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CONTAINER TRANSSHIPMENT PROBLEMS AND THE SOLUTION

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Abstract: *One of the obstacles to the spread of rail-road intermodal freight transport is the lack of efficient container handling equipment on the rail-road hubs. The known and widely used solutions (gantry crane, reach stackers) are apparently not able to increase the volume of intermodal transport. The goal, which is uniformly desired by the professionals, the growth of rail-road intermodal freight transport, can be served by a container transhipment device that allows unit loads to be transferred between road and rail vehicles even under railway contact line. The new container transhipment technology, proposed in the article can be the missing hardware device for physical internet hubs. The highly automated handling robot meets the requirements of Industry 4.0 and Logistics 4.0.*

Key words: *Intermodal rail-road freight transport, container transhipment, transhipment robot, Industry 4.0, Logistics 4.0.*

Problemi sa pretovarom kontejnera i rešenje. *Jedna od prepreka širenju železničko-drumskog intermodalnog teretnog transporta je nedostatak efikasne opreme za rukovanje kontejnerima na železničko-putničkim čvorištima. Poznata i široko korišćena rešenja (portalni kran, regalni viljuškari) očigledno nisu u stanju da povećaju obim intermodalnog transporta. Cilj, koji profesionalci jednoobrazno žele, odnosno rast železničko-drumskog intermodalnog teretnog transporta, može da se ostvari uređajem za pretovar kontejnera koji omogućava prenos jediničnih tereta između drumskih i šinskih vozila čak i ispod železničke kontaktne linije. Nova tehnologija pretovara kontejnera, predložena u članku, može biti nedostajući hardverski uređaj za fizička Internet čvorišta. Visoko automatizovani robot za rukovanje ispunjava zahteve Industrije 4.0 i Logistike 4.0.*

Ključne reči: *Intermodalni železničko-drumski teretni transport, pretovar kontejnera, pretovarni robot, Industrija 4.0, Logistika 4.0.*

1. INTRODUCTION

There are several analyses in the literature to examine the problems of intermodal rail-road freight transport. Perhaps the most important issues in this regard are container handling technique and the terminal network. One of the prerequisites for rail-road intermodal freight transport is the existence of a relatively dense container terminal network with advanced container handling [1, 2]. According to the expert's conclusions rail freight transport has a significant competitive disadvantage compared to road freight transport, which is caused by the inflexibility of rail transport.

In this article, we review the known and lesser-known container handling technologies that we are evaluating in the light of the fact that the European rail network is 100% electrified on the main lines. Consequently, a prerequisite for the rail transport of different containerized unit is the transfer of the containers from one kind of transport to another one under the railway contact line.

Intermodal road-rail freight transport is often mentioned as a top priority for the sustainable of the European transport system [3]. These antecedents justify keeping the issue on the agenda and examining it as thoroughly as possible.

In the next part of the article, we offer a solution for modern container handling, the construction of a container transhipment robot. Regarding time and price a competitive continental intermodal freight transport system can be developed using technical solution described in the article.

2. WIDELY USED CONTAINER HANDLING TECHNOLOGY

The examples below illustrate the most common container handling techniques used at continental container terminals. The widely used container handling methods shown in Figures 1 and 2 are called vertical transhipment due to their relatively high lifting height. The disadvantages of each technical solution are giving in relation to the ideal container handling process. The cost of container transhipments with these technical devices is high, which may have an impact on the development of intermodal freight transport. In their study, Ballis and J. Golias [18] examined the cost of different container handling technologies, considering all cost factors, without government involvement. According to them, in addition to 100-250 transhipments per day, the price of one transhipment for side loaders can vary between 35-65 €, while for a gantry crane the price per transhipment can vary between 36-54 €. The lower value is of course valid for the higher transhipment number.

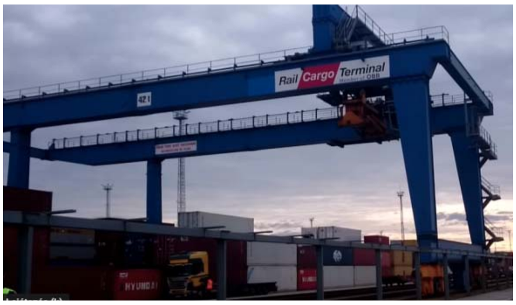

Fig. 1. Bridge crane [4]

Fig. 2. Reach stackers [5]

In the case of the bridge crane shown in Figure 1, the disadvantages are the high investment cost and the concentration of freight traffic. In the case of the side loader shown in Figure 2, the heavy-duty concrete demand, the diesel engine and the large space requirement can be described as disadvantages.

The disadvantage of the known vertical container handling is that they cannot be used under railway contact lines. This feature has a negative impact on the development of intermodal freight transport. Vertical container handling technologies are not able to overcome the competitive disadvantages of rail-road intermodal freight transport in time, especially for shorter distances (less than 300 km). As a result, the proportion of domestic intermodal rail-road freight transport in Hungary is very low, around 2-3%. Nevertheless, domestic investors and terminal design professionals are not open to new solutions.

3. HORIZONTAL TRANSHIPMENT TECHNOLOGY

Over the last twenty years, a number of innovations have been made to develop intermodal freight transport in order to increase the market share of intermodal transport [6]. Nevertheless, the interest of professionals in railway freight and intermodal transport has been modestly aroused. The following are some examples of newly developed container handling techniques, we called them horizontal container transhipment technology or process.

Horizontal container transhipment is a transhipment procedure of low lifting heights that can be used under the railway contact line. The latter property is decisive difference compared to the vertical container transhipment. The equipment shown in Figures 3 and 4 was developed between 1997 and 2000 with the active participation of the Swiss Railways (SBB) [7].


Fig. 3. KORAX-MIKON RTS 501 [8]


Fig. 4. NETHS [9]

In the case of the device shown in Figure 3, the following disadvantages should be highlighted:

- the transhipment machine and the truck must be parallel,
- not suitable for stacking,
- does not handle swap bodies,
- side grip of the loaded container is not according to the standards.

The disadvantages of the device shown in Fig. 4:

- not suitable for stacking,
- moves on non-standard railway tracks,
- distance from the contact line is not safe enough.

Only a prototype is known about the devices shown in Figures 3 and 4. Although the main technical requirements were met by the equipment, their further development is unknown.

A common disadvantage of the horizontal transhipment technologies presented below is that they require the simultaneous presence of the rail wagon and a road transport vehicle. Their typical application is possible in the transport of goods served by directional trains. Mobiler (Figure 5) and ACTS systems (Figure 6) may be suitable to serve a closed logistics chain. In some cases, ÖBB has examples for their use.


Fig. 5. Mobiler [10]

The disadvantage of Mobiler is that:

- it requires a special container and a special road vehicle,
- the railway wagon has to be supplemented.

Fig. 6. ACTS [9]

The disadvantage of ACTS systems is that requires:

- the special railway wagon and a special supplemented lorry,
- the special container (for bulk materials).

The BOXmover by Figure 7 has below disadvantages:

- requires a special truck,
- the operator has to perform many tasks,
- the transhipment time is relatively long,
- containers that are tightly stacked must not be lifted.

Fig. 7. BOXmover [11]

Fig. 8. ContainerMover [12]

Innovatrain's ContainerMover (Fig. 8) technology is similar to the Mobiler (Fig. 5)system, except that no special container construction is not required. The disadvantage of ContainerMover is that it requires:

- a special truck,
- and a supplemented railway wagon for its application.

The devices shown on Figures 7 and 8 are only prototypes. In these cases, too, there is no knowledge of the wider application of the systems.

Figure 9: Meclift ML5016SR [13]

The horizontal container transhipment methods, the Meclift shown in Figure 9 cannot be used under an overhead contact line because the structural height of the container gripper (sprider) significantly reduces the safety distance. The disadvantages of the device shown in Fig. 9:

- it can only serve only one side,
- it has limited use under contact line.

In the case of Metrocargo (Fig. 10), the following disadvantages should be highlighted:

- a lifting device must be built on both sides of the railway track,
- the lorry must be provided with lifting device, which can to lift containers on both sides
- has not stacking ability.

The Metrocargo system of Figure 10 provides transhipment between a wagon and a buffer.

Fig. 10. Metrocargo [14]

4. ADVANCED HORIZONTAL TRANSHIPMENT REQUIREMENTS

The literature data mentioned above support that one of the preconditions for the development of rail-road intermodal freight transport is modern container handling [2]. Examining the design of known vertical and horizontal container transhipment equipments and assessing the requirements of rail-road intermodal freight transport can determine the main functional requirements that an efficient container transhipment equipment must meet. The functions to be fulfilled can be identified as follows:

- safe applicability under the railway overhead contact line,
- transhipment of ISO 668 containers (20-40 feet),
- transhipment of class “C” swap bodies according to EN 284,
- transhipment of class “A” swap bodies according to EN 452,
- be electrically operated for environmental purposes,
- be able to operate partially or completely automatically (operator-free, robot-like operation).

Under current rules, no container handling can be performed under a contact line with electrical voltage. A technical solution is described below which is able to meet the above functional requirements and can be used safely under contact lines. In other words, in the light of technical progress, certain railway safety standards must also be reviewed.

5. THE NEW RAILWAY CONTAINER TRANSHIPMENT

As the efficiency of container handling technologies greatly influences the development of intermodal freight transport [16], the aim was to maximize automation. According to the state of the art, the electric railway transport is a sustainable mode of continental freight transport. There is a need for the container handling equipment what can provide container transhipment between rail wagons and road vehicles. The robot-like operation of the proposed design enables the automatic container handling, which improves competitiveness [6] and largely meets the requirements of Industry 4.0. The patent of EP 1401693 [15] is such a technical solution that can meet the functional requirements set out above. The equipment of the patent in HCT – Horizontal Container Transhipment. The evolution and modifications of the construction can also be observed in the figures.

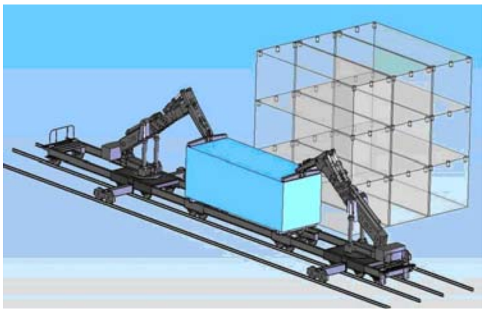

Fig.11. A model image of the early construction of HCT

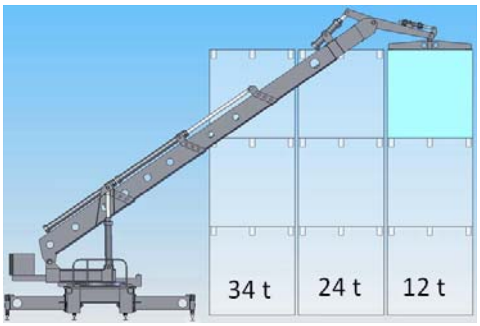

Fig. 12. HCT stacking positions

Figure 11 shows the HCT model according to the 2006 design. The HCT is a fixed track hoist with a design capacity of 40 tons. The machine is 26 m long and has a total weight of 52 tons. The track spacing of the supporting rail is 5200 mm, the gauge of the middle tracks is 1435 mm. The machine moves longitudinally parallel to the train. The 3x3 stacking positions shown in Figure 12 can be arranged only with restrictions. The figure shows the maximum container weight that can be used in each row. In the first row, the 40-foot container can be handling with the maximum weight, in the second row, the 20-foot container with the maximum weight, or the 40-foot container with partial load. In the third row, partially loaded or empty containers can be placed.

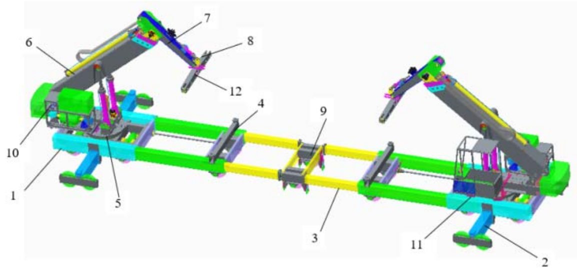

Fig. 13. Model image of the HCT equipment

Figure 13 shows the later version of the HCT equipment, which differs from the previous version mainly in the bullet points below:

- the auxiliary wagons originally used at both ends of the machine have been abandoned,
- the beam connecting the right and left units has a telescopic construction,
- unlike the prototype, the hydraulic cylinder is placed on top of the lower boom,
- unlike the prototype, the chain stroke can be used instead of a telescopic hydraulic cylinder.

The main structural elements of HCT (Figure 13):

- undercarriage (1), ensures movement in the direction of the railway track,
- support structure (2) ensures the stability of the equipment,
- connecting beam (3) provides a mechanical connection between the right and left machine units,
- container holder (4) provides a support function and ensures temporary holding of the container,
- rotating platform (5) in the range of +/- 90 degrees allows the lifting device to be rotated,
- lower boom structure (6) for lifting loads and telescopic design for longer range operation,
- upper boom structure (7) provides penetration under the overhead line, has a low structural height,
- lifting beam (8) includes container gripping pins,
- auxiliary carriage (9) fixes the middle part of the equipment to the rail, thus providing a fixed reference point for controlling the movements,
- hydraulic power supply (10) with electrically driven twin-pump with LS control,
- operating cab (11),
- beam joint (12) allows the lifting beam to rotate about the vertical axis as well as tilt to be parallel to the ground.

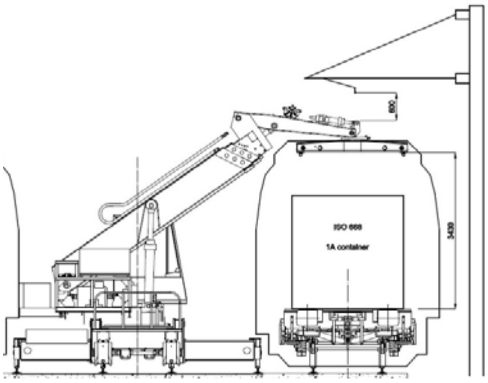

Fig.14. Position of HCT components on the railway side

As shown in Figure 14, the structural elements of the HCT do not approach the overhead contact line less than 0.6 m. Despite the safe distance, the current rules only allow container handling under the contact line when it is de-energized. The two machine sides of the HCT have autonomous hydraulic power unit with a power output of 2x37 kW. The current supply is sliding type, that can placed between the railway lines. The power supply may be diesel-powered, but it is less environmentally friendly.

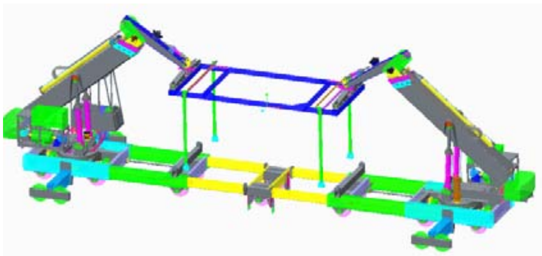

Fig. 15. HCT equipment with lifting frame

Figure 15 shows an HCT equipped with a lifting frame for transhipment of "Class C" swap body. In this case, the HCT can use the lifting frame as a device. The lifting frame suitable for longer "Class A" swap body's has not been designed yet. Figure 16 shows the HCT machine with a Roll-off container that has ISO corner elements. This type of container also complies with DIN 30722, thus it can be transported by the hook lift truck. The bulk material (grain) can be transported in an environmentally friendly manner by using this type of container.

In the case of the HCT construction shown in Fig. 17, there is no support rail, the stability is ensured by dynamic counterweights (1). While this solution may increase the cost of manufacturing the machine, it can be installed in return at a significantly lower cost. Another advantage of applying dynamic counterweight is the increased mobility of the machine, i.e. it becomes easily movable between intermodal transfer points.

It is important to mention the price per transhipment when using HCT. According to the author's preliminary calculation, the price per transhipment is significantly lower than the price per transhipment of the known transhipment technologies (reach stackers, gantry crane) mentioned in point 2.

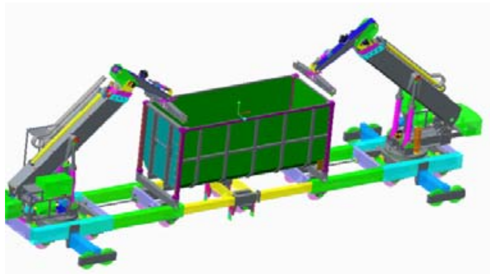

Fig. 16. The HCT is equipped with a 20-foot container

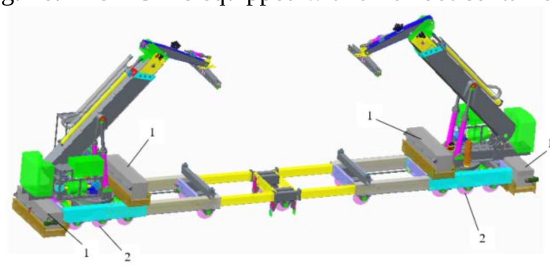

Fig. 17. The HCT is the latest version

6. HOW HCT WORKS

The HCT contains two machines robot-like operating symmetrically with 16 degrees of freedom. The control has shared intelligence, as each components have a PLC unit suitable for solving an independent task. The HCT can help containers get on and off the train.

Phases of HCT operation:

- By driving the undercarriage, the container holders are set at a distance corresponding to the container to be lifted (20 ’or 40’) and are attached to the telescope.
- By driving the undercarriages, the HCT stands next to the container to be transhipped. The camera on the container holder transmits the image of the corner element to the control system.
- The middle auxiliary carriage is attached to the rail crown.
- The right and left lifting units rotate by driving the rotating platforms, during which the undercarriages approach each other and the container hatches are retracted by the actuating hydraulic cylinder. During turning, the lifting beam remains perpendicular to the rail axis.
- After turning, the centre line of the machine units A and B coincides with the centre line of the corner element of the container to be lifted.
- Place the mast on the container by retracting the lower boom or tilting the upper boom. Fine control of the movement is performed by the control system based on the image of the video cameras built into the lifting beams.
- Connect the lifting beam and the container by turning the gripping pins.
- By synchronizing the two sides with the extension of the lower boom and by tilting the upper boom, the container is raised by 100-150 mm.
- Turning the lifting units A and B by driving the rotating platforms. At the same time, the undercarriages move away from each other and the

hydraulic cylinders moving the container holders are pushed out.

- Laying the container on the container holders by retracting the lower booms and tilting the upper booms. Unlocking the centre carriage.
- Rail track movement by driving the undercarriages to the unloading position. Precise determination of the unloading position (eg. wagon or truck container holder) based on the image of the camera installed in the container holders.
- Unload the container by repeating the above operations as appropriate.

The position of containers on the truck can be many, and the positioning of the truck next to the transhipment machine does not need to be parallel, thanks to the construction of HCT. There are 8 physically independent controlled axles per sides (bottom carriage, container carrier, rotating platform, boom lift, boom tilt, overhead boom tilt, beam rotation), i.e. the machine has a total of 16 degrees of freedom. The movement of all axes is controlled by PLC unit since the movement of each axis describes an arc, but the desired displacement must take place along a line. The search for a container on the train and its corner elements (both on the railway and road side) is supported by networked IoT devices and a complex electronic system supported by camera image processing and image control.

Fig. 18. Prototype HCT control panel

The electrical power supply is placed between the railway lines thus enables its environmentally friendly operation, irrespective of fossil fuels. The machine is not served by an operator, but the operator can intervene in case of need. The high degree of automation and the widespread use of various sensors (load force meters, continuous rotary and linear displacement meters, image processing based positioning, image based container identification, laser distance meter) also allow the machine to be used in extreme weather conditions (rain, snowstorm, frost) for transhipment of containers. Each container transhipment task is defined in such a way that the service of the train is given top priority [17]. The road vehicle can be served when there is no train at the intermodal transhipment point.

7. CONCLUSIONS

At continental intermodal transhipment points (ITP), the provision of container handling with a transhipment robot (like HCT) allows safe operation also under the overhead contact line. Stacking capability ensures efficient area utilization. The new container handling technology enables the implementation of a sustainable intermodal rail-road freight transport that is competitive in time and price.

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