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Seakeeping assessment of fishing vessels in conceptual design stage

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Abstract

The main idea of this paper is to identify functional relations between seakeeping characteristics and hull form parameters of Mediterranean fishing vessels. Multiple regression analysis is used for quantitative assessment through a computer software that is based on the SQL Server Database. The seakeeping attributes under investigation are the transfer functions of heave and pitch motions and of absolute vertical acceleration at stern, while the ship parameters influencing motion dynamics have been classified into two groups: displacement (Δ) and main dimensions (L, B, T), coefficients that define the details of the hull form (C_{WP}, C_{VP}, LCB, LCF, etc.).

Four multiple regression models having different parameter combinations are here investigated and discussed, giving way to the so-called ‘Simple Model’, ‘Intermediate Model’, ‘Enhanced 1 Model’ and ‘Enhanced 2 Model’. The obtained results are more than satisfactory for seakeeping predictions during the conceptual design stage.

Keywords: Fishing vessels; Conceptual design; Ship motions; Data analysis

1. Introduction

Several methods of incorporating seakeeping assessment into the conceptual design of fishing vessels have been proposed, since it is ascertained that rational consideration of potential seakeeping behaviour from the real beginning of the design process is economically sound. They are based either on direct computations over pre-designed hull forms, or they rely on results from systematic series analysis.

Whichever method, computer code, and/or approach are used through the design process, it is well known that the relative requirements for seakeeping and other hydrodynamic issues are often in conflict. For instance, whilst resistance and powering are sensitive to changes in local hull geometry, seakeeping performance generally depends on primary geometric characteristics (main dimensions, hydrostatics and weight distribution) and is slightly sensitive to small changes in the hull form, both general and local. Therefore, it should be mandatory to consider vessel’s behaviour in a seaway from the very initial (conceptual) stage, since the related improvements are difficult and expensive to obtain afterwards.

It is generally accepted that conceptual design procedures require simplicity in use while assuring sufficient accuracy in prediction. This is also true for seakeeping evaluation that implies a specialisation in terms of the class of vessels as well as of realistic operating environment. To this end, the transfer functions for a set of medium-size Mediterranean fishing vessels are here assessed to build general regression formulae, suitable to predict the ship behaviour in regular waves and, moreover, in irregular sea by means of the well known superposition technique. Since the seakeeping ability of a fishing vessel drives the effectiveness of the fishermen and the operability of the fishing systems in rough weather, the present analysis has been carried out with the main scope of investigating the effect of different hull forms and loading conditions on ship motions and vertical accelerations on board. In this

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respect, the present paper represents a natural extension and completion of previous contributions (Trincas et al., 2001; Nabergoj et al., 2003).

2. Design strategy

Among different approaches in conceptual design, the most promising strategy to model vessel hydrodynamics is to employ approximating functions, which describe specific ship responses. Statistical techniques are widely used in design to build approximate formulae, based on expensive computer analysis, since they are much more efficient to run and easier to integrate. At the same time, they yield insight into the functional relationship between design variables and performance responses (screening tests preliminary to sensitive analysis).

Seakeeping prediction methods basically rely on linear hydrodynamic theory for estimating vessel motions and corresponding induced effects. This is more than sufficient at conceptual design stage, where extensive use of CFD codes is certainly unpractical. In fact, the results of strip theory for ship motions are in general accurate enough, even for hull forms and vessel speed to wavelength variations that do not respect the basic assumptions of the theory.

Here, the very scope is to develop an efficient seakeeping prediction model to be included in a fast and comprehensive evaluation procedure of several alternative designs. The functions employed for seakeeping trade-offs and feasible for design modelling are polynomial response surfaces. The coefficients of the approximating polynomials are calculated using a least-squares regression analysis to fit the response surface approximation to existing data, which have been previously generated off-line through simulation/analysis routines and stored in the design database. The approximating functions can then be used for design predictions and/or to build a meta-model for the class of fishing vessels considered. In this respect, seakeeping modelling can be carried out at different levels of interest, from transfer functions (Moor, 1967) to short-term statistics (Nabergoj et al., 2003; Moor and Murdey, 1968; Loukakis and Chryssostomidis, 1975) and further up to ship response ranking (Trincas et al., 2001; Bales, 1980; Wijngaarden, 1984; Nabergoj et al., 1989; Alkan et al., 2003).

In any regression procedure, seakeeping modelling requires the previous building of a design database comprising geometric variables and parameters of vessels (Hull Form Database) as well as their responses in specific seaways (regular and/or irregular waves) and different operating conditions (Seakeeping Database). A linear multivariate regression analysis was here performed with the main scope of identifying the independent variables that mostly affect the considered responses in regular waves, i.e., heave, pitch and vertical acceleration at given location. As the analysis was restricted to a specific class of fishing vessels, it has been assumed that the response surface is approximated by a simple mathematical model where underlying equations are linear (polynomial response surface).

3. Design databases

3.1. Hull form database

The lines plans for a set of 13 medium-sized Mediterranean fishing vessels have been faired and stored to build the relational geometric database (Hull Form Database). Hull forms of the vessels are shown in Fig. 1 while their main geometric particulars are given in Table 1. The population includes a large variety of single-screw hull forms, ranging from ‘U’ to ‘V’ sections forward, from rounded sections to underwater chines, and from large bulbous bows to the removal of bulb.

The locations of the longitudinal centres are given relative to after perpendicular and normalised by ship length. For example, LCF/L and/or LCB/L values lower than 0.50 denote that the longitudinal centre of flotation and/or the longitudinal centre of buoyancy are located aft of amidships and vice versa. Static stability was checked in detail by considering geo-mechanical properties of the vessels at different loading conditions.

Each fishing vessel has been evaluated at three different loading conditions, denoted by the last digit of the label in the first column of Table 1. In particular, digits 1–3, refer, respectively, to: LC1—leaving to the fishing ground (100% consumables); LC2—leaving from the fishing ground (full holds and 40% consumables); and LC3—arrival to port (full holds and 10% consumables).

In Table 1, we also show the ranges of the geometric variables and hull parameters, thus providing all basic information to ascertain if a candidate design of given variables and parameters is within the region of the present database. The database capability to implement reliable regression formulae can be highlighted by checking the normal distribution of geometric descriptors. For some variables the correspondence is not so fair.

3.2. Seakeeping database

A total population of 39 cases (13 hull forms times three loading conditions) is used to build the Seakeeping Database. To this aim, the seakeeping computations have been carried out by means of a two-dimensional computer code based on Frank close-fit method. A very accurate hull geometry description has always been used, both for sectional offsets and number of stations. The pitch gyradius was held constant and fixed at 26 percent of vessel length for whichever vessel.

The seakeeping responses in head sea are generally the most important responses for mono-hulls and constitute the starting point for the evaluation of seakeeping performance of a vessel. Thus, all calculations were carried out for vertical motions and related kinematics. Roll is