

Innovative Technology of Transshipment in Inland Ports Constituting Interchanges of Intermodal Transport Chains

Lech Tołkacz*
Włodzimierz Rosochacki**

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Abstract

The work presents an innovative solution of integrated load units transport with the use of inland waterways. The proposed concept of transport system utilizes river barges with construction allowing their positioning in relation to loading dock. Such solution creates a possibility to conduct transshipment works at high fluctuation of water levels, and leads to shortening the transshipment cycle using typical loading devices.

Keywords: transport, stabilization, barge, innovative solution positioning

1. Introduction

New transport technologies that appeared in the last decades of the 20th century contributed to the intensive development of cargo transport in containers and other integrated units. Possibility of packeted cargo transportation from the sender to the recipient provided basis for dynamic development of intermodal transport. Implementation of this transport idea in Poland is now possible only thanks to available railway and road infrastructure. In the case of inland waterways, their unsatisfactory management condition makes them useless for this form of transport.

* West Pomeranian University of Technology, Faculty of Maritime Technology, al. Piastów 41, 71-065 Szczecin, Poland

** West Pomeranian University of Technology, Faculty of Maritime Technology, al. Piastów 41, 71-065 Szczecin, Poland

Bearing in mind the modern transport ideas [1], one may attempt to state that presently the largest innovative challenge for both state and regional authorities is and will be the need to deal with the quasi monopoly of car transport in the existing transportation systems and to precipitate the creation of alternative transportation forms. An opportunity for implementation of such postulate – particularly in the case of Poland – one may seek in undertaking activities for significant improvement and use of inland waterways.

The postulate of undertaking such actions in the present moment finds a special justification. Subsequent, in short a period of time, floods covering substantial areas of the country and hardly effective system of protection against their effects indicate the need for making a strategic decision. Construction of modern anti-flooding protections is unavoidable. On this background, there appears a great chance of conducting modernization of inland waterways infrastructure including the appearing strong tendencies towards strengthening the role of inland transport in Europe.

In the Integrated European Actions Programme for Inland Waterway Transport, it is indicated that the inland waterway transport offers a significant possibility of improvement in the European transport system, being vulnerable to formation of bottlenecks and delays, as well as harmful to the environment. In Programs Marco Polo and Marco Polo II also indicated is significant importance of activities pointed at direct and immediate relocation of carriages from, among others, road communication to short-range sea transport and inland waterway transport. Such actions are to lead to improvement in the synergy effect of the inland waterway and short-range sea transport sectors.

Implementation of innovative solutions in inland navigation is particularly difficult owing to natural restrictions of waterways. However, such characteristics of inland transport like its economy and limited – in comparison with other means of transport – adverse impact on the natural environment, determines the attractiveness of attempting to introduce such innovations that would become recognized both in the eyes of shipowners and regional authorities handling the navigable routes. Issues of inland transport and innovations in this field of the economy occupy a broad place in many studies [1, 2, 3]. A comprehensive review and analysis of innovative solutions in the scope of containers' transshipment is included in publication [4]. The issues of technology and organization of transport processes in container marine terminals are presented in work [5].

In the modern seaports, attempts are being made to modify the reloading processes consisting in the introduction to the market of the so-called container cassettes, used for creating four 20-foot container units or two 40-foot ones (TTS system – Terminal Cassette System [6]). Simultaneously, research is being conducted, aimed at preparation and implementation of modern container transfer systems in sea ports with the use of container pallets containing up to 20 20-foot containers (CPT system – Container Pallet Transfer System [7]). Also, recognition of efficiency problems of harbor overhead cranes operated in marine-river ports is being attempt-

ted [8]. Analyzed as well is the impact of operating conditions of modern structures of barges on the inland transportation costs [9].

The primary purpose of this study is to propose and moot the concept of extending the existing transport system with Polish inland waterways. Important elements forming a new quality in the offered concept are: upper-deck river barge with innovative load-carrying structure and – cooperating with it – docking position. Innovative transshipment system provides a possibility of effective loading and unloading of a vessel in ro-ro technology without involvement of specialized transshipment devices for this purpose. This also applies to ports, for which high fluctuations in the level of water are characteristic. As a result, an innovative concept of integrated load units and transport of containers is suggested, which will define the inland transport system binding sea ports with inland transport system by means of inland waterways with the use of new water transport means and the new transshipment technologies.

2. Transshipment System Innovation Concept

2.1. Idea of innovation

In the presented system, the integrated load units and containers (put in packages on special passable platforms) are moved in the transport rolling system onto the inland vessels. These can be motor barges (i.e. with their own drive) or towed sets, consisting of towboat and one or few towed barges. Application of ro-ro technology imposes the need for application of upper-deck barge structure, in which a continuous deck forms a basic plane for cargo space. The type of transported loads and the selected transshipment technology requires a stable loading plane created by pavement of the quay and the loading deck of a barge. Relatively high – as compared to the own mass of a barge – mass of transported cargo unit, forms a complex conditions for vertical and horizontal stabilization of a vessel. The main condition for vertical stabilization of a barge is to maintain the constant value of uplift pressure force acting on it and a permanent location of uplift pressure center.

2.2. Alternative solutions of location stabilization of inland transport means

In each option of the solution presented below, the barge is equipped with ballast tanks.

Option 1

In the first option of the loading project implementation outlined in schematic on drawing 1, the barge freely moors by front to the loading quay.

The force of gravity acts upon the barge, with the value determined by mass of K structure, uplift pressure force W , as well as force of ballast weight M . With due observance of vertical stabilization condition of a vessel:

$$W = const \quad (1)$$

and the initial mass of the ballast must correspond to the sum of load units' masses P_i transported onto the barge.

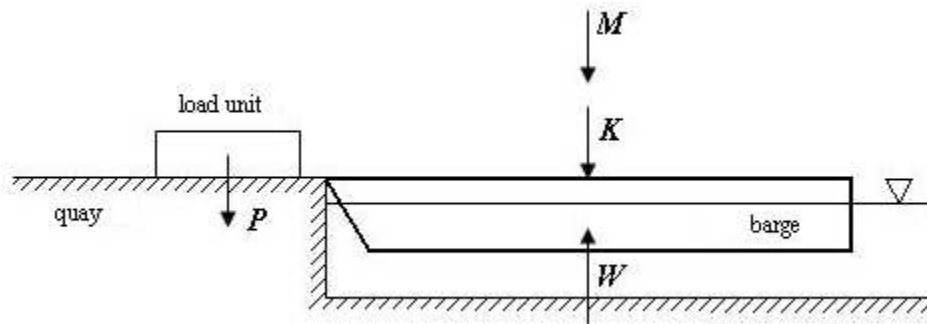


Fig. 1. Uninhibited location of a barge at the quay

Because of the foregoing, the following relation must be met:

$$M_{\max} = \sum_{i=1}^n P_i \quad (2)$$

During successive loading of the subsequent load units, the ballast mass must be gradually lowered, and the application point of force of ballast weight should be in position ensuring the temporary balance condition. For loaded j units this condition assumes the form of:

$$\left(M_{\max} - \sum_{i=1}^j P_i \right) b = p \sum_{i=1}^j P_i \quad (3)$$

where:

b – distance between the uplift pressure center and the point of force application

M_{\max} ;

p – distance between the uplift pressure center and the point of force application

$\sum_{i=1}^j P_i$.

The temporary value of force of ballast weight and its center of gravity location depend on the temporary values of forces of load units' weight located on the

vessel and a place of their location. This method of vertical stabilization of a barge will require very dynamic ballast system and a complex algorithm of its control. An additional complication for this system forms, possible for application here, a vertical division of ballast space that will allow only a quasi continuous change of distance values between the uplift pressure center and the point of ballast weight force application. Discontinuity of changes in b value and high inertia of the ballast system resulting from flow resistances of ballast water, may create disturbances in transshipment of a vessel by failing to meet the condition of permanent location of uplift pressure center, resulting in turn of deck plane around its transverse axis.

Fluctuations in the level of water should be considered in the method of operation presented above [10]. Unless the condition (2) can be referred to low water levels, (LW), then each higher state requires additional ballast mass allowing location of the loading deck of barge on the level of quay plane. Maximum ballast mass for this case will M'_{\max} therefore result from high levels of navigable water (HW) occurring in the aquatory of the transshipment terminal, i.e. that:

$$M'_{\max} = \sum_{i=1}^n P_i + \Delta M \quad (4)$$

$$\Delta M = \Delta h L B \delta \rho g \quad (5)$$

where: ΔM – additional ballast mass,

Δh – difference of water levels (current and minimum),

L – length of a barge,

B – width of a barge,

δ – hull block coefficient,

ρ – water density,

g – gravitational acceleration.

Value Δh directly determines growth in vessel immersion ΔT and, therefore, its immersion shall adopt the following values:

$$T = \Delta T + T_{LW} \quad (6)$$

where:

T_{LW} – immersion for the conditions of low water levels.

An increase in ballast mass under conditions of higher water levels increases the requirements concerning rational division of ballast space of a barge in the context of its vertical stabilization during the loading processes.

Option 2

In order to decrease the abovementioned risk of undesirable effect during barge loading, one may “support” the sledge bow of a vessel on the structure of a quay (as in Fig. 2a) or support it on a threshold (as in Fig. 2b), in cases of various shapes of the bow e.g. spoon, always present in motor barges.

With this second method of vessel location, at the moment of appearance of trends to trim the barge to bow – as a result of discontinuity of ballast's center of gravity relocation change – at the place of vessel support, a reaction R appears counteracting this phenomenon.

a) support of the bow on an oblique wall



b) support of the bow on a threshold

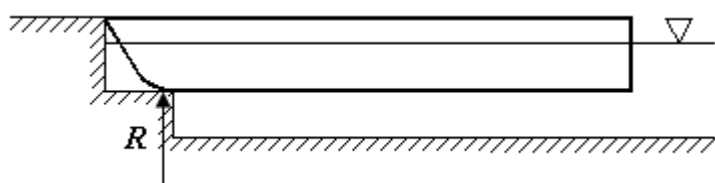


Fig. 2. Partially limited (supported) location of a barge at the quay

It is particularly hazardous in the phase of transportation of load from the quay onto the barge or from the barge to the quay. Additionally, support of the vessel's bow requires strengthening of its structure. In this case, occurring changes of water levels cause the need to increase the ballast mass above the mass of load units according to rule (4), which leads to increase of the required barge immersion determining the threshold location.

Option 3

A possibility of elimination of vessel tendencies towards angular vertical displacements (pitching), provides another, the third, way of its foundation at the quay. It is pictured by Fig. 3.

In this method, the barge is founded on a grate that eliminates all of its vertical movements. This allows reduction of requirements concerning dynamics of the ballast system and simplification of its control algorithm. Similarly, as in the first two methods of barge location, two conditions concerning the ballast mass, and, as a consequence, immersion of the vessel, must be met. It is the condition (2), specifying the mass of ballast at low levels of water and the condition (4) specifying the mass of ballast at levels of waters higher than LW .

In these latter conditions determined by the occurrence of water levels higher than low – in all three presented methods of barge location at quay – the output effect is an increase in immersion of a vessel at the time of its location at the quay.

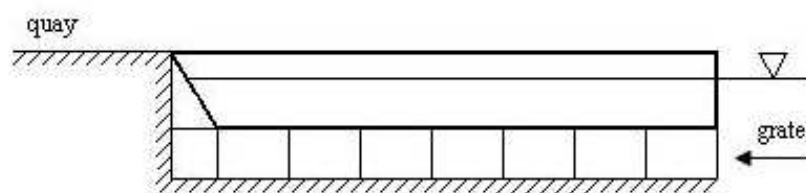


Fig. 3. Support of a barge on its entire length on a grate

This immersion must be greater than minimum required value of this parameter resulting from own weight of the floating structure and mass of the load.

With the assumption that loading should proceed under conditions of immersion included in the range of:

$$T_{LW} > T > T_{HW} \quad (7)$$

where:

T_{HW} – immersion for the conditions of high navigable water level, i.e. meeting the requirements throughout the whole range of navigable water levels, then the adequate minimum depth of basins for these conditions h_{\min} should meet the inequality:

$$h_{\min} > T \quad (8)$$

The relation of barge immersion during the transshipment operations to water conditions, leads to an increase of side height, creating, above all, ballast space, as well as an increase in own weight of the vessel, restricting, in turn, its load capacity. In commonly occurring in practice cases of large difference of water levels HW and LW , an increase in side height of a barge and the consequences of such increase would have to be significant.

Option 4

Possibility of elimination of negative phenomena generated as a result of water level changes, as well as vertical movements of a barge, contains yet another, fourth of the presented, method of its foundation at the quay, pictured by Figure 4.

The barge is founded on a grate in dry dock, whose basin is formed by: tight bottom, tight walls and dry dock gates. This method of vessel location does not require ballasting for the needs of transshipment regardless of the water level in the aquatory. Ballast system is therefore not so significant as in the previous solutions. There is no need to divide the ballast space above the construction requirements, because foundation of a barge on a grate ensures its horizontal stability in each phase of transshipment process.

Stabilization of a barge in the horizontal plane

Stabilization of barge's position in horizontal plane may be examined in two configuration options of the transshipment position. In cases when a vessel is situ-

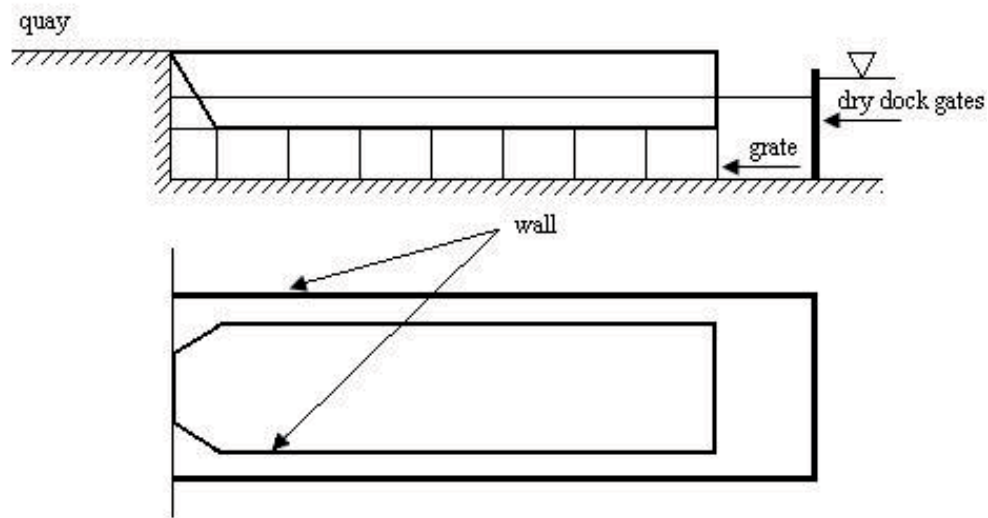


Fig. 4. Barge in dry dock

ated perpendicularly to the linear quay, its horizontal stabilization can be achieved through appropriate fastening of bow lines (Fig. 5). Additional limitation of movements can be introduced by dolphins placed along the sides of a barge.

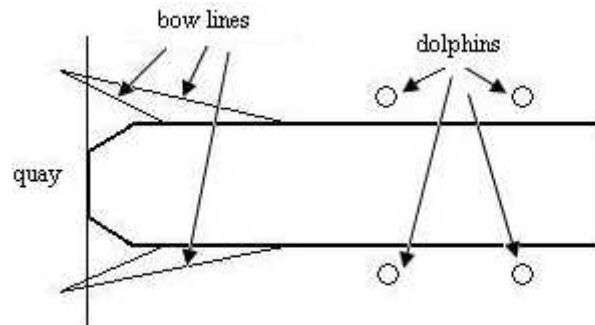


Fig. 5. Mooring a barge perpendicularly to the linear quay

This method of horizontal stabilization applies to, above all, the first two of the considered options of barge location, when they sail freely or are supported only in the bow part. Foundation of a barge on the grate practically eliminates the possibility of its horizontal movements.

Alternatively, the barge may be situated in parallel to the quay with a step, on which the loading units move (Fig. 6).

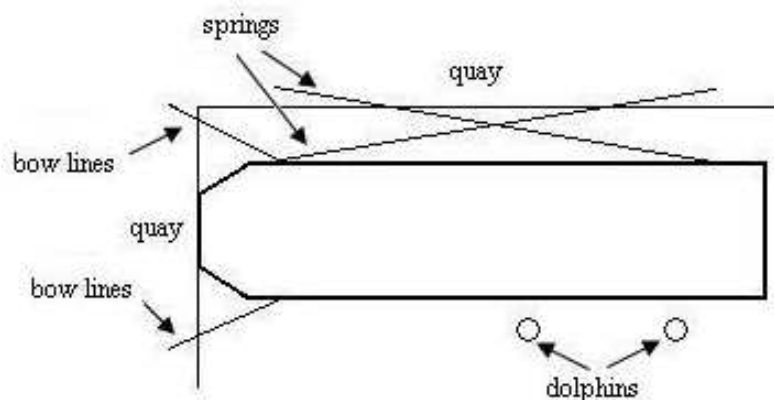


Fig. 6. Mooring a barge in parallel to the quay with step

In the case of a barge sailing freely or partially supported, its horizontal stabilization should be ensured by bow lines and springs which may be supplemented with dolphins. Barges located on a grate do not require such precautions, especially when the grate is in dry dock. Solutions of this type require construction of a special quay but do not form obstacles for traffic of other vessels, moving through the aquatory.

3. Conclusions

From among the proposed methods of vertical and horizontal stabilization of a barge during its transshipment, a solution of the transshipment terminal preferred by the Authors is a dry dock situated in parallel to the quay with a step (Fig. 4). In this solution, the front wall and one side wall of a dock are formed by quay walls, thus reducing dock construction costs. "Dry" foundation of a barge on a grate ensures its sufficient location stabilization without the need to use additional equipment elements such as mooring devices and dolphins. Location of a dock grate in relation to horizontal plane of the quay should ensure a possibility of entrance to and exit from the dock for barge with immersion resulting from its maximum load and low water levels. Preference of this solution – despite high construction costs, is supported by the fact that implementation costs of floating transport means handling the inland container terminals equipped with docks – will be the lowest.

Adoption of a concept, in which an innovative structure of a vessel is statically positioned in relation to the quay using a special dock and undertaking activities for implementation of such a solution, would, in the opinion of the Authors, create a possibility of process rationalization of container and integrated cargo units transport from sea ports further into the country with emphasis on opportunities offered by the proposed technology with regard to transport by inland routes. Intensification

of the Polish inland transport with regard to transport tasks finds both economic justification (a relatively cheap branch of transport) and justification from the point of view of environmental protection. Geopolitical conditions are also significant. The proposed solution may contribute to achieving a high reliability in the process of managing supply chains through reductions in the number and duration of the transshipment operations. The new technology may constitute an alternative to the existing solutions and make the process of container transport on the Polish inland routes more dynamic. Their transit depth is usually sufficient, at the number of container layers limited to one, for vessel immersion to not exceed 140 cm. At the same time, the height of this container layer increased by the height of free board and the height of passable loading platform, requires the height of clearances under bridges with values of 320 cm over *LW*, present on the majority of Polish waterways of classes II – V.

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