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ANALYSIS OF TRENDS IN ENERGY DEMAND FOR MAIN PROPULSION, ELECTRIC POWER AND AUXILIARY BOILERS CAPACITY OF GENERAL CARGO AND CONTAINER SHIPS

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Abstract

The paper deals with the problem of energy demand for the main propulsion as a function of deadweight and speed for general cargo vessels built in the 60-ties, multi-purpose general cargo vessels built In the 80-ties as well as recently built container vessels. Changes in power of the main propulsion and trends observed in the matter are defined. In the same way the analysies of electric power and boilers capacity are carried out. In the summary conclusions and prognosis concerning energetic plants of general cargo and container vessels are expressed.

Keywords: *cargo ship, container ship, main propulsion power, electrical power, auxiliary steam delivery, statistics*

1. Introduction

General cargo vessels built in the 60-ties were designed for carriage of general cargo i.e. industrial goods counted in number and packed in boxes, drums, bales, bags or other similar packages. Such vessels were usually provided with cargo handling equipment (deck cranes, cargo booms) to make possible cargo operation without aid of harbour cargo facilities. Cargo space of the vessel was divided by bulkheads and twin decks to optimise the space utilisation and to separate different kinds of cargo as well as to separate cargo of different destinations. The speed of these vessels was 16 ÷17 knots. At the turn of the 60-ties and the 70-ties a new kind of general cargo vessels fitted for container carrying named **universal** or **multi purpose general cargo vessels** were built. They achieved service speed of 18÷20 knots. In the mid of 70-ties traditional general cargo as well as multi purpose general cargo vessels were almost entirely replaced by containerised cargo and ships named **container vessels.**

Container vessels are the ships equipped with special guides to freight vertically loaded and unloaded containers. The first ship adapted in 1956 from tanker for container transport was *Ideal-X*. Nowadays, the biggest container vessels can carry above 10,000 TEU and can hardly be situated in panamax class dimensions. The number of those ships is bigger than panamax class and they are used on routes excluding Panama Canal passing e.g. China – USA West Coast. Today the biggest container vessel is MS EMMA MAERSK with carrying capacity of 11,500 TEU shown in fig. 1.To ensure quick transport of containers all around the world and to minimise transport expenses large container vessels travel overseas calling at a number of big ports called *hubs*. Containers are delivered from smaller ports to *hubs* by small container vessels (200-500 TEU) named *feeders*. A number of small container vessels (below 3000 TEU) is equipped with cargo handling facilities (deck cranes or bridge cranes), so they are able to call at ports not equipped with cargo facilities. Bigger container vessels have to use harbour equipment. Regarding vessel dimensions and weight of containers a special goliath gantry cranes are used. Container vessels are the quickest freighters. They achieve service speed of 24-26 knots.

Fig.1. M/S EMMA MAERSK at sea

An initial analysis shows as follow:

- the main propulsion is executed by low speed diesel engines; in case of modern container vessels steaming with high speed very large and powerful diesel engines of 100,000 HP and bigger shaft power are used,
- three diesel generators create onboard power station on general cargo vessels; sometimes an additional shaft generator is used; in case of container vessels the onboard power station is considerably bigger due to the necessity of bow thrusters and refrigerated containers supply,
- a boiler room usually consists of two auxiliary steam boilers one fuel fired and the second one heated by main engine exhaust gases; capacity of boilers 2000-3000 kg/h and considerably higher on big container vessel.

The aim of this paper is an analysis of the trends in development of main propulsion power, electric power and auxiliary boiler capacity on general cargo and container vessels by means of statistics.

2. Analysis of main propulsion plants development

To determine main propulsion power of general cargo vessels built in the 60-ties the data of 287 such ships was taken to considerations [3]. The result of statistic calculations is the formula (1) [3] [5] which shows the dependency of main propulsion power on deadweight and ship service speed:

$$\mathbf{N_n = 0{,}039 \cdot D^{0{,}435} \cdot v^{2{,}918} \quad [kW],} \qquad (1)$$

where: N_n [kW] – shaft power of the main engine,

D [tons] – deadweight,

v [knots] – ship service speed.

Statistic researches of container vessels built in the last years gave formula (2) [2]:

$$\mathbf{N_n = (0{,}99179 + 0{,}00003412 \cdot D) \cdot v^3 \quad [kW],} \qquad (2)$$

On the basis of formulas (1) and (2) the dependency of main propulsion power on deadweight and different service speed for general cargo vessels is shown in figure 2 and the same for container vessels is shown in figure 3. To enable the comparison of main propulsion plants development in last years for both cases, the approximation of both formulas was done by means of linear functions. An example of the final analysis concerning main propulsion power of both types of vessels for given speed v=18 knots is shown in figure 4.

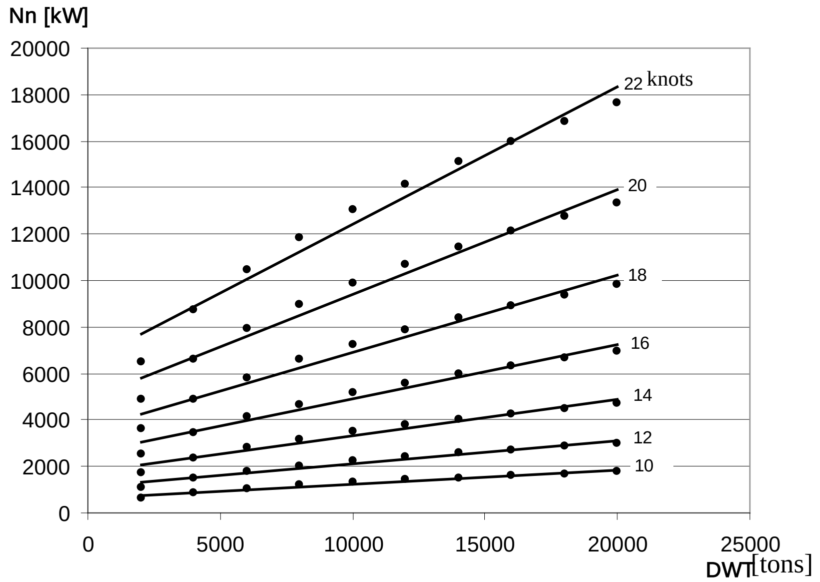

Fig. 2. Dependency of general cargo vessels main propulsion power on deadweight for different speed

$N_n = 0{,}0287 * D^{0{,}435} * v^{2{,}918}$ [kW] DWT [tons], v [knots]

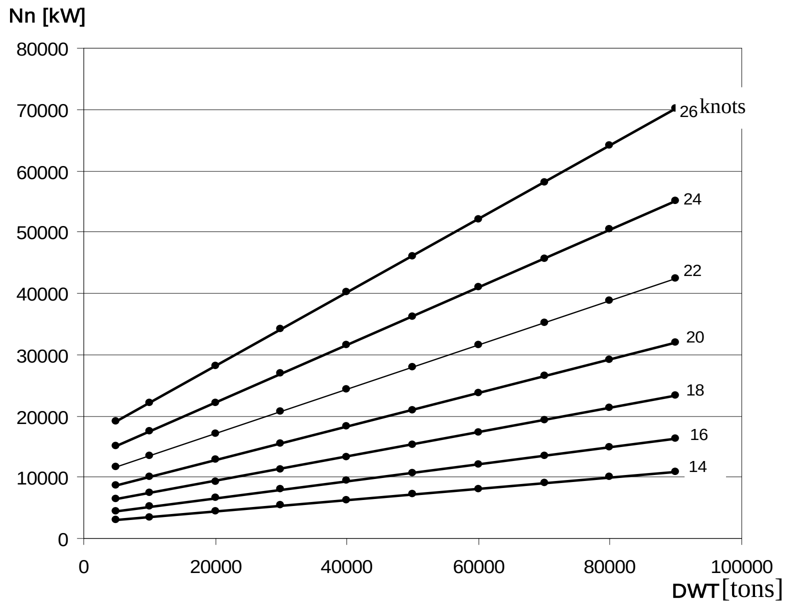

Fig. 3. Dependency of general container vessels main propulsion power on deadweight for different speed

$N_n = (0{,}9179 + 0{,}00003412 * D) * v^3$ [kW] DWT [tons], v [knots]

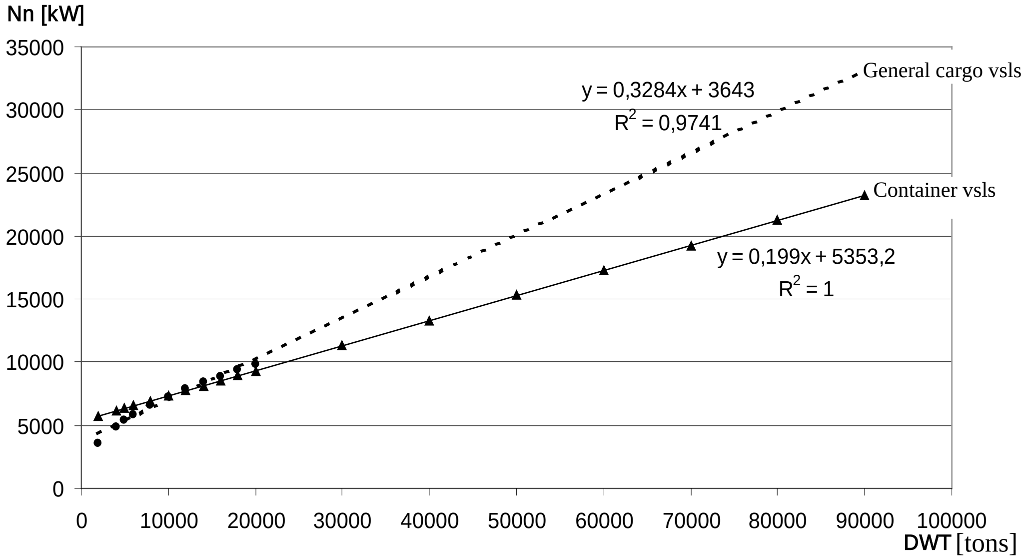

Fig. 4. Comparison of main propulsion power of general cargo vessels and container vessels at service speed 18 knots

As the largest built general cargo vessels achieved deadweight of about 20,000 tons to make it possible to compare with container vessels an extrapolation of power describing function was executed as a prognosis. The result of comparison (fig. 4) shows that for vessels larger than about 15,000 tons the main propulsion energy demand of general cargo vessels is much bigger than the same of contemporary built container vessels. It is probably possible due to the improvement in hull construction. General cargo vessels built in the 60-ties and the 70-ties did not have bow bulb and modern stern construction thus the resistance of ship hull in motion was higher and the same for main propulsion power demand. On the other hand, a high main propulsion power of container vessels is the result of high service speed because container vessels are the fastest merchant vessels.

3. Analysis of onboard power station development

The total electric power of general cargo vessels onboard power station can be approximately estimated from formula (3) elaborated by Centrum Techniki Okrętowej in Gdańsk [4]:

$$\mathbf{\Sigma N_{el} = 23 + 0{,}1088\, N_n} \text{ [kW]}, \tag{3}$$

where: ΣN_{el} [kW] – total electric power,
N_n [kW] – main propulsion power (main engine shaft power).

Next, the total electric power of container vessels power station is given in formula (4) described in method [1]:

$$\mathbf{\Sigma N_{el} = 1077 + 0{,}1580\, N_n} \text{ [kW]}, \tag{4}$$

The dependencies of total electric power on main propulsion shaft power for general cargo vessels and container vessels from formulas (3) and (4) are compared in figure 5. It is possible to observe much bigger demand of electric power for container vessels than for general cargo vessels. However some general cargo vessels were equipped with cargo handling facilities which increase electric power demand, container vessels have bigger electric power demand due to installation of bow thrusters and the necessity of power supply for a big number of refrigerated containers.

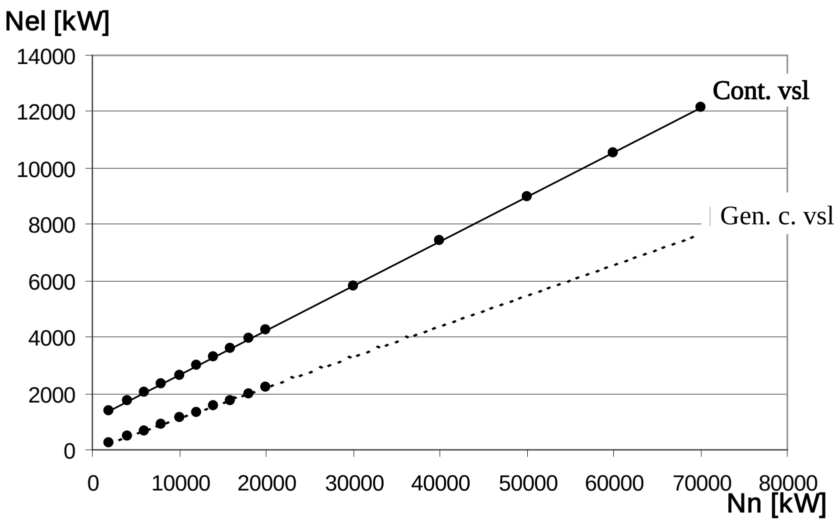

Fig. 5. Comparison of total electric power installed on general cargo vessels and container vessel as a function of main propulsion power

4. Analysis of auxiliary steam boilers development

To determine total auxiliary boilers capacity on general cargo vessels formula (5) given in [2] was used:

$$\mathbf{D_k = 0{,}075045\ N_n + 1054{,}5\ [kg/h],} \qquad (5)$$

where: D_k [kg/h] – total boilers capacity,
N_n [kW] – main propulsion power (main engine shaft power).

In turn total auxiliary boilers capacity on container vessels is given in formula (6) described in [1]:

$$\mathbf{D_k = 0{,}0657\ N_n + 2536{,}6\quad [kg/h],} \qquad (6)$$

Dependency of total boilers capacity on main propulsion power for general cargo vessels and container vessels calculated according to formulas (5) and (6) is compared in figure 6.

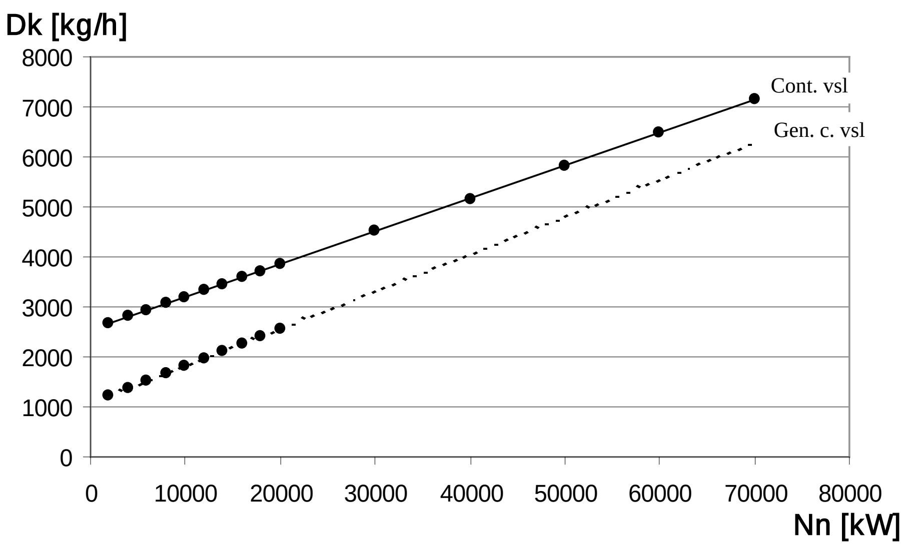

Fig. 6. Comparison of total boilers capacity on general cargo vessels and container vessel as a function of main propulsion power

Much bigger heat energy consumption on container vessels (fig. 6) is the result of a considerably higher heavy fuel oil consumption. Heavy fuel oil system is the biggest heat energy consumer on board up to 70% of produced energy. On the other hand powerful engines of container vessels produce more exhaust gases which are used in gas heat boilers.

5. Summary

Obviously contemporary container vessels belong to ships with the biggest energetic plants i.e. main propulsion plant, electric power station and steam boilers. An example of these is the biggest container vessel in the world MS EMMA MAERSK built in 2006 with loading capacity 11,500 TEU and service speed 25 knots (fig.1). The main propulsion of the vessel is low speed diesel engine Wartsila Sulzer 14RT-flex 96C nominal shaft power 80,080 kW. Onboard power station consists of 5 diesel generators of total power 20,700 kW and additional 8,500 kW steam turbo alternator using steam from main engine exhaust gases heat auxiliary boiler. Thanks to high waste heat utilisation the energetic efficiency of engine room achieves 70% during sea passage. Economic analysis show that even bigger container vessels are expected. However there is a limitation in the maximum power of the main engine. The main engine mounted on MS EMMA MAERSK is the biggest diesel engine offered up till now by diesel engine producers. Today, the only alternative is double engine propulsion the same as used on modern biggest liquefied gas tankers. Other possibilities are turbine propulsion, COGES propulsion system and V-type slow speed diesel engines which have not been constructed yet.

References

[1] Giernalczyk, M., Górski, Z., *Method for determination of energy demand for main propulsion, electric power production and heating purposes for modern container vessels by means of statistics.* Marine Technology Transactions. Marine Technology Commity of the Polish Academy of Sciences. Gdańsk 2004

[2] Michalski, R., *Ship propulsion plants. Preliminary calculations.* Szczecin Technical University. Szczecin (1997).

[3] Nowakowski, L., *Obliczenie przybliżonej mocy napędu drobnicowców w zależności od nośnosci i prędkości (Calculation of approximate proulsion power of general cargo ships relation of deadweight capacity and speed).* Budownictwo Okrętowe IX/1970,

[4] *Unification of ship engine room. Part V. Ship power plant.* Study of Ship Techniques Centre (CTO). Gdańsk 1978.

[5] Urbański, P., *Gospodarka energetyczna na statkach.* Wydawnictwo Morskie. Gdańsk 1978.