Proceedings of the Sixth International Conference on
Railway Technology: Research, Development and Maintenance
Edited by: J. Pombo
Civil-Comp Conferences, Volume 7, Paper 21.6
Civil-Comp Press, Edinburgh, United Kingdom, 2024
ISSN: 2753-3239, doi: 10.4203/ccc.7.21.6

Conceptual Design of Shunting Automation Elements Utilising the Digital Automatic Coupler

G. S. Himmelbauer[1], T. Hasenleithner[1], M. Egger[1],
B. Skok[2], A. Kaltenbrunner[3] and B. Stadlmann[1]

[1]Rail Automation and Traffic Telematics Research Group, University of Applied Sciences Upper Austria, Wels, Austria
[2]Management, ULBRICH Maschinenbau- und Export- Import Betriebsg.m.b.H., Tribuswinkel, Austria
[3]ÖBB Infra Betrieb, ÖBB-Infrastruktur Aktiengesellschaft, Wien, Austria

Abstract

To fully utilise the potential of the Digital Automatic Coupling, especially as an enabler, systems making use of its enabler function have to be developed. This paper lays out the conceptual design of three such systems, meant to ease the required manual labour of shunting work. It gives a rough overview of necessary shunting tasks, state of the art solutions and research and lays out the conceptualisation and design of new systems. The systems presented here aim to automate the decoupling process, securing the ends of tracks against rolling wagons, and the braking and securing of wagons as well as performing an automated brake test. The overall goal is a highly automated shunting operation using the possibilities of the Digital Automatic Coupling.

Keywords: railways, rail freight, automation, digitalisation, shunting, automated shunting operation, Digital Automatic Coupling

1 Introduction

With the climate crisis looming overhead, threatening our livelihoods and our economies, governments have announced policies, measures and laws aimed at combating their emissions. The European Union has announced the Green Deal, a plan for reaching net zero emissions by 2050, including a 90% reduction in transport-related greenhouse gas emissions by 2050. This plan involves the railways taking on a larger role in the transportation sector, with the intent of doubling high-speed rail traffic by 2030 and doubling rail freight traffic by 2050 [1].

To achieve these goals, simply building twice as many tracks is neither sufficient nor viable. The railway sector needs to become more efficient, and in order to achieve this, the EU has funded large initiatives to drive innovation and investment in the stale, conservative rail sector. The Shift2Rail initiative and its successor, the European Rail Joint Undertaking, were and are developing inventions to improve our railways – One of these inventions is the so-called Digital Automatic Coupling (DAC).

The DAC is a new coupler for rail freight wagons and locomotives, set to replace the obsolete buffers and chain coupler. Like other automatic couplers across the world, namely the American Janney coupler and the Soviet SA-3 coupler, it couples automatically upon contact and decouples easily via the pull of a cable. Uniquely, however, the DAC allows for the automatic coupling of data, power and air pipes. This eases shunting work, but perhaps more importantly, acts as an enabler for other technologies and systems. New train functions on cargo trains, such as EP-brakes, train integrity checks for moving block safety systems, brake test sensors, and more are now feasible with the DAC.

This paper goes one step further and uses the DAC as an enabler for infrastructure-based devices which would not have been feasible using the old coupler type. The aim is to reduce the manual effort required for shunting work, as it is unpleasant and unsafe, and since infrastructure operators are struggling to find staff. The first device aims to autonomously decouple wagons during shunting in a hump yard. The second device aims to autonomously catch wagons rolling over a hump into the sorting tracks, braking them to a standstill and performing a simple brake test. The third device aims to secure the ends of tracks against wagons rolling out.

2 Autonomous Decoupler

2.1 Introduction

As mentioned before, the DAC automatically couples with another DAC on contact, however, in order to decouple, staff on site has to pull a lever or similar decoupling mechanism. While there are considerations of using a motor mounted inside the coupler, which allows for wagons to decouple on command from e.g. the locomotive, it is unclear if, when and how such a system will be implemented. Until 100% of wagons in single wagonload transport are equipped with this feature, staff in shunting yards has to be present to manually decouple. Therefore, this chapter aims to lay out the concept for an autonomous decoupler placed to the side of the track which is able to interact with the manual decoupling mechanism on the DAC to autonomously decouple two wagons.

Earlier stages of development of this autonomous decoupler are described in [2,3,4], in chronological order. This paper extends the most recent of those works by describing plausible decoupling mechanisms and the device’s interaction with such.

2.2 Existing Solutions

As the DAC itself is new and unique, no automatic or autonomous decoupling devices for it exist yet; However, such systems have been proposed and developed for other couplers. A system to autonomously decouple the buffers and chain couplers was developed and tested successfully in [5], while a patent for a similar system has been granted in [6]. Proposals, mostly patents, for devices able to decouple the SA-3 couplers exist in [7], [8]. A device able to autonomously decouple the Z-AK, an earlier attempt of introducing an automatic coupler in Europe, is proposed in [9]. All of these proposals can be generalised as a type of robot which moves with the train to interact with the coupler in some way, depending of course on the coupler type.

2.3 Conceptualisation

The first question to be answered is where and when the wagons can and should be decoupled. Currently, in Austria, the screw of the coupler is loosened on the stopped train in the entrance group of the yard, then the staff unhooks it on the moving train on the hump, just before its peak. This retains the braking capability of the train in a way, as the wagons would continue moving over the hump when the locomotive brakes if they are unhooked earlier. Still, most other European countries completely uncouple in the entrance group, as this means no staff has to interact with a moving train and the train can move over the hump with a higher velocity, accepting that in the case of an emergency stop, wagons will continue rolling over the hump. For the purposes of our device, placing it on or just before the hump and decoupling there is preferable, as all trains must pass this position and the device only needs as much movement range as it needs for decoupling a single coupler on a moving train, while it would otherwise need to cover the entire entrance group.

The second question is how the wagons can be decoupled. As the DAC is still in development, no standard has been published as to what the decoupling mechanism will look like. As such, it is quite difficult to invent a device to interact with this mechanism, but we can speculate on its final design. Looking at other automatic couplers, namely the Janney- and SA-3-Coupler, their decoupling mechanism is placed on the side of the wagons, easily accessible to staff and easily graspable by humans. Tests on the Scharfenberg coupler, the mechanical basis for the DAC, have shown that the current cable pull for decoupling requires about 400 N of force over a distance of about 0.25 m, resulting in circa 100 J of work necessary to decouple. This is considerable effort and has raised concerns about ergonomics and how staff could reasonably exert this effort constantly during their work. Further issues include that staff should not exert any force pulling away from the moving train, as they could pull themselves into it, and that preferably they do not have their back towards an approaching train. Under these circumstances the simplest solution would be to place a lever on the side of the wagon, which flips from the bottom upwards or vice versa, parallel to the rails. This design is robust, allows for easy integration into existing wagons and leaves room for adaptability – The force and angle required to decouple via this lever can be changed using gearboxes or pulley systems.

Figure 1. Render of the DAC decoupling mechanism design by Dellner [10].

Figure 1 shows a proposal by the company Dellner for a new decoupling mechanism for the DAC, seen in its decoupled position. The lever[1], seen on the side of the wagon, is completely horizontal in its coupled position, so staff only needs to push it down to decouple and pull it out towards themselves to engage the “prevent recoupling” function, if desired. This would most likely mean that the prevent recoupling function can not be engaged on a moving train due to the safety reasons mentioned before. A lever is placed on each side of the wagon, with the two connected via a rod so that the prevent recoupling function can be engaged and disengaged from either side. This design seems relatively complex and heavy, particularly due to this connection between the two levers, but the ergonomics have the advantage that pushing down is relatively easy and not as dangerous as pulling towards or away from a moving train. An autonomous decoupler could also interact with this decoupling mechanism quite easily, as it seems as though with the given geometry a simple rod or something similar pushing straight down on the lever would suffice to decouple. It would also be easy to interact with both levers of a coupler pair, as you just need a second rod.

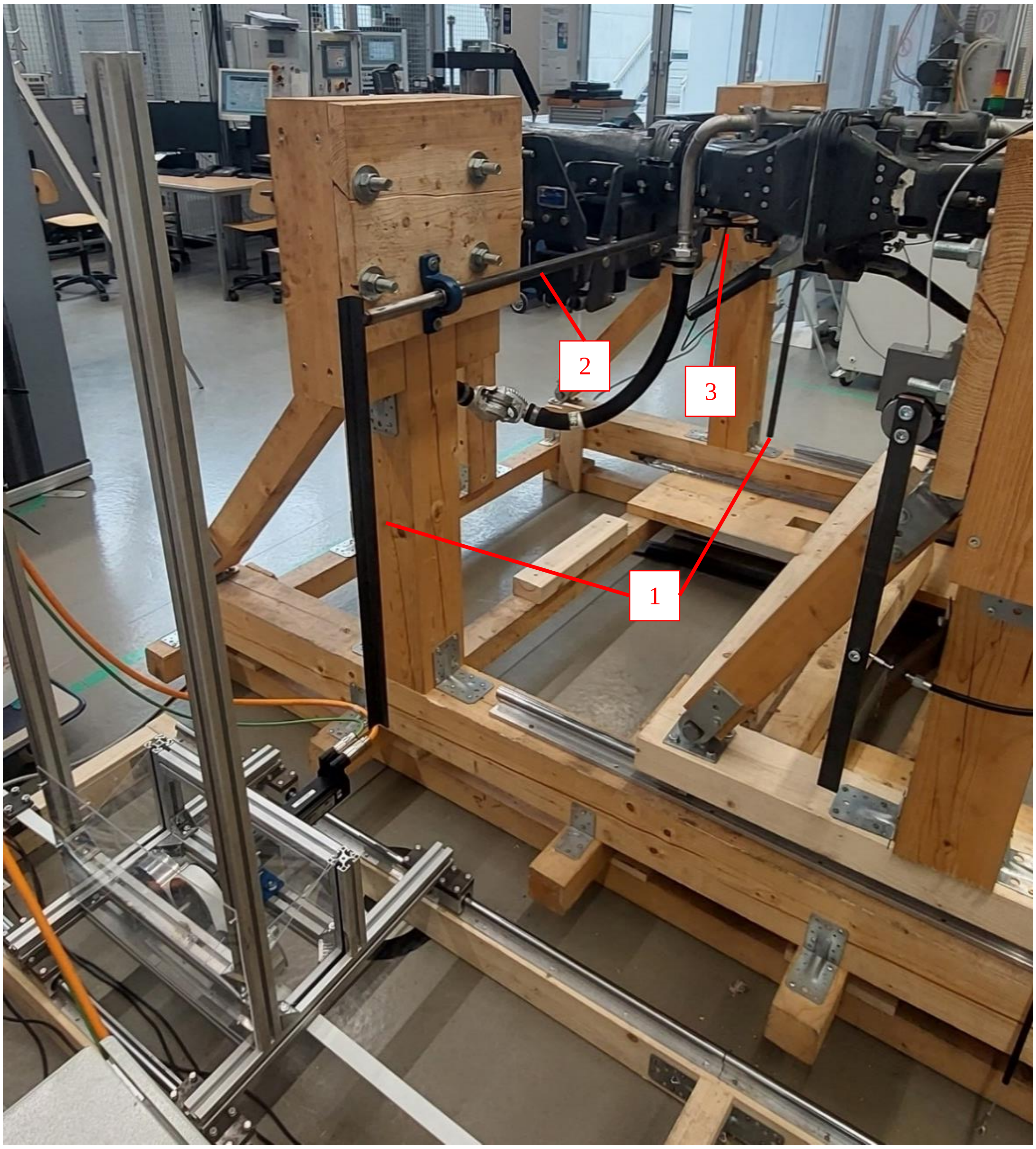

Figure 2. Photograph of the DAC test bench with a custom decoupling mechanism.

Figure 2 shows our proposal for a decoupling mechanism for the DAC. It consists of two levers^1 mounted on the side of wagon connected by a hollow shaft^2, with the pulley from the standard Scharfenberg decoupling mechanism extended and connected to one of these levers via a Bowden cable^3. It is mounted on a test bench with two Scharfenberg couplers. It is essentially the simplest mechanism conceivable, useful for experimentation and further developments. This setup allows for easily varying parameters of the design like the length of the lever, mounting positions, pulley mounting, different prevent recoupling function designs, and so on. However, ultimately the parameters of the Scharfenberg coupler itself cannot be changed and the spring inside the coupler, which needs to be counteracted to decouple, is as heavy as it is for it to properly couple at higher velocities. Overcoming these 100 J every time you decouple is challenging for a human, no matter what the design of the decoupling mechanism is ultimately going to look like, especially if done constantly over an 8-hour shift. This highlights the opportunity for a system like the one proposed here to automate this strenuous task. As for interacting with this decoupling mechanism autonomously, it is still relatively simple. Instead of pushing a lever straight down, it could push one of the levers straight to the side. On a moving train the device could even be static, as the linear motion is just done by the train, so it just pushes a rod in front of the first lever moving in the direction of the train. Decoupling via both levers, however, is a little more difficult, as both the levers and the device mechanism move towards each other, limiting the length of the levers and the space available to the device.

Working on these assumptions the autonomous decoupler probably needs to be placed on the side of the track and has to be able to perform a relatively simple motion, such as flipping a lever. For this it has to either be very fast, the train very slow or the device can move along the train for the duration of this decoupling process. As the exact details of the decoupling mechanism are not known yet, the most flexible option is chosen and the device is designed to be placed next to the track and able to move along the track in a range of about 3m.

With these decisions in mind, the last question is how the autonomous decoupler localises the decoupling mechanism. Again, as this decoupling mechanism is not known yet, this question is instead rephrased into how the autonomous decoupler localises the coupler, as it can be assumed that the decoupling mechanism is in a fixed relative position to the coupler. Several sensor concepts and algorithms were evaluated and tested. The best results were provided by a simple sensor setup utilising radar distance sensors measuring the distance from the side of the track towards the moving train at the height of the coupler. As the buffers are no longer present with the DAC, a passing coupler provides a characteristic gap between the wagons. Different methods were tested to identify the coupler position from the sensor signal, with a combination of a histogram analysis and a cross correlation proving the most effective.

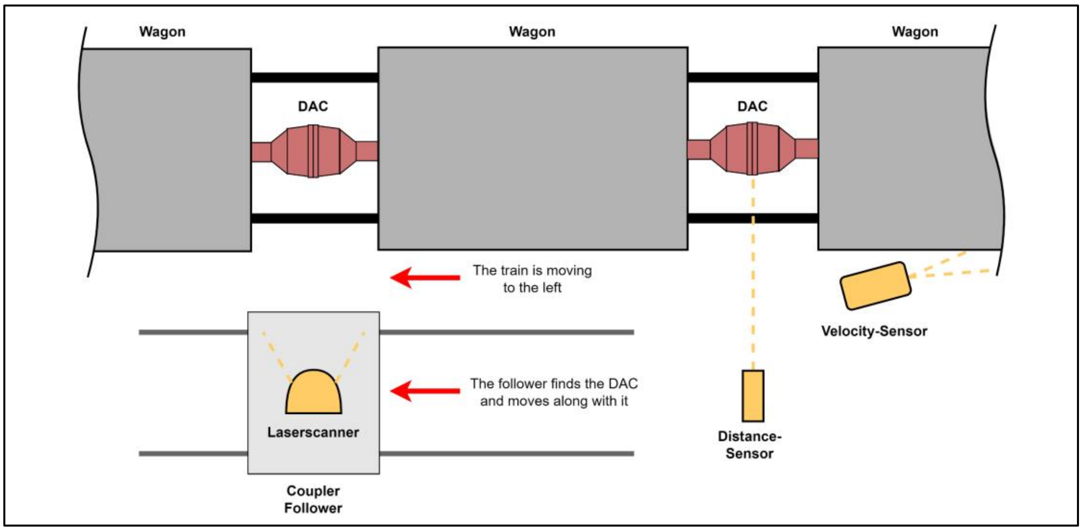

Figure 3. Diagram of the concept of the autonomous decoupler.

Figure 3 depicts the general design and concept of the autonomous decoupler. The distance sensor on the right localises the couplers on the passing train, while the coupler follower on the left follows the passing couplers.

2.4 Tests

The autonomous decoupler was built as a lab and field test demonstrator, so it could be tested in a controlled lab environment and in actual operation. It was tested twice on the DAC4EU demonstrator train in the field; The first time only the sensor system was tested and evaluated, the second time the sensor system was combined with a mechanical system to test a coupler follower.

Figure 4. Photograph of the test setup of the autonomous decoupler, focusing on the sensor system.

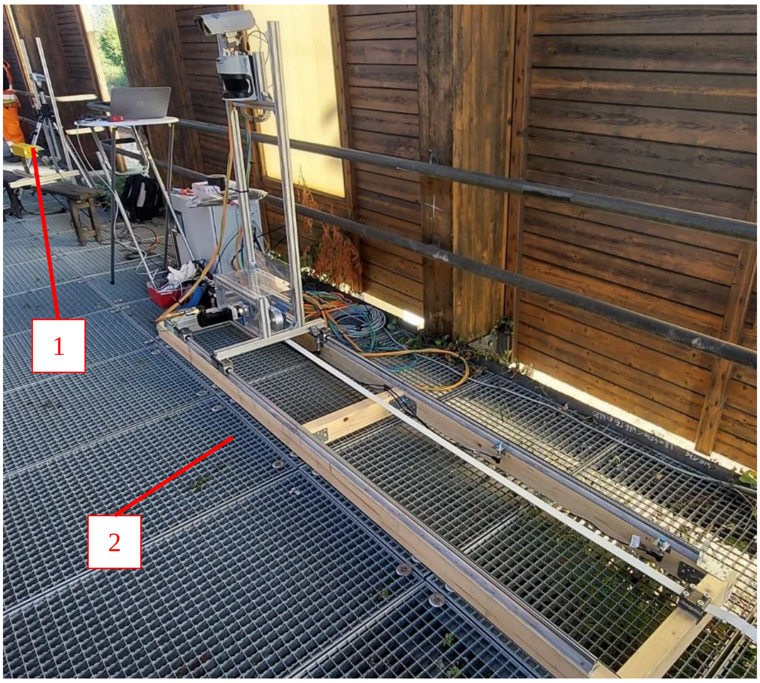

Figure 5. Photograph of the test setup of the autonomous decoupler, focusing on the mechanical system.

The device consists of a static sensor system[1], seen in the Figure 4 on the tripod on the left, and a mobile frame on rails[2], seen in Figure 5 on the right, which stands in as a placeholder for a decoupling device and acts as a coupler follower in these tests. The results of these tests were quite promising. The proposed coupler localisation works relatively well. Depending on the sensor configuration, the system can generally localise more than 80% of the couplers with a positional accuracy of less than 10 cm, or it can localise more than 90% of the couplers with a positional accuracy of less than 30 cm. This difference is due to the different settings for the filtering of the signal, with more filtering leading to more reliable but less accurate localisation, and less filtering leading to a less reliable but more accurate localisation. To achieve a solution which is both reliable and accurate, additional information or sensors are required. A one-layer laserscanner is seen mounted on the frame of the coupler follower in Figure 5, which has provided accurate, but unreliable results in earlier tests. The idea for future developments is to use it to more accurately determine the positional relation between the moving frame and the coupler, improving the accuracy of the localisation, however, this could not be implemented so far. Another approach is to improve the reliability of the localisation with axle counters and/or light curtains. A wagon generally has its axles mounted symmetrically to its centre, meaning that if you know which wagons are approaching and their number of axles, you can determine its centre by localising these axles with a simple axle counter and velocity measurement. From the centre you can estimate the distance to the coupler using the wagon’s length over buffers or length over headstock. Alternatively light curtains, positioned to the side of the track or even between the rails under the wagons, could be used to identify possible coupler locations, however the effectiveness of this approach would need some testing.

The proposed mechanical design for the follower also worked well. The combination of the coupling localisation and the mechanical frame following the results of the localisation worked as expected and without any considerable issues. It managed to follow localised couplers accurately. Future developments include the mechanism to actually decouple and verifying if the current drive system would be powerful enough for this decoupling process. Both of these developments are dependent on the final design of the manual decoupling system of the DAC.

3 Automatic Brake Test Device

3.1 Introduction

In a hump yard, a train is pushed over a hump while wagons are split approaching the peak. The wagons then roll over the hump and are sorted into their respective sorting tracks by setting switches accordingly. The wagons then roll into these sorting tracks and are generally braked to a standstill by braking shoes set up by staff. Currently, the staff then couple the old buffer and chain coupler, connect the air pipes and secure the wagons as necessary. Once all the wagons for this train have arrived, some yards connect these wagons to a static brake test device – Essentially a compressor which is able to fill the brake reservoirs, vent the braking pipes and fill them back up on command. This way a preliminary brake test can be performed before the locomotive arrives, saving valuable time and resources.

The aim of this chapter is to lay out the concept for a device in the sorting tracks, which is able to brake the wagons to a stop, secure them, fill their brake reservoirs and perform a preliminary brake test automatically.

3.2 Existing Solutions

As mentioned before, static brake test devices are often used in high capacity yards to save time and locomotive capacities. These are simple devices, essentially just compressors with a control panel, which allows staff to connect the air pipes of the wagons to the device and to control the brakes of the wagons via this control panel. This means that everything has to be done manually, from connecting the pipes to controlling the brakes and checking their function. Checking their function involves staff walking around the train and visually inspecting the brakes, which can take around 40 minutes on longer trains.

Therefore, efforts have been made to reduce the time and costs required for this important task. Most prominently, the company PJM has presented their solution of a sensor system mounted on the wagons which can inform staff about the function of the brakes, making the costly walk around the train for the purpose of a brake test obsolete. 200 SBB Cargo wagons are fitted with this system, with the intent to roll it out to even more transport operations in 2024 [11].

While this system saves staff the inspection of the brakes, the other tasks mentioned before still have to be done manually. Braking the wagons to a standstill is feasible with existing controllable braking systems, such as beam retarders, and new concepts, such as the ones presented in [12]. However, such systems only really benefit operation if there are no further manual tasks to perform at this stage of the process, as braking and securing wagons is only a small part of the work done by staff on wagons arriving in the sorting tracks. With the current buffer and chain coupler, the wagons still need to be coupled and the brake pipes connected manually. For these tasks, there seems to be no reasonable method of automation, although a concept for automatic coupling is presented in [13], which seems to have never been tested as a prototype. Regardless, with the DAC, the coupling of the couplers themselves and the air pipes is automatic anyways, which leaves the braking of wagons and performing a brake test to be automated.

3.3 Conceptualisation

The automatic brake test device to be developed therefore needs to be able to brake rolling wagons to a standstill, to secure the wagons and to perform a brake test. For the latter part the device needs to be able to connect to air, power and data lines of the wagons. As this is something the DAC can do automatically, the device could just integrate a DAC to perform this task. In order to start the brake test and to evaluate the results of the sensors, the device would need a control unit of a locomotive, or something similar with reduced functionality. The device also needs to permit normal operation, meaning in this particular case that trains can still pass through the track, since wagons generally enter a sorting track from one end and leave via the other. For the design it is assumed that the device needs to be able to stop a wagon group weighing a maximum of 400t coming into the sorting track at 2m/s, as these are common limits currently imposed at Austrian shunting yards.

As for braking the wagons, common braking means, such as brake shoes or beam retarders could be used, but this would be difficult to combine with the DAC necessary for the brake test. Another option for braking wagons are buffer stops – Although they are usually meant as emergency braking means at the end of tracks, the working principle could still be used for routine operation. This design could also easily integrate a DAC, as buffer stops for central buffer couplers generally act upon the coupler. To absorb the energy of a moving train, these buffer stops utilise either friction, hydraulic buffers or deformation [14].

The different options are analysed and as a result as the final design a foldable buffer stop which includes a DAC is chosen. It absorbs the energy via hydraulic cylinders, which allows for a certain degree of control over the braking process and to move the device back to its starting position. A braking distance and therefore cylinder length of 3 m is chosen, as this still allows for common, easily purchasable cylinders and hydraulic components, while providing enough energy to brake the given wagon groups. The device and its periphery are mounted in a pit below the track, allowing the device to fold into and out of the track to stop wagons and allow trains to pass respectively.

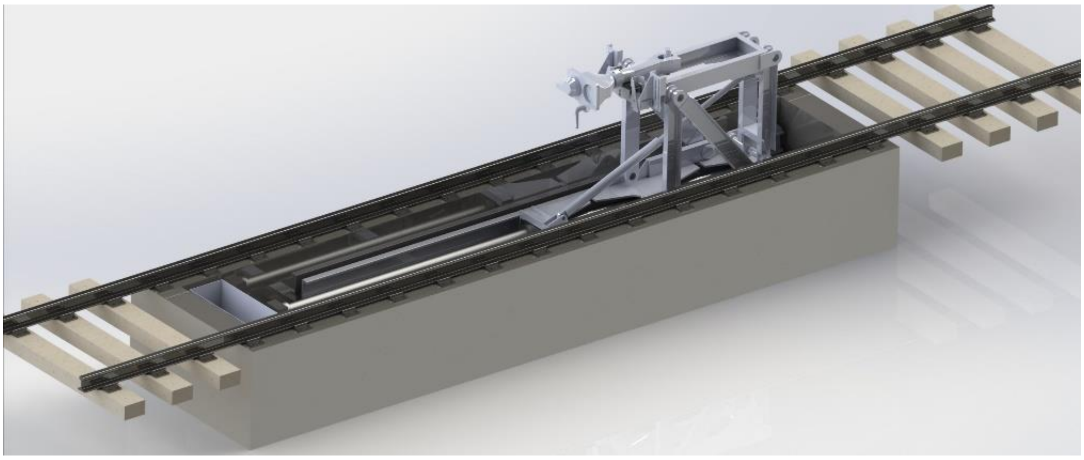

Figure 6. Render of the preliminary design of the automatic brake test device folded into the track.

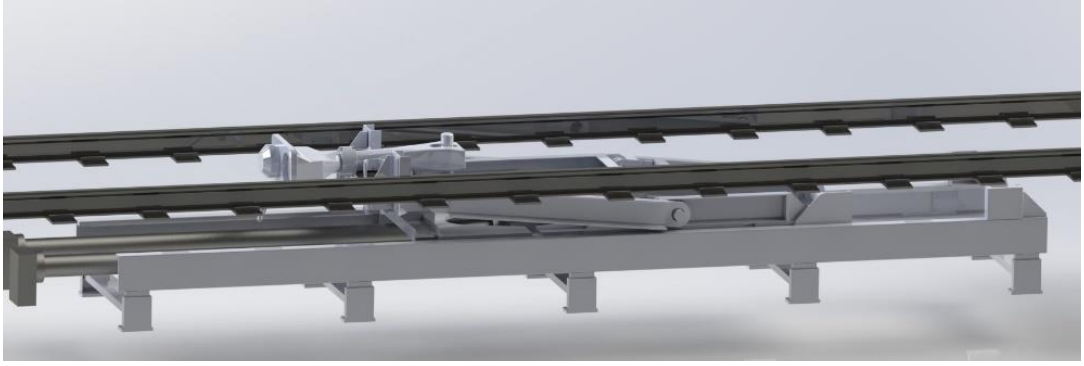

Figure 7. Render of the preliminary design of the automatic brake test device folded out of the track.

Figure 6 and Figure 7 show renders of the preliminary design of the device. It can be seen in Figure 6 in its extended position, at the end of its movement range, while Figure 7 shows it in its folded position, allowing for trains to pass overhead. No tests of this design could be done so far, however, a demonstrator is currently being developed.

4 Automatic Track Guard

4.1 Introduction

Tracks in sidings, shunting yards and loading facilities generally go out into the mainline tracks, as that is how wagons are transported to and from these locations. However, these connections need to be secured with special care, as an unsecured wagon rolling into the mainline where it could collide with a passenger train is an unacceptable risk. This chapter aims to lay out the concept of a new device for securing these connections, which is more suitable for a digitalised railway than existing solutions.

4.2 Existing Solutions

The described safety requirement of securing the end of tracks going into the mainline seems to be common. Solutions include derailers, which can be controlled like a switch, or brake shoes, sometimes implemented as a variant which can be essentially screwed “onto” the track, which still lets them slide along the rails, but not be lifted off them. Neither of these solutions involves a detection of an incident occurring, and while the derailer can be automated, a derailed wagon can be pretty costly to fix, while the brake shoe requires staff to lay them out.

4.3 Conceptualisation

Looking at existing solutions, a combination of the two concepts found is proposed: An automatic brake shoe layer, which can furthermore detect if a wagon is actually braked by it.

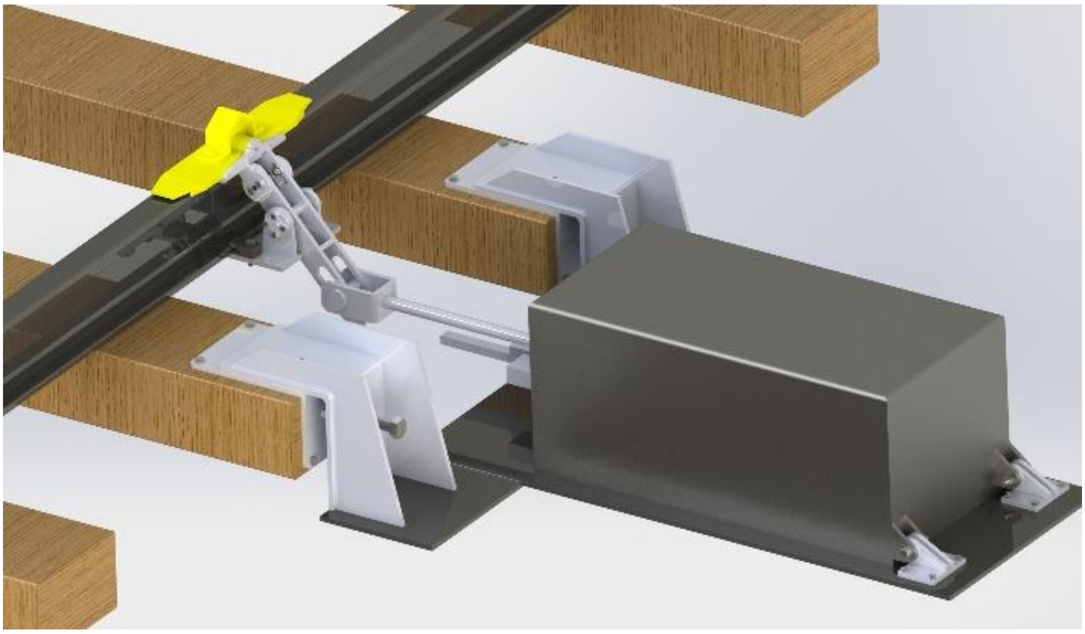

Figure 8. Render of the preliminary design of the automatic track guard.

Figure 8 depicts a render of a preliminary design for the automatic track guard. The device is powered by a switch motor, just as controllable derailers are today, and uses it to lay a symmetrical brake shoe onto the rails. The brake shoe is connected to the device via a pin which breaks off in the case of a wagon rolling onto the brake shoe. This incident can then be detected by e.g. a simple inductive sensor or just a cable running from the device to the brake shoe.

5 Conclusions and Contributions

This paper has laid out just some of the opportunities for innovation introduced mainly by the DAC and its enabler function. A concept for an autonomous decoupler for the DAC is presented, and first tests show that the current approach is very promising. A concept for an automatic brake test device is presented, which will be tested on real wagons in the near future. Lastly, a concept for an automatic track guard is presented, which could replace current, obsolete solutions.

All of these devices strive to achieve the same things: To make shunting safer, more efficient and ultimately to make single wagonload transport more economical, all while digitalising and automating shunting yards. The DAC provides a unique opportunity in this regard, as it acts as a driver for innovation in this stale industry and can finally bring our freight railways into the 21st century.

Acknowledgements

This paper was written within the projects DACIO, funded by the Austrian ministry BMK and the Austrian FFG, and FP5-TRANS4M-R, supported by EU-Rail. Co-

Funded by the EU. Author’s views not necessarily reflect EU/EU-Rail JU’s position who can’t be held responsible.

Co-funded by
the European Union

References

[1] “THE TRANSPORT AND MOBILITY SECTOR,” European Commission - European Commission. Accessed: Feb. 05, 2024. [Online]. Available: https://ec.europa.eu/commission/presscorner/detail/en/fs_20_2350

[2] G. S. Himmelbauer, “Konzeptionierung und Evaluierung der Sensorik zur automatischen Entkupplung von Bahnwagons,” Master Thesis, University of Applied Sciences Upper Austria, Wels, Austria, 2022.

[3] G. S. Himmelbauer, “Conceptual design and evaluation of sensor technology for automatic uncoupling of railroad wagons,” Lisbon, Portugal: Zenodo, May 2023. doi: 10.5281/zenodo.8010863.

[4] G. S. Himmelbauer, “Conceptual Design and Evaluation of a Device for Automatic Uncoupling of Railroad Wagons [Submitted to conference],” Dublin, Ireland, Apr. 2024.

[5] C. Zellner, “Automatische Trennvorrichtung für Güterwagen,” Dissertation, TU Wien, 2019.

[6] M. Bruns *et al.*, “Device and method for the automatic separation of goods wagons with screw couplings,” DE3819388A1, Dec. 14, 1989 Accessed: Feb. 08, 2024. [Online]. Available: http://depatisnet.dpma.de/DepatisNet/depatisnet?action=bibdat&docid=DE000003819388A1

[7] Wadim Borissowitsch Swerdlow, Sabit Gaidanievich Akmalov, and Grigory Yulievich Irger, “Automatic system to uncouple cars on hump yard,” Russian Patent RU2450946C1, May 20, 2012

[8] Shao Zhiguo, Sonne Changhui, Zhou Runsheng, Xie Ping, Lu Jianfei, and Wei Mingguang, “A kind of suspension type railway freight automatic decoupling device, system and method,” Chinese Patent CN110281970A, Aug. 01, 2019

[9] M. Bruns, “Einrichtung und Verfahren zum automatischen Trennen von Güterwagen mit Schraubenkupplungen,” DE3819388, Jun. 02, 1989

[10] F. Nordström, “Dellner DAC Decoupling Mechanism,” Dellner - Train Connection Systems. Accessed: Mar. 07, 2024. [Online]. Available: https://www.linkedin.com/posts/dellner-couplers_dellner-bilateral-uncoupling-handles-for-activity-7009089789337452544-Eux0/?utm_source=share&utm_medium=member_desktop

[11] “SBB Cargo receives type approval for automatic brake test,” Railvolution. Accessed: Feb. 06, 2024. [Online]. Available: https://www.railvolution.net/news/sbb-cargo-receives-type-approval-for-automatic-brake-test

[12] F. Michelberger *et al.*, “Studie für eine innovative, lärm- und verschleißarme Bremsung am Abrollberg - StilvA.” FFG, Aug. 2018.

[13] J. A. Ferri Polo, “Konstruktive Umsetzung eines seitlich agierenden Kupplungsroboters zum Kuppeln von Standardgüterwagen,” Master Thesis, Karlsruhe Institute of Technology, Karlsruhe, 2016.

[14] “Buffer stops: RAWIE barriers systems, buffer stops, access systems.,” A. Rawie GmbH & Co. KG. Accessed: Feb. 08, 2024. [Online]. Available: https://www.rawie.de/en/buffer-stops/