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Feasibility study of reach stacker model choice

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Abstract. The paper considers an approach to choosing the optimal reach stacker model for container terminals based on engineering-and-economic performance. The technical characteristics of models from leading global manufacturers of handling machinery are analyzed. A methodology to determine the technical and operational productivity of reach stackers in the absence of complete data from the manufacturer is proposed. Five key efficiency criteria are identified: specific power, energy saturation, economic efficiency, cost power and cost mass. The most effective model choice is justified based on the ranking of models for each criterion and the calculation of the final score.

The study results can be applied when forming technical requirements and specifications for the purchase of handling machinery. They also serve as an analytical basis for making informed management decisions in the field of logistics infrastructure development, and cargo terminals and ports modernization.

Keywords: reach stacker, container, productivity, efficiency criterion.

INTRODUCTION

Mechanization of container handling operations in cargo terminals and ports is currently mainly carried out using reach stackers.

Although reach stackers produced by different manufacturers share the same general design type, certain models incorporate specific design features. These include variations in the relative positioning of the cabin and boom and differences in boom shape. Such modifications enable the equipment to perform specialized tasks, such as loading containers into the holds of watercraft or handling containers placed on railway platforms and special trailers [1–4]. Among the leading manufacturers of reach stackers, one can identify companies such as Ferrari (Italy), Liebherr (Germany), Kalmar (Sweden), Terex (USA), Hyster (Netherlands), Fantuzzi (Italy), Konecranes (Sweden), ZPMC (China), Taylor (USA), Sany (China), Volvo (Sweden), and others.

One of the key tasks for the effective functioning of transshipment complexes and container terminals is the choice of the optimal reach stacker model, as well as determining their required quantity, which allows fully ensuring the specified cargo flow.

The following main parameters should be taken into account when choosing the reach stacker: carrying capacity, tiers number of containers for stacking, productivity (containers per hour), and specific efficiency indicators that take into account the economic and operational aspects of the machinery. Additional characteristics include compatibility with various types of spreaders, engine power, transmission type, features of the running gear.

PURPOSE OF THE PAPER

The purpose of the paper is to develop the choice methodology of the optimal reach stacker model from the available list of machines for specific production conditions, taking into account their engineering-and-economical performance.

RESEARCH RESULTS

For example, all CVS Ferrari models are equipped with Kessler drive axles featuring oil-bath multi-disc brakes. Most models in the main series are fitted with a rotary spreader (capable of rotating 95° to the left and 185° to the right) with an upper grip, enabling them to handle both 20- and 40-foot containers. The equipment also includes a CANBUS control system, overload and overturn protection system, rollback prevention system during boom lowering, and full set of components for operation in low-temperature environments [5].

Hyster, which operates production facilities in Europe, the USA, Japan, Australia, Brazil, Mexico, and the Philippines, introduced a new line of reach stackers following successful testing. For the IH-type models, an automatic cab displacement of 2.6 meters is a standard feature, providing enhanced visibility at low lifting heights, particularly useful for monitoring the load base and ground clearance. In contrast, the SN models feature a manually adjustable cab, which can also be shifted up to 2.6 meters to facilitate access to the engine and subframe components.

The Liebherr LRS 545 reach stacker, developed by the West German company Liebherr, is designed for handling containers with a capacity of up to 45 tons. It is capable of stacking containers up to the fifth tier in the first row. A common operational issue with the hydraulic boom drive is the occurrence of asymmetric loads, which may result from malfunctions of the hydraulic cylinder locks or from lateral force-induced overloads. The boom’s box-section telescoping mechanism is driven by two hydraulic cylinders arranged coaxially within the boom housing. The first cylinder is installed at the base of the boom, while the second is located in the upper telescopic section, near the boom head.

The key distinguishing feature of SMV Konecranes reach stackers, apart from the use of axial-piston pumps, is their chassis frame, which is constructed from a welded box-profile design with reinforced upper and lower walls. Notably, throughout the entire production history, the company has reportedly never received complaints regarding cracks in this structural design.

Kalmar Industries operates manufacturing facilities in Sweden, Finland, the Netherlands, and the USA, with its equipment used in more than 140 countries worldwide. For handling loaded containers in the second and third rows, Kalmar offers «heavier» models equipped with support jacks. These models are particularly suitable for transferring containers from railway platforms located on adjacent tracks or for overloading containers from car trailers.

Terex offers several models designed for handling containers with a carrying capacity of up to 45 tons, including the TFC45, TFC45R, and TFC45RS, all featuring a 6,000 mm wheelbase. Additionally, the company produces extended-base versions TFC45L, TFC45LS, and TFC45LSX characterized by a 7,000 mm distance between wheel axles, as indicated by the letter «L» in the model index.

To list reach stacker models that meet the company’s requirements for carrying capacity and the number of container tiers, it is necessary to determine their productivity in the absence of relevant information from the manufacturer. This can be achieved by estimating the key performance indicators of each model based on available operational data and industry benchmarks [5–8]. Factors such as carrying capacity, handling time per container, movement speed, stacking height, and the efficiency of the equipment in real-world conditions must be considered [9].

The reach stacker productivity depends on:

– design features of the specific machine model;

– organization level of container handling operations;

– adopted technology for performing operations and qualifications of an operator.

The technical productivity of the reach stacker is determined by equation

$$P_t = \frac{3600 \cdot Q_n}{T_c},$$

where Q_n – cargo mass moved by the machine in one cycle, t (nominal carrying capacity); T_c – cycle time, s.

We determine the cycle time for the reach stacker by the equation

$$T_c = k_{op} \cdot \left(t_1 + t_2 + ... + t_9\right),$$

where k_{op} – combination factor of operations by time; t_1 – time for grabbing the container and preparing for transportation, s (includes partial extension of the boom, grabbing the container and partial lifting of the boom); t_2 – time for turning the reach stacker with the container, s; t_3 – moving time of the machine with the container to the required distance, s; t_4 – time for lifting the container to the required height, s (depending on the tiers number); t_5 – time for stacking the container in a stack, releasing the spreader from the container, s; t_6 – time for folding (retracting) the telescopic boom and lowering it to a horizontal position, s; t_7 – turning time of the reach stacker without the container, s, $t_7 = t_2$; t_8 – reverse idle time of the reach stacker, s; t_9 – total time for controlling the machine and turning on the hydraulic units, s.

The moving time of the reach stacker with and without the container is determined by equation

$$t_3 = t_8 = \frac{L}{v_m} + t_a,$$

where L – average distance of transporting the container to the stacking location, m (depends on the layout and size of the container yard); t_a – time for acceleration and deceleration of the reach stacker, s; v_m – movement speed of the reach stacker, m/s (with and without the container, respectively).

The operational productivity of the reach stacker is determined by equation

$$P_o = k_t \cdot P_t,$$

where k_t – utilization factor of the reach stacker by time.

The productivity of the reach stacker can also be determined by the number of container operations per hour [10], that is, the number of technological cycles («lifts» of the container) performed by the machine per unit of time.

The appearance of reach stackers allows you to significantly speed up the operation with containers in cargo terminals and ports.

Let us give an example of calculating and choosing the optimal reach stacker model from the considered list of machines based on efficiency criteria that reflect the ratio of technical and cost characteristics for each model.

The main technical characteristics of reach stackers, analyzed taking into account the relevant efficiency criteria, are given in Table 1.

Fig. 1 shows histograms illustrating the calculation results of the efficiency criteria for the compared reach stacker models. However, the efficiency criteria of reach stackers and the corresponding calculation equations are given in Table 2.

It is assumed that all the presented efficiency criteria have equal weight in determining the optimal reach stacker model [11–13].

The compared reach stacker models are ranked by each efficiency criterion in places – from 1 to 6 by given the results of the calculations (Fig. 1). In this case, the number of the place obtained by the reach stacker according to a certain criterion corresponds to the number of points that are accrued when calculating the final indicator.

Thus, the best is considered to be the reach stacker model with the lowest total score, for the comprehensive assessment of efficiency.

The calculation results of the efficiency criteria and the corresponding ranking of reach stacker models for each criterion are presented in Table 3.

Table 1. Technical characteristics of reach stackers

No. s/n	Reach stacker model	Carrying capacity, t	Tiers number of containers	Engine power, kW	Operating weight, t	Average cost, UAH million*
1	CVS Ferrari F500-RS8 (Italy)	45	5	257	87.0	6.35
2	Hyster RS45-27IH (USA)	45	5	223	78.0	5.0
3	Liebherr LRS 545 (Germany)	45	5	230	69.0	6.95
4	Konecranes SMV 4531TC5 (Sweden)	45	5	265	71.8	3.97
5	Kalmar DRF 450 (Sweden)	45	6	182	76.0	4.0
6	Terex TFC 46MX (USA)	45	6	239	78.6	4.36
Notes: 1) *average cost of the used reach stacker model, produced in 2005–2010 (based on market price analysis); 2) all considered reach stacker models are designed to handle 20’…40’ containers.						

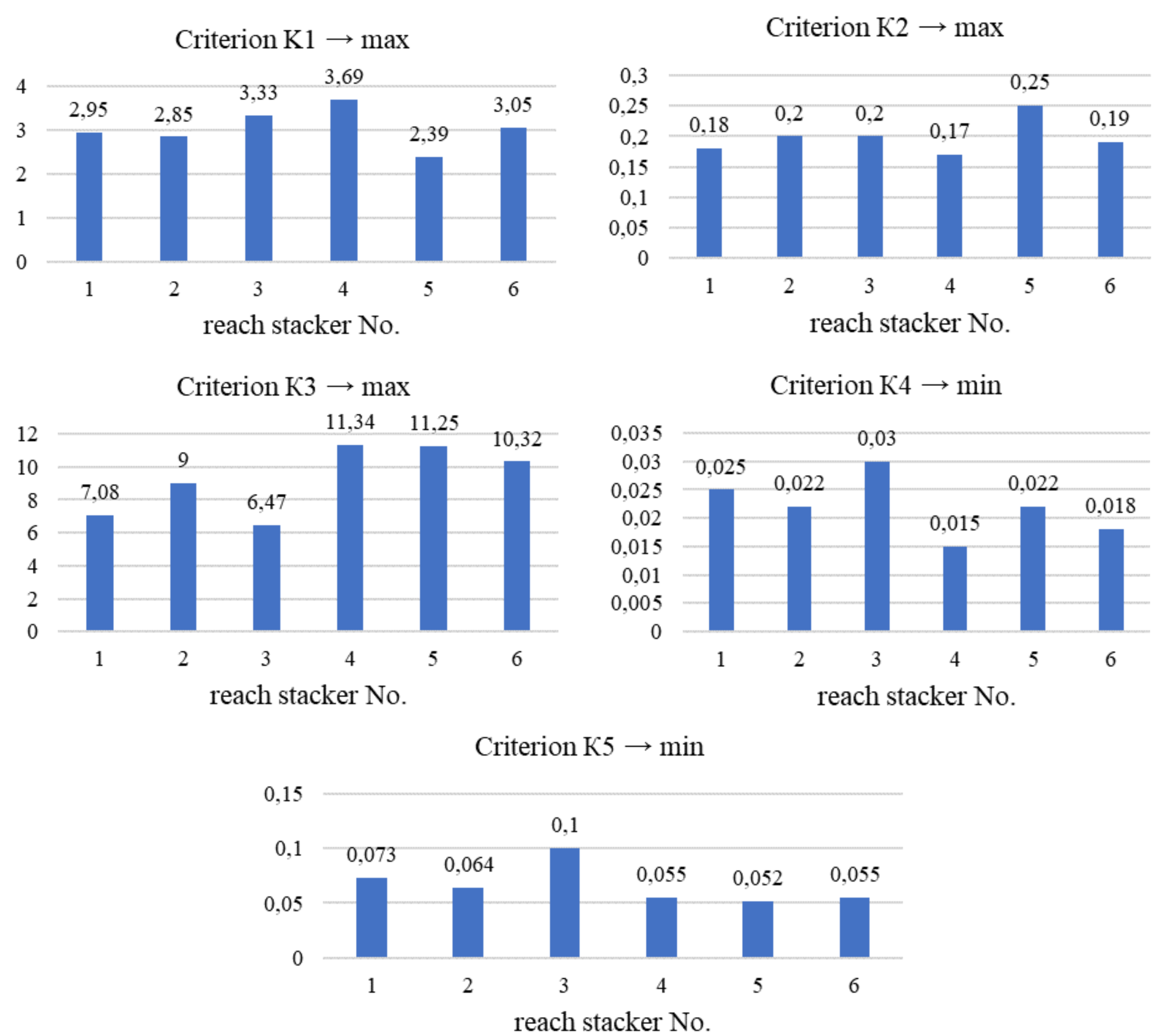

Fig. 1. Calculation results of the efficiency criteria for reach stacker models

Table 2. Efficiency criteria of the reach stacker

Marking	Name	Units	Calculation formula	Efficiency under the condition
K1	Specific power	kW/t	P/m	K1 → max
K2	Energy saturation	t/kW	Q/P	K2 → max
K3	Economic efficiency	t/UAH million	Q/B	K3 → max
K4	Cost power	UAH million/kW	B/P	K4 → min
K5	Cost mass	UAH million/t	B/m	K5 → min

Table 3. Ranking of reach stacker models by efficiency criteria

No. s/n	Reach stacker model	Efficiency criterion					Final score
		K1	K2	K3	K4	K5	
1	CVS Ferrari F500-RS8 (Italy)	4	4	5	4	3	20
2	Hyster RS45-27IH (USA)	5	2	4	3	4	18
3	Liebherr LRS 545 (Germany)	2	2	6	5	5	20
4	Konecranes SMV 4531TC5 (Sweden)	1	5	1	1	3	11
5	Kalmar DRF 450 (Sweden)	6	1	2	3	1	13
6	Terex TFC 46MX (USA)	3	3	3	2	2	13

The reach stacker model Konecranes SMV 4531TC5 (Sweden) can be recommended as the best option for commissioning, as it provides the best ratio of engineering-and-economic performance among the analyzed samples according to the results of a comprehensive performance assessment. At the same time, models No. 5 and No. 6 reach stackers can be considered as alternative solutions, especially if certain specific criteria or budget constraints are prioritized.

CONCLUSIONS

The proposed methodology allows for the comprehensive and valid choice of the optimal reach stacker model, taking into account technical characteristics and efficiency criteria that consider the machinery economic and operational aspects. Ranking of models by each efficiency criterion and subsequent calculation of the total score ensures transparency and objectivity in the decision-making process.

The study results can be used in the formation of technical specifications for the handling machinery purchase, as well as for making management decisions in logistics and port complexes.

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Техніко-економічне обґрунтування вибору моделі річстакера

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[1,3,4,5]*Відокремлений структурний підрозділ Миколаївський будівельний фаховий коледж Київського національного університету будівництва і архітектури*

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Анотація. У роботі розглянуто підхід до вибору оптимальної моделі річстакера для контейнерних терміналів на основі техніко-економічних показників. Проаналізовано технічні характеристики ряду моделей провідних світових виробників перевантажувальної техніки. Запропоновано методику визначення технічної та експлуатаційної продуктивності річстакерів за відсутності повних даних від виробника. Визначено п'ять ключових критеріїв ефективності: питома потужність, енергонасиченість, економічність, вартісна потужність та вартісна маса. На основі ранжування моделей за кожним критерієм та підрахунку підсумкового балу обґрунтовано вибір найефективнішої моделі.

Результати проведеного дослідження можуть бути застосовані під час формування технічних вимог і специфікацій при закупівлі перевантажувальної техніки, а також слугувати аналітичною основою для обґрунтованого прийняття управлінських рішень у сфері розвитку логістичної інфраструктури та модернізації вантажних терміналів і портів.

Ключові слова: річстакер, контейнер, продуктивність, критерій ефективності.