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ANALYSIS OF ROLLING STOCK COUPLING DESIGNS AND TECHNOLOGIES FOR THE IMPLEMENTATION OF INTERNATIONAL RAILWAY OPERATIONS BETWEEN UKRAINE AND THE EUROPEAN UNION

Summary. *The purpose of this study is to analyze the existing and prospective coupling device designs and technologies for their application in organizing international railway operations between Ukraine and the European Union. The research identifies the main technical barriers associated with domestic rolling stock and explores optimal pathways for integrating Ukrainian rolling stock into the European transport system. The study also considers the possibility of adapting EU-member-state wagons for operation within the railway network of JSC “Ukrzaliznytsia”.*

An analysis of regulatory and technical documentation was conducted, including DSTU, UIC, and EN standards, as well as regulatory documents of the Council for Rail Transport, which define the requirements for coupling devices and rolling stock. A comparative review was conducted, followed by a detailed investigation and analysis of the design, operating conditions, and structural features of various types of couplers: SA-3 automatic couplers, screw couplings, universal systems, and digital automatic coupling systems (DAC).

The research employs a systematic approach, providing a comprehensive assessment of operational performance, safety levels, and the economic feasibility of deploying each of the examined coupling technologies.

The object of the study comprises the designs and performance characteristics of railway rolling stock coupling devices and the technologies governing their use in international railway operations on both 1520 mm and 1435 mm gauge networks.

The results obtained based on a systematic analysis of regulatory documents for rolling stock operating on 1520 mm and 1435 mm gauge networks, as well as the design features and engineering solutions of coupling systems. They also include the identification of key directions for the development and implementation of modern coupling technologies for international railway operations involving both freight wagons and passenger rolling stock. The analysis considers the specific operational conditions at border crossing points and stations, as well as the local operational and environmental constraints that affect rolling stock operations.

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A comprehensive assessment of the compatibility between SA-3 automatic couplers and screw coupling systems under international transport conditions between Ukraine and EU member states has been performed. Contemporary technologies enabling the adaptation of rolling stock for joint operation on 1520 mm and 1435 mm gauge networks have been systematized, including adapter devices, variable-gauge systems, and combined coupling configurations. A model for the phased integration of the Ukrainian automatic coupling system into European standards has been developed, utilizing transitional technical solutions.

The results of the research can be applied to the development of technical regulations for rolling stock modernization, wagon and train handling technologies, and engineering solutions for designing wagons and locomotives intended for interoperable operation on both 1520 mm and 1435 mm gauge systems. The proposed recommendations will help reduce dwell times at border crossing points by eliminating the need for coupling device replacement. Additionally, they will help reduce operating costs and increase the efficiency of logistics processes for wagons equipped with screw coupling systems by automating train formation procedures, while enhancing operational safety. The findings of this study may be useful for infrastructure projects aimed at integrating the Ukrainian railway network into the European transport system.

Key words: *rolling stock, coupling devices, automatic coupler, screw coupling, buffer assemblies, regulatory documents.*

1. INTRODUCTION

The railway transport sector of Ukraine currently plays a leading role in ensuring international logistics between Ukraine and the European Union. However, given the dynamic development of the railway industry abroad and the protracted processes of transformation and reform within the country, there is a risk of a gradual decline in its competitiveness. This risk may materialize if technical safety regulations are not adhered to and if adequate solutions are not implemented to ensure the safe operation of 1435 mm gauge rolling stock on the Ukrainian network with the existing 1520 mm gauge.

One of the main technical barriers between Ukraine and the EU is the difference in track gauge and the incompatibility of coupling device designs. The gauge difference is successfully addressed at border stations by replacing bogies or by using wheelsets equipped with automatic gauge-changing systems. In recent years, sections of railway track leading to Mukachevo and Uzhhorod have been modernized and connected to the 1435 mm gauge network, further expanding the possibilities for the mixed utilization of 1520 mm and 1435 mm gauge rolling stock. The strategic plans of both the EU and Ukraine include the extension of the 1435 mm gauge to Kovel, Lviv, and other major cities.

Nevertheless, these developments neither eliminate the issue of differences in rolling stock coupling systems between the 1520 mm and 1435 mm gauge networks, nor the task of accelerating train formation processes and enhancing operational safety in the presence of screw coupling systems. Therefore, the issue of rolling stock coupling remains unresolved. Currently, the replacement of coupling devices is performed using traditional “legacy methods”, i. e., by substituting the automatic coupler with a screw coupling assembly, which is acceptable only for short trains. However, considering that freight trains operating in Ukraine may consist of 40–60 wagons of the 1435 mm gauge, the process of changing coupling systems will inevitably cause delays and raise several technological concerns, including the provision of adequate stocks of automatic couplers and screw couplings, storage, and designated locations for replacement operations.

A similar challenge arises for 1520 mm gauge rolling stock intended for operation on 1435 mm gauge infrastructure. These factors create significant difficulties in organizing uninterrupted freight flows in both directions – towards Ukraine and towards EU countries – and necessitate additional operations at border crossing points or at stations with dual-gauge infrastructure. It, in turn, reduces the efficiency of logistics processes.

For these reasons, the issue of rolling stock coupling remains a highly relevant and technically critical problem. It requires a thorough analysis of coupling designs used in the existing fleet, which is currently widely deployed and operated, as well as in new wagons and locomotives that will be introduced in the near future for international railway operations.

2. STATEMENT OF THE PROBLEM AND RELEVANCE OF THE STUDY

The growing volume of railway transport between Ukraine (1520 mm gauge) and the European Union (1435 mm gauge), as well as the increasing need for operational stability and safety, is accompanied by a number of technical barriers, among which the incompatibility of rolling stock coupling systems is one of the most critical. In Ukraine, the SA-3 automatic coupler (international Willison type) is traditionally used, whereas in Europe, the standard system is the buffer and screw coupling. Currently, the EU is implementing Digital Automatic Couplers (DAC), which combine mechanical, pneumatic, and electro-digital connections. These developments have been ongoing for many years, but in recent years, following the adoption of new EU Railway Directives [1, 2], the work has received additional funding and, consequently, gained new momentum in research and implementation.

During the transitional period, several countries have developed hybrid coupling solutions, including the combined C-AKv coupler [3] and the LAF system (CIM Groupe) [4], which offer automation while remaining compatible with the existing buffer-and-screw rolling stock fleet.

The current challenge is in identifying a technically and economically justified solution that will allow the integration of the Ukrainian railway network into the European transport system with minimal costs and maximum efficiency.

The purpose of this study is to analyze existing coupling device designs used on 1520 mm and 1435 mm gauge rolling stock, as well as the new digital couplers that are undergoing extensive testing and evaluation on EU railways. The research also examines modern coupling technologies and their potential application in organizing international transport between Ukraine and EU member states, identifies key technical barriers, and outlines optimal pathways for integrating Ukrainian rolling stock into the European transport system.

The principal approaches to solving this problem can be summarized as follows:

- the use of transition couplers at border stations, for example, the LAF-type automatic coupler;
- the deployment of barrier wagons equipped with different coupling systems at each end (SA-3 coupler on one end and screw coupling on the other);
- the formation of mixed rolling stock, with locomotives of different standards arranged according to predefined operational schemes;
- the use of dedicated adapter devices enabling the connection of wagons equipped with automatic couplers to those with screw couplings;
- the gradual introduction of UIC-type automatic digital couplers (DAC) as a long-term strategic objective for EU railways.

3. ANALYSIS OF THE RECENT RESEARCH AND PUBLICATIONS

The basic coupling system used for freight and conventional passenger trains in EU member states is shown in Fig. 1. It differs significantly from the one employed in Ukraine, illustrated in Fig. 9. The coupling of trains (wagons) presents difficulties and requires additional devices to ensure compatibility when connecting locomotives and wagons equipped with different coupling systems.

The “buffers + screw coupling” arrangement is the dominant coupling configuration on 1435 mm gauge railways. This system consists of two primary components: a hook with a screw traction and coupling device, and buffers. The hook and screw coupling (screw coupling system) provides manual coupling with length adjustment and buffer compression / locking. According to EN 15566, this coupling system is classified by permissible working force levels of 1.0 / 1.2 / 1.5 MN [5] and performs solely a traction function, transmitting tensile forces only.

The buffer devices used on 1435 mm gauge wagons (a pair of side-mounted components on each end of the vehicle) are designed to absorb and dissipate longitudinal impacts. Their technical characteristics, parameters, and categories (energy-absorption performance ranges) are defined in

UIC 526-1 and EN 15551 [3, 4]. Typical buffer devices for freight wagons provide an energy absorption capacity of 70–80 kJ under compression forces of approximately 625–1000 kN, while crash-optimized solutions may reach 250–400 kJ.

In recent years, several EU countries have initiated the development and implementation of DAC for freight wagons. These systems are intended to replace traditional screw couplings and to digitalize train operations. DAC systems integrate pneumatic lines, power supply circuits, control systems, and incorporate a data bus enabling the exchange of wagon- and train-related information. The development of DAC technology is supported by the European DAC Deployment Programme (EDDP / Europe's Rail) [8] under the Europe's Rail Joint Undertaking.

Fig. 1. General view of the screw coupling with buffer devices

A design decision has been taken at the European level to adopt the latch-type coupler, based on the Scharfenberg automatic coupler, as the principal and target standard for future DAC implementation. A general view of the Scharfenberg-type DAC manufactured by Voith, specifically the CargoFlex model, is presented in Fig. 2 [9].

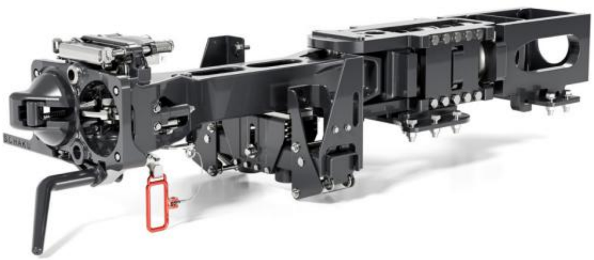


Fig. 2. General view of the Scharfenberg-type DAC (CargoFlex) manufactured by Voith for freight wagons [9]

According to the assessment of developers and researchers [9], this DAC has the potential to revolutionize rail freight transport by enabling automatic connection and disconnection of air brake lines, data transmission lines, and power supply systems within trains. Its declared functions promise to make rail freight transport significantly faster, safer, and more efficient compared to existing solutions, while simultaneously reducing environmental emissions, both material and noise-related. Noise reduction is one of the priority objectives of the European Green Deal, which is increasingly shaping regulatory changes in the transport sector.

In summary, DAC establishes an entirely new technological standard that is crucial for the future success of European rail freight systems. In addition to the developer Voith, there are a number of other major developers such as: Dellner Couplers AB [10] (Fig. 3), Knorr-Bremse AG [11] (Fig. 4) and Wabtec Corporation (Fig. 5) [12].

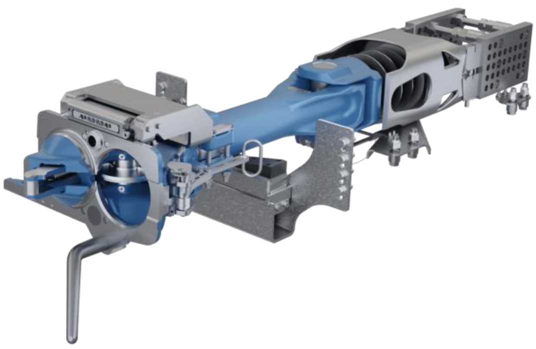


Fig. 3. General view of the Scharfenberg-type automatic coupler manufactured by Dellner Couplers AB [10]

Fig. 4. General view of the Scharfenberg-type automatic coupler manufactured by Knorr-Bremse AG [11]

Fig. 5. General view of the Scharfenberg-type automatic coupler manufactured by Wabtec Corporation [12]

As can be seen from their general appearance, all the couplers share the Scharfenberg-type architecture, with specific design differences.

The use of DAC has been studied in accordance with the DAC deployment project [8], with evaluations carried out by approximately 100 EDDP experts representing 36 companies. The experts assessed the results of two testing consortia – DAC4EU (funded by BMVI) and the Trafikverket / Swedish Winter Tests (funded by S2R), as well as previous Shift2Rail research, during specialized workshops dedicated to each coupler type held in late July 2021. As a result, only three types of DAC were identified and recommended for use on European railways [8]. However, it does not impose any strict limitations and leaves the market open to a broad range of companies that adhere to and implement the European standard for digital automatic coupling, EN 18171:2025 [13], which is currently under development.

According to publicly available sources, the DAC must withstand specified static loads without exhibiting any plastic deformation. It must also comply with the requirements of EN 12663-1:2010+A2:2023 or EN 12663-2:2024 [14]. According to these standards, the tensile load capacity is 1000 kN, the compressive load capacity is 2000 kN, and the nominal breaking load under tensile forces is 1500 kN.

These values are significantly higher than the current regulatory limits for wagons operating in international traffic, as specified in OSJD Leaflet O 521 [15], where the tensile and compressive load ratings for the screw and hook are 850 kN and 1000 kN, respectively. Compressive loads are transmitted through buffer devices, with the standardized compressive capacity of buffer systems set at 2500 kN according to OSJD Leaflet O 529/1 [16].

A significant step toward the deployment of DACs has been taken by Dellner Couplers AB, which to date has delivered several versions of DAC and is systematically adapting its designs to emerging requirements (Fig. 6).

The C-AKv coupler enables the transmission of both tensile and compressive forces for heavier and consequently longer freight trains, with the potential to double the train length (Fig. 7). Furthermore, it provides an automatic connection of the pneumatic interface, the electrical power supply interface, and the data communication line running through the train, while remaining fully compatible with both the existing buffer and screw coupling system and the SA-3 automatic coupler, widely used on Ukrainian railways.

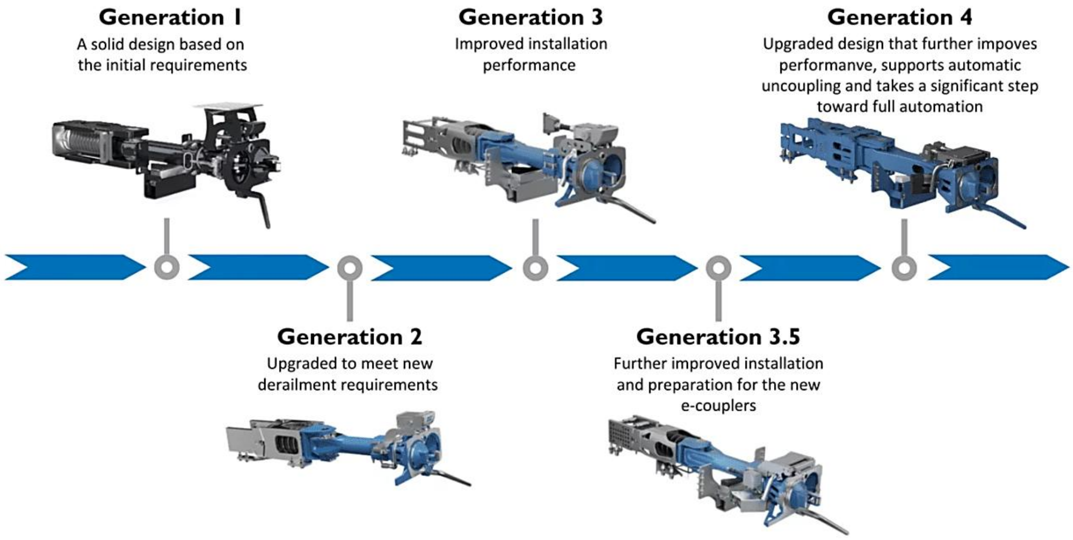


Fig. 6. Variants of DACs manufactured by Dellner Couplers AB [7]

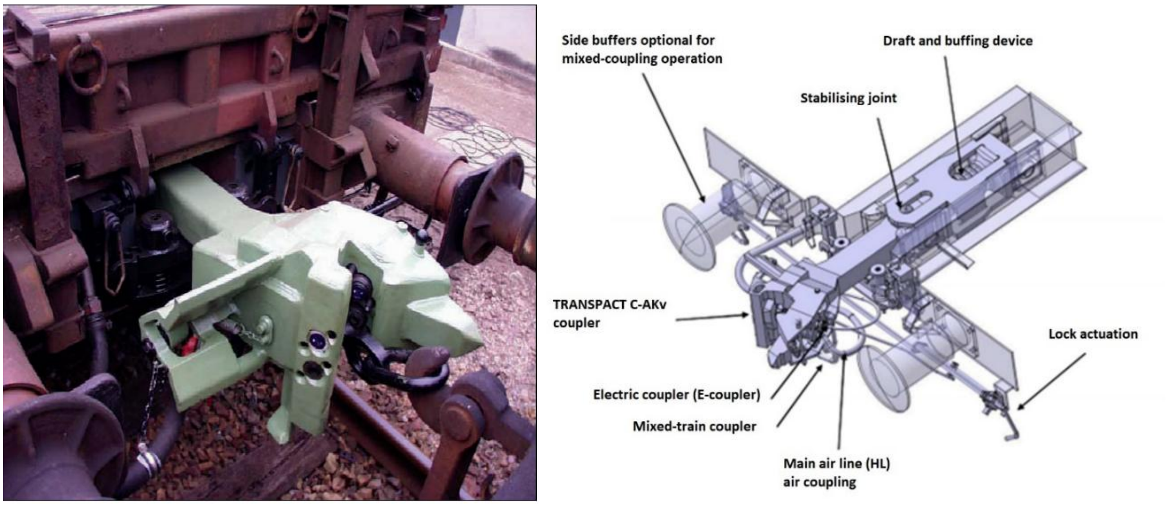


Fig. 7. General view of the C-AKv automatic coupler and its principal components [3]

It ensures the possibility of establishing a transitional phase for retrofitting the wagon fleet with modern DACs.

One variant of automatic coupling systems is the LAF-type coupler [14], as shown in Fig. 8.

For Ukrainian railways, several types of automatic couplers are in use, specifically the SA-3 coupler and its upgraded versions, including the SA-4 [9]. A general view of these couplers is shown in Fig. 9.

The C-AKv coupling system [3] automates coupling and uncoupling operations, thereby accelerating the entire rail freight handling process. It results in significantly higher system performance and increases the turnover rate of rolling stock.

The SA-4 automatic coupler features a reinforced shank compared with the SA-3. In the central part of the shank's end face, there is a flat bearing surface along the width of the draft-wedge opening [17, 18]. This design partially reduces stress concentration in the shank web. The web surface on the wedge-opening side is enlarged, and the draft wedge itself is made thicker, thereby reducing contact stresses in this zone.

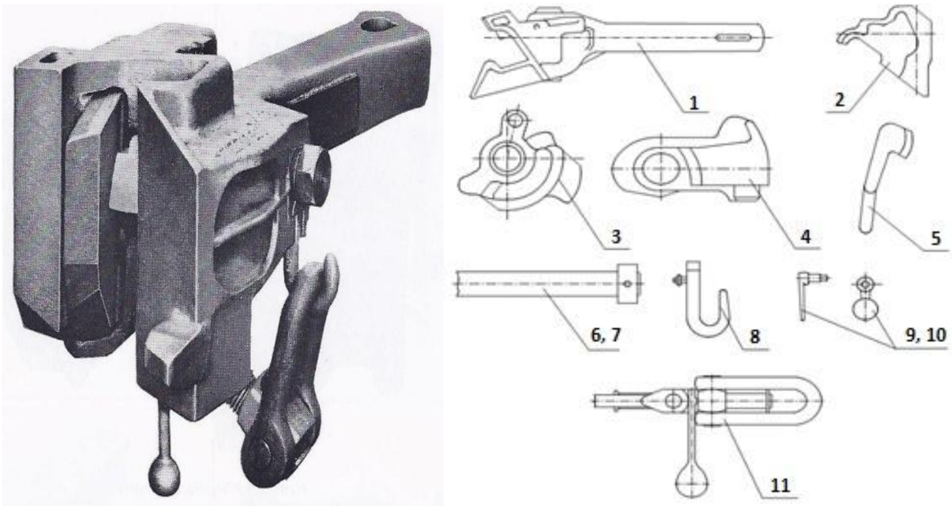


Fig. 8. LAF automatic coupler [14]: 1 – coupler head;
2 – locking mechanism; 3 – unlocking cam; 4 – protective housing;
5 – latch; 6 – head bolt; 7 – nut; 8 – screw-coupling suspension;
9 – lever; 10 – optical indicator (coupling status indicator); 11 – special screw coupling

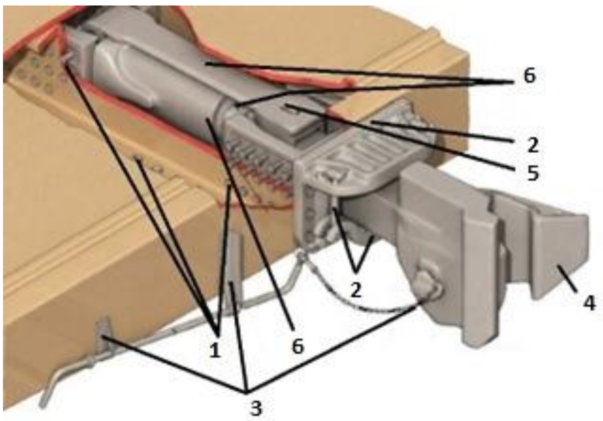


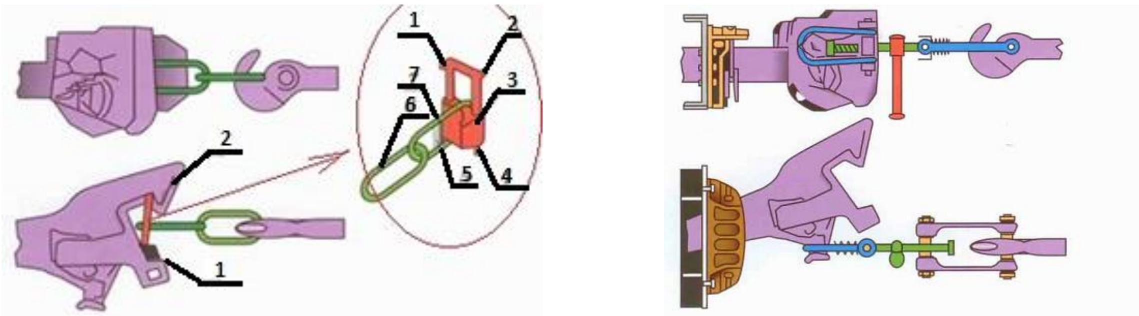
Fig. 9. General view of the SA-type automatic coupler
and its mounting on the wagon [17]: 1 – front and rear stops;
2 – components of the draft and centering gear (draft pocket, pendulum
suspension links, centering beam); 3 – components of the uncoupling mechanism
(two-arm lever, uncoupling chain, brackets); 4 – automatic coupler with mechanism;
5 – draft wedge; 6 – yoke (draft gear)

A guiding wing is installed in the lower part of the coupler body, limiting the vertical movement to 100 mm and converting the originally non-rigid coupler into a semi-rigid coupling system. The use of this guiding wing increases the “capture zone” to 140 mm between longitudinal axes, eliminating the possibility of buffer-overrun.

The uncoupling mechanism features a rigid design with a sliding joint, preventing accidental uncoupling in the event of a coupler-head break and preventing the head from falling onto the track. The redesigned coupling mechanism excludes damage to components under any coupling conditions.

The coupler lock is spring-loaded and capable of translational movement, preventing the possibility of the lock jamming in an intermediate position. This type of coupler was intended for installation on new-generation wagons. The SA-4 coupler retains the standard SA-3 coupling contour, ensuring full mechanical interoperability with SA-3. However, operational experience revealed persistent problems with the mechanism, and the SA-4 design has since been abandoned.

There is also the option of connecting wagons equipped with an automatic coupler to wagons with a screw coupling by means of special adapter devices (Fig. 10).



a *b*

Fig. 10. Adapter devices and variants of connecting an automatic coupler to a screw coupling with using an adapter (a) or using a special seal on the coupler body (b) [18]: Adapter (highlighted): 1 – small knuckle (SA-3); 2 – large knuckle (SA-3). Adapter components: 1,2 – adapter cross-bars; 3 – lock housing (adapter body); 4,5 – lock guides; 6,7 – two rings.

For rolling stock operating in international connection, the OSJD (Organization for Cooperation between Railways) [19] technical requirements prescribe coupling configurations presented below.

Variant A. Wagons are equipped with automatic couplers on both ends. It is permitted that, when transferring from the 1520 mm network to the 1435 mm network, the automatic couplers of these wagons may be replaced with draw gear and buffing gear (screw coupling and side buffers). Conversely, when transferring from the 1435 mm gauge network to the 1520 mm network, the traction and buffing devices of EU wagons may be replaced with automatic couplers accordingly [6, 20].

Variant B specifies that wagons are equipped with side buffers at each end, in accordance with UIC Leaflet No. 526-1 [6, 20] and feature a mixed traction coupling system (TCS). Under this configuration, the use of a mixed-operation coupling, which combines the properties of an automatic coupler and the ability to connect to a screw coupling, is permitted. Therefore, in this variant, it must be ensured that, in the event of an emergency, the mixed SA-3/screw-coupling arrangement installed for operation on networks with differing track gauges can be replaced with standard coupling equipment for wagon interconnection.

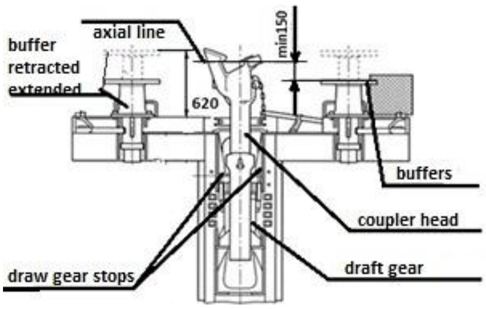


Fig. 11. Wagon equipment with draw and buffing gear according to Variant C (OSJD / ISZD) [20]

According to Variant B, the SA-3 automatic coupler shall have dimensions of 1000–1010 mm from the end face of the shank to the coupler centerline.

Variant C provides that wagons are equipped on each end (console) with both automatic couplers and side buffers [6, 20] (in accordance with UIC Leaflet No. 526-1), with two buffer positions relative to the wagon buffer beam: a retracted (short) position and an extended (long) position.

In this configuration, the buffers [6, 7, 20] are fastened to the buffer beam using additional mounting elements (Fig. 11). Wagons built according to this scheme are equipped with an energy-absorbing draft gear, which simultaneously complies with the requirements of UIC Leaflet 526 (in terms of parameters) and with the requirements of the 1520 mm gauge railways [6, 7, 19].

Buffers in the retracted position (short position) must ensure that wagons coupled by automatic couplers operate without contact between the buffer plates under any operating conditions.

Buffers in the extended position (long position – 620 mm) must ensure correct operation for wagons coupled by mixed traction couplings, as well as for wagons coupled by screw couplings, with the required installation dimensions and arrangement on the wagon in accordance with Fig. 11.

The energy-absorbing draft gear must also allow the installation of a mixed SA-3 transition coupling (screw coupling with wedge insert).

The requirements for automatic couplers for wagons are defined in the Rules for the Use of Freight Wagons in International Connection [21]. For wagon equipment, a semi-rigid SA-3 automatic coupler or prospective variants currently undergoing testing on EU railways, such as the CargoFlex type or other DAC, shall be used. The basis for these coupling requirements is the technical specification applicable to the 1520 mm gauge.

The automatic coupler and the energy-absorbing draft gear installed on wagons must comply with current requirements of the 1520 mm gauge railways. They must have the appropriate authorization for service issued by these railways or their respective regional directorates.

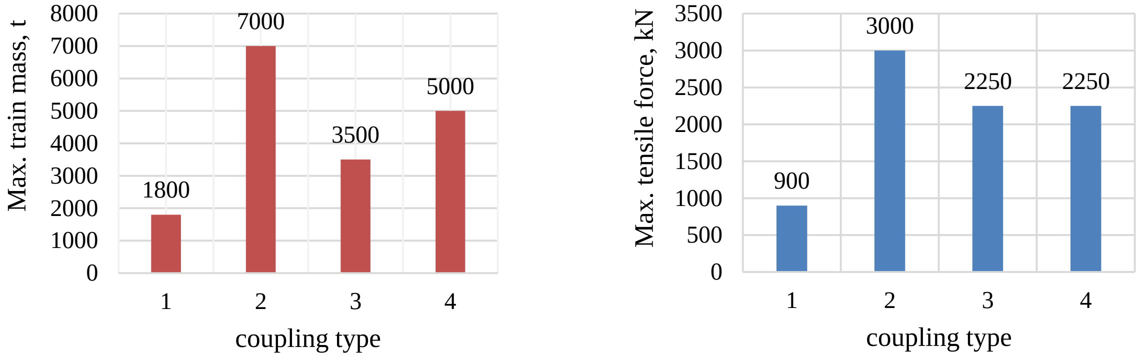
Summarizing the technical properties, capabilities, and characteristics of automatic couplers and screw couplings, a consolidated comparative overview can be presented, as shown in Table 1.

Table 1

Comparative characteristics of coupling systems in the EU and in Ukraine

Parameter	Buffer & Screw, (EN 15566)	Willison type (CA-3)	C-AKv / LAF (hybrid automatic)	DAC (Knorr-Bremse, Voith CargoFlex)
Type of coupling	Manual, with buffers	Automatic, central	Automatic, central + hybrid compatibility	Automatic: mechanical, pneumatic, digital
Max. tensile force	~850–1000 kN	≈3000 kN (working); up to 4000 kN (peak)	≈2000–2500 kN (depending on design)	~2000–2500 kH (standard DAC4EU)
Max. compressive force	~1500–2000 kN (via buffers)	~2500–3000 кN	≈2000–3000 kN	~2000–2500 кN
Max. train length	~750 m (EU standard)	≈1500 m (possible >1000 m)	up to 1500 m (depending on design)	1500–2000 m (as specified in DAC projects)
Max. train mass	1500–2000 t	6000–12000 t	4000–9000 t	4000–7000 t
Automation	none	mechanical	partial (mechanical + pneumatic / electric optional)	full (mechanical, pneumatic, electrical, digital)
Digital integration	none	none	optional	full (data bus, ECP, diagnostics)
Interoperability	full in the EU	compatible via adapter (buffer + screw)	compatible with SA-3/ buffer-screw (adapter)	requires full fleet conversion
Coupling speed	3–5 min per wagon (manual operation)	<30 s (automatic)	30–60 s (automatic)	<30 s (automatic, with data)
Staff safety	unsafe (staff enters between wagons)	safe (no staff between wagons)	automatic	automatic

The following charts and diagrams were obtained by visualizing the data presented in the table, as shown in Fig. 12.



a *b*

Fig. 12. Diagrams of maximum train mass and maximum tensile force in coupling systems:
a – max. train mass; b – max. tensile force; 1 – Screw coupling; 2 – SA-3; 3 – C-AKv / LAF; 4 – DAC

The digitalization of coupling processes can be achieved only with modern automatic coupling systems and, to a certain extent, with hybrid couplers of the LAF and C-AKv types.

4. TECHNICAL AND ECONOMIC COMMENTS AND ASPECTS

Based on the analysis of the technical parameters and characteristics of different coupling systems, the findings were summarized and systematized according to the technologies applied during gauge change operations. These aspects may be grouped into two categories: technical and economic. The technical aspects are discussed first.

Screw coupling – the least expensive solution and fully interoperable with the entire EU fleet. However, it has critical limitations in terms of maximum train length and mass, and it does not meet the requirements of railway digitalization.

SA-3 – an exceptionally strong coupling system capable of forming very heavy train rolling stock. However, it lacks integrated electrical, pneumatic, and data interfaces and is incompatible with 1435 mm gauge rolling stock without the use of adapters, which are applied only to a limited extent.

C-AKv / LAF – a compromise solution combining automation with partial compatibility with the buffer-and-screw system, suitable as a transitional standard.

DAC (Voith, Knorr-Bremse, and other manufacturers) – the strategic direction for EU railways. It provides full automation, digital capabilities, and interoperability of all onboard services (braking, power supply, and data communication). Its primary drawback is the high implementation cost and the need for large-scale fleet modernization.

If recommendations regarding the prioritization of coupling systems for wagons in international connection are to be formulated, they may generally be summarized as follows, depending on the parameters considered:

1. If the priority is maximum traction forces and operational simplicity under harsh conditions (the 1520 mm area), then the SA-3 automatic coupler remains a highly suitable choice: robust, reliable, and well-proven in the operating environment of the 1520 mm gauge network and on the lines of JSC “Ukrzaliznytsia”.
2. If the priority is future integration into the Trans-European transport area, digitalization, reduction of shunting time, wagon monitoring, and preparation for ECP / intelligent trains, the DAC (Knorr-Bremse, Voith, or other manufacturers) is the target direction. Several pilot projects are currently underway in the EU (Knorr-Bremse has tested the e-coupler; Voith supplies CargoFlex for DAC4EU). The transition will require substantial investment and staged fleet modernization [10, 11].

3. For phased transition and interoperability with the existing 1435 mm fleet, hybrid solutions are most often considered (C-AKv, LAF/Willison-type couplers, C-AKv as a transitional standard). These systems combine the benefits of automatic coupling with the capability to interface with legacy buffer-and-screw couplings or SA-3 using adapters or combined coupler heads. This option reduces the "transition shock" of large-scale modernization [4].
4. Economics and standards. The implementation of DAC requires not only equipping wagons and locomotives but also establishing harmonized standards and supporting documentation (EN 18171 – the emerging DAC standard currently under development), as well as operational procedures. Until complete standardization is achieved, the most realistic option for mixed-operation traffic remains a combination of hybrid couplers, adapters, and local pilot solutions [10, 11].

Based on the above, a roadmap may be formulated and recommended for Ukraine and for operators working with 1520/1435 mm gauge rolling stock:

1. Assess current freight-flow profiles and the share of long heavy trains that would benefit from the use of the SA-3 automatic coupler. At this stage, operators should evaluate, based on infrastructure characteristics, the feasibility of operating with screw couplings or automatic couplers.
2. Initiate pilot projects for DAC compatibility on selected corridors, in cooperation with manufacturers such as Voith and Knorr-Bremse. This work should be carried out on specific routes identified by operators as future priorities, taking into account forecasted freight volumes. Similar pilot activities are currently being conducted by foreign operators in Switzerland, Austria, and other EU countries [11].
3. Modernize part of the locomotive fleet and key wagons using hybrid C-AKv/LAF solutions to ensure immediate interoperability with the EU network. These technical solutions are particularly relevant at border stations where intensive shunting operations take place or where wagons are processed in large groups.
4. Plan capital investments in standardization efforts (EN 18171 – monitor ongoing development) and in infrastructure adaptations (stations, operational yards, testing equipment). Operators must closely follow the evolution and performance of modern coupling systems, as well as the adoption timeline of EN 18171, which is currently under development and has not yet been finalized [13].

5. CONCLUSIONS AND PERSPECTIVES FOR FURTHER RESEARCH

The conducted analysis confirms that the main technical barrier to integrating Ukrainian rolling stock into the EU transport system is the incompatibility between the SA-3 automatic coupler and the buffer and screw coupling systems widely used in EU member states. While the SA-3 coupler demonstrates high strength and efficiency in forming long and heavy trains, it does not provide automation of auxiliary systems (pneumatics, power supply, data communication).

The traditional buffer and screw coupling system used in EU countries is fully interoperable with the European fleet. However, it imposes significant limitations on maximum train mass and length, and no longer meets modern requirements for railway digitalization and the technological development of the EU railway sector. Transitional and hybrid solutions (C-AKv, LAF) offer a compromise between compatibility and automation, making them suitable as an intermediate stage for integration between the 1520 mm and 1435 mm networks.

DACs, including systems developed by Voith (CargoFlex), Knorr-Bremse, and Dellner, represent the strategic direction for future development as they combine automatic mechanical coupling with integrated pneumatic, electrical, and digital communication interfaces.

Based on the above, the following conclusions may be drawn:

– retention of the SA-3 coupler for heavy trains within the 1520 mm gauge network;
– deployment of hybrid coupling systems (C-AKv/LAF) along border corridors;

– implementation of DAC pilot projects in cooperation with European manufacturers;
– gradual modernization of infrastructure and rolling stock with orientation towards the EN 18171 (DAC) standard;
– harmonization of national standards and technical requirements with European ones in view of Ukraine's integration into the Trans-European Transport Network (TEN-T).

The results of this research can be used to develop of technical regulations for wagon modernization, reduce operational time at border crossing points (stations), and increase the efficiency of Ukraine's international logistics. These findings may also support decision-making by logistics companies and railway operators when selecting suitable rolling stock or planning modernization and repair programs.

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АНАЛІЗ КОНСТРУКЦІЙ ТА ТЕХНОЛОГІЙ ЗЧЕПЛЕННЯ РУХОМОГО СКЛАДУ ДЛЯ ЗДІЙСНЕННЯ МІЖНАРОДНИХ ПЕРЕВЕЗЕНЬ МІЖ УКРАЇНОЮ ТА ЄС

Анотація. *Мета дослідження – аналіз наявних та перспективних конструкцій зчіпних пристроїв та технологій для їх застосування під час організації перевезень між Україною та країнами ЄС. Виконано дослідження та визначено основні технічні бар'єри для вітчизняного рухомого складу, а також здійснено пошук оптимальних способів інтеграції українського рухомого складу в європейську транспортну систему. Проаналізовано нормативно-технічну документацію України, країн ЄС та документи країн залізничної співдружності, що регламентують вимоги до зчіпних пристроїв та рухомого складу.*

Об'єктом дослідження є конструкції та характеристики зчіпних пристроїв залізничного рухомого складу та технології їх застосування для здійснення перевезень як на колії 1520 мм, так і 1435 мм.

На основі системного аналізу нормативних документів для рухомого складу колії 1520/1435 мм та конструктивних особливостей зчіпних пристроїв визначено ключові напрями розвитку й упровадження сучасних технологій та типів зчеплення для здійснення перевезень у міжнародному залізничному сполученні з урахуванням ситуаційної обстановки на прикордонних пунктах і станціях.

Здійснено комплексний аналіз сумісності конструкцій автозчепів СА-3 та гвинтового зчеплення в умовах міжнародних перевезень між Україною та країнами ЄС. Систематизовано сучасні технології адаптації рухомого складу, сформовано модель поетапної інтеграції для сумісної експлуатації на коліях 1520/1435 мм.

Результати виконаних досліджень можна використовувати для розроблення технічних регламентів під час модернізації рухомого складу, технологій оброблення вагонів та поїздів, технічних рішень із конструювання вагонів та локомотивів для сумісної експлуатації на коліях 1520/1435 мм. Запропоновані рекомендації зменшать тривалість простоювань на прикордонних переходах, оскільки не потрібні операції заміни зчіпних пристроїв.

Ключові слова: *рухомий склад, зчіпні пристрої, автозчеп, гвинтова стяжка, буферні комплекти, нормативні документи.*