The prediction of some hull manufacturing parameters during early stages of ship design

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Abstract

Proposed paper is a short description of the activities taken to create the tools for the prediction of the hull manufacturing parameters at the early stage of ship designing. It includes the stages of steel preparation, assembly and erection of the hull. The key characteristics of hull manufacturing process will be defined to allow the planning of the building. The relationships will be presented linking the basic ship parameters as known in early stages of design (type of the vessel, main dimensions, block coefficient) with those characteristics. The final remarks indicating the further topics development will conclude the paper.

1 Introduction

The designing and engineering in modern shipbuilding is running under strong time pressure raised up by hard competition between particular shipyards with the purpose to obtain the order. The shipyards apprehend the designing as not only the spatial and functional ship identification, not only raw material and equipment specification, but also a complete package of bidding information including such topics as planned delivery date and production costs split into material, man-hours and others. To create such package of information under very general knowledge about the ship designed some specific tools are necessary. Those should allow to define the building strategy as well as some production planning parameters to estimate labour consumption, production capabilities utilisation, required areas under the roof and open air etc. Proposed paper is a short description of the activities taken to create such tools.
2 The hull building cost estimation

The hull building cost is the sum of material and personal costs. For this paper purposes the hull is understood as the steel structure of ship envelope. This steel was delivered to the yard, then cut, welded and mounted in panels and blocks and finally erected on the slipway or at the drydock, where the hull is built. The installation of hull equipment, fittings, opening closings, painting etc. is not considered as the part of the hull manufacturing, but only cutting, welding and erection of steel hull.

The cost of material depends of the actual price of the steel and of the following factors:
- cost of ordered steel (and indirectly of the steel hull weight),
- assortment (plates, profiles, pipes, forgings, castings),
- type of material (mild steel, high tensile steel, stainless steel, others).

The estimation of the hull steel weight is a comprehensive problem of initial and basic ship design and will be not discussed in this paper.

Personal costs depends of the hull worker average hour rate and the number of man/hours necessary for the processing of ordered steel into the hull.

At the preliminary stage of the design the cost of the hull can be defined as the product of the cost of 1 ton of the steel hull and the hull weight. This cost of one ton of the hull is a function of the some number of variables such as hull form parameters, type of the vessel, and the productivity of hull manufacturing shop. This way of hull cost estimation is named as the Top-Down method and make use of primary design data i.e. steel hull weight, block coefficient, principal dimensions, vessel type. Insufficiency of this method depends on its high level of generalisation and lack of the possibility to estimate the impact of some manufacturing parameters (for example – the length of welding connections) to the hull cost.

The contrary to the Top-Down method is the analytical method called Bottom-Up method. This method decomposes the manufacturing process into the number of elementary activities related to the arbitrarily chosen part of the construction. As an example may serve the number of flat plates and straight frames, type of welding, plates thickness, flame cutting length – all for the predetermined shell plating panel. The work content is calculated separately for every activity and then summed up for the whole panel. The cost of the panel manufacturing is calculated in compliance with man/hour rate differentiation for particular activity. The results obtained with this method are generally more accurate, the method allows to analyse the impact of local hull geometry on the work content, but it needs substantially advanced stage of hull project and that is why this method is not suitable during initial stages of ship designing.

In this paper an attempt is made to estimate some hull manufacturing process parameters at the moment, when the knowledge about the ship designed is limited to such data as the type, principal dimensions, block coefficient what usually occur during the acquisition and contractual design preparation. Those
parameters can be used for the early estimation of hull work content and other planning activities.

3 The scope of the investigation

The investigated manufacturing parameters are connected with three basic types of hull work planning i.e.
- share of particular material assortment,
- steel preparation (blasting, rolling, flame cutting, bending),
- fabrication and assembling,
- hull erection at the berth.
Those include among others:

material assortment and preparation:
- total plates weight,
- total profiles weight,
- total number of plates including the breakdown into particular thicknesses,
- share of curved plates in side and bottom shell,
- length of straight line and curvilinear flame cutting,

fabrication:
- number of flat panels,
- total butt welding length including the breakdown into particular groups,
- total fillet welding length including the breakdown into particular groups,

erection:
- units or blocks average quantity,
- units or blocks average weight.

4 Output data

For 17 vessel types built during 1989 –1998 years the manufacturing parameters were collected as recorded in hull workshop documents. Each type was represented by one vessel. It means that output data does not include the deviations which usually occur between particular vessels of given type. Those deviations can be the object of separate study. The set of data consists of 8 container vessels, 4 tankers and 5 bulk carriers. The bigger vessel of the set was 45000 DWT multipurpose bulk carrier, the smaller one - 6000 DWT chemical carrier. All vessels corresponds generally to the same level of manufacturing method, excluding one early built container vessel, which was in some cases omitted because its structural and manufacturing parameters as well as manufacturing method were outlying too strongly from the population. The size of particular type populations was rather unsatisfactory and the decision was made to consider all vessels as one population consisting of 16 (17) vessels of diverse types.
5 The review of some obtained relationships.

1. Steel material assortment

1.1 The weight of ordered steel [t]

\[ MS = 32 + 1.116PK \] (1)

1.2 The weight of steel plates [t]

\[ MB = 1.027MS - 0.015L(B+2H) \] (2)

1.3 The weight of profiles [t]

\[ MP = -0.16MS - 0.201B - 0.446LBHC_b + 13.03BH + 0.818LB \] (3)

1.4 The number of plates [pcs]

\[ IBL = 880 + 0.253MS \] (4)

2. Preparation

2.1 Length of straightlinear flame cutting [m]

\[ DPP = 101480 - 1404L - 756H^2 - 615B^2 - 35.6L(B+2H) + 1191BH + 138.7LB \] (5)

2.2 Length of curvilinear flame cutting [m]

\[ DPK = -1643L + 10855B + 12,86PK + 59,86 - 400B \] (6)

3. Fabrication

3.1 Number of flat panels

\[ IPP = 0.074PK + 0.00962LBHC_b - 0.0145LBH + 1.92H^2 \] (7)

3.2 Total length of butt welding [m]

\[ SC = 2.55PK + 317.9B - 2.085LH \] (8)

3.3 Total length of fillet welding [m]

\[ SP = -1156L + 29,26PK - 115.6LBHC_b + 501.4BH + 8.25L^2 \] (9)
4. Erection

4.1 Number of blocks at berth mounted

\[ ISB = 0.00536 \, LBHC_b - 0.0158 \, PK - 0.003 \, L^2 + 13.08 \, H - 1.41 \, H^2 + 0.0731 \, LH \]  

(10)

6 The investigation procedure description

The analysis was conducted using statistics methods. Preliminary estimations show that simple regression methods will not act in this case because of extremely great scatter of results. It was clearly seen that the parameters explored are the function of many variables including nonlinear combinations of principal dimensions of the vessel. An assumption was made that demanded manufacturing parameter is a random variable with normal distribution, unknown average \( \mu \) and unknown variance \( \sigma^2 \) and that \( \mu \) is a linear function

\[ \mu = a_0 + a_1 \, X_{i1} + a_2 \, X_{i2} + \ldots + a_m \, X_{im} \]

of certain subset of variables (\( X_{i1}, X_{i2} \ldots, X_{im} \)), being known geometrical or weight hull parameters and/or its nonlinear combinations. The hypothesis was tested that the coefficients \( a \) of the equations are equal zero. It was assumed that Fisher-Snedecor statistics will be \( F = 4 \) with with significance level value \( \alpha = 0.05 \) as usually adopted. It means that zero hypothesis will be rejected if \( F > 4 \) and significance value \( \alpha < 0.05 \).

For every relationship the error characteristics were estimated as follows:

1. mean absolute error (MAE) defined as

\[ d = \frac{1}{n} \sum_{i=1}^{n} |\Delta z| \]  

(11)

2. average quadratic error (ME)

\[ M = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (\Delta z)^2} \]  

(12)

where \( \Delta z \) is a distance between adjusted trend line and measurement point, but \( n \) is a number of points. The correlation level is characterised by determination coefficient \( R^2 (R^2) \) varying in range \( 0 - 1 \).

The characteristics of error and \( R^2 \) are presented in Table 1.
7 The error characteristics

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<th>Eq. No</th>
<th>Symbol</th>
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8 Conclusion

1. Presented relationships can be suitable for the prediction of some manufacturing parameters of the ships with size and type as presented in Output Data.
2. The number of ships in the particular groups (types) is still unsatisfactory and the relationships should be continuously updated by the introducing to the data base the information about the parameters of further newbuildings.

9 Acknowledgement

This paper cover the presentation of some results obtained during the realisation of the extensive project targeted to the improving of the shipyard facilities utilisation. The author express his gratitude to all those who participated in the collecting and interpretation of hull manufacturing process data as well as to the manager of the project mr. T. Jabłoński for his supporting.