plans of scientific and research works, running dynamic tests were performed and computer simulation of dynamics of cars with VGW of SUW2000 system was made [4, 6].

Theoretical and experimental studies have found that 25AN/S-type bogies with VGW of SUW2000 system provide dynamic performance of traffic safety and smoothness of movement of passenger cars at the level sufficient for normal operation on the railways with 1520 mm track. In view of the positive results of these studies it is recommended to equip the batch of cars with 25AN/S-type bogies in order to carry out experimental operation on the route chosen for the organization of high-speed passenger transportation in international traffic. In autumn 2003, there was a series of experimental runs of passenger cars with 25AN/S-type bogies, including the route Warsaw – Krakow – Lviv – Kyiv – Dnipropetrovsk – Sevastopol. Since December 2003, passenger trains composed of cars with 25AN/S-type bogies were in experimental operation in transportations between Ukraine and Poland. At the first stage, these trains run on the route Kyiv – Krakow for three years.

During operation on this route a number of weaknesses of VGW related to the manufacture of individual units was found. After the implementation of measures to ensure traffic safety that were justified by the results of scientific, and R&D works, the operation of trains on the line Lviv – Krakow – Wroclaw (second stage) has been renewed since May 2009. The analysis of operation of bogies with VGW of SUW2000 system showed that the technical problems that prevent the spread of this system have been mostly resolved, and that it is possible to create conditions under which these vehicles can operate without fails.

DB AG/Rafil Type V variable gauge wheelsets

The development of the first versions of this system started in 1965-67 years in Ilsenburg. The series of variable gauge wheelsets for freight cars named RS DR I – RS DR IV was developed. In the 1990s, German railway DB AG became interested in this technology and took part in developing the latest version of DB AG/Rafil Type V VGW [16], which is similar to SUW2000 system wheelset in means of operation (Fig. 4). Thanks to the compliance of mechanism of interaction with track structure in the area of transition from one track to another VGW of SUW2000 system and DB AG/Rafil VGW the same gauge changeover device can be used for variable gauge wheelsets of both Polish and German production.

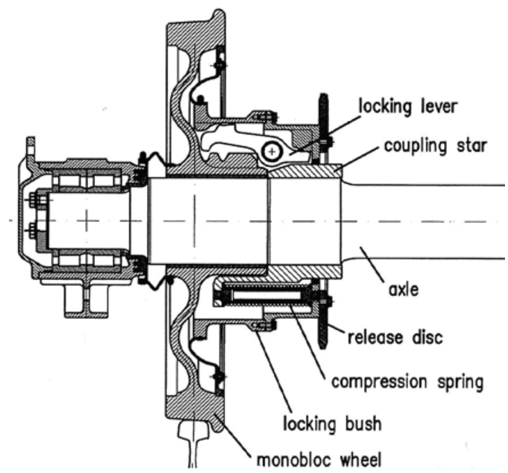

Fig. 4. The structure of the mechanism DB AG/Rafil Type V VGW (unlocked state)

Prototype models of DB AG/Rafil VGW were primarily established in 18-100 bogies of freight cars for 1520 mm track. These cars were equipped with automatic devices for rearrangement of brake blocks. Experimental operation of upgraded cars was held in Germany – Poland – Lithuania route.

It should be noted that the upgrading of existing freight cars for 1520 mm tracks by application of DB AG/Rafil VGW has a fundamental disadvantage which is that the cars with 18-100 bogies cannot be operated on the European railways with 1435 mm track with maximum speeds above 80 km/h. Moreover, according to the UIC Leaflet 505-1, cars for 1520 mm track exceed the allowable dimensions. In this regard, upgraded freight cars for 1520 mm track can be used on 1435 mm track but with major operational constraints, which certainly will affect the indicators of economic feasibility of such transportations.

Y25 Lsd1-type bogies are equipped with DB AG/Rafil variable gauge wheelsets. The design of Y25 Lsd1-type bogie is based on a standard car bogie and is designed for the use on tracks with standard gauge, VR Finnish Railways tracks and tracks of the CIS and Baltic countries.

The design of the bogie corresponds to the structure of Y250type bogie, but the frame width is increased so that to increase the distance between the axes of the side beams to 2036 mm for operation on broad gauge tracks. Cars with DB AG/Rafil Type V wheelsets have been successfully tested for several years in different countries and in different climatic conditions (from Spain to Sweden / Finland). These wheelsets are universal and can be used in any freight or passenger bogies with block or disk brakes.

3. Prospects for development of cars fleet for 1520/1435 mm track

An important decision regarding considerable improvement of conditions of freight transportation by international transport corridors is the introduction of the rolling stock that would operate on 1435 mm and 1520 mm tracks. Creation of cars for 1520/1435 mm track or, in other words cars of „East-West" type, for transshipment-free transportation between railways of different standards, including transportation with mixed schemes will significantly increase the volume of international transportations, which will contribute to unloading of highways and environmental protection.

There are following options to organize transshipment-free transportation in „East-West" directions by adapting the 1435 mm track cars to conditions of 1520 mm track railways:

1. Production of 1520/1435 mm track cars in accordance with OSJD/UIC and TSI Leaflets.
2. Adapting 1435 mm track cars to conditions of 1520 mm track railways.

The first option is the most complex and is designed for long-term prospects as a universal and one that requires considerable fleet of „all-terrain" 1520/1435 mm track cars. The second option seems to be achievable in the short term with a possible purpose of freight transportation on certain routes from Ukraine and in Ukraine mainly by trains of permanent set with 1435 mm track cars. It would also be possible to include groups of such cars in freight trains on 1520 mm track railways. Implementation of this option is possible through the purchase of certified cars for 1435 mm track (purchase, leasing, creation of compatible fleet of cars etc.).

It is necessary to perform specific types of adaptation of cars brake equipment in order to ensure compatibility with systems of brake control of locomotives for 1520 mm track. It is also necessary to prepare the required number of transition cars at border stations.

To set the security conditions for trains composed of 1435 mm track cars or groups of such cars on 1520 mm track railways it is necessary to perform appropriate dynamic calculations using mathematical simulation methods. According to the results of computer modeling, it will be necessary to prepare and perform test runs with the measurement of dynamic processes in the experimental train.

The necessary step to organize work on transportation without transshipment is the development of instructions for station employees, cars' inspectors and drivers on the specified routes for trains with cars or groups of cars of Western European type. Road staff on routs of trains' runs should get appropriate training on issues related to maintenance of new types of cars. Furthermore, the necessary spare parts for braking systems and coupling devices should be prepared on these routes. After commissioning of trains for freight transportation without transshipment it will be required to organize works on constant monitoring of upgraded bogies, brakes and traction equipment devices in some areas of the route.

Currently, there are no specific procedures for admission to operation of the rolling stock designed for the use on 1520 mm and 1435 mm tracks railways [5]. Therefore, the question of admission to operation of cars in international traffic is determined by bilateral or multilateral agreements between the railway administrations as transportation participants. Basic requirements for procedural provisions of admission are listed below.

Cars for international transportations must undergo the following extensive tests before the admission to operation: stationary, structural, running, braking and train tests. These tests are necessary to determine the extent of compliance of the car with technical requirements on criteria of traffic safety, fatigue life, reliability and functionality.

It is necessary to verify calculations and simulations of dynamics and strength appointed according to the required standards before the series of necessary tests for cars with bogies with variable gauge wheelsets on 1520 mm track. For the purpose of admission to model tests it is necessary to verify the conformity of solution for bogies with variable gauge wheelsets with technical requirements and design documentation, as well as to assess the compliance with regulatory requirements for freight cars for 1520 mm track. There is also a need to check the quality certificates, permits, certificates, conclusions regarding each element and material.

4. Conclusions

The implementation of ATGS technology in railway and piggyback traffic from Ukraine to the EU will reduce the logistics costs of transportation of goods by rail, decrease the sources of risk by providing more secure and preserved transport, reduce losses and damageability of cargo, speed up the turnover of working capital cargo, increase the efficiency of operating cars, will create favorable conditions for railway transportation service users. The use of automated systems at transition points of 1520/1435 mm tracks is rather attractive because it substantially reduces the time of crossing the borders with EU countries and eliminates the need for storage of exchangeable bogies at the points of cars rearrangement or transshipment organization.

The systematic work on the organization of transshipment-free transportation in „East-West" strategic directions should include the formation of specialized fleet of cars adapted to conditions of operation on the railways with both 1520 mm and 1435 mm track gauge.

The creation of cars of the „East-West" type for combined transport will significantly increase the volume of international transportation, which will contribute to unloading of highways as well as to environmental protection. The rolling stock of the said type will provide the solution for problems with the supply of a wide range of goods, including transshipment cargo, to the EU and in the opposite direction. The owners of such rolling stock will get certain economic and competitive advantages in European market of transportation services.

Literature

1. Álvarez A.G.: *Automatic track gauge changeover for trains in Spain*, *Documentos de explotación económica y técnica del ferrocarril,* Fundación de los Ferrocarriles Españoles, 2010, 107 p.
2. Basiewicz T., Gołaszewski A., Towpik K.: *Nowa technologia na kolejach o różnej szerokości torów.* Problemy Kolejnictwa, Warszawa, Zeszyt 144, 2007, s. 5–19.
3. *Brama na Wschód*, Nowe Sygnały, 2000, No20, s. 12–13.
4. Diomin Yu., Chernyak A.: *Interaction of gauge change wheelsets and the rail track.* Proceedings of 17th International Wheelset Congress, Part 1. Kiev, September 22–27, 2013, p. 70–75.
5. Diomin Yu., Domin R.: *Procedural issues acceptance of rolling stock gauge 1435/1520 mm,* Prace Naukowe Politechniki Warszawskiej, Transport, z. 98, 2013, s. 119–124.

6. Domin Yu., Suwalski R., Cherniak A.: *Ride quality of the car on tracks with gauge change wheelsets,* Journal of Volodymyr Dahl East Ukrainian National University, No6 (52), 2002, p. 62–65.
7. Domin Ju.: *Techniczne problemy przewozów kolejowych Wschód – Zachód,* Przegląd Komunikacyjny, No 6, 2008, s. 3–7.
8. Domin Ju., Slobodian A.: *Technika kolejowa kombinowanego transportu Ukrainy*, Problemy Kolejnictwa, Warszawa, Zeszyt 156, 2012, s. 5–15.
9. Garicoix M.: *La saga des frères ennemis*. La Vie du Rail, No3173, 2008, p. 20–25.
10. Gomez J.L.L., Aisa J.L.: *Talgo automatic gauge change system for freight wagons*, Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, Vol. 215, Part F, 2001, p. 13–24.
11. Graff M.: *System SUW2000 w komunikacji przestawczej 1435/1520 mm*, TTS Technika Transportu Szynowego, z. 1–2, 2016, s. 34–53.
12. Poliński J.: *Technika przesuwnych kół taboru warunkiem usprawnienia przewozów na styku kolei 1435/1520 mm,* Problemy Kolejnictwa, Warszawa, Tom 59, z. 167, 2015, s. 57–68.
13. Suwalski R. M.: *Wózki 25AN i 25ANa do wagonów osobowych i typu osobowego*, TTS Technika Transportu Szynowego, z. 2, 1994, s. 4–12.
14. Suwalski R.M.: *SUW2000: Wózki towarowe i osobowe w automatycznym ruchu przestawczym 1435/1520 mm,* TTS Technika Transportu Szynowego, z. 7/8, 2000, s. 32–44.
15. Suwalski R. M., Lustych M., Gołaszewski A.: *Udoskonalona technologia pokonywania różnic szerokości toru*, Przegląd Komunikacyjny, z. 6, 2000, s. 1–10.
16. Villmann J., Schwartze M.: *Vorstellung des Spurwechselradsatzes „RAFIL/DB AG Typ V" sowie der zugehörigen Systemkomponenten,* Symposium „Automatische Umspurung von Schienenfahrzeugen", Wien, 2005, s. 22.

Techniczne i technologiczne środki zapewnienia rozwoju transportu interoperacyjnego pomiędzy Ukrainą i Unią Europejską

Streszczenie
Artykuł charakteryzuje aktualne trendy rozwoju międzynarodowego transportu kolejowego pomiędzy Ukrainą i krajami Unii Europejskiej. Przedstawia stan wdrożenia wyników badań w zakresie technologii bezprzeładunkowej w transporcie towarów, a zwłaszcza doświadczenia związane z Europejskim Systemem Automatycznej Zmiany Kół (AGCS). Opisuje prace naukowo-techniczne dotyczące transportu intermodalnego, wykorzystującego technologię AGCS. Analizuje perspektywy rozwoju i praktycznego zastosowania podobnych systemów w warunkach akcesji Ukrainy do sieci transportowej Unii Europejskiej.

Słowa kluczowe: transport kombinowany, tabor, zmiana rozstawu kół

Технические и технологические средства обеспечения развития совместимого транспорта между Украиной и Европейским союзом

Резюме
В статье представлены реалистические тенденции развития эффективного международного железнодорожного транспорта между Украиной и странами Европейского союза, основанных на внедрении результатов научных и технических исследований, касающихся технической поддержки грузового транспорта согласно безперегрузочным технологиям, особенно опыт по Европейской системе автоматического изменения расстония колес (AGCS). Представлены информации на тему научно-технических проектов касающихся интермодального транспорта основанного на технологиях, позваляющих использовать систему AGCS. Обсуждаются перспективы развития и практического использования похожих систем на фоне присоединения Украины к транспортной сети Европейского союза.

Ключевые слова: комбинированные перевозки, подвижной состав, изменение межосевого расстояния