SEAKEEPING ANALYSIS OF A MALAYSIAN FISHING VESSEL

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Dedicated

To my parents who are no more in this world
and
To my beloved wife for her encouragement

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ABSTRACT

This thesis describes a comparative study of seakeeping analysis for a fishing vessel in Malaysia. Three different methods were used for the seakeeping analysis namely; full scale trial, model experiments and time domain simulation. The simulation program was developed at Universiti Teknologi Malaysia (UTM). In this study, a Malaysian fishing vessel was taken as the basis for the seakeeping analysis. In the full scale trial, the wave data were recorded by a wave buoy to obtain the wave spectra. The responses of the vessel were recorded by the Vessel Motion Monitoring System (VMMS) to obtain the motions response spectra. A scaled (1: 10.6) model was tested in the towing tank of the Department of Marine Technology, UTM to obtain the responses of the model in regular waves and Response Amplitude Operator (RAO) in irregular waves. Roll decay tests were also conducted to obtain the roll natural frequency, damping coefficient and the position of center of gravity (KG) of the model. The time domain simulation program was used to obtain the six-degrees of freedom motions of the vessel both in regular and irregular waves. Finally, the RAO and the responses obtained from the three different methods were compared. The Root Mean Square (RMS) values obtained from the responses were used to assess the seakeeping performance of the vessel. The results indicated that the measured wave spectrum is similar to that of the Pierson-Moskowitz spectrum. This is a good indication for ship designers to use the spectrum in the absence of actual wave data. The RMS values from simulation and measured methods (model test and full scale trial) indicated that they are in good agreement except for pitching motion. The disagreement in pitching motion is mainly due to the effect of non-linear coupling motions. Generally, from the comparison, it can be concluded that the developed ship simulation program could be used to predict seakeeping behaviour of fishing vessels operating in Malaysian waters.

ABSTRAK

Tesis ini menerangkan tentang satu kajian perbandingan analisis pergerakan kapal bagi sebuah kapal nelayan di Malaysia. Tiga kaedah berbeza digunakan untuk menganalisis pergerakan kapal tersebut iaitu; ujian skala penuh, ujikaji model dan simulasi berdomainkan masa. Program simulasi yang digunakan telah dibangunkan di Universiti Teknologi Malaysia (UTM). Dalam kajian ini, sebuah kapal nelayan tempatan diambil sebagai asas untuk tujuan kajian analisis pergerakan kapal. Di dalam ujian skala penuh pula, data ombak direkodkan dengan menggunakan boya ombak untuk memperolehi spektrum ombak. Manakala, Sistem Pengawasan Pergerakan Kapal (VMMS), telah digunakan untuk mengukur sambutan kapal di laut dan seterusnya, spektrum pergerakan diperolehi. Sebuah model berskala (1:10.6) telah diuji di dalam tangki tunda Jabatan Teknologi Marin, UTM untuk memperolehi sambutan model dalam ombak teratur dan Pengendali Amplitud Sambutan (RAO) dalam ombak tak tentu. Ujian olengan juga dijalankan untuk memperolehi frekuensi tabii, pekali redaman dan kedudukan pusat graviti (KG) model tersebut. Simulasi berdomainkan masa itu digunakan untuk mendapatkan enam-darjah kebebasan pergerakan kapal dalam ombak teratur dan tak tentu. Akhirnya, RAO dan sambutan yang diperolehi daripada tiga kaedah berbeza itu dibandingkan. Nilai punca min kuasa dua (RMS) yang diperolehi daripada sambutan kapaldigunakan untuk menilai prestasi pergerakannya. Keputusan yang diperolehi menunjukkan bahawa spektrum yang diukur adalah sama dengan spektrum Pierson-Moskowitz. Ini menunjukkan bahawa perekabentuk kapal boleh menggunakan spektrum tersebut dalam keadaan ketiadaan data ombak yang sebenar. Nilai punca min kuasa dua daripada simulasi dan kaedah pengukuran juga menunjukkan bahawa kedua-duanya tidak mempunyai banyak perbezaan kecuali bagi pergerakan anggul. Perbezaan ketara bagi pergerakan anggul adalah disebabkan oleh kesan pergerakan gandingan yang tak linear. Secara umumnya, daripada perbandingan ini, boleh disimpulkan bahawa program simulasi kapal yang dibangunkan mempunyai kemungkinan untuk digunakan dalam meramal pergerakan kapal nelayan yang beroperasi di perairan Malaysia.

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NOMENCLATURES

Vessel and Environmental Parameters

LOA - Length Overall in meter

L_{BP} - Length between perpendiculars in meter

L_{WL} - Length of waterline in meter

B - Breadth in meter

D - Depth in meter

T - Draught in meter

C_B - Block coefficient

C_{WP} - Waterplane area coefficients

C_M - Midship area coefficients

KG - Vertical distance of the centre of gravity from the keel

GM_T - Transverse Metacentric height

V_S - Forward speed of the vessel in m/sec

Δ - Vessel displacement in Tonne

κ - Wave number

T_W - Wave period in seconds

L_W - Wave length in meter

V_W - Wave celerity

H_S, $H_{1/3}$ - Significant wave height in meter

ζ - Distance from still water free surface

ζ_W - Wave profile

D_W - Water depth

T_Z - Average zero crossing periods in seconds

T_R - Natural roll period

T_E - Encounter Period

T_m - Modal Period in seconds

ω - Wave frequency in rad/sec

$S_R(\omega_e)$ - Spectral density for response in m^2.s/rad

$S_\zeta(\omega_e)$ - Encounter wave spectral density in m^2.s/rad

ω_S - Mean frequency

RMS - Root mean square value

K_{yy} - Radius of gyration about y axis

A_{WP} - Waterplane area coefficient

I'_{xx} - Moment of inertia about x axis

H_ω - Wave height in meter

ξ - Wave elevation in meter

RAO - Response Amplitude Operator

$S_\zeta(\omega)$ - Wave spectral density in m^2.s/rad

$S_Z(\omega)$ - Spectral density for heave motion m^2.s/rad

$S_\phi(\omega)$ - Spectral density for roll motion in deg^2.s/rad

$S_\theta(\omega)$ - Spectral density for pitch motion in deg^2.s/rad

ω_e - Encounter frequency in rad/sec

γ - Peak enhancement factor

Ω - Peak frequency in the wave spectra

α - Philips constant

K_{xx} - Radius of gyration about x axis in m

I_v - Virtual mass moment of inertia in tonnes.m^2

ω_n - Natural frequency in rad/sec

ω_d - Damped frequency in rad/sec

T_d - Damped period in sec

ω_p - Peak frequency in rad/sec

ω_z - Zero crossing frequency in rad/sec

ω_θ - Natural period for pitching in rad/sec

ω_ϕ - Natural period for rolling in rad/sec

Co-ordinate Systems

$Gxyz$ - Body co-ordinate system about centre of gravity

$O_W\xi\eta\zeta$ - Wave co-ordinate system about still water surface amidships

ϕ,θ, ψ - Euler angles (roll, pitch, and yaw respectively)

$\phi_{\max}$ - Roll response

ϕ_3 - Roll amplitude at time t_3

ϕ_1 - Roll amplitude at time t_1

κ - Non dimensional damping factor

Λ - Tuning factor

μ_ϕ - Magnification factor

γ - Damping ratio

a_n - Added mass

Equations of Motion

m - Mass of body

I_x, I_y, I_z - Principal mass moments of inertia about the x, y and z axes respectively

u, v, w - Linear velocities along the respective x, y and z axes

p, q, r - Angular velocities along the respective x, y and z axes

F_x, F_y, F_z - Force acting in x, y and z direction respectively

K, M, N - Moment acting about x, y, z axes respectively

Forces and Moments

p - Pressure acting on the wetted surface

ρ - Density of water

g - Gravitational acceleration

S - Wetted surface area of vessel

∇ - Under water volume of vessel

ω - Frequency of excitation

n_j - Outward unit normal vector in the j^{th} mode of motion

ϕ - Time dependent velocity potential

ϕ_I - Incident wave potential

ϕ_D - Diffracted wave potential

ϕRj - Generated wave potential due to motions of the body in the jth direction

Hydrodynamic Coefficients

m_j - Mass or mass moment of inertia of body in the j^{th} direction ($j = 1,2,\ldots,6$)

A_{jj} - Hydrodynamic reaction in phase with acceleration (added mass) in the j^{th} direction ($j = 1,2,\ldots,6$)

B_{jj} - Hydrodynamic reaction in phase with velocity (damping) in the j^{th} direction ($j = 1,2,\ldots,6$)

C_{jj} - Hydrostatic stiffness of body in the j^{th} direction ($j = 1,2,\ldots,6$)

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CHAPTER 1

INTRODUCTION

1.1 Background

Fishing vessel is one of the traditional vessels in Malaysia as well as all over the world. A large number of the population depends on these fishing vessels for catching fish to fulfil their livelihood. On the other hand these fishing vessels are providing the people of all over the world with essential nutrition to survive. Most of their operational life they are more likely to operate in deep sea and to sustain harsh weather. Sometimes it is very difficult for them to overcome such weather. Such harsh weather can cause excessive motions, which can degrade the performance; the operation of crew on board, even it can be the cause for the capsizing of the vessel.

Study has been showed that most of the fishing vessels in Malaysia are built traditionally. Except in some modern shipyards in Malaysia, master-builders normally use their intuitive experience and directly implement their designs into the building process without the use of plans or sophisticated calculations (Yaakob, O., 1998). Although the method is simple, quick and tested, since it is based on age-old tradition of trial and error. As a consequence these fishing boats may experience critical situation in severe weather condition.

In the past seakeeping analysis was ignored in most of the design of fishing boats in Malaysia because of the complexity and tediousness of such analysis. Because of neglecting these analysis several accidents occurred in the past. For instance, February 23, 1991, in which a fishing boat capsized in rough seas while ferrying about 20 tourists back from Pulau Kepas was one of the most obvious case.

The frequently happened sea accidents had led to the consideration of analyzing the motion and improving safety at sea and many actions have been taken to remain the sea worthiness of ships at sea. Among them seakeeping analysis was one of the practices to ensure that a ship would always safe in sailing. Nowadays seakeeping analysis has become more and more common practice in the ship design process.

The seakeeping is critical for small vessel like fishing vessel. This is due to her size and mission. The small vessel tends to experience excessive motion than others. The main reason is her underwater hull shape. Throughout this period, numerous methods have been incorporated to evaluate the ship seakeeping. Nowadays naval architect has some numerical tools to study the seakeeping behaviour of a ship design, but these tools have to be used carefully, as most of them are limited due to the theoretical assumptions made (Arribas, P. and Fernandez, C., 2005).

1.2 Research Objective

The objectives of the present research are described as follows:

i. To choose the closest theoretical wave spectra for Malaysian water by comparing the wave spectra obtained from wave buoy and theoretical calculation.
ii. To predict the motion of the vessel based on the local sea environment
iii. To compare the response spectra obtained from full scale measurement spectra by experiment and simulation and vice versa.
iv. To assess the seakeeping performance based on RMS motion

1.3 Scope of Research

The scope of research in the field of seakeeping is very wide. Only the motion related seakeeping will be studied here in this research.

i. Through this research closest theoretical wave spectra can be chosen for the purpose of floating structure design in Malaysia.
ii. The simulation program can be applied to find the response amplitude operator (RAO) of the vessel.
iii. The experimental results can be used to verify the output of the simulation program.
iv. Full scale test results can provide the real motion of the vessel in waves.
v. The combined results from the three different methods can be applied to obtain more realistic behaviour of the vessel in waves.

1.4 Research Outline

This study starts with the critical review of the importance of the study of the prediction of seakeeping for fishing vessel. Then it concentrates on the problem of an existing Malaysian fishing vessel. Then it describes the way to find out the procedure to predict seakeeping performance of a vessel. There are several methods to find out the seakeeping performance of fishing vessel. Here three different approaches have been adopted to find the seakeeping behavior of fishing vessel.

In this research study is carried out to find the behaviour of the vessel in Malaysian water. The vessel is chosen for analysis is small fishing vessel “TRF1010” which is operating in the east coast of Peninsular Malaysia. This vessel was used for the sea trial. The result obtained from the trial was compared to the model testing and simulation output. The detail of full-scale measurement is provided in Chapter 7. The full-scale trial also describes the way to choose suitable theoretical wave spectra for local sea condition.

The model testing was carried out to find the Response Amplitude Operator (RAO) of the vessel for different ship heading and sea conditions. These RAOs is used to obtain the motion response of the vessel in different ship heading. The roll decay tests were also conducted to obtain the natural rolling period. From the roll decay test the KG of the vessel was also obtained. This determined KG is used to validate the KG of the full scale vessel for a certain loading condition.

In the simulation part, a six-degrees-of-freedom mathematical model is adopted to the simulation program. The main effort of this model is based on the accurate computation in time domain of the motion of the vessel. Whilst, the dynamic term in the equation of motion is estimated by using the frequency dependent coefficient, which can be obtained through the published literatures. Finally the response amplitude operator can be obtained by the computed motion for different wave condition.

Finally the computed RAO is compared to the RAO obtained from sea trial and model experiment. From the RAO obtained from simulation and experiment the motion response is obtained through the principle of superposition and they were compared to the full scale motion which was measured by vessel motion monitoring system (VMMS).