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Experimental Study of the Probability Distributions on the Seakeeping Performance of Monohull and Catamaran Design

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ABSTRACT

A safety and a comfort criteria of ship, one of them which can be known from ability of the ship motion on sea wave . The development of maritime technology in particular shipbuilding, catamaran ship design is one of the considerations in modern ship design, in addition to monohull ship design. This research describes the analysis of seakeeping model test of monohull and catamaran ship. The seakeeping model test is performed on sea-state 4 with a heading of 45 deg, 90 deg, 135 deg and 180 deg. Ship motion responses in the form of heave, pitch and roll motion, are presented in the form of the probability distribution curves. From the results of seakeeping test, it can be seen that the catamaran ship provides motion response relatively smaller than the monohull ship .

KEY WORDS: *Catamaran, Monohull, Model test, Seakeeping, Probability Distribution*

1.0 INTRODUCTION

There are some aspects of transportation modes required for inter-island shipping and inter-island passengers, that is the availability of ferry more efficient, safe and cheaper. The fleet ferry have an important role in supporting the economic activities of a maritime country. Therefore, the selection of a good criteria of ferry design is required to support its operations.
In the operation of the ferry, in addition to having adequate speed, also required the ability to motion response of the ship to the sea waves. These problem caused the development of ferry design more convenient, safe, fast and competitive , and continue its to achieve the best product of ferry. Sometimes, to improve the capability of ferry motion, designer propose a variety of rules ranging from monohull design (conventional) to multi-hull, especially catamaran or Small Water Plan Area Twin Hull (SWATH) configuration [Piscopo & Scamardella, 2015].
The ship design with the form of multi-hulls or catamaran as one of the alternative for ferry that has not been widely used in Indonesian, which the monohull ferry is used a commonly. The monohull and the catamaran design are two different geometries, all the arrangements about the ship's design allow the pros and cons [Bouscasse et al, 2013]. Designers be supposed to realize a good performance of ships in the seas, it is necessary for conduct the model test for different types of hull. So, this experimental to research the effects of monohull and catamaran design on ship motion.
The characteristics of ship or marine building motion to the random waves is called seakeeping. The ship motion can be generate by all aspects of ship design such as hull design, stability, construction, endurance, etc., these all cause sea worthiness on the ship. There is no single parameter that can be used to define seakeeping performance design. A good seakeeping qualities is obviously important, but it is difficult to lay down the provision of compromised design features to improve good seakeeping. Comparisons of monohull and multi-hull to ship's motion are difficult. As a development of twin hull vessels form has been proposed, because many design studies indicated many advantages with no significants disadvantages [Molland A. F., 2008].

2.0 EXPERIMENT METHOD

The ship motion is define as a motion of the ship's center of gravity. Rotational motion around the orthogonal axis of the center of gravity (CG), as the motion of the ship is two-ways,

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translation and rotational motion.

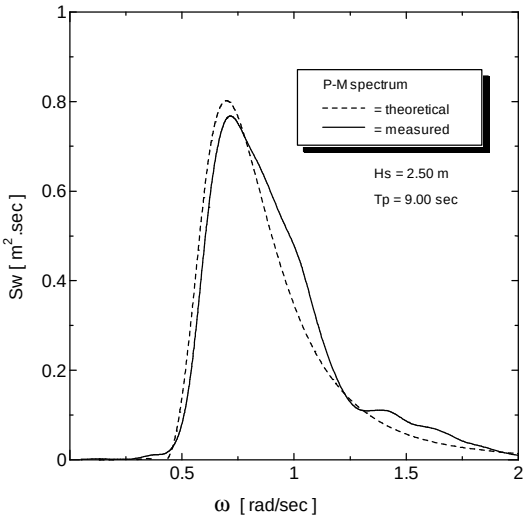

Figure 1: Measurement of the wave spectrum

This research conducted a testing on two types of models, that monohull and catamaran ferry model . It will be analyzed a motion performance of the ship. The model test conducted at Manuevring Ocean Basin facility where basin test facility belongs to Indonesian Hydrodynamic Laboratory - BPPT Surabaya.
The monohull and catamaran model are used ferry grade 1500 GT, the main model dimension are shown in table 1. The models are made with a scale of 1 : 26. The seakeeping model test performed on irregular wave conditions equivalent to sea-state 4, significant wave height Hs = 2.5 m and peak period Tp = 9 s with Pierson-Moskowitz spectrum type. Each heading angles at 45 deg, 90 deg, 135 deg and 180 deg.

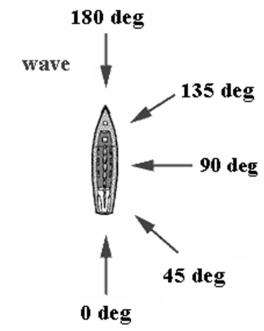

Figure 2 : Definition of heading angle of ship against wave

The seakeeping test method is done by using free running method. This method uses the equipment of controlled drive system, so that the model can move in 6 degrees of freedom. It is get motions of 6 degrees of freedom of data recorded by using wireless optical tracking system. The target sensors attached to the model and detected by the motion tracking equipment, subsequently recorded in the form of a raw motion data. This system is expected to describe the phenomenon of the movement of the ship while operating in the sea on random waves. During the model testing also taken the motion video shoot model in the basin tank.
The object of the model test is done a setting of the model center of gravity according to vertical center of gravity and longitudinal center of gravity values. Then, model test is placed in the basin, and conducted decay test to find a roll natural period.

Table 1 : Main particulars of model

Symbol / Unit	Dimension	
	Monohull	Catamaran
Lpp (m)	2.50	2.50
B (m)	0.53	0.806
D (m)	0.18	0.211
T (m)	0.12	0.122
Δ (kg)	99.46	105.078

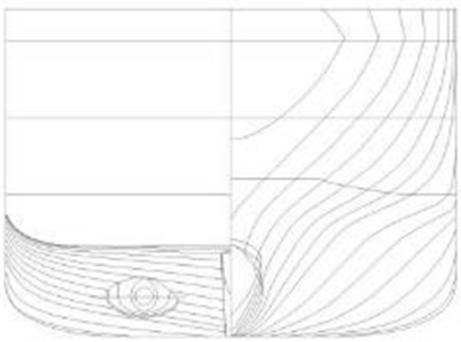

Figure 3 : Body plans of monohull design

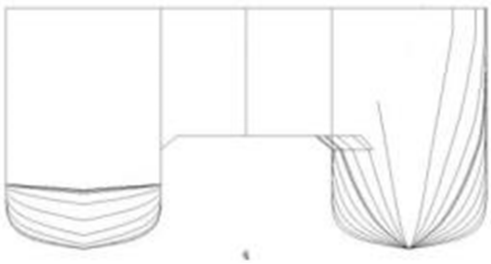

Figure 4 : Body plans of catamaran design

3.0 RESULT ANALYSIS AND DISCUSSION

The results of the seakeeping test are only a heave, roll and pitch motion, there are performed by analysis. Since a dominant mode of ship's motion occur on vessels with forward speed, instead of an others motion mode such as surge, sway and yaw. The seakeeping test is analysed by a presenting of the data in the form probability distribution of occurrences, and compared with the Rayleigh probability distribution to observe the linearity of the pattern of ship's motion. The cumulative distribution equation of Rayleigh is shown as bellow :

$$P(X \leq x) = 1 - \exp(-x^2/2\sigma^2) \quad (1)$$

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Where x is the peak value of occurrences for positive or negative of each occurance cycle, and σ is the standard deviation.

The probability distributions of heave, pitch and roll motion with each heading angle of 45 deg, 90 deg, 135 deg and 180 deg, are shown in figure 5 ~ 16. The statistical data of monohull model test, symbol ■ for positive peak values and □ point to negative peak values. As well as statistical data of catamaran, ● for positive peak values and ○ show negative peak values.

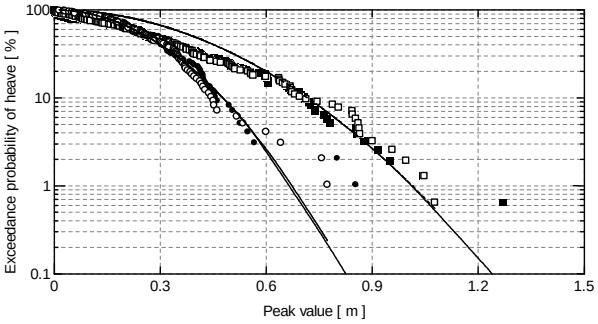

Figure 5 : The probability distribution of heave motion on heading 45 deg

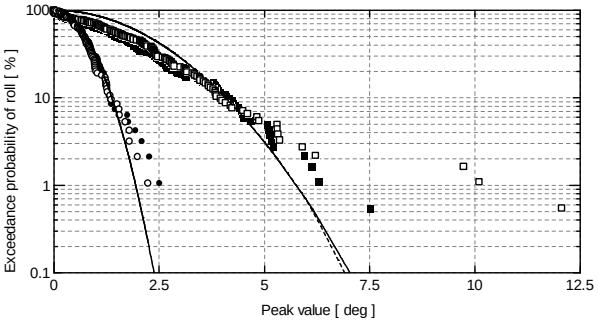

Figure 6 : The probability distribution of roll motion on heading 45 deg

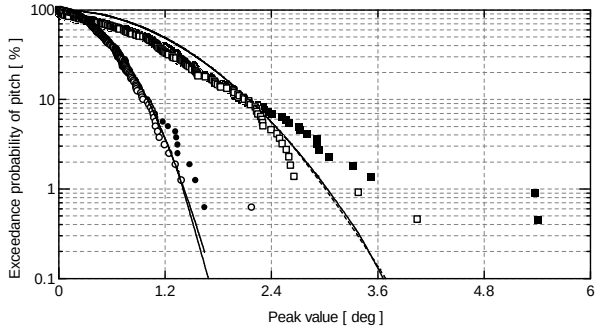

Figure 7 : The probability distribution of pitch motion on heading 45 deg

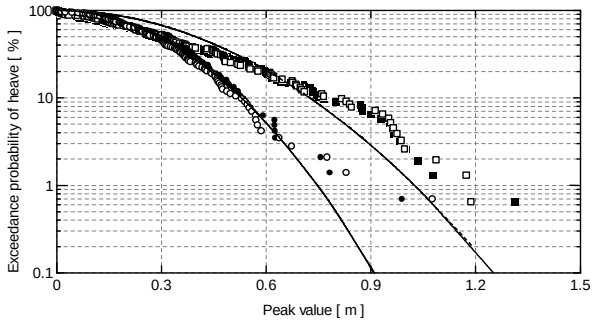

Figure 8: The probability distribution of heave motion on heading 135 deg

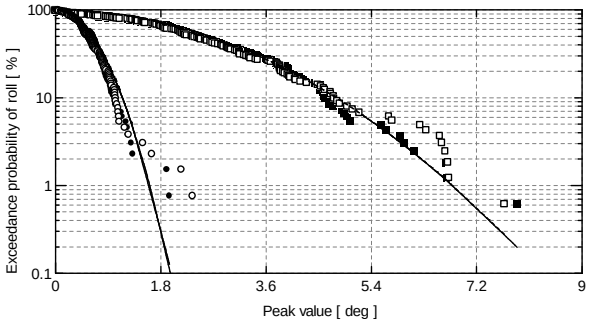

Figure 9: The probability distribution of roll motion on heading 135 deg

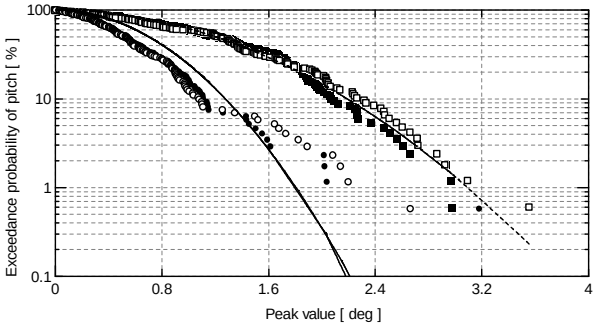

Figure 10: The probability distribution of pitch motion on heading 135 deg

In figures 5 ~ 10 explain that ships's motion for wave heading of stern quartering seas or 45 deg and bow quartering seas or 135 deg, peak values normally be distributed for the amplitude of a small motion. But, it will become a non-linear when motion response of the ship is enlarged. It is shown at the ends value that will keep away from the Rayleigh distribution.
An analysis of motion response for wave heading of beam seas or 90 deg and beam seas or 180 deg, its shown in figures 11 ~ 16. The statistical data explain a similarity amplitude of distribution as well as an others heading. The linearity assumption in hydrodynamic theory is used in the prediction of motion response of ship. Then, if the result of seakeeping analysis conducted by numerical computation, it will be deviation or less accurate at in

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extreme condition. By model testing, it represented non-linearity and approximates the actual conditions. A relevant aspect of consideration in future research could be the study of non-linearities of ship's motion response both a computational and an experimental point of view [Castiglione et al, 2011].

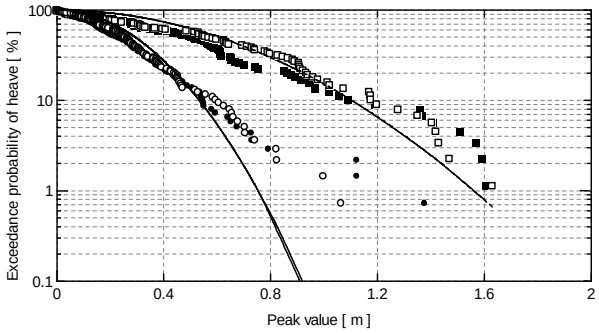

Figure 11: The probability distribution of heave motion on heading 90 deg

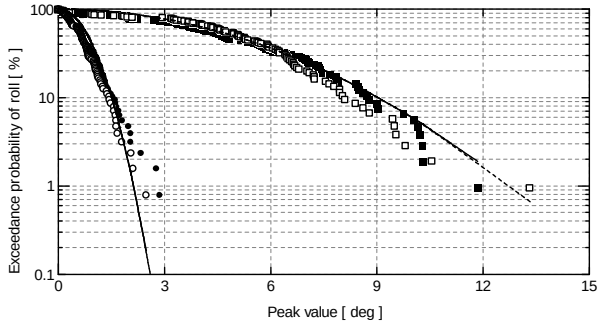

Figure 12: The probability distribution of roll motion on heading 90 deg

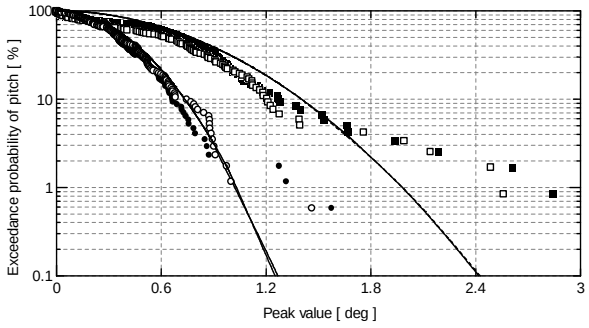

Figure 13: The probability distribution of pitch motion on heading 90 deg

One of an important mode of motion response is rolling motion, because this motion mode is related to the stability of the ship. The roll motion will be easy to happen or the greatest occurs in the heading of side wave or head seas. As the results of model test of roll motion can be observed in figures above.

In the science of hydrodynamics, roll motion is strongly influenced by roll damping, to get values of ship roll damping, which shall be tested by roll decay test.

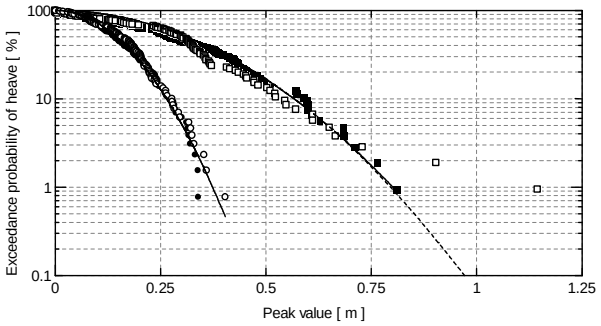

Figure 14: The probability distribution of heave motion on heading 180 deg

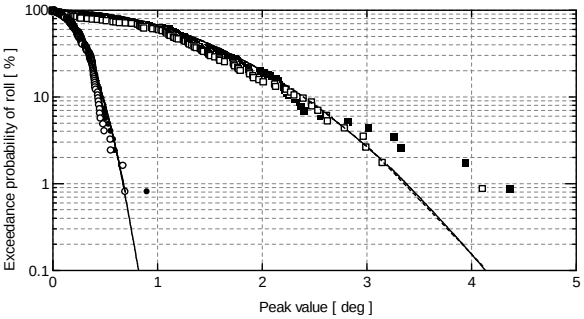

Figure 15: The probability distribution of roll motion on heading 180 deg

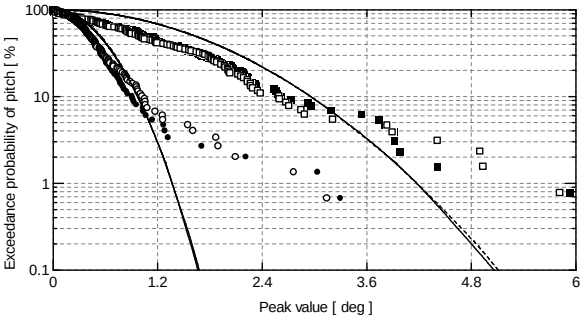

Figure 16: The probability distribution of pitch motion on heading 180 deg

In the extreme condition of sea-state 4 is obtained the testing results of a hull type of ferry. The monohull ship has a tendency of motion amplitude that greater than the catamaran ship. In particular of roll motion, the maximum motion of the catamaran ferry shown 75 % smaller than the monohull ferry. It is indicated that the catamaran ferry has a roll damping larger than monohull ferry. From the results of decay test obtained that catamaran has a large roll damping.

As a passenger ship, the safety and the comfort factor become thing a very important for the ferry, which the ship has to be demonstrated with a minimal motion response. The motion

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response in addition to being influenced by the sea wave and characteristics of the vessel, the speed of ship and the wave directions are also an important considerations. That is related to the safe vessel operation. That all of heading angles, sea-states, and operating scenarios a significantly influence the overall of hull performance, there are important to refined optimization procedure and the ana;ysis clearly [Piscopo and Scamardella, 2015].

Hydrodynamic configuration of the hull on the body of the catamaran ship, occur in a smaller motion response than the monohull. However, the catamaran hull, as it is known to be highly susceptible to the moment on both of the hull of body connecting deck due to the hydrodynamic force of a sea water passing through a double ship's hull. It is necessary to be concerned in designing of the strength of the construction, in addition to the motion response of ship. That the drag experienced by the catamaran is almost always large than twice the drag of the monohull [Broglia et al, 2015]. Therefore, the risk of the failure of a structure design of the catamaran ship needs to be considered. A catamaran design may assist in streamlining the flow, additional reinforcement of the wave-piercing bows is required, which may not be a practical solution from a structural strength point of view as lateral vibrations forward of the jaws can occur [Lavroff et all, 2017].

The discussion of the results of model test, obtained a description of the characteristics of monohull and catamaran ferry based on hydrodynamic theory. These are some of the most important considerations in design and operation, resulting in an optimum ferry design.

4.0 CONCLUSION

This research used the experimental investigation method to cognize a seakeeping for two types of hulls of ship design, there are monohull and catamaran design. The result of hydrodynamic test of seakeeping, obtained a catamaran provides the motion response smaller than a monohull design. The characteristics of motion of ship influenced that angle of a ship heading against the sea wave.

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