Portal cranes with Tandem spreaders and their economic benefits

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Abstract. This paper describes an innovative system of container reloading. The system involves Tandem spreaders included in portal cranes moving at the quay edge of maritime port container terminals. Thanks to the modern construction, it is possible to reload up to four ISO 1C containers at the same time, which not only reduces the reloading time, but also increases the reloading capacity of the terminal. The paper also discusses the economic aspects of the introduction of these new spreaders.

1 Introduction

In container terminals, mostly portal cranes are used to reload and unload containers to or from sea container ships. Their working space is limited (by the dimensions of the quay edge, length of the railway, availability of crane beams, etc.). Depending on their size, these cranes can even serve multiple road lanes and railway tracks, or storage lanes (lines) on the ground. The cranes are constructed based on the operator's requirements and parameters of the maritime port. The lifting capacity of cranes is usually between 40 t and about 70 t, and depending on the height of the construction, they allow for stacking containers in up to six layers (the largest port container cranes have a span of 60 m and can reload the largest sea container ships wide enough to contain up to 22 rows of containers). [4]

The actual container reloading is not very time-consuming. What also adds to the total time of reloading is not only the time the spreader with containers spends riding between the quay edge and container ship, but also the time spent attaching the individual containers. Currently, the most frequently used spreaders are the standard ones allowing for the attachment of one container. [1]

To speed up the loading and unloading of containers from large sea container ships, special Tandem spreaders have started to be used allowing for the lifting of multiple containers at the same time [6]:

- Twin-lift spreader for two ISO 1C containers (see Figure 1);
- Tandem spreader for two ISO 1A containers or four ISO 1C containers (see Figure 2).

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Fig. 1. Twin-lift spreader for two 20-foot containers. Source: www.vdlcontainersystemen.com

Fig. 2. Tandem spreader for two 40-foot containers. Source: www.dpworld.ae

2 Tandem spreaders

Different types of spreaders are used in reloading containers using portal cranes with Tandem spreaders. These spreaders can be either telescopic or fixed. Based on the spreader type, it is possible to reload a 20' container, a 40' and 45' container or their combinations. [3] The following overview includes 4 basic types of these Tandem spreaders.

1. Tandem telescopic 40'/45' spreader allowing for the reloading of up to two 20', 40' and 45' containers within one lift cycle (see Figure 3). The spreader capacity depends on the combinations of individual types of containers and can be up to 82 t.

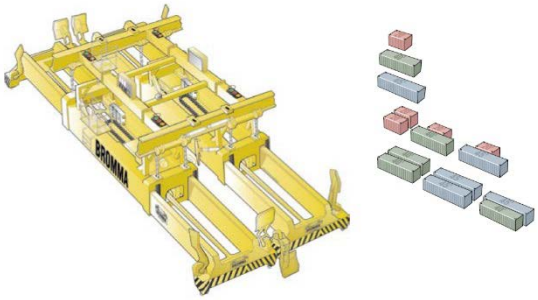


Fig. 3. Tandem telescopic 40'/45' spreader and possible container combinations. Source: www.bromma.com

2. Tandem telescopic 45' spreader allowing for the reloading of up to four 20', 40' and 45' containers within one lift cycle (see Figure 4). Thanks to the telescope, the reloaded 20' containers can be moved up to 1.5 m apart. The spreader capacity depends on the combinations of individual types of containers and is between 100 and 130 t.

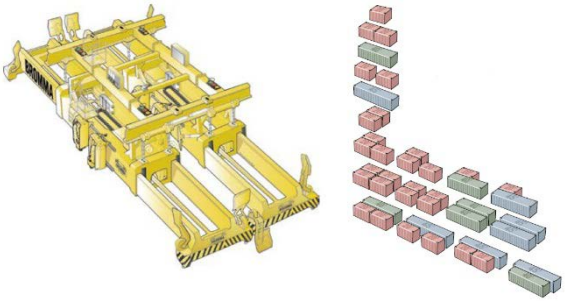


Fig. 4. Tandem telescopic 45' spreader and possible container combinations. Source: www.bromma.com

3. Tandem telescopic Fix 40' spreader allowing for the reloading of up to two 40' and 45' containers within one lift cycle (see Figure 5). Its versatility is significantly limited by the fixed spreader span. The spreader capacity is 77 t.

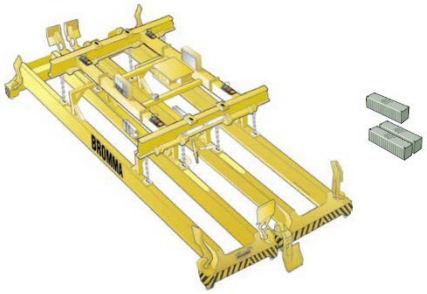


Fig. 5. Tandem telescopic Fix 40' spreader and possible container combinations. Source: www.bromma.com

4. Tandem telescopic Quattro spreader allowing for the reloading of up to four 20', 40' and 45' containers within one lift cycle (see Figure 6). Due to its simplified construction, it cannot lift a single 20-foot container alone (always a pair of containers only). The spreader capacity is the same as in the 45' type (100–130 t depending on the combinations of individual types of containers).

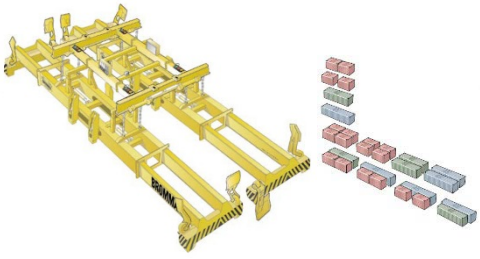


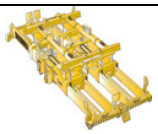
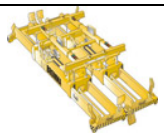
Fig. 5. Tandem telescopic Quattro spreader and possible container combinations. Source: www.bromma.com

All the above mentioned types of tandem spreaders have different constructions, and as such they can lift different container combinations. The Tandem telescopic 45' spreader appears to be the most useful one allowing for all possible combinations of the above mentioned containers. In addition to the longitudinal arm spread to contain a 20' and 40' container, it is possible to do side shift on individual spreaders as well. This allows for a

smooth reloading of two containers in the longitudinal direction onto terminal carriers, as can be seen in Figure 2. Yet another advantage to this spreader is the height adjustment of both carriers to handle containers of different heights (8' 6", 9' 6"). The use of a given type of Tandem spreader also depends on the loading capacity of the specific portal crane. Based on the loading capacity of the crane beams, the appropriate spreader type can be selected.

Technical data of the individual Tandem spreader types is summarized in the following overview (see Table 1).

Table 1. Technical data of Tandem spreaders. Source: www.bromma.com, modified by the author

Technical data	Tandem 40´/45´	Tandem 45´	Tandem Fix 40´	Tandem Quattro
				
Spreader lifting capacity	2 x 41 t	2 x 51 t 4 x 32.5 t	2 x 35 t	2 x 51 t 4 x 32.5 t
Spreader tare weight	23.2/25 t	31 t	16 t	24 t
Total spreader height	2,800/2,900 mm	2,900 mm	2,400 mm	2,900 mm
Tandem separating	1,000 mm / 10 seconds	1,000 mm / 10 seconds	1,000 mm / 10 seconds	1,000 mm / 10 seconds
Flipper arm speed	180° / 3-5 seconds	180° / 3-5 seconds	180° / 3-5 seconds	180° / 3-5 seconds
Twistlock rotation	90° / 1 second	90° / 1 second	90° / 1 second	90° / 1 second

Most portal cranes in container terminals can currently perform up to 30 reloading operations per hour. The newly constructed portal cranes with a beam of 60 m and more and with twin-lift Tandem spreaders can do up to 40 reloading operations per hour. This increases not only the daily, but also the annual capacity of the cranes and container terminals (see Table 2). [2]

Table 2. Terminal operations – portal cranes. Source: www.cargosystems.net, modified by the authors

Parameter	2010-2016	Present
Feasible reloading	3,000-4,000 cycles / 24 hours	5,000 cycles / 24 hours
Feasible reloading using portal cranes	20-30 cycles/hour	40 cycles/hour
Utilisation of crane's working hours	75%	90%
Average number of portal cranes	3-4	6
Annual crane performance (containers)	800,000 containers/year	1,000,000 containers/year
Annual crane performance (TEU)	1,000,000 TEU/year	1,500,000 TEU/year
Annual crane performance per 1 meter of quay edge (TEU)	1,000 TEU/year	3,500-4,500 TEU/year

3 Economic evaluation of Tandem spreaders

As mentioned above, the use of of twin-lift Tandem spreaders increases the productivity of reloading operations. Other benefits of using this system for the container terminal operator include:

- more efficient use of labour force, reducing the personnel costs (for crane operators, auxiliary staff) and the cranes' operating costs.
- increased operating capacity of the quay edge, reducing the costs per reloading operation at the quay edge.
- shorter time the vessels spend at the port and lower costs related to the vessel's stay (thanks to which the operator can make changes to liner shipping and offer more above-standard services related to the higher number of lines (vessels)).

It is to be noted that using these spreaders won't double the terminal's operating capacity for reloading operations. Studies carried out by AECOM show that in using standard spreaders, the hourly capacity of a crane is 30 reloading operations, whereas in using Tandem spreaders, it is possible to achieve up to 40 (a maximum of 45) reloading operations per hour (considering 100% Tandem spreader capacity utilisation and 5000 reloading operations per day). This increase is due to a number of factors including the storage of containers on the ship, their attachment by the spreader or the availability of terminal carriers for reloading. It is to be noted that the use of Tandem spreaders increases the number of operations, but also increases the number of terminal carriers (tractors with semi-trailers) used to move the containers from the quay edge to the individual terminal units where they are reloaded by portal cranes. [8]

The following Table (see Table 3) compares the total costs of reloading operations using portal cranes with standard and Tandem spreaders. The comparison shows that the use of a Tandem spreader saves 11 dollars per reloading operation. [7]

Table 3. Comparison of total costs of reloading operations (in dollars). Source: www.cargosystems.net, modified by the authors

Parameter	Standard spreader	Tandem spreader
Assigned terminal carriers (tractors with semi-trailers) for individual cranes	6	10
Total costs of loading and unloading per hour (in dollars)	2,560	3,370
Number of operating terminal cranes in terminal units	1.5	3
Crane productivity (number of reloading operations per hour)	30	45
Costs per reloading operation (in dollars)	85.34	74.15

The benefits of the use of Tandem spreaders are obvious for shipowners as well. The following Table (see Table 4) shows the potential difference in the costs of vessel's stay at the port. Assumed is the use of a large container ship with daily operating costs of 40,000 dollars. This price includes the rent at the port, crew costs, costs of energy at the port, and costs related to the stocktaking of goods on board. In evaluating the costs, 16 working hours

are assumed per day. As for the size of the container ship, 6,000 reloading operations are considered per day. The Table shows that in a best case scenario, using the Tandem spreader can save about 7 dollars per reloading operation of the costs of an operating vessel due to the shorter time spent at the port. It is apparent that with a greater number of reloading operations, the vessel's operator can save a considerable amount of operating costs.

Table 4. Comparison of total costs of vessel's stay at the port (in dollars). Source: www.cargosystems.net, modified by the authors

Parameter	Standard spreader	Tandem spreader
Daily vessel operating costs	40,000	40,000
Expected number of reloading operations	6,000	6,000
Number of operating portal cranes at the quay edge	4	4
Crane productivity (number of reloading operations per hour)	30	45
Daily working hours spent reloading (in hours)	16	16
Number of days the vessel spends at the port	3.13	2.08
Vessel operating costs	125,000	83,333
Vessel operating costs per reloading operation	20.83	13.89

Very interesting is the evaluation of costs in relation to the container terminal's infrastructure (see Table 5). The use of Tandem spreaders increases the terminal's operating capacity. In a model terminal, an annual operating capacity of 300,000 reloading operations per anchorage can be assumed using standard spreaders. A ship length of 400 m (approx. 1,300 feet) can be assumed per anchorage. In evaluating the costs, a lifespan of 30 years and interest rate of 6% were considered. Table 4 shows that in a best case scenario, a Tandem spreader portal crane can save about 6 dollars per reloading operation of the terminal's infrastructure costs.

Table 5. Comparison of total costs of vessel's stay at the port (in dollars). Source: www.cargosystems.net, modified by the authors

	Standard spreader	Tandem spreader
Length of quay edge for ships (in metres / feet)	400 (1,300)	400 (1,300)
Unit costs per 1 foot of quay edge	60,000	60,000
Total costs of quay edge	78,000,000	78,000,000
Costs of quay edge per year	5,666,615	5,666,615
Reloading capacity of quay edge (number of operations per year)	300,000	450,000
Costs of quay edge per reloading operation	18.89	12.59

However, it is not quite clear that the terminal would be able to reach the best productivity of reloading operations (45 operations per hour) using a Tandem spreader. To be able to

evaluate potential advantages or disadvantages of potential costs, AECOM simulated individual technological operations in reloading and distributed the benefits of use of a Tandem spreader between 30 to 45 operations per hour (the results were related to 0 to 15 reloading operations) considering the performance advantage compared to portal cranes with standard spreaders.

Table 6. Comparison of benefits of the increased number of reloading operations in relation to individual port operating costs (in dollars). Source: www.cargosystems.net, modified by the authors

Benefit of reloading operations	Personnel cost saving	Vessel operating cost saving	Anchorage cost saving	Total saving
15	11.19	6.94	6.30	24.43
10	1.92	5.21	4.72	11.85
5	- 10.00	2.98	2.70	- 4.32
0	- 25.89	---	---	- 25.89

Table 6 and the visualization of total savings (see Figure 6) of the use of Tandem spreaders show that the break-even point is reached with about seven reloading operations, i.e. in using a Tandem spreader the hourly operating reloading capacity of which is at least 37 operations. In other words, if there are additional 7 reloading operations per hour, the terminal will profit from the introduction of Tandem spreaders for portal cranes. This analysis is indeed related to a model terminal. It is to be noted that in different parts of the world, some costs have different values (mainly the personnel costs, use of terminal carriers). That's why the analysis is to be carried out considering the specific conditions of a given terminal.

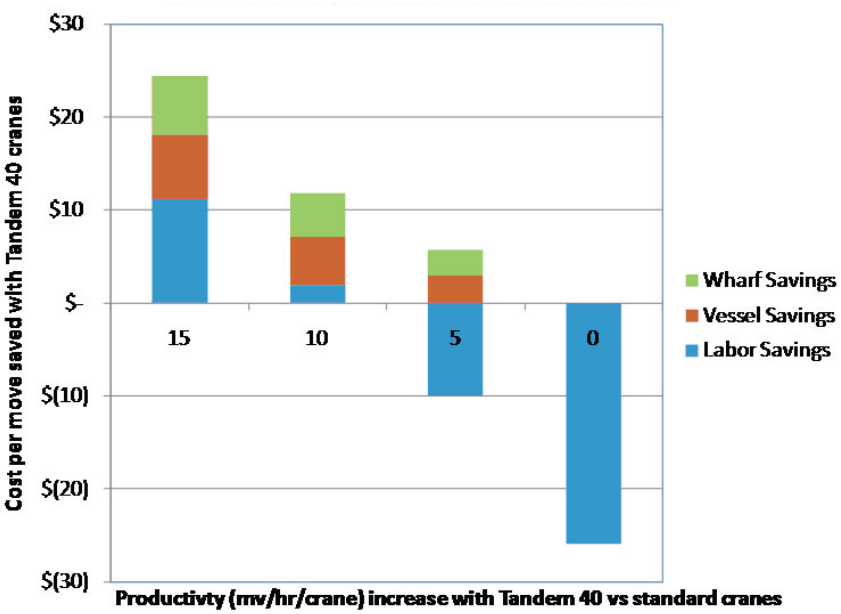


Fig. 6. Visualization of cost savings when increasing the reloading capacity with 0, 5, 10 and 15 reloading operations per hour. Source: www.cargosystems.net, modified by the authors

However, the use of the twin-lift technology is also related to the subsequent distribution of containers to the individual terminal units and increased reloading in the individual units. The higher number of reloaded containers simultaneously increases the number of mobile vehicles necessary. A number of technologies is used in the subsequent distribution of containers, including tractors with semi-trailers, straddle carriers and automatic guided vehicles (AGVs). [5]

However, the number of vehicles used only increases by a few. This increased number of vehicles is thus not so significant in the overall container reloading process at the terminal.

4 Conclusion

This paper dealt with the benefits, mostly economic ones, related to the introduction of Tandem spreaders with twin-lift technology. It was shown that their use not only increases the reloading capacity, but with the given number of reloading operations, it also makes the reloading system more profitable. Based on the great success of Tandem spreaders, ZPMC (Shanghai Zhenhua Port Machinery Co. Ltd) developed triple-lift spreaders. These can lift one, two and even three ISO 1A containers. Every spreader is naturally equipped with the twin-lift technology allowing for lifting 2 ISO 1C containers by one spreader. The total capacity is thus 6 ISO 1C spreaders. Compared to the twin-lift spreader, the reloading is by 15–20% faster. The system has been tested and is in full operation at the Ma Wan Container Terminal in Shenzhen (China).

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