Test train with digital automatic couplers DAC in Poland

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The article presents an overview of the construction of automatic couplers and their digital version of the DAC for freight wagons. In the article, particular attention was paid to the process related to the development and popularization of the design of automatic digital couplers in the European Union countries. Poland, the automatic coupler train was presented in July 2022 and tested under various conditions. This is related to the current trend of improving rail safety and accelerating the procedure of forming trains, and, consequently, sending a freight train on its way. Automatic digital couplers will allow, in addition to mechanical connection, also pneumatic and electrical connection without the participation of an employee for coupling and uncoupling carriages.

1. Introduction

The implementation of passenger and freight transport is possible thanks to the fulfillment of many technical requirements, and one of them is the possibility of quick coupling and uncoupling of wagons. For this purpose, mechanical couplings are used as devices for directly connecting vehicles to each other. A separate group are pneumatic brake couplers for supplying the braking system and electric couplers used in passenger carriages. The classic way of connecting the wagons is a mechanical screw coupler consisting of a hook and a screw coupler attached to it, consisting of a splint, a turnbuckle and a shackle. The view of the screw coupler is shown in Fig. 1. Coupling the wagons with a screw coupling consists in manually attaching the shackle of the screw coupling to the hook and twisting the turnbuckle of the entire eye assembly to the required coupling length. Most often to the contact of car buffers. In the past, when connecting freight cars, loose connections were used, which facilitated the starting of the train. Currently, twisting is used until the buffers are slightly compressed. The description of the correct twist of freight wagons is described in [6].

![View of screw couplers: a) on a locomotive, b) on a cargo wagon [photo by W. Sawczuk](image)
When connecting passenger carriages, tight twisting of the coupler is practiced (the car bumpers are compressed), then when starting the locomotive there is no jerking effect of individual carriages.

Screw couplers are the most frequently used mechanical couplings on railways in Europe. In railway technology, there was also a link and pin coupling used in the USA before the introduction of screw couplings, a T-bar and a chain coupling used on narrow-gauge vehicles, and a trumpet and Albert type coupling used in trams.

Unfortunately, the screw coupler requires a coupling worker to enter between the carriages (even in difficult weather conditions, i.e. rain, snow and icing of the railway infrastructure). It should be emphasized that the coupling of wagons is a dangerous activity. The worker has to climb under the buffers between the carriages (which is inconvenient), then lift the screw coupler, the weight of which is about 30 kg, and put it on the hook, depending on the vehicles to be connected (freight car–freight car, passenger car–locomotive etc.) he must also connect the electric and pneumatic cables and shorten the coupling by turning the turnbuckle. This activity is performed many times during the day and night and is accompanied by accidents among employees. As a rule, these are very severe or fatal cases, which is the biggest disadvantage of this method of connecting cars [3].

2. Automatic couplers

Screw couplers and hooks, although they are the most frequently used method of connecting carriages on standard gauge railways in Europe, but due to their limitations, their further development is not justified. The main disadvantages, apart from the safety issues of workers linking the wagons together, is their limited strength. The strength of the currently strongest screw couplers is 350 kN, and the hooks are 1500 kN. A major disadvantage of screw couplings is that they can only be mechanically connected to two vehicles. It is not possible to connect the pneumatic system automatically, and in the case of passenger carriages – the electrical system. Another disadvantage of screw couplings is the transfer of only tractive (tensile) forces, and the compressive forces arising during braking are transmitted through buffers mounted on the wagon endcarriage. Incorrect twisting of screw couplings creates a risk of excessive thrust forces and trains tearing apart. In operating conditions, the screw couplers, due to their limited strength, are constructed in such a way that in the event of an increase in tractive force or dynamic forces during starting, the splines break as the cheapest elements. In practice, it often happens that bolts, arches and even hooks break.

Due to a number of mechanical limitations of screw couplers, the first work on automatic couplings took place in the USA in the mid-nineteenth century. It was related to the need to pull heavier and heavier trains and to ensure a higher level of reliability and safety for people connecting the wagons. The first design similar to the automatic coupler in the United States was the Miller draw hook [4]. Then there was a dynamic development of various designs, which led to a situation that in 1895 there were already 119 different variants of automatic couplers. Ultimately, 3 designs were selected and other solutions were forbidden [4]. On the other hand, in Europe, due to the presence of many railway authorities assigned to a given country, it was not possible to introduce a uniform system of automatic coupler. So far, there have been two attempts to implement automatic couplers in Europe: the first in the seventies based on the so-called UIC automatic coupler, the second one in the nineties on the Z-AK design by Knorr-Bremse. Automatic couplers, such as the Schafenberg coupling, are only used within a given country or several neighboring countries. However, according to the initial plans of the European Commission, in this decade (from 2026) the use of screw couplings in new vehicles, as well as in the rolling stock used so far, is to be limited.

Currently, the most popular automatic couplers used in railways all over the world are couplers [4]:

- Janney's also known as the AAR coupler – an American design developed in 1876 and developed for many years to carry more and more tractive forces (Fig. 2).

![Fig. 2. Janney automatic coupler: a) front view, b) top section, 1 – catch, 2 – lock [4]](image)

- SA-3 used on Russian railways (Fig. 3a) – a design similar to the American Willison coupler developed in 1916, and used in the former USSR from 1935;

- Schafenberg, popular in Europe (Fig. 3b) – it is a coupler with limited strength and intended for con-
necting light passenger trains and in electric and diesel traction units, metro vehicles, etc;

- Shibata used in Japan, developed in the 1930s for electric multiple units and in suburban and subway trains.

![Image](image1.png)

Fig. 3. View of the automatic couplers: a) SA-3, b) Scharfenberg [photo by W. Sawczuk], c) C-AKv Transpact [5]

The group of less popular automatic couplers includes the BSI automatic coupler proposed by Faiveley Transport for light passenger trains in Denmark and for trams in Bielefeld, Germany. Another interesting design is the Wedgelock coupler used in the London Underground or the Z-AK, developed in 1994 by Knorr Bremse, with the possibility of connecting to a traditional draw hook and additional terminals for automatic connection of pneumatic and electric lines. In this group of automatic couplings, it is worth mentioning the C-AKv Transpact couplings created in the 1990s by SAB Wabco BSI Verkehrstechnik Products GmbH (now Faiveley Transport), which is a reinforced variant of the SA-3 coupler and the Schwab coupler developed by Schwab Verkehrstechnik AG (now Faiveley Transport), which is part of the Swiss rail passenger fleet. The coupler can connect pneumatic lines and optionally electric lines [8].

3. DAC digital couplers

For many years, the European Transport Workers’ Federation (ETF) has been pointing to the causes of the rail freight crisis, which on the one hand results from the lack of investment in the freight train system, and on the other hand from the growing shortage of workers to form trains, in particular shunting workers. Moreover, the EU’s rail policy, favoring market opening and intra-sector competition, has not resulted in regulations favorable to rail freight [9]. In order to change the unfavorable situation of rail freight, steps were taken to develop automatic digital couplers that do not require as much involvement of people in preparing a freight train to the road as it is today. The assumption is that most of the activities should be performed by the driver without leaving the locomotive’s cabin. First of all, functionalities such as automatic connection/disconnection of wagons with their automatic parking brakes, creation of train documentation such as a list of wagons or automatic train brake tests are to be introduced. In order to develop technical specifications, but also to prepare for migration, the European DAC Delivery Program (EDDP) was initiated, involving over 70 companies from the European railway sector, who delegated over 230 experts in the field of railways to work in 8 working groups. In Poland, a member of this program is, among others PKP CARGO, GREENBRIER, AXTONE and CHEMET [8]. The main objective of this program (project) is the successful and effective implementation of a digital automatic coupler for European Rail Freight (DAC) in close cooperation between railway undertakings, infrastructure managers and wagon keepers as well as rail product suppliers, entities in charge of maintenance, research centers and national and European political institutions [10]. The European DAC program is implemented as one of the activities of the large international program Shift2Rail (S2R). At the end of 2022 the program will be modified, part of the work will be transferred to the Europes Rail program [11]. In Europe, research and tests of freight trains with DAC automatic couplers have been carried out for several years, which was described in the paper [5]. In newly designed and constructed freight wagons, work is already underway on the possibility of installing automatic couplers, including new DAC couplers [1, 7].

The main advantage of digital couplers is the simultaneous mechanical, pneumatic, current connection and data transmission between the wagons and the locomotive. The use of DAC digital couplers in freight wagons will also allow for the following advantages in relation to the classic connection of wagons with screw couplings:

- automatic connection and disconnection of wagons, also with a locomotive,
- automatic train brake test, electronic creation of the list of wagons in the train set and brake test cards,
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- increase in train speed due to lower longitudinal forces,
- monitoring the technical condition of wagons while driving, in particular reducing damage to wheels and heating of wheel set axle bearings,
- tearing of the train set is minimized due to the greater strength of the automatic coupler,
- providing additional services to customers through the use of GPS and current information about loading and unloading of wagons.

The main disadvantage of the DAC digital coupler is the inability to connect with a screw coupler, in the case of a locomotive this issue was solved with a hybrid DAC coupler, as shown in Fig. 4.

Fig. 4. Hybrid DAC coupler view for locomotives: a) 3D view of the coupler, b) view on the locomotive [12]

The general structure of the DAC automatic coupler is shown in Fig. 5. The main element of the coupler is the Scharfenberg head (1), but cast as a structure of greater strength. The head connects to the pull-shock device (2) by means of a connector. The whole thing is based on a support designed in such a way that the coupling centers itself. The pneumatic connection (4) and the electrical connection (5) are made automatically upon connection. Mechanical levers or electric buttons are provided for operation.

Fig. 5. Design of the DAC digital coupler: 1 – coupler head (Scharfenberg, 2 – shock absorber, 3 – release lever, 4 – main line with shut-off valve, 5 – electrical connector) [13]

Within the EDDP program, different levels of automation of DAC couplers have been defined for the connection of wagons [10]:
- only mechanically (Level 1),
- mechanically and pneumatically (Level 2),
- mechanically, pneumatically + current + data bus (Level 3 and Level 4),
- with Level 4 and manually disconnectable with the electric button of the wagons (Level 4+),
- with Level 4 and with the disconnection of carriages remotely by the driver from the cabin (Level 5).

Currently, the project considers and proposes Levels 4 and 4+ (Fig. 6b) as the minimum for migration in 2025-2030. However, we are already working on introducing us from the very beginning of a full Level 5.

Fig. 6. Ways of uncoupling the wagons: a) manual for Level 4 [photo by W. Sawczuk], b) electric button for Level 4+ [12]

The current experience gathered with four designs of the tested digital DAC couplers has led to the selection of couplers based on the Scharfenberg head for further tests. The prototypes for testing were provided by Voith and Dellner, as shown in Fig. 7 and 8. Recently, Knorr-Bremse has also presented its prototype.
4. DAC test train

In cooperation with PKP CARGO and DB, the DAC train as part of the DAC4EU consortium was tested in Poland on July 10-20, 2022. The test train system with Voith and Dellner DAC digital couplers is shown in Fig. 9.

During this period, the process of coupling and uncoupling the wagons was checked at the Poznań-Franowo marshalling yard, the Lafarge cement plant in Bielawy near Inowrocław (research carried out jointly with CEMET), the JSW Przyjaźń coking plant in Dąbrowa Górnicza and at the Zabrzeż Czarnolesie marshalling yard. The selection of the DAC train test sites was due to the specific conditions of use of freight wagons. At the Poznań-Franowo marshalling yard, the timing of the train on the hump was checked, in Lafarge cement, due to dustiness during loading, contamination of the coupler heads by limestone was checked, and under these conditions, tests were carried out to couple and uncouple the wagons on a track with a radius of 160 m (Fig. 10).
At the JSW Przyjaźń coking plant, the handling of carriages with DAC automatic couplers was checked during the placing and setting of the car on a turntable. During the simulated unloading of the wagon, the possible damage was monitored (Fig. 11).

![Fig. 11. a) view of the turntable with the wagon during unloading, b) view of the track brake on the hump [13]](image)

At the Zabrzeż-Czarnolesie marshalling yard, the possibility of effective timing of various groups of wagons in empty and loaded condition was checked. A special feature of the marshalling yard is the braking of wagons leaving the hump with skids on direction tracks, in the case of Poznań-Franowo stations, braking of wagons is performed using point track brakes.

**Summary**

The article presents information on the wagon coupling systems based on screw couplers and hooks, as well as information on various constructions of automatic couplers. A test train of the DAC4EU consortium with Voith and Dellner self-acting digital couplers was presented, which is tested on European tracks during the testing phase of automatic couplers, and under the cooperation of PKP CARGO and DB, it was tested in Poland under various operating conditions in the period from 10 to 20 July. During this period, the processes of coupling and uncoupling the wagons, the operation of the coupler in conditions of high pollution and on coal tippers were checked, which will enable the development of a final technical solution for DAC couplings suitable for various operating conditions in Europe.

It should be noted that the next stage of the program implementation will be changes in the regulations of the European Commission in the field of top-down provisions within TSI WAG, TSI LOC & PAS and TSI OPE implementing the use of digital interfaces. In line with the ongoing work, the new DAC regulations will introduce:

1) Limiting the possibility of using screw couplers in new manufactured rolling stock and in already existing wagons and locomotives.
2) Technical specifications for wagon and hybrid couplings.
3) Rules for admitting to use vehicles modernized for the assembly of DAC couplings.
4) Exceptions and special cases for the introduction of DAC couplings.
5) Clear guidelines for the electrical system and data transmission between carriages to locomotive.

**Nomenclature**

- DAC digital automatic coupling
- DB Deutsche Bahn
- EDDP European DAC Delivery Program
- ETF European Transport Workers’ Federation
- S2R Shift2Rail
- TSI technical specification for interoperability
- UIC International Union of Railways

**Bibliography**


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