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PREDICTION OF THE MAIN ENGINE POWER OF A NEW CONTAINER SHIP AT THE PRELIMINARY DESIGN STAGE

Tomasz CEPOWSKI
Maritime University of Szczecin

Abstract:
The paper presents mathematical relationships that allow us to forecast the estimated main engine power of new container ships, based on data concerning vessels built in 2005-2015. The presented approximations allow us to estimate the engine power based on the length between perpendiculars and the number of containers the ship will carry. The approximations were developed using simple linear regression and multivariate linear regression analysis. The presented relations have practical application for estimation of container ship engine power needed in preliminary parametric design of the ship. It follows from the above that the use of multiple linear regression to predict the main engine power of a container ship brings more accurate solutions than simple linear regression.

Key words: *container ship, design parameters, preliminary design stage, power, main engine power, length between perpendiculars, number of containers, TEU capacity, design, simple regression, multiple regression, approximation*

INTRODUCTION

Ship designers often need to have estimated total main engine power of different vessels at the preliminary design stage. Depending on the available information, total engine power of newbuilding's is either approximate or specific.

Engine power estimation of vessels is most often carried out at the stage of general transport studies, aiming at the choice of the mode of transport [6, 8, 9]. An estimated engine power of a ship is also carried out at its preliminary design stage [1, 2, 4, 5, 8, 10, 11]. Since ship design is a multi-stage process, at each stage design parameters are optimized relative to the criteria and design constraints, where power engine analysis plays an essential role. Proper conduct of this analysis is the basis for the development of ship design of highest operational values [3, 7, 8, 9].

Prediction of the engine power of the ship is of particular importance when concurrent methods of ship design are used. In this case, the estimated engine power should be known at the preliminary design stage.

The preliminary design stage consists of parametric and geometric design phases [3, 4, 5, 6, 8]. Estimating the engine power of the ship at preliminary parametric design is problematic. During the parametric design only general design parameters of the ship are known, such as main geometric dimensions, general assumptions regarding the quantity of cargo or ship's speed. For this reason, at this stage the power engine analysis covers only basic technical parameters of the vessel, such as displacement, geometric parameters, speed or cargo capacity.

AIM OF THE RESEARCH

This article describes methods of engine power estimation for the purpose of preliminary parametric design of a container ship. The aim of the study was to develop mathematical relationships that allow performing total engine power estimation of container ships built in the years 2005-2015 on the basis of their basic design parameters.

The practical aim of the research was to develop a mathematical function f for predicting the total engine power of a container ship P using technical parameters $X_1, X_2...X_n$:

$$P \approx f(X_1, X_2, ..., X_n) \tag{1}$$

where
P – engine power,
$X_1, X_2... X_n$ – technical parameters of the vessel,
n – number of parameters,
f – searched-for mathematical function.

The analysis took into account a set of 4414 new container ships built in the years 2005-2015, whose parameters ranged as follows:

- displacement from 500 to 258 000 t,
- number of containers (TEUs): from 30 to 19200,
- length between perpendiculars: from 38 to 383 m,
- total power of main engine from 280 to 81200 kW.

In addition to the above parameters the study included:

- deadweight, the weight of light ship,
- gross tonnage GT,
- main hull dimensions: length overall, breadth, moulded depth, moulded draft,
- service speed.

The study assumed that the function f in equation (1) will be determined using simple linear regression and multiple regression methods.

SIMPLE LINEAR REGRESSION OF ENGINE POWER ON THE BASIS OF THE LENGTH BETWEEN PERPENDICULARS AND TEU CAPACITY

Simple linear regression analysis showed that the engine power of a container ship is mainly dependent on container capacity (TEUs) and length between perpendiculars. Of all the investigated statistical relationships, the following proved to be the best:

$$P = \left(-74.65 + 3.83 \cdot \ln(TEU)^2\right)^2 \qquad (2)$$

$$P = -2992 + 0.623 \cdot L_{pp}^{\ 2} \qquad (3)$$

where:
P – main engine power kW,
TEU – number of containers,
L_{pp} – length between perpendiculars m.

Equation (2) is characterized by:
- correlation coefficient $R^2 = 0.9$,
- standard error σ = 7054 kW,

while equation (3) is characterized by:
- correlation coefficient $R^2 = 0.93$,
- standard error σ = 6025 kW.

Figures 1 and 2 show relations (2) and (3) relative to reference data.

MULTIPLE LINEAR REGRESSION OF ENGINE POWER ON THE BASIS OF THE LENGTH BETWEEN PERPENDICULARS AND TEU CAPACITY

Multivariate linear regression model was developed for predicting the main engine power of a container ship based on the length between perpendiculars and TEU capacity:

$$P = -531.38 + 0.0388 \cdot L_{pp}^{\ 2.5} - 8.321 \cdot TEU^3 \qquad (4)$$

where:
P – main engine power kW,
TEU – number of containers,
L_{pp} – length between perpendiculars m.

Equation (4) is characterized by:
- high value of correlation coefficient $R^2 = 0.95$,
- low value of standard error σ = 5260 kW.

Figure 3 shows the prediction of the main engine power of a container ship based on the length between perpendiculars and the number of 20-foot containers according to formula (4).

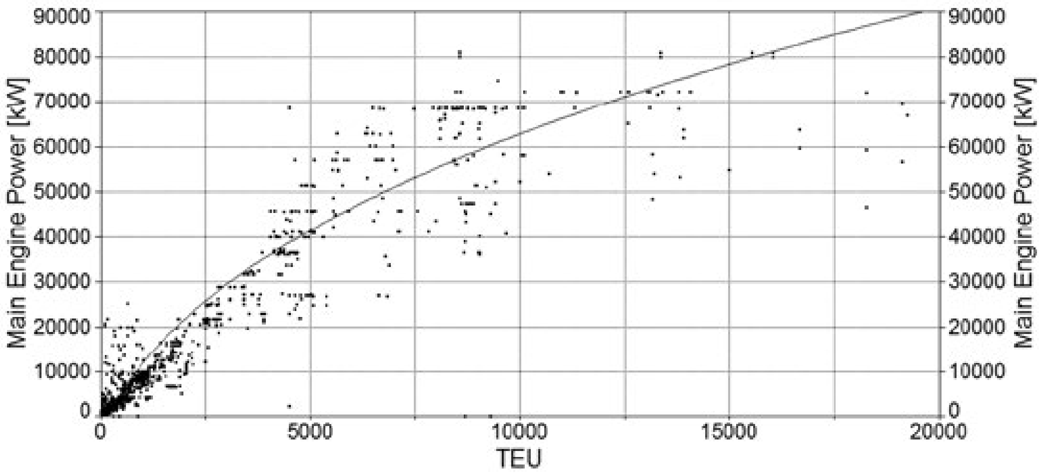

Fig. 1 Approximations of main engine power depending on the number of containers, the relationship (2) in comparison with reference data

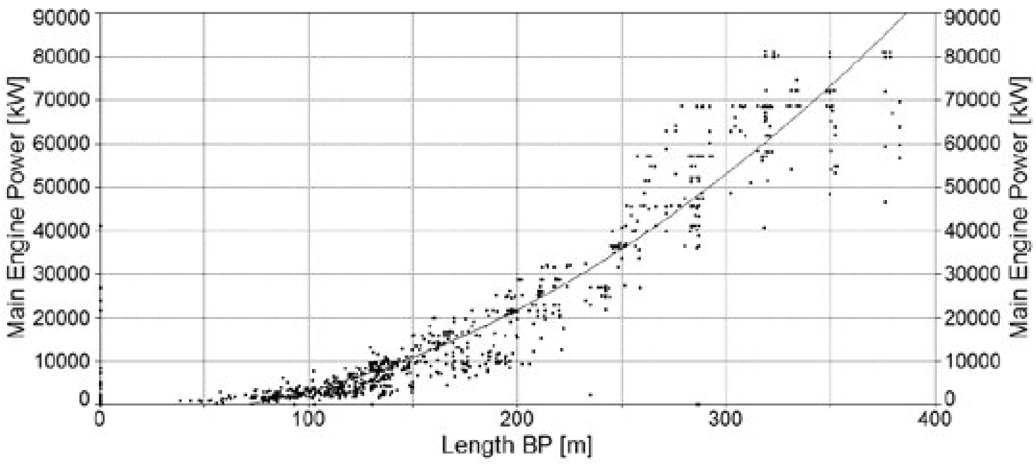

Fig. 2 Approximations of main engine power on length between perpendiculars, relationship (3) in comparison with reference data

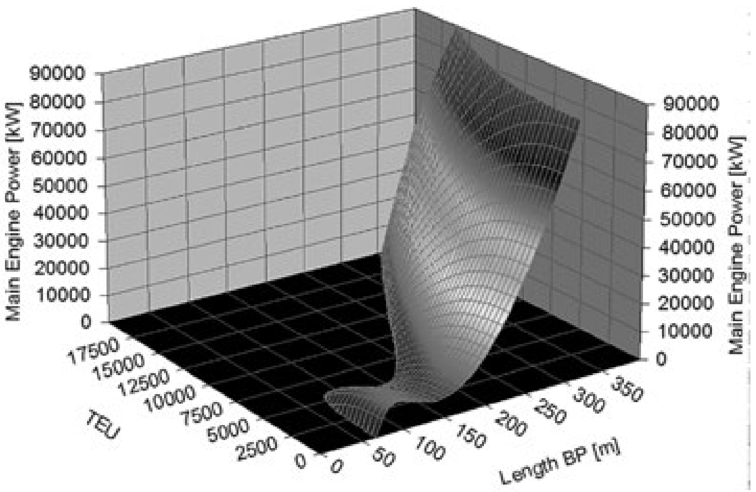

Fig. 3 Projecting the main engine power of a container ship depending on the length between perpendiculars and TEU capacity according to formula (4)

CONCLUSIONS

The study shows that the engine power estimate of a new container ship is influenced mainly by the TEU capacity and length between perpendicular. The article presents a series of mathematical formulas that allow to forecast the main engine power of a container based on these quantities. The relations have been developed from data on engine powers of 4414 container ships built in 2005-2015.

Formulas (2) and (3) may be used interchangeably as the ship's length depends mainly on the number of containers. Formula (4), which takes into account both length between perpendiculars and TEUs (number of containers), is characterized by highest accuracy and lowest error than formulas (2) and (3). Therefore, the practical value of this formula is height.

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dr hab. inż. Tomasz Cepowski, prof. AM
Maritime University of Szczecin
Faculty of Navigation
ul. Wały Chrobrego 1-2, 70-500 Szczecin, POLAND
email: t.cepowski@am.szczecin.pl