Makara Journal of Technology

Volume 15 | Issue 1 Article 5

4-1-2011

An Investigation Into the Resistance/Powering and Seakeeping Characteristics of River Catamaran and Trimarana

Murdijanto Murdijanto
Department of Naval Architecture and Shipbuilding Engineering, FTK, ITS, Surabaya 60111, Indonesia

I Ketut Aria Pria Utama
Department of Naval Architecture and Shipbuilding Engineering, FTK, ITS, Surabaya 60111, Indonesia, kutama@na.its.ac.id

Andi Jamaluddin
Senior Researcher, Indonesian Hydrodynamics Laboratory, Surabaya 60111, presently PhD Student at the Faculty of Marine Technology, ITS, Surabaya 60111, Indonesia

Recommended Citation

Murdijanto, Murdijanto; Utama, I Ketut Aria Pria; and Jamaluddin, Andi (2011) "An Investigation Into the Resistance/Powering and Seakeeping Characteristics of River Catamaran and Trimarana," *Makara Journal of Technology*: Vol. 15: Iss. 1, Article 5.
DOI: 10.7454/mst.v15i1.853
Available at: https://scholarhub.ui.ac.id/mjt/vol15/iss1/5

AN INVESTIGATION INTO THE RESISTANCE/POWERING AND SEAKEEPING CHARACTERISTICS OF RIVER CATAMARAN AND TRIMARAN

Murdijanto[1], I Ketut Aria Pria Utama[1*)], and Andi Jamaluddin[2]

1. Department of Naval Architecture and Shipbuilding Engineering, FTK, ITS, Surabaya 60111, Indonesia
2. Senior Researcher, Indonesian Hydrodynamics Laboratory, Surabaya 60111, presently PhD Student at the Faculty of Marine Technology, ITS, Surabaya 60111, Indonesia

*)E-mail: kutama@na.its.ac.id

Abstract

The increase of fuel price has caused fleet operational and shipping business to be in danger situation. The fuel consumption of a ship is influenced by ship volume or wetted area which contributes directly to the increase of ship resistance and the size of main engine. In order to find out the appropriate answers, a series of investigation into river transportation using monohull, catamaran and trimaran types of vessel was carried out. The work focused on the estimation of total resistance and powering as well as seakeeping characteristics and carried out experimentally using tank test and numerically using a ship design software (Maxsurf). It was found out that the catamaran and trimaran could have less resistance and hence power compared to monohull of similar displacement. The seakeeping characteristics of the multihull vessels were also comparable with those of the monohull. This is a good indication that river catamaran/trimaran is an efficient and comfortable vessel. If a prototype or real vessel is developed, it can be a very efficient ship as well as a ship with high safety standard.

Keywords: catamaran, monohull, resistance, seakeeping, trimaran

1. Introduction

In the last thirty years, there is a significant increase on the use of multihull vessels for various applications such as ferries, fishing vessels, sporting craft, and oceanographic research vessel [1-2]. The principal advantages of these vessels compared to monohull type of vessel are more attractive of layout accommodation, better transverse stability, and in certain case it could reduce total resistance and hence the size of main engine [3]. Various types of vessel are further developed in order to satisfy the design criteria. Among others, the concept of catamaran is preferred and becoming more popular [4]. Pal and Doctors [5] developed a preliminary design method to provide accurate solution of catamaran passenger vessel operated in a river.

Meanwhile, trimaran hull form or vessel with three hulls has received considerable attention because it can provide even bigger deck area and shallower-draft [6-8]. The form of trimaran is known at the beginning as 'perahu bercadik', and at present is popularly used as warships because of its high quality of maneuvering and stability [9].

The calculation of power required by the catamarans needs an investigation into the resistance characteristics entirely in order to obtain the most by ship design [10]. The resistance of catamaran can provide complex phenomena to ship designers particularly with the appearance of interaction between the demihull of catamaran. Therefore, it has been a basic need to obtain the breakdown and understanding of correct ship resistance components in order to obtain accurate calculation based on scaling transformation from model to the real ship.

A systematic investigation has been made by Insel and Molland [11-12] showing that there is a certain separation between 2 demihulls causing very small interaction or in practice it can be said that there is no interaction. The small interactions occur at separation to length ratio (S/L) of 0.4 and 0.5 and this provides an idea that a catamaran with similar displacement to comparable monohull could have smaller resistance and power of main engine.

Further investigation on the catamaran resistance is pioneered by Soeding [13] who found out that the reduction of ship resistance significantly when the demihull is varied longitudinally and this is known as staggered catamaran. Utama *et al*. [14] applied NPL 5c model and found out that the reduction of resistance occurs when the catamaran was varied transversely (un-staggered) and longitudinally (staggered). If this is applied to a real ship, it has the potency to safe the use of fuel significantly.

The most widely used estimation of catamaran resistance is the method proposed by Insel and Molland [11]. In this case, catamaran hull consists of 2 isolated demihulls and creates wave and viscous resistance interference and formulated as follows:

$$C_T = (1+\phi k)\sigma C_F + \tau C_W \quad (1)$$

Where:
C_T is total resistance coefficient,
C_F is frictional resistance coefficient and obtained from ITTC-1957 correlation line,
C_W is wave resistance coefficient of isolated demihull,
(1+k) is form factor value of isolated demihull,
ϕ is used to estimate the change of pressure around demihull,
σ represents additional velocity between demihulls and calculated from the summation of local frictional resistance around wetted surface area.

In fact, the factors of ϕ and σ are difficult to measure hence for the practical purposes, the two factors can be combined to form viscous resistance interference factor (β) where $(1+\phi k)\sigma = (1+\beta k)$ hence:

$$C_T = (1+\beta k)C_F + \tau C_W \quad (2)$$

Where for monohull or demihull at isolation the value of β=1 and τ=1.

Empirical formulation to estimate the total resistance of trimaran is so far not known and depends highly on the experimental results [15]. This is attributed to the minimum publications of trimaran resistance both experimentally and numerically.

2. Methods

The investigation was carried out both experimentally and numerically. The experimental work was conducted using towing tank and 3 ship models were applied, namely monohull, catamaran and trimaran and tested at various speed and separation to length (S/L) ratios. The numerical work was carried out using commercial ship design software (Maxsurf).

Physical models of the monohull, catamaran and trimaran are shown in Figures 1 to 3. The models were made from FRP (fibreglass reinforced plastics) in order to obtain appropriate displacement as scaled from full ship mode in accordance with Froude law of similarity. Principal particulars of the three ships are given in Tables 1 to 3.

The models were tested at speed equal to the speed of real vessel at open sea from about 5 to 10 knots and the Froude numbers are about 0.30 to 0.40. The catamaran and trimaran modes were tested at separation to length (S/L) ratios of 0.2, 0.3 and 0.4 following the works of Insel and Molland [11] and Utama [16]. Details of the results can be found in Utama *et al*. [17].

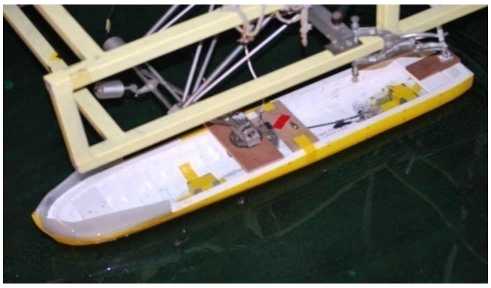

Figure 1. Monohull Model

Figure 2. Catamaran Model

Figure 3. Trimaran Model

Table 1. Principal Data of Monohull

LWL (m)	B (m)	D (m)	H (m)	C_B	Displ. (ton)
13.8	2.88	0.65	1.3	0.498	11.8

Table 2. Principal Data of Catamaran

Parameter	Catamaran	Demihull
LWL (m)	14.5	14.5
B	7.655	1.855
D	0.65	0.65
C_B	0.382	0.382
Displ.	11.8	5.9

Table 3. Principal Data of Trimaran

Parameter	Mainhull	Sidehull
LWL (m)	14.5	12.0
B	2.00	1.147
D	0.72	0.52
H	1.44	1.24
C_B	0.384	0.39
Displ.	6.96	2.42

Table 4. Results of Monohull Testing

V (knots)	Fr	Rt (kN)	Cf	Ct
5.7063	0.2461	1.0706	0.0023	0.0070
6.0896	0.2627	1.7393	0.0023	0.0100
6.6939	0.2887	2.2364	0.0023	0.0107
7.2591	0.3131	2.8835	0.0023	0.0117
7.6605	0.3304	3.7134	0.0022	0.0135
8.1306	0.3507	4.9951	0.0022	0.0162
8.4204	0.3632	6.0649	0.0022	0.0183
8.9417	0.3857	7.2606	0.0022	0.0194
9.2831	0.4004	7.6677	0.0022	0.0190

3. Results and Discussion

Resistance/Powering. Results of the experimental work were tabulated in Tables 4 to 6, which described the correlation of resistance against speeds of ship.

The results from Maxsurf were shown in Tables 7. Despite the software does not take resistance interaction between the hulls, the numerical study was taken at S/L=0.4 when there is presumably no significant interaction between demihulls [11,16].

Seakeeping. Experimental investigation into seakeeping of the three ship modes was carried out under head sea condition, ship speed of 6.5 knots and sea state of 3 which indicates a condition known as sea breeze [18-21]. The tests were focused on the motions of heave, pitch and surge. Roll motion was not investigated because of the equipment problem. The rolling apparatus did not work when the test was carried out. However, the roll motion is considered to be small in head seas [22]. The results are shown in Figures 4 to 6.

Response of ship motion (heave, pitch and roll) using Maxsurf are shown in Tables 8. The test was carried out at various wave directions and up to sea-state 3 where waves move in regular mode with wave height up to about 0.5-1.0m [18-21].

Experimental results shown in Tables 4 to 6 and the Maxsurf results in Tables 7 described the relation between speed and resistance at various configurations. Results of monohull configuration are presented in Tables 4 and 7 and further plotted in Figure 7. This

Table 5. Results of Catamaran Testing

V (knots)	Fr	Catamaran Resistances (kN)		
		S/L=0.2	S/L=0.3	S/L=0.4
5.7877	0.2496	1.8206	1.6586	1.6585
6.2183	0.2682	2.1414	1.8513	2.0613
6.6768	0.2880	2.4428	2.2386	2.3475
7.0513	0.3041	2.8519	2.6778	2.9465
7.5599	0.3261	3.4600	3.5677	3.5471
8.0322	0.3465	4.4674	3.9536	3.7658
8.3841	0.3616	4.8439	4.3450	4.3408
8.8179	0.3803	5.1490	4.7904	4.6623
9.2331	0.3983	5.8067	5.5916	5.5146
9.8126	0.4233	7.1005	6.4480	6.1378

Table 6. Results of Trimaran Testing

V (knots)	Fr	Trimaran Resistances (kN)		
		S/L=0.2	S/L=0.3	S/L=0.4
5.7322	0.2473	1.9173	1.8264	1.6574
6.364	0.2745	2.1432	2.4283	2.0548
6.6664	0.2875	2.7617	2.7001	2.3037
7.153	0.3085	3.7216	3.4895	2.6235
7.6583	0.3303	4.3319	4.2296	2.8026
8.085	0.3487	4.9553	4.8044	3.0118
8.5617	0.3693	5.5774	5.4003	3.3778
8.8295	0.3808	6.1487	5.8512	3.5788
9.2848	0.4005	7.2261	6.8137	3.8127
9.6301	0.4154	8.1004	7.8182	4.3141

Table 7. Results from Maxsurf

V (knots)	Fr	Hull Forms		
		Monohull	Catamaran	Trimaran
5.90	0.264	1.06	1.20	1.34
6.23	0.278	1.18	1.32	1.47
6.55	0.293	1.30	1.44	1.62
7.20	0.322	1.66	1.68	1.91
7.53	0.337	1.85	1.82	2.06
7.85	0.351	1.99	1.94	2.21
8.18	0.366	2.10	2.08	2.39
8.50	0.380	2.20	2.24	2.57
8.82	0.394	2.31	2.40	2.78
9.15	0.409	2.88	2.56	3.00
9.80	0.438	4.54	3.16	3.66

indicates similar trend of resistance increase. However, Maxsurf shows a little increase compared to the experimental result and this also occurrs at catamaran and trimaran configurations. This is attributed to the exclusion of resistance interference and wave breaking phenomenon by Maxsurf. The last term occurs at higher speed or Froude numbers and further discussion about this can be found in Hogben and Standing [23] and Utama *et al*. [24].

Similar phenomena are also shown by catamaran with clearance S/L=0.4 (Tables 5 and 7 and Figure 8) and trimaran with clearance S/L=0.4 (Tables 6 and 7 and Figure 9) configurations. The catamaran form (Figure 8) shows lower resistance and the trimaran mode (Figure 9) indicates even lower resistance than the monohull mode of similar displacement. The reason for this, despite similar displacement, is because the catamaran and trimaran modes have slenderer hull-form than the monohull one. Thus, this has caused the resistance interaction and hence total resistance to decrease. By the use of Maxsurf, however, there is no indication of resistance decrease since the software or code does not take both resistance interaction and wave breaking phenomenon into consideration.

Among the catamaran and trimaran modes, it is clear that the total resistance decreases as the separation to length (S/L) ratio increases and this is caused by the decrease of resistance interaction following the increase of S/L ratios. This is in a good agreement with [1] and [11].

Table 8. Ship Motion Responses

Ship Motion	Sea State -3				
	0^0	45^0	90^0	135^0	180^0
Monohull					
Heave (m)	0.197	0.216	0.252	0.370	0.221
Roll (deg)	0.000	4.350	8.930	4.960	0.000
Pitch (deg)	2.480	2.290	1.260	2.060	2.330
Catamaran, S/L=0.4					
Heave (m)	0.168	0.199	0.245	0.227	0.201
Roll (deg)	0.000	3.220	6.840	4.150	0.000
Pitch (deg)	2.030	1.950	1.600	1.660	1.530
Trimaran, (S/L=0.4)					
Heave (m)	0.169	0.201	0.249	0.228	0.207
Roll (deg)	0.000	3.210	6.430	3.890	0.000
Pitch (deg)	2.036	1.954	1.610	1.667	1.534

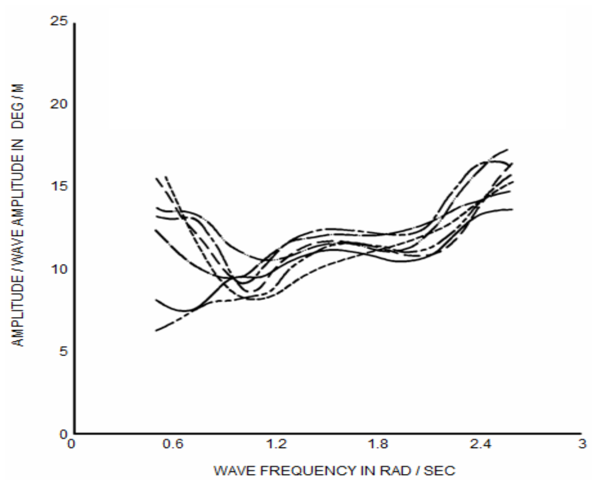

Figure 5. Response of Pitch Motion. Monohull (—), Cataramaran S/L 0.2 (----), Cataramaran S/L 0.3 (– – –), Cataramaran S/L 0.4 (– – –), Trimaran S/L 0.2 (– – – –), Trimaran S/L 0.3 (– - –), Trimaran S/L 0.4 (– - - –)

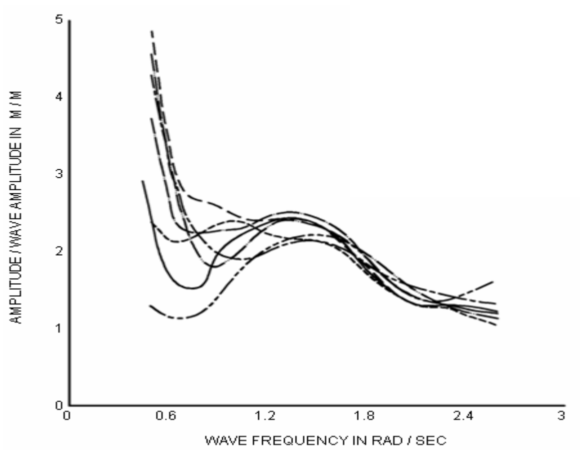

Figure 4. Response of Heave Motion. Monohull (—), Cataramaran S/L 0.2 (----), Cataramaran S/L 0.3 (– – –), Cataramaran S/L 0.4 (– – –), Trimaran S/L 0.2 (– – – –), Trimaran S/L 0.3 (– - –), Trimaran S/L 0.4 (– - - –)

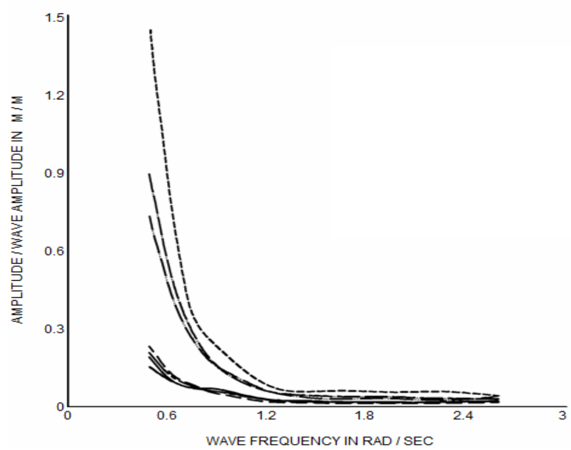

Figure 6. Response of Surge Motion. Monohull (—), Cataramaran S/L 0.2 (----), Cataramaran S/L 0.3 (– – –), Cataramaran S/L 0.4 (– – –), Trimaran S/L 0.2 (– – – –), Trimaran S/L 0.3 (– - –), Trimaran S/L 0.4 (– - - –)

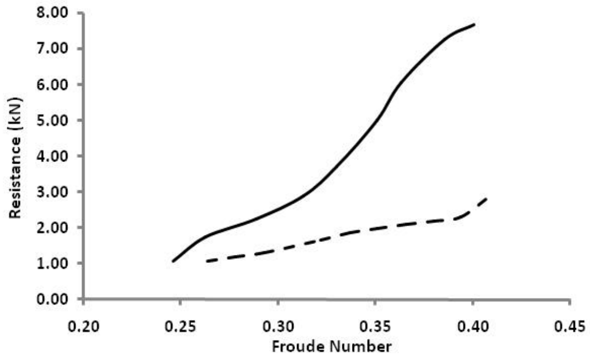

Figure 7. Plot of Resistance of Monohull Type. Experiment (—), Maxsurf (---)

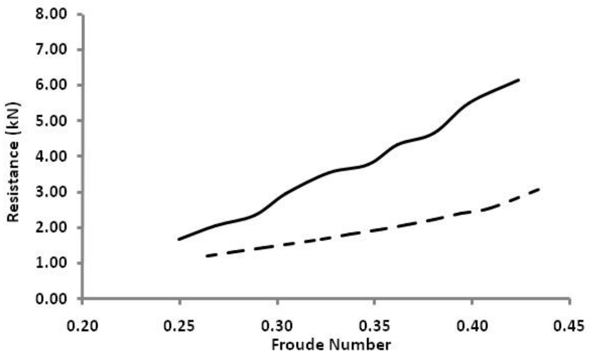

Figure 8. Plot of Resistance of Catamaran Type. Experiment (—), Maxsurf (---)

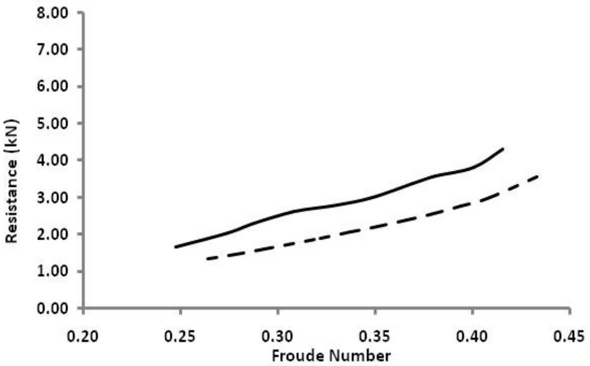

Figure 9. Plot of Resistance of Trimaran Type. Experiment (—), Maxsurf (---)

Results of ship motions experimentally presented in Figures 4 to 6, show that motion of catamaran and trimaran are slightly higher than the monohull's motion. However, the motion under numerical search using Maxsurf (Table 8) shows that the multihull modes have better characteristics, although the discrepancy is not significant. It can be said in general that the motion of multihulls are comparable with the motion of monohull. This fact is in a good agreement with the work done by Molland *et al*. [25].

Response of heave and pitch reach maximum values under following sea condition (0^o). Waves coming from behind cause the vessel to move up and down more excessively. Meanwhile, roll motion arrives at maximum value under beam sea condition (90^o). This has caused the vessel to move from one side to other side (known as roll) more extremely. Again, this is in good agreement with the results of Molland *et al*. [25].

In addition, among the multihulls, the catamaran mode demonstrates slightly smaller heave and pitch responses compared to the trimaran. Conversely, the trimaran showed smaller roll response to the catamaran. This is because of the number of hulls, in which trimaran has more hulls and hence the total ship breadth. This further cause better or lower roll response, but higher heave and pitch responses, and this corresponds well with Rawson and Tupper [26].

4. Conclusion

The calculation and analysis shows that the catamaran and trimaran configurations provide lower total resistance than monohull one with equal displacement. The main and most significant factor is the geometry of ship hull and arrangement of ship wetted surface area. The trimaran mode demonstrates higher resistance or power effective at lower separation ratio (S/L=0.2 and 0.3). This is because the main hull of trimaran is bluff enough to cause higher flow interaction between the hulls hence causes higher resistance and power effective. In addition, the trimaran possesses three hulls, whilst the catamaran does have only two hence resistance and resistance interaction of the trimaran are consequently higher than those of the catamaran. However, at S/L=0.4 the interaction decreases significantly hence total resistance and power effective become much smaller. The multihull modes show almost similar motion characteristics as compared to the monohull. This is an indication (up to sea state 3), that catamaran and trimaran are as comfortable as the monohull. Furthermore, the effect of wave direction on ship motion is clear. Heave and pitch motions of both multihulls are more excessive under following sea condition, whilst roll motion is more extreme under quartering and beam sea conditions.

Acknowledgement

The authors expressed their sincere gratitude to the Ministry of Research and Technology of the Republic of Indonesia which funded the research under the scheme known as Applied Incentive Research of the year 2008-2009. The authors also thanked to Mr Langgeng Condro, from ITS Hydrodynamics Laboratory and Mr Nanang Joko from Indonesian Hydrodynamics Laboratory (LHI), for their helps in making the models, setting and conducting the experimental work.

References

[1] I.K.A.P. Utama, J. Res. Eng. 12 (2006) 1.

[2] A.D. Papanikolaou, Norwegian Maritime Technology Forum, November 22-23, 2001.

[3] S. Groleau, J. Revord, T. Robins, B. Vandedrinck, Naval Architecture Research Group, Ocean Engineering Design, Final Report 2007, Florida Institute of Technology, 2007.

[4] P.K. Sahoo, S. Marcos, A. Schwetz, Ships and Offshore Structures 2/4 (2007) 307.

[5] P.K. Pal, L.J. Doctors, Proc. FAST Sea Transportation, Germany, 1995, p.139.

[6] I.K.A.P. Utama, Murdjanto, I.G.M. Santosa, Seminar Nasional Teori dan Aplikasi Teknologi Kelautan (SENTA), Proc. 2007, p.1.

[7] I.K.A.P. Utama, Murdijanto, A. Hardika, Hairul, National Seminar Opportunities Challenges and Prospects of Sea Transportation in Indonesia, ITATS, 2007.

[8] V.A. Subramanian, G. Dhinesh, J.M. Deepti, J. Ocean Technol. 1 (2006) 1.

[9] K. Hebblewhite, P.K. Sohoo, L.J. Doctors, Ships and Offshore Structures 2 (2008) 149.

[10] A.F. Molland (Ed.), A Guide to Ship Design, Construction and Operation, The Maritime Engineering Reference Book, Butterworth-Heinemann, Elsevier, 2008, p.902.

[11] M. Insel, A.F. Molland, Transactions of the Royal Institution of Naval Architects (RINA) 134 (1992) 1.

[12] I.K.A.P. Utama, A.F. Molland, Procs. FAST'2001, UK, 2001.

[13] H. Soeding, Procs. FAST Sea Transportation, Australia, 1997, p.339.

[14] I.K.A.P. Utama, Murdijanto, Hairul, Proceedings of RIVET Conference, Malaysia, 2008, p.14.

[15] L.J. Doctors, M.R. Renilson, G. Parker, N. Hornsby, Procs. FAST Sea Transportation, Norway, 1991, p.35.

[16] I.K.A.P. Utama, PhD Thesis, Dept. of Ship Science, the University of Southampton, UK, 1999.

[17] I.K.A.P. Utama, Murdijanto, A. Sulisetyono, A. Jamaluddin, Development of Adjustable Sections to a Transport Ship and Transitions Through the Safe, Comfortable and Efficient, Final Report, Applied Incentive Research, KNRT, 2009.

[18] R. Bhattacharyya (Ed.), Dynamics of Marine Vehicles, John Wiley and Sons, Toronto, Canada, 1978, p.498.

[19] S.F. Beaufort, Beaufort Scale - Wikipedia, *http://www.stormfax.com/beaufort.html*, 2010.

[20] H.P. Douglas, Douglas Sea Scale, World of Earth Science, *http://www.enotes.com/earth-science*, 2010.

[21] O.M. Faltinsen (Ed.), Sea Loads on Ships and Offshore Structures, Cambridge University Press, Cambridge, U.K., 1990, p.630.

[22] J.B. Jia, Z. Zong, H.Q. Shi, J. Int. Shipbuilding Prog. 56 (2009) 3.

[23] N. Hogben, R.G. Standing, Transactions of the Royal Institution of Naval Architects 126 (1975) 279.

[24] I.K.A.P. Utama, P.E. Panunggal, Murdijanto, Proceedings of Marine Technology Conference (MARTECH), Depok, Indonesia, 2008, p.1.

[25] A.F. Molland, J.F. Wellicome, J. Cic, D.J. Taunton, Transactions of the Royal Institution of Naval Architects (RINA) 142 (2000) 268.

[26] K.J. Rawson, E.C. Tupper (Ed.), Basic Ship Theory, Vol. 2, Longman Scientific and Technical, Oxford, UK, 1994, p.26.