Journal of POLISH CIMAC
Faculty of Ocean Engineering & Ship Technology
GDAŃSK UNIVERSITY OF TECHNOLOGY

ANALYSIS OF TRENDS IN ENERGY DEMAND FOR MAIN PROPULSION, ELECTRIC POWER AND AUXILIARY BOILERS CAPACITY OF TANKERS

Zygmunt Górski, Mariusz Giernalczyk

Gdynia Maritime University
83 Morska Street, 81-225 Gdynia, Poland
tel.: +48 58 6901307, +48 58 6901324
e-mail: magier@am.gdynia.pl, zyga@am.gdynia.pl

Abstract

The paper deals with problem of energy demand for main propulsion as a function of deadweight and speed for tanker ships built in 60-ties, 70-ties, 8--ties as well as recently built. Changes in power of main propulsion and trends observed in the matter are appointed. In the same way analysis of electric power and boilers capacity are carried out. In summary conclusions and prognosis concerning energetic plants of tanker ships are expressed.

Keywords: *Tanker, main propulsion power, electrical power, auxiliary steam delivery, statistics*

1. Introduction

Tankers the largest merchant ships are used for transport of liquid cargo. Their deadweight excess even *500000 tons*. Such a transport capability have crude oil carriers belonging to ULCC class (*Ultra Large Crude Carrier*). A view of ULCC class tanker is shown on figure 1.

Fig. 1. ULCC class tanker Knock Nevis: length 458,45 m, 564763 DWT

Tankers are mostly used for transport of crude oil and crude oil products (*product tankers*), liquefied sulphur (sulphur carriers), liquefied chemicals (c*hemical carriers*) and liquefied gases (*gas carriers LNG and LPG*). Combined bulk cargo ships for example *OBO* (*oil-bulk-ore*) or *COB* (*container-oil-bulk*) are also classified as tankers.

Recently built tankers are constructed as double-hull (double skin) to protect sea environment against cargo leaks in case of hull defects (due to collision, grounding etc.).

The subject of this analysis are crude oil tankers and product tankers. Depending on cargo properties (density, viscosity) there are some differences in propulsion plants construction of these ships mainly in boilers capacity and onboard electric power station size. It depends on different configuration of cargo pumps. In case of crude oil carriers and large product carriers three or four big cargo pumps with capacity $3000 \div 5000\ m^3/h$ steam turbine driven are used. It results in high steam demand and high boilers capacity. Turbine driven cargo pumps are shown on figure 2.

a) **b)**

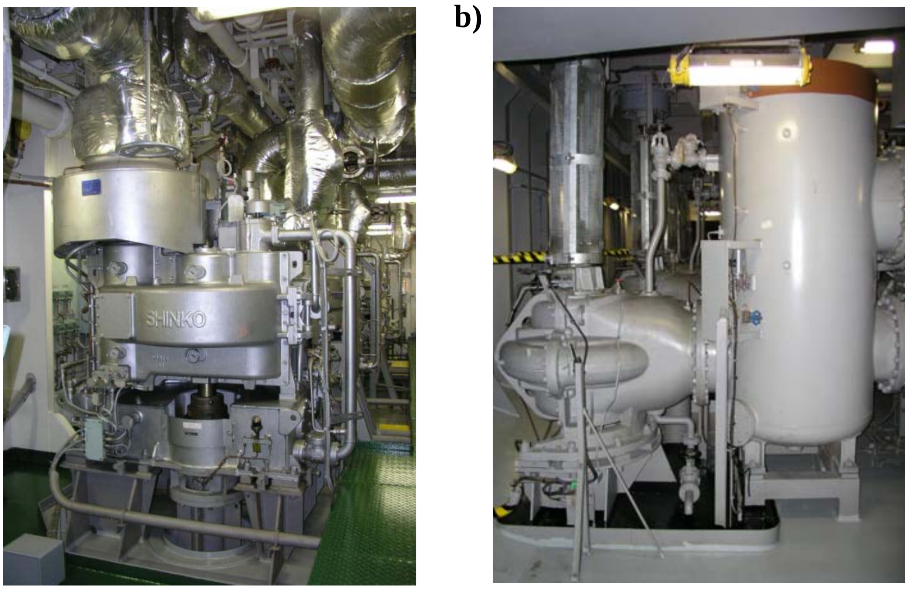

Fig. 2. View of crude oil tanker's cargo pumps:
a) driving turbine b) cargo pump

Separate cargo pumps for each cargo tank are used on smaller products tankers, sulphur carriers, chemical carriers and liquefied gas carriers LNG and LPG. These pumps are driven by electric motors or hydraulic motors thus the electric power demand increases. According to these circumstances described ships were divided to two groups in statistic analysis of boilers capacity and electric power demand.

The preliminary analysis of energetic plants configuration considered ships gives the following conclusions:

- slow speed diesel engines are mostly used for main propulsion,
- steam turbine propulsion dominates on VLCC (*Very Large Crude Carriers*) and ULCC class tankers,
- the speed of tankers is about $14 \div 16$ *knots*,
- onboard electric power station consists of three diesel alternators of moderate power as these ships do not have large electric power consumers e.g. bow thrusters; only some number of product carriers equipped with separate electrically driven cargo pumps for each cargo tank have higher electric power demand,

- tankers are distinguished in comparison to other types of ships by larger steam systems particularly on crude oil carriers where boilers steam capacity achieves *50000÷100000 kg/h* at pressure *1,8÷3,0 MPa*.

The target of this work is analysis of development of main propulsion plants, onboard electric power station and boilers capacity on crude oil tankers and large product tankers on the base of statistic methods.

2. Analysis of main propulsion plants development

To determinate main propulsion power of tankers built *60-ties* technical data of *637* ships were used [4]. As a results of statistics calculations and after determination of regression coefficients formula (1) was obtained [4]. Tanker propulsion power is described in dependence on ship deadweight and ship speed:

$$N_n = 0{,}0566 * D^{0{,}476} * v^{2{,}564}\ [kW], \qquad (1)$$

where:

N_n *[kW]* - shaft power of main engine,
D [tons] - ship deadweight (DWT),
v [knots] - ship speed.

Statistic calculations carried out in Marine Power Plants Department of Gdynia Maritime University made possible to determine formula (2) for recently built tankers [2]:

$$N_n = (2{,}2215 + 0{,}0000172 * D) * v^3\ [kW], \qquad (2)$$

where:

D [tons] - ship deadweight (DWT),
v [knots] - ship speed.

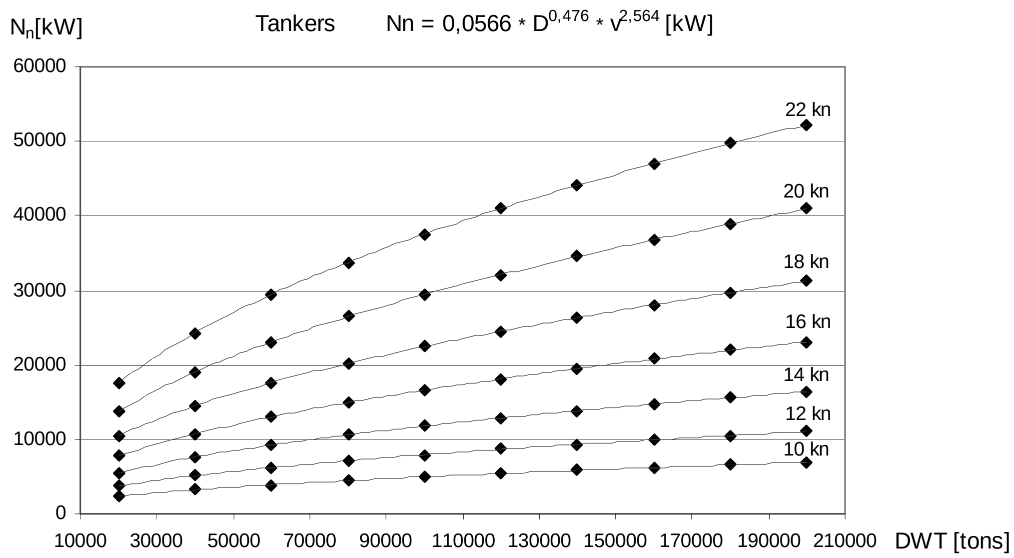

Fig. 3. Dependency N_n =f(D) at different ship speed for tankers built in 60-ties according to formula (1)

The dependence of ship main propulsion power on ship deadweight for different ship speeds according to formulas (1) and (2) is shown on figures 3 and 4. Dependency between main propulsion shaft power and ship deadweight at different ship speed for tankers built in 60-ties according to formula (1) is shown on figure 3.

The same dependences for recently built tankers according to formula (2) are shown on figure 4. Aby móc porównać i ocenić rozwój mocy napędów tych statków w ostatnich 50-ciu latach dla wybranej prędkości pływania *v=14 węzłów* przedstawiono na rys. 5 wykresy zbiorcze, celem dokonania analizy porównawczej zmian mocy tej kategorii statków.

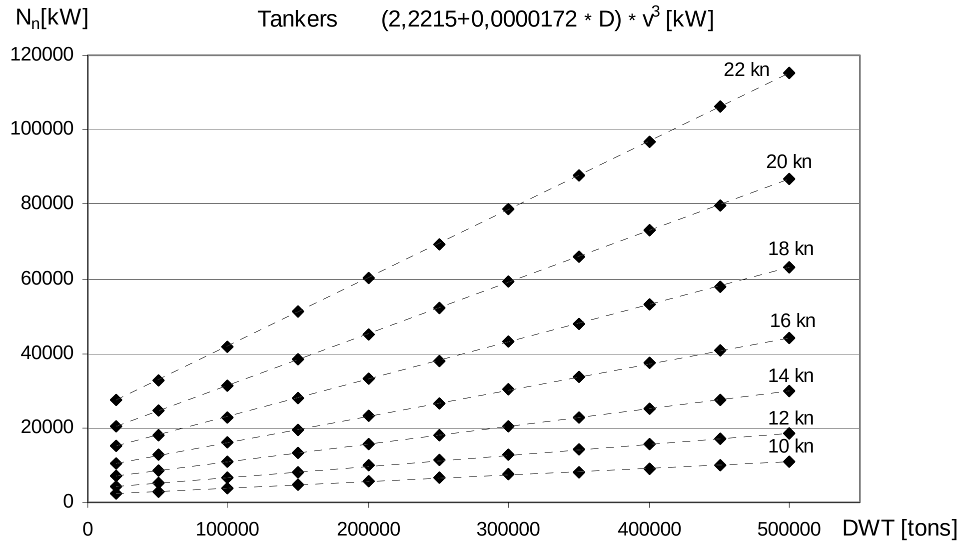

Fig. 4. Dependency N_n =f(D) at different ship speed for recently built tankers according to formula (2)

To compare and evaluate the development of tankers main propulsion power in recent years a cumulative diagrams were executed. An example of cumulative diagram for ship speed 14 knots is shown on figure 5.

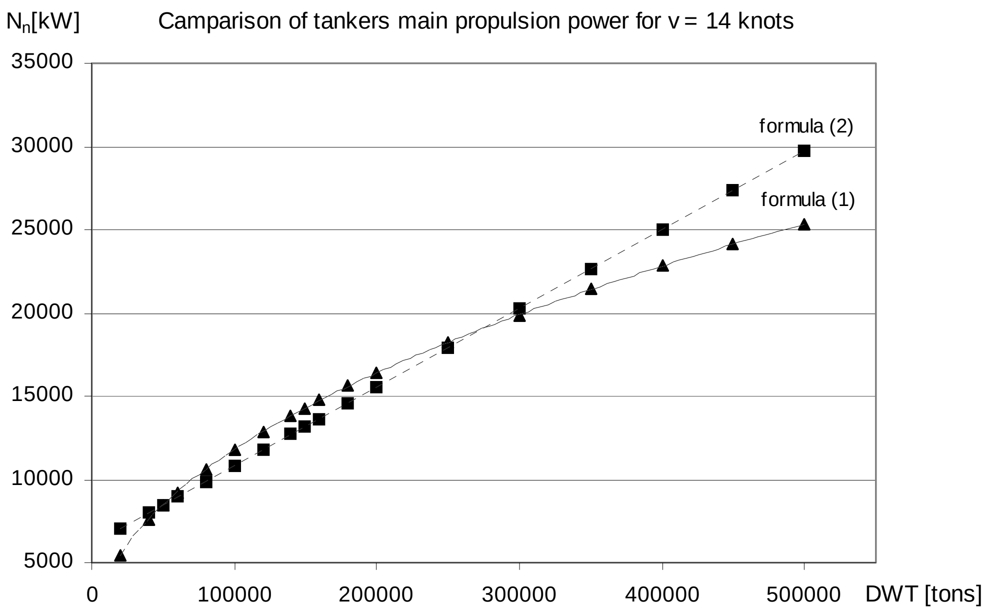

Fig. 5. Comparison of main propulsion power at v=14knots for tankers built in 60-ties and nowadays

As the deadweight of tankers built in *60-ties* achieved maximum *200000 tons* to make possible comparing analysis especially for VLCC and ULCC class tankers the extrapolation of dependencies was executed for main propulsion power of tankers built in 60-ties. Results of comparative analysis (fig. 5) show that for tankers of deadweight up to *300000 tons* main propulsion power demand did not change during last 50 years. It results from small modification of tankers hull construction and still used ship operational speed about *14÷16 knots*. Considering larger ships i.e. ULCC class (above *300000 DWT*) main propulsion power demand is moderate higher. It is probably the result of slightly higher operational speed and minor changes in hull construction.

3. Analysis of onboard electric power station development

Total electric power of older tankers onboard power station can be approximately estimated using formula (3) elaborated by Ship Design and Research Center in Gdańsk [5]:

$$\Sigma N_{el} = 663 + 0{,}0748 * N_n \ [kW], \qquad (3)$$

where:
N_n *[kW]* - main engine shaft power.

In turn total electric power of recently built tankers onboard power station is described by formula (4) elaborated in Marine Power Plants Department of Gdynia Maritime University [2]:

$$\Sigma N_{el} = 1225 + 0{,}07443 * N_n \ [kW], \qquad (4)$$

where:
N_n *[kW]* - main engine shaft power.

Dependencies of total electric power on main engine shaft power elaborated according to formulas (3) and (4) are shown on figure 5. It makes possible to compare total electric power of older and recently built tankers.

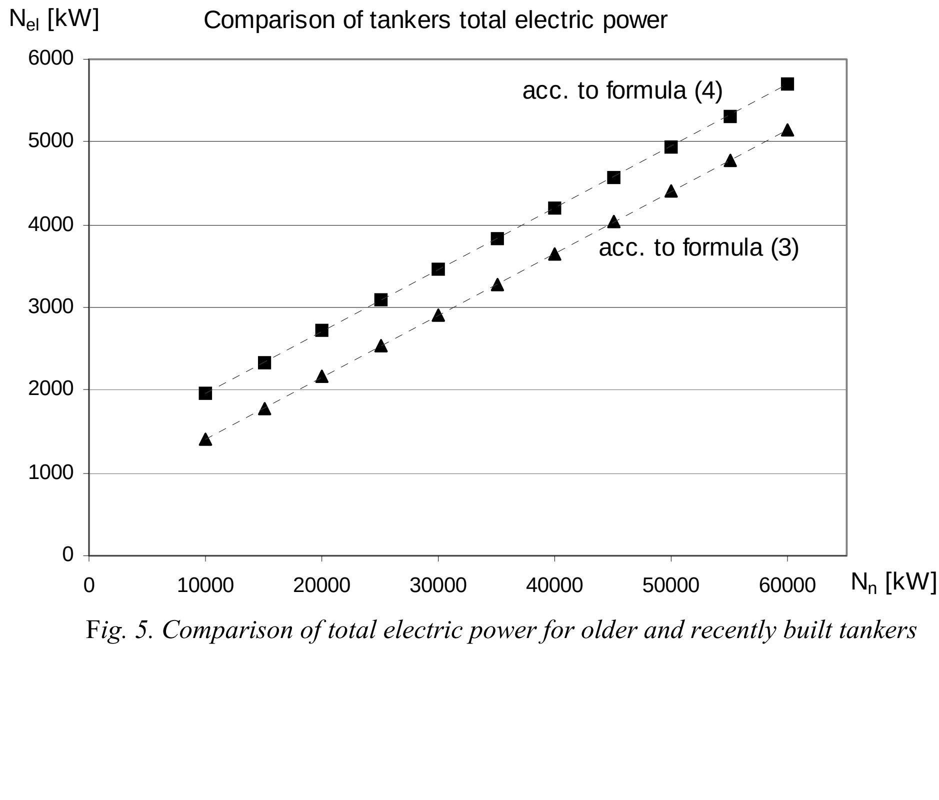

Fig. 5. Comparison of total electric power for older and recently built tankers

Comparing total electric power (fig. 5) it is found that total electric power of recently built tankers is higher than for older construction in whole range of main engine shaft power. It results from tendency to fit out ships with higher number of electrically driven plants and equipment. A typical example are modern navigation equipment, automatically controlled modern machinery equipment, modern air condition equipment etc.

4. Analysis of steam boilers capacity development

To estimate total boilers capacity mounted onboard of tankers propelled by diesel engines built in 70-ties and 80-ties the formula (5) given in [3] was used:

$$D_k = 1{,}2507 \cdot 10^{-8} \cdot (N_n)^3 - 3{,}7444 \cdot 10^{-4} \cdot (N_n)^2 + 5{,}60705 \cdot N_n - 7960 \ \ [kg/h], \qquad (5)$$

where:

N_n *[kW]* - main engine shaft power.

Whereas total boilers capacity mounted onboard of recently built tankers propelled by diesel engines the formula (5) from [2] was used:

$$D_k = 24981 + 2{,}4289 * N_n \ \ [kg/h], \qquad (6)$$

where:

N_n *[kW]* - main engine shaft power.

Dependencies of tankers total boilers capacity on main engine shaft power according to formulas (5) and (6) is matched on figure 6.

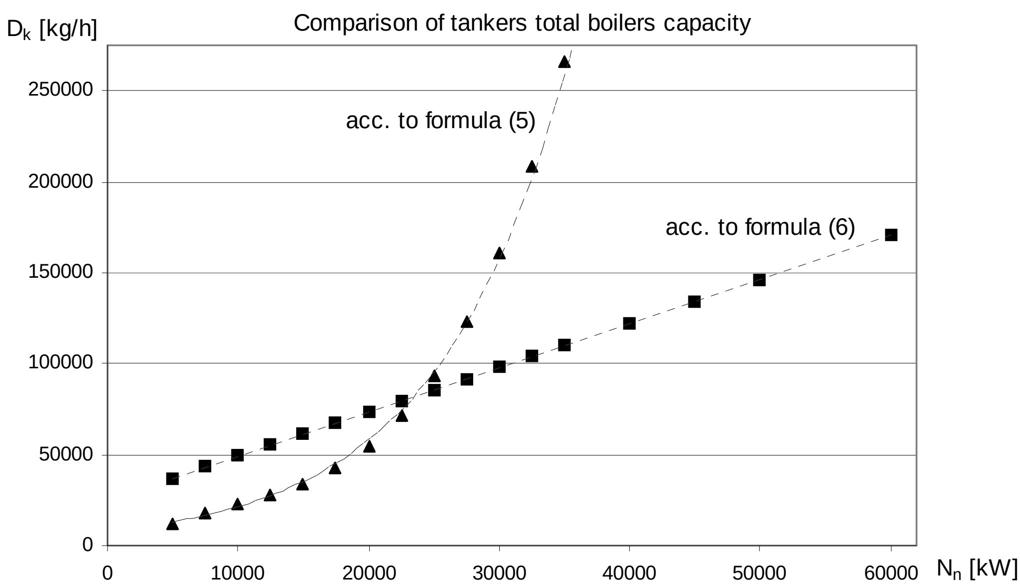

Fig. 6. Comparison of total boiler capacity for older and recently built tankers

As shown on figure 6 the formula (5) comes true only for smaller tankers having main engine shaft power up to *15000 kW* built in 70-ties of last century. Presently built much bigger VLCC and ULCC class tankers have considerably higher propulsion shaft power. Statistic analysis [2] affirms that total boilers capacity on recently built tankers is strongly linearly depended on main propulsion shaft power. Total boilers capacity on such tankers estimated according to formula [6] have very good correlation (above *0,8*) with reference to main propulsion shaft power. Thus to use formula (6) for recently built tankers is entirely justified.

5. Conclusion

Nowadays tankers are the largest operated merchant ships. The population of these ships is distinguished by increasing cargo capacity and increasing operational speed. As a result the main propulsion shaft power also increases. Some limitation in tankers size is the possibility in passing through Suez Channel and Panama Channel.

Increase of total installed electric generators power is a result of fitting recent ships with large number of electrically driven equipment (for example bow thrusters), increasing tendency in automation and increasing comfort in ships crew working and living conditions (air condition of accommodation, air condition of working rooms etc.).

In turn high demand for steam on diesel engine propelled tankers is a result of using steam turbine driven cargo pumps and ballast pumps. The power necessary for cargo pumps propulsion is a result of high cargo unloading rate imposed by charter contracts.

References:

[1] Górski, Z., Giernalczyk, M., *Analysis of trends in energy demand for main propulsion, electric power and auxiliary boilers capacity of general cargo and container ships,* Journal of POLISH CIMAC – ENERGETIC ASPECTS, Vol.4. Gdańsk 2009.

[2] Giernalczyk, M. , Górski, Z., *A Statistics-based Method for the Determination of energy demands for main propulsion, electric power and auxiliary boiler capacity for modern crude oil and products tankers, Explo-ship 2006*, Szczecin pp 183-192.

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

[4] Nowakowski, L., Wyznac*zenie przybliżonej mocy napędu zbiornikowców w zależności od nośności i prędkości (Calculation of approximate propulsion power of tankers relation of deadweight capacity and speed),* Budownictwo Okrętowe I/1970.

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

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