Journal of the Korean Society of Marine Environment & Safety
Vol. 23, No. 3, pp. 301-312, May 31, 2017, ISSN 1229-3431(Print) / ISSN 2287-3341(Online)
Research Paper
https://doi.org/10.7837/kosomes.2017.23.3.301

Improving the Design Process of Pleasure Yachts for CE RCD Certification via Modification to Buoyancy and Stability Assessment Method

Daekyun Oh*† · Chang-Woo Lee**

* Department of Naval Architecture and Ocean Engineering, Mokpo National Maritime University, Mokpo-si 58628, Korea
** Jeonnam Regional Division, KOMERI (Korea Marine Equipment Research Institute), Jellanam-do 58457, Korea

Abstract : *CE RCD (Recreational Craft Directive) is a certification for the design and construction of small vessels, including pleasure yachts, which are widely used not only in the countries within the European Union, but also in Japan and Southeast Asia. Recently, South Korean leisure craft shipyards have developed interest in exporting to foreign leisure craft markets such as Europe; however, they have encountered difficulties because of the CE RCD regulations, which are relatively complex and difficult to understand. The requirements for buoyancy and stability, which are essential properties that must be understood within the early stage of ship design, are defined based on ISO 12217. However, preparing this assessment according to ship classification regulations is an exceedingly complex task, even with knowledge of naval architecture. In this research, we have developed design support tools to systematically support assessments and preemptively define design information so that buoyancy and stability assessments based on ISO 12217 can be systematically prepared. Our research results were applied to actual examples of yacht design to confirm validity. We believe that the improved yacht design process presented in this research can act as a foundational reference for enhancing the effectiveness and systematic buoyancy and stability assessments.*

Key Words : *Pleasure yacht, CE RCD, ISO 12217, ISO 8666, Stability assessment*

1. Introduction

CE RCD (Recreational Craft Directive) is an EU certification that defines the standards for the design, construction, and quality of leisure crafts less than 24 m in length; this includes pleasure yachts. In the EU and other countries where the CE RCD is recognized, a CE certification mark must be received in order to develop and distribute a leisure craft. CE RCD is based on approximately 50 ISO standards, including 10 standards related to naval architecture; there is an assessment for buoyancy and stability, which are critical properties that must be carefully considered from the early step of ship development. This assessment is defined in ISO 12217 and details methods for an evaluation of the basic buoyancy and stability of a ship according to the hull weight balance; however, preparing stability assessments according to ship classification is an exceedingly complex task, even with knowledge of naval architecture. Recently, South Korean leisure craft shipyards have developed interest in exporting to foreign leisure craft markets such as Europe, but they have encountered difficulties because of the CE RCD regulations, which are relatively complex and difficult to understand.

In this research, we aim to analyze ISO 12217 and develop an evaluation process that includes an assessment of buoyancy and stability from the early design stages, while also analyzing the related design variables. By developing design support tools for systematically supporting assessments, in addition to a preliminary definition for which design information must be prepared for effective assessment, we aim to fundamentally improve the pleasure yacht design process. In addition, we have verified the effectiveness of the improved design process presented in this research by applying it to the design of a 52 ft. cruiser.

2. Analysis of Buoyancy and Stability Assessment (3-Test) according to ISO 12217

ISO 12217 (ISO, 2002a) is a regulation for evaluating the buoyancy and stability of small vessels, and it defines evaluation standards for stability assessments against downflooding, offset loading, and rolling resistance to waves and wind according to the weight balance and shape of a vessel. ISO 12217 is separated into the following three regulations as based on the length and

---

† Corresponding Author : dkoh@mmu.ac.kr 061-240-7318

※ This paper is based on proceedings presented by the authors at the 2013 KAOST Conference held in Jeju, South Korea (Lee at al., 2013).

propulsion type of a vessel:

- ISO 12217-1 6m≦LH≦24m Non-sailing boats
- ISO 12217-2 6m≦LH≦24m Sailing boats
- ISO 12217-3 LH≦6m Boats

The European ship classification society included in the CE RCD classification are based on the ISO 12217 standards, which discuss the safety of the vessel; these classes are evaluated by means of strengthened self-defined standards as it pertains to buoyancy and stability.

In this research, we arranged the design variables and evaluation process for a stability assessment of a vessel based on the Pleasure Yacht Rule (RINA, 2013) of the Italian Ship Classification Society (Registro Italiano Navale), as well as the ISO 12217-1 standard for non-sailing boats longer than 6 m, upon which the rule is based. In addition, the principal dimensions and loading conditions, etc., used in this research followed the ISO 8666 (ISO 2002b) standards.

2.1 Assessment items and criteria

Buoyancy and stability assessments adhering to ISO standards are comprised of three general types of tests.

The first type of test is the downflooding requirement test; the second type of test examines buoyancy via an offset-load test, and the third type evaluates the righting moment according to changes in loading conditions. Further descriptions are provided below.

(1) Downflooding test

Assessment of demand values that will be used to define the downflooding-related opening standards, such as downflooding height ($h_{D(R)}$) and downflooding angle ($\phi_{D(R)}$), to be applied in the design.

(2) Offset-load test

Assessment of the heeling angle (ϕ_O) during offset loading situations caused by loading shifts (e.g., crew movement).

(3) Righting moment test

Calculation of the wind and wave resistances according to design category; assessment of the downflooding angle, vanishing stability angle, and heeling moment caused by the resistance.

The demand value required to perform additional assessments is shown in Appendices 1 and 2.

2.2 Verification procedure and related design variables

RINA has a verification checklist document entitled DIPCE 13 (RINA, 2011) that delineates vessel buoyancy and stability assessment. The assessment process used in this study is summarized below.

(1) Definition of vessel design information

Defining principal dimensions and design conditions, such as the design category and crew limit, for downflooding requirements, off-set loading tests, and righting moment calculations.

(2) Downflooding Test

Collecting required information on opening shape, downflooding height, and downflooding angle for downflooding verification; there is also a test according to the corresponding regulations.

(3) Offset-load Test

Entering relevant information on the crew such as mass and crew area for residual freeboard and heel angle testing to evaluate offset loading capacities; there is also a test according to the corresponding regulations.

(4) Righting Moment Test

Entering critical information such as the heeling moment calculation results; a righting moment test takes into account the anticipated resistance resulting from the design and loading conditions.

In DIPCE 13, vessel information is entered according to the process defined above, and buoyancy and stability verification are performed according to the design conditions.

In each step of the process, there is design information that is required to perform the corresponding test item; the items in Table 1 show the design variables needed to perform the three assessments according to DIPCE 13.

2.3 Preliminary information for 3-Test

To perform the buoyancy and stability assessment (3-Test) as according to DIPCE, there is preliminary information in addition to the design variables presented in Table 1 that must be calculated or prepared. To perform the 3-Test, a preliminary preparation process is required; this process can be classified into six categories. Table 2 shows the six categories and the corresponding design variables and additional information required for each; this has been defined as "preliminary information" in this research. For each category, design variables as well as additional information such as vessel shape and design category are needed, and depending on the case, CAD models may be necessitated to prepare information.

Table 1. Design variables for tests: calculations and requirements for determining downflooding, offset load, and resistance to waves and wind

Test Procedure and Item		Design Variable
Downflooding Test	Downflooding openings	L_H, B_H, F_M, T
	Downflooding height ($h_{D(R)}$)	L_H, B_H, F_M, V_D
	Downflooding angle ($\phi_{D(R)}$)	L_H, B_H, m_{MOC}, m_{LDC}
Offset-load Test	Offset-load heel angle ($\phi_{O(R)}$)	L_H
Righting Moment Test (Resistance to waves and wind)	Heeling moment due to wind (M_W)	L_{WL}, B_H, T, m_{MOC}, m_{LDC}
	Assumed roll angle (ϕ_R)	V_D, m_{MOC}, m_{LDC}
	Maximum righting moment occurs at a heel angle of 30°	m_{MOC}, m_{LDC}
	Maximum GZ occurs at a heel angle of 30°	m_{MOC}, m_{LDC}

Table 2. Preliminary information: design variables and additional information according to assessment procedure

Pre-	Design Variable	Additional Information	
1. Common Information	L_H, B_H, F_M, CL(crew limit), m_{MOC}, m_{LDC}	h_D, Type of craft	Design category
2. Downflooding Opening	L_H, B_H, F_M, T_M	ISO 12216, ISO 9093, ISO 9094	Design category
3. Downflooding Height : $h_{D(R)}$	L_H, B_H, F_M, V_D	h_D, x_D, y_D, a, x'_D	Design category
4. Downflooding Angle : $\phi_{D(R)}$	L_H, m_{MOC}, m_{LDC}	ϕ_O, ϕ_D, z_D, y'_D	Design category
5. Offset-load Test(Heel angle) : $\phi_{O(R)}$	L_H, B_H, CL	ϕ_O, F_A, F_F	Design category, Option
6 Resistance to waves and wind : M_W	L_H, L_{WL}, B_H, T_M, F_M, m_{MOC}, m_{LDC}, V_D	A_R, A_{RF}, A_{LV}, A'_{LV}, ϕ_D, ϕ_V, ϕ_{A2}, ϕ_R, $A1$, $A2$, ϕ_{GZMAX}, RM_{30deg}, GZ_{30deg}, RM_{max}, GZ_{max}	Design category, V_W

The downflooding test necessitates a relatively large amount of shape information that must be imported from a CAD model, while the righting moment test requires not only shape information imported from a CAD model, but also numerous design variables for calculations. The offset-load test appears to not require much data, but this is because many judgments must be made by performing manual tasks; this is a consequence of the heeling angle for certain loading conditions necessitating judgments based on these tasks rather than calculations being performed with design variables. This particular type of off-set load test executes calculations, in addition to performing physical tests following construction of the vessel.

2.4 Use of preliminary information

The following is an example of the method for using the preliminary information (Table 2) presented above.

The General Information category presented in Table 2 yields all of the information needed for all verification procedures. For the Downflooding Opening category, the opening shape defined in ISO 12216, ISO 9093, and ISO 9094 should be confirmed and the required items should be examined. Here, the demand value is determined by the design variables.

Resistance to waves and wind requires calculation of the heeling moment M_W, as shown in Eq. 1; to do this, additional information such as the A_{LV} (windage area) and V_W (wind speed) is needed.

A_{LV} can be determined by utilizing information on the longitudinal cross section of the hull, thus necessitating a CAD model; V_W is the wind speed according to the design category, which is presented in ISO 12217.

$$M_W = 0.3A_{LV}\left(\frac{A_{LV}}{L_{WL}}+T\right)\nu_W{}^2 \tag{1}$$

Fig. 1 demonstrates how the design variables and additional information presented in Table 2 are used in the righting moment test.

If the preliminary information presented in Table 2 is prepared beforehand, the 3-Test can be easily and systematically performed.

3. Design Process Improvements

If the preliminary information is properly delineated beforehand, there will be no significant problems when performing the 3-Test; however, preparing such detailed design information and forming accurate assumptions from the initial design are not simple tasks. However, continuously and carefully considering preliminary information by gathering and analyzing design information from the initial designs of similar ships can facilitate the subsequent design process.

This chapter describes a method for using the previously presented preliminary information to improve the pleasure yacht design process. The following items were considered to improve the design process.

(1) It is necessary for the design process to adhere to the primary design variable delineations, which are defined in general terms in ISO 8666 and ISO 12217 standards. In subsequent design stages, it is particularly useful to utilize design variables that comply with these standards, in addition to the design variables acquired from data analyses of similar ships in the initial design stage, to estimate principal dimensions.

(2) In the case of the downflooding test, it is very effective to use a CAD model rather than a test simulation developed using calculations; if this technique is used in conjunction with consideration of the design variables, test execution will be straightforward.

(3) In the case of the offset-load test, the assessment is primarily performed via ship calculations, with numerous physical tests also being performed.

(4) In the case of the righting moment test, it is very useful if the test can be simulated by directly applying the data on

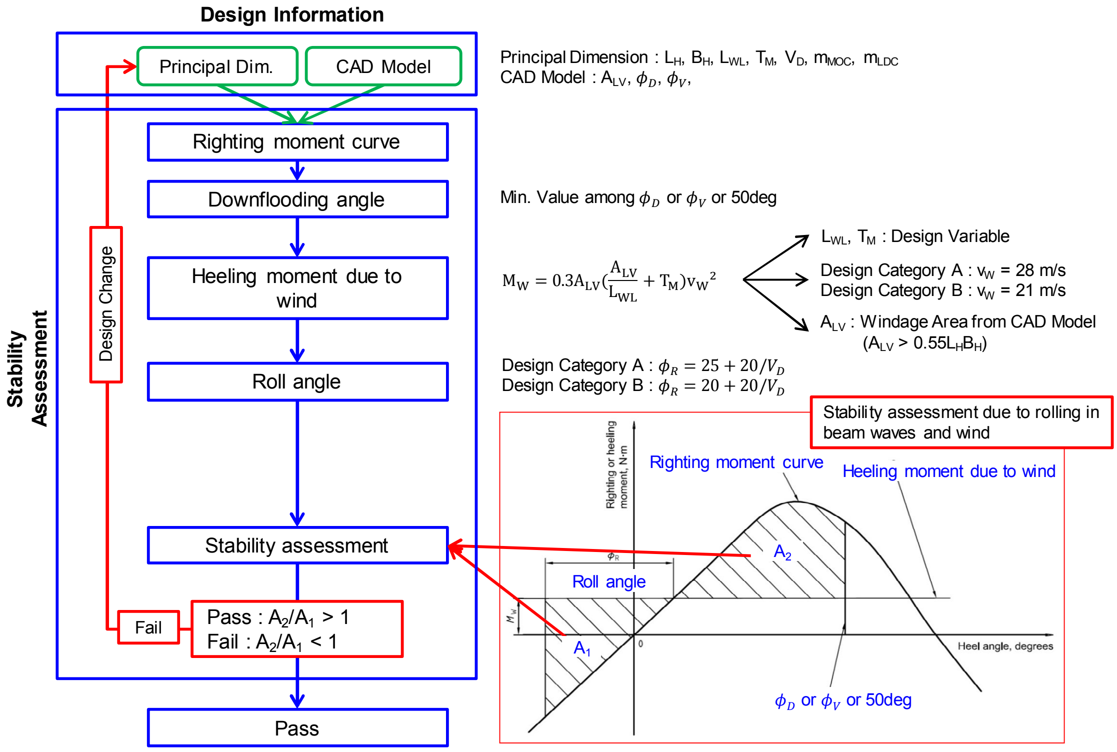


Fig. 1. Righting moment test process flow diagram for rolling in beams due to waves and wind. (Kim et al., 2014).

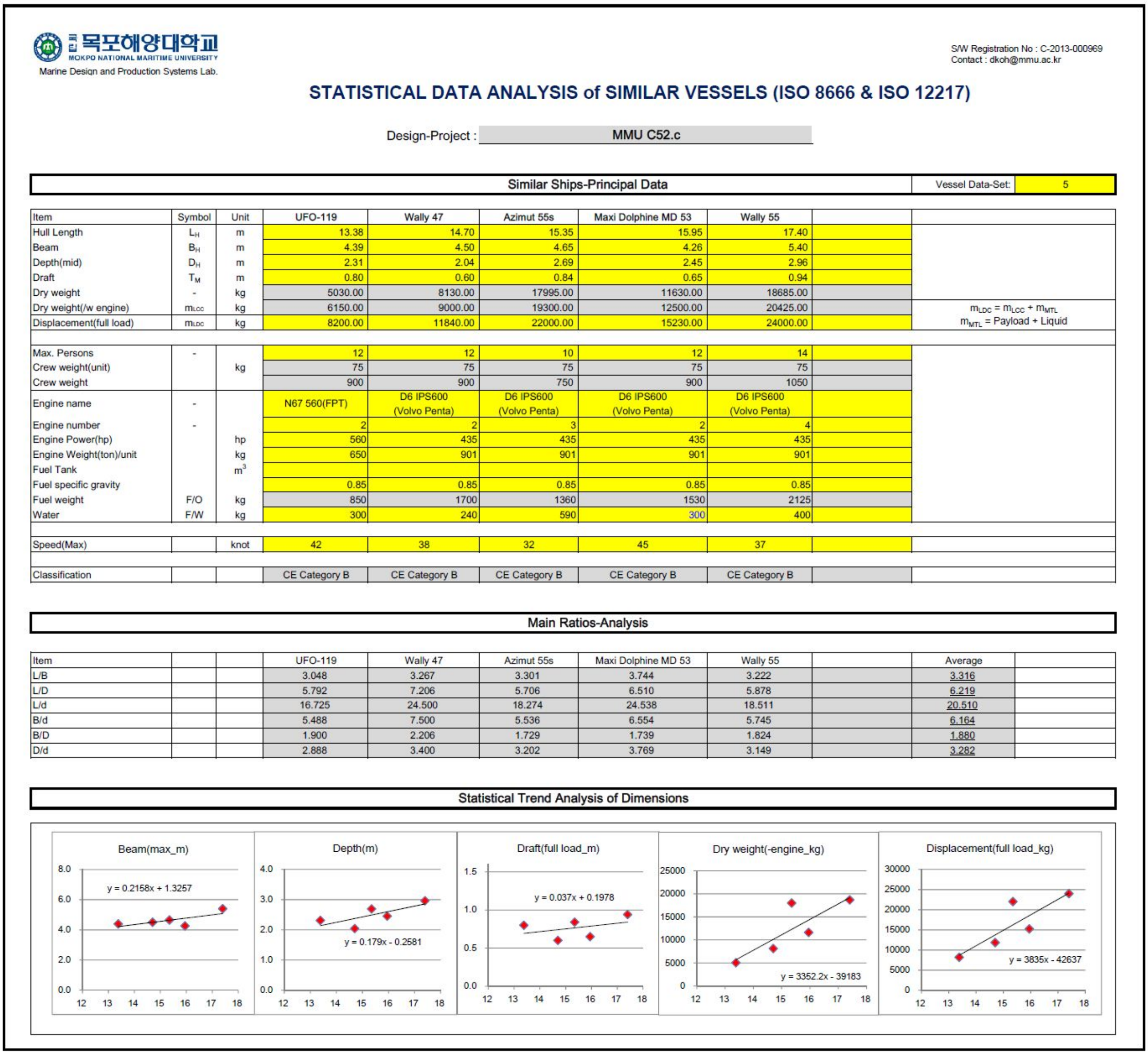
resistance, which varies according to the design category and loading conditions.

Three design support tools have been developed to improve on design processes (1) and (4) of the four processes listed above. The tools are outlined below.

3.1 Development of design support tools

3.1.1 Statistical data analysis tool in accordance with ISO 8666 and ISO 12217

The ISO 8666 and ISO 12217 standards are followed from the stage where design information on similar ships is gathered as part of the initial design stage; thus, design support tools that enable effective adherence to the ISO standards and delineation of principal dimensions were developed. While performing analysis of similar ships, the principal dimensions are delineated according to ISO standards, thus enabling statistical analysis of dimensions that is in accordance with the standards. Additionally, if data on similar ships is entered according to the divisions of the previously divided weight items, loading conditions in agreement with the ISO standards can be estimated. Fig. 2 is a screenshot of the developed statistical data analysis tool; it shows the tool being used to enter



S/W Registration No : C-2013-000969
Contact : dkoh@mmu.ac.kr

STATISTICAL DATA ANALYSIS of SIMILAR VESSELS (ISO 8666 & ISO 12217)

Design-Project : MMU C52.c

Similar Ships-Principal Data Vessel Data-Set: 5

Item	Symbol	Unit	UFO-119	Wally 47	Azimut 55s	Maxi Dolphine MD 53	Wally 55		
Hull Length	L_H	m	13.38	14.70	15.35	15.95	17.40		
Beam	B_H	m	4.39	4.50	4.65	4.26	5.40		
Depth(mid)	D_H	m	2.31	2.04	2.69	2.45	2.96		
Draft	T_M	m	0.80	0.60	0.84	0.65	0.94		
Dry weight	-	kg	5030.00	8130.00	17995.00	11630.00	18685.00		
Dry weight(/w engine)	m_{LCC}	kg	6150.00	9000.00	19300.00	12500.00	20425.00		$m_{LDC} = m_{LCC} + m_{MTL}$ m_{MTL} = Payload + Liquid
Displacement(full load)	m_{LDC}	kg	8200.00	11840.00	22000.00	15230.00	24000.00		
Max. Persons	-		12	12	10	12	14		
Crew weight(unit)		kg	75	75	75	75	75		
Crew weight			900	900	750	900	1050		
Engine name	-		N67 560(FPT)	D6 IPS600 (Volvo Penta)	D6 IPS600 (Volvo Penta)	D6 IPS600 (Volvo Penta)	D6 IPS600 (Volvo Penta)		
Engine number	-		2	2	3	2	4		
Engine Power(hp)		hp	560	435	435	435	435		
Engine Weight(ton)/unit		kg	650	901	901	901	901		
Fuel Tank		m^3							
Fuel specific gravity			0.85	0.85	0.85	0.85	0.85		
Fuel weight	F/O	kg	850	1700	1360	1530	2125		
Water	F/W	kg	300	240	590	300	400		
Speed(Max)		knot	42	38	32	45	37		
Classification			CE Category B	CE Category B	CE Category B	CE Category B	CE Category B		

Main Ratios-Analysis

Item			UFO-119	Wally 47	Azimut 55s	Maxi Dolphine MD 53	Wally 55		Average	
L/B			3.048	3.267	3.301	3.744	3.222		3.316	
L/D			5.792	7.206	5.706	6.510	5.878		6.219	
L/d			16.725	24.500	18.274	24.538	18.511		20.510	
B/d			5.488	7.500	5.536	6.554	5.745		6.164	
B/D			1.900	2.206	1.729	1.739	1.824		1.880	
D/d			2.888	3.400	3.202	3.769	3.149		3.282	

Statistical Trend Analysis of Dimensions

Fig. 2. Design tool screenshot of principal dimension estimation in accordance with ISO 8666 and ISO 12217.

data on five similar ships and perform statistical analysis.

3.1.2 Principal dimensions estimation tool in accordance with ISO 8666 and ISO 12217

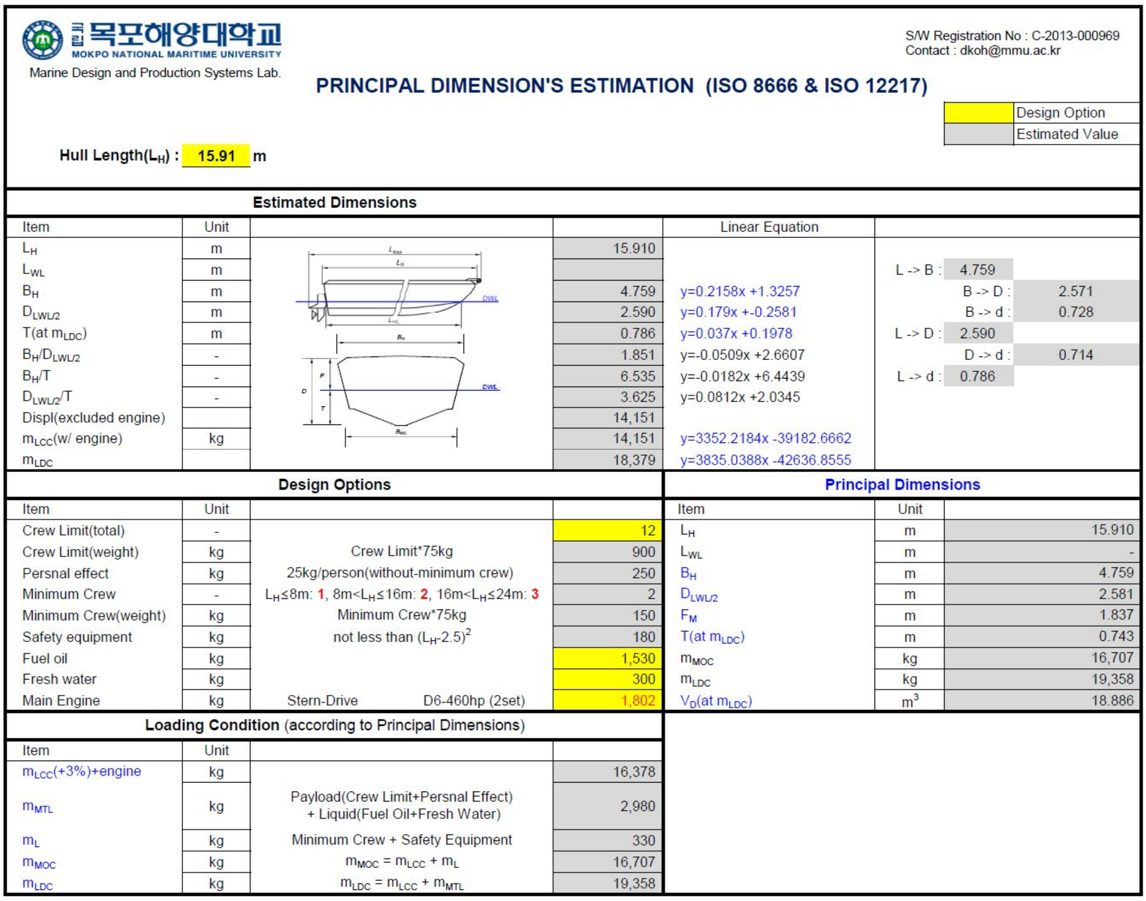
The statistical analysis tools can be used to analyze trends in the data on similar ships; if this tool is used, the principal dimensions of a vessel can be estimated according to its hull length, which is based on the analyzed data. In addition, weight estimation that is in agreement with ISO standards can be performed with respect to options for operating the vessel, such as the amount of crew, the fuel oil and freshwater volumes, and the engine weight. The principal dimensions and other results, such as loading conditions , that are estimated using this method, can be subsequently used as design variables in the 3-Test. Fig. 3 is a screenshot of the developed principal dimensions estimation tool; it illustrates the principal dimensions and loading condition estimation results for a vessel with a hull length of 15.91 m, as based on an analysis of data on similar ships (described in Section 3.1.1).

3.1.3 Stability assessment tool in accordance with ISO 12217

Generally, the righting moment test does not require complex calculations. Furthermore, there are various general righting moment calculation tools. In this research, we developed a tool that utilizes righting moment calculation results as input to subsequently perform a stability assessment test that takes into account the additional resistance resulting from the design category, windage area conditions, etc. Figs. 6 and 7 are screenshots of the developed stability assessment tool being used to assess the stability of an example vessel.

3.2 Design process improvement using developed tools

In this research, we have emphasized the importance of preparing preliminary information to efficiently perform the 3-Test, and we have developed three tools for making such preparations. It should be noted that using these tools alone does not mean that the 3-Test can be entirely automated; however, as previously mentioned, these



Marine Design and Production Systems Lab.

S/W Registration No : C-2013-000969
Contact : dkoh@mmu.ac.kr

PRINCIPAL DIMENSION'S ESTIMATION (ISO 8666 & ISO 12217)

🟨 Design Option
▨ Estimated Value

Hull Length(L_H) : 15.91 m

Estimated Dimensions

Item	Unit		Linear Equation		
L_H	m	15.910			
L_{WL}	m			L -> B : 4.759	
B_H	m	4.759	y=0.2158x +1.3257		B -> D : 2.571
$D_{LWL/2}$	m	2.590	y=0.179x +-0.2581		B -> d : 0.728
T(at m_{LDC})	m	0.786	y=0.037x +0.1978	L -> D : 2.590	
$B_H/D_{LWL/2}$	-	1.851	y=-0.0509x +2.6607		D -> d : 0.714
B_H/T	-	6.535	y=-0.0182x +6.4439	L -> d : 0.786	
$D_{LWL/2}/T$	-	3.625	y=0.0812x +2.0345		
Displ(excluded engine)		14,151			
m_{LCC}(w/ engine)	kg	14,151	y=3352.2184x -39182.6662		
m_{LDC}		18,379	y=3835.0388x -42636.8555		

Design Options

Item	Unit		
Crew Limit(total)	-		12
Crew Limit(weight)	kg	Crew Limit*75kg	900
Persnal effect	kg	25kg/person(without-minimum crew)	250
Minimum Crew	-	L_H≤8m: 1, 8m<L_H≤16m: 2, 16m<L_H≤24m: 3	2
Minimum Crew(weight)	kg	Minimum Crew*75kg	150
Safety equipment	kg	not less than $(L_H-2.5)^2$	180
Fuel oil	kg		1,530
Fresh water	kg		300
Main Engine	kg	Stern-Drive D6-460hp (2set)	1,802

Principal Dimensions

Item	Unit	
L_H	m	15.910
L_{WL}	m	-
B_H	m	4.759
$D_{LWL/2}$	m	2.581
F_M	m	1.837
T(at m_{LDC})	m	0.743
m_{MOC}	kg	16,707
m_{LDC}	kg	19,358
V_D(at m_{LDC})	m^3	18.886

Loading Condition (according to Principal Dimensions)

Item	Unit		
m_{LCC}(+3%)+engine	kg		16,378
m_{MTL}	kg	Payload(Crew Limit+Persnal Effect) + Liquid(Fuel Oil+Fresh Water)	2,980
m_L	kg	Minimum Crew + Safety Equipment	330
m_{MOC}	kg	$m_{MOC} = m_{LCC} + m_L$	16,707
m_{LDC}	kg	$m_{LDC} = m_{LCC} + m_{MTL}$	19,358

Fig. 3. Design tool screenshot of principal dimension estimation in accordance with ISO 8666 and ISO 12217.

tools can be used in combination with CAD modeling to perform a buoyancy and stability assessment that is relatively more systematic and effective as compared to existing approaches. If the method presented in this research is used with a CAD model to create a design, the improved design process will be as follows.

(1) Gather data on similar ships and use the statistical data analysis tool to analyze trends; if there is additional required information, add the data provided by the tool according to the relevant standards.

(2) Use the principal dimensions estimation tool to determine the principal dimensions of the vessel; here, the data provided by the tool, such as data regarding the design category, crew number, fuel oil, and freshwater volume of the vessel to be designed, is delineated according to the relevant standards.

(3) Use the estimated principal dimensions to develop a hull form and position the weight according to the estimated loading conditions.

(4) Design the structure, including the cabin house, according to the hull form and build a CAD model for the vessel being constructed.

After the above four steps have been performed, the basic preparations for the 3-Test are complete. The prepared preliminary information and CAD model are subsequently used to perform the 3-Test.

4. Case Application : 52ft Cruiser Design

The developed design support tools were implemented according to the design method presented in Chapter 4 to perform a case study. The vessel used in this case study was a power yacht with a hull length of 15.91 m and a displacement of 18.18 m^3 (at m_{LDC}).

4.1 Basic design using developed tools

To design the yacht, data were gathered on five similar ships; the statistical data analysis tool was then used to analyze the data, as shown in Fig. 1. The hull length was determined to be 15.91 m; the principal dimensions estimation tool was used to define the principal dimensions, as shown in Fig. 2. The design category was defined as B, and the crew number and fuel oil and freshwater volumes were defined as shown in the Design Options section of Fig. 2. Following this, the loading conditions of the yacht were found to be as shown in the Loading Condition section of Fig. 2.

Based on the principal dimensions and loading conditions that were determined according to the above-mentioned methods, the hull form and a CAD model incorporating the cabin house were developed, as shown in Fig. 4. In the CAD model, additional tank information was defined by considering the capacity of the tank to hold fuel oil and freshwater; the weight position information, including information on the weight of the corresponding engine, was reflected in the CAD model. Fig. 5 shows the general arrangement (G/A) derived from the completed CAD model.

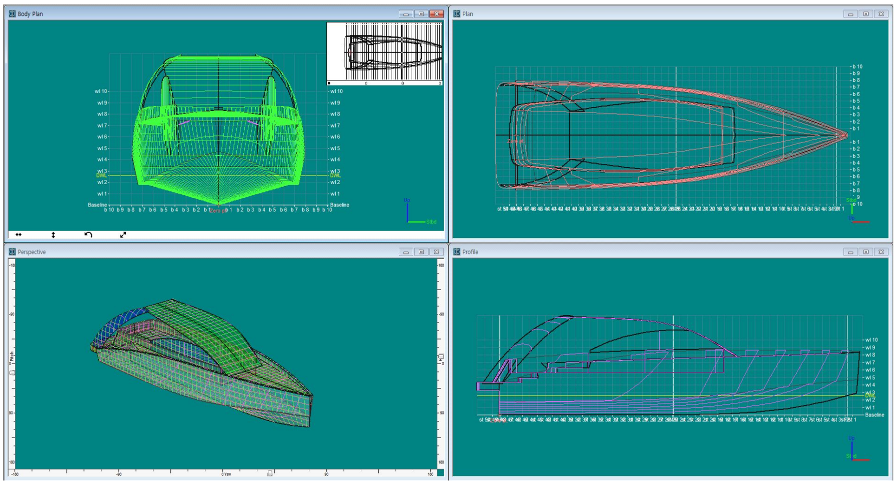


Fig. 4. 3D CAD model of the case study.

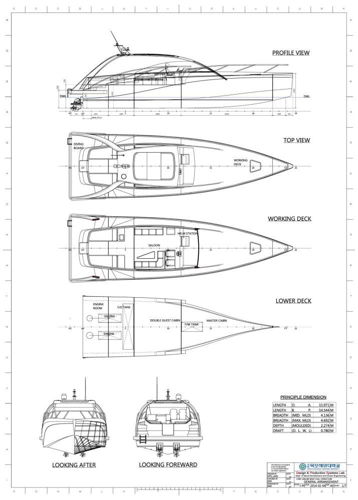


Fig. 5. G/A of the case study.

4.2 Buoyancy and Stability Assessment (3-Test)

The preliminary information, including the previously defined principal dimensions, was used in combination with the CAD model to perform the 3-Test.

4.2.1 Downflooding test

The CAD model was used to confirm that the downflooding opening complied with regulations; it was modified and supplemented accordingly. Measurement of the downflooding height and angle was made relatively simple using the CAD model. In the case of a yacht in design category B with a hull length of 15.91 m, the minimum required height to avoid downflooding is 0.936 m. In the case of this yacht, the results of measuring with the 3D CAD model confirmed that there were no problems at 1.449 m in the loaded displacement condition . Regarding the downflooding angle, the results of measuring with the CAD model showed that the minimum operating and loaded displacement conditions were 73.1 and 67.4 degrees, respectively. Fig. 6 shows the measurement of the downflooding angle in the two loading conditions using the CAD model.

4.2.2 Offset-load test

The offset-load test can be performed without difficulty by using the ship calculations; additionally, previously defined information can be applied for the design category, crew number, and other required information. For this yacht, the crew number was set at twelve; for the offset-load test, six people were placed at the helm station and six people were placed at the weather deck's afterward ; results confirmed that the offset-load heel angle satisfied the minimum required conditions.

4.2.3 Righting moment test

The righting moment test was performed in consideration of the waves and wind conditions for the design category. Here, the additional required design variables can be found in predefined preliminary information and values determined by the CAD model. As an example, the ALV (windage area), which is required to calculate the resistance to waves and wind, was determined via the CAD model. Fig. 7 presents a screenshot of the righting moment assessment results and the setting design variables that account for the wave and wind conditions; Fig. 8 shows the screenshot of the final stability assessment that reflects this information. The yacht was confirmed to exhibit no problems with stability in the given conditions.

4.3 Effects of using the improved design process

The improved design process presented in Chapter 3 was used and a buoyancy and stability assessment (3-Test) was performed on a 52 ft. cruiser. Below is an overview of the effects of using this process as compared to existing design methods.

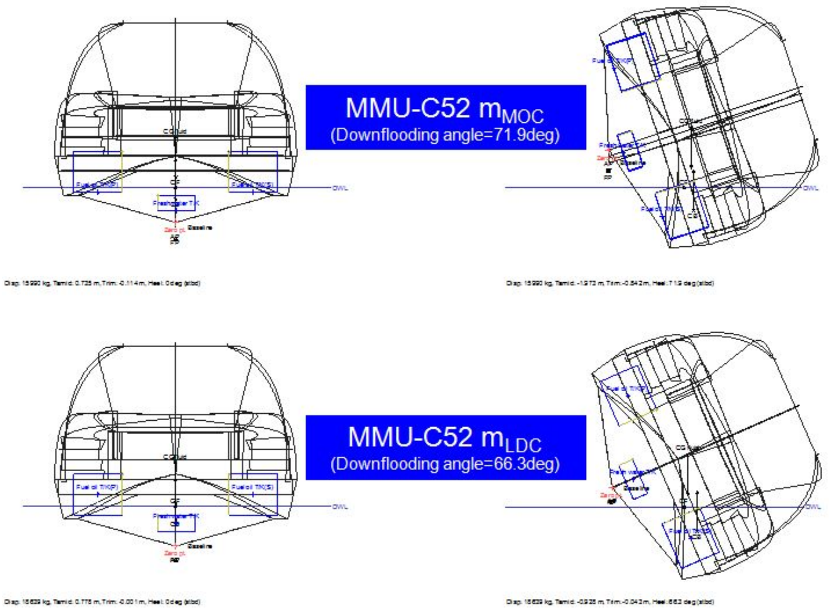
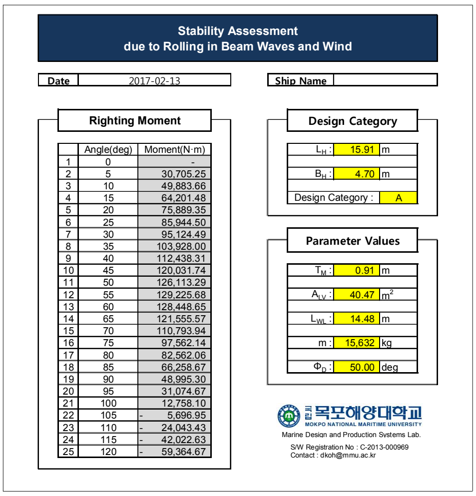


Fig. 6. Downflooding test of the case study.



Stability Assessment
due to Rolling in Beam Waves and Wind

Date 2017-02-13
Ship Name

Righting Moment

	Angle(deg)	Moment(N·m)
1	0	-
2	5	30,705.25
3	10	49,883.66
4	15	64,201.48
5	20	75,889.35
6	25	85,944.50
7	30	95,124.49
8	35	103,928.00
9	40	112,438.31
10	45	120,031.74
11	50	126,113.29
12	55	129,225.68
13	60	128,448.65
14	65	121,555.57
15	70	110,793.94
16	75	97,562.14
17	80	82,562.06
18	85	66,258.67
19	90	48,995.30
20	95	31,074.67
21	100	12,758.10
22	105	- 5,696.95
23	110	- 24,043.43
24	115	- 42,022.63
25	120	- 59,364.67

Design Category

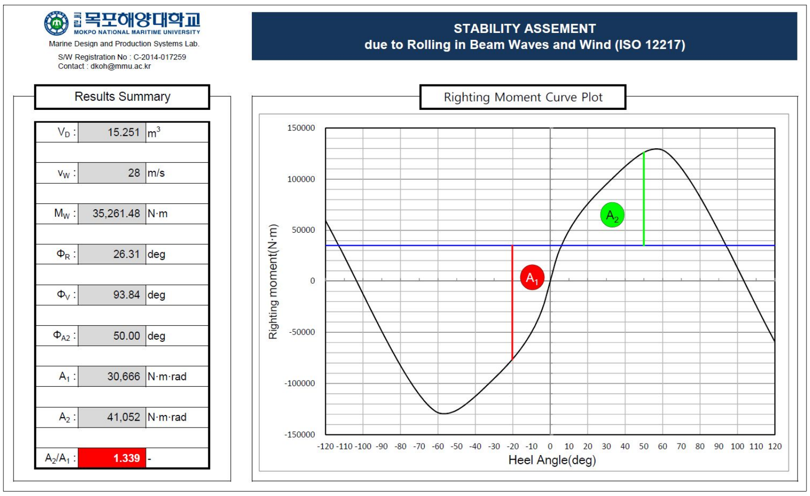
L_H :	15.91	m
B_H :	4.70	m
Design Category :	A	

Parameter Values

T_M :	0.91	m
A_{LV} :	40.47	m^2
L_{WL} :	14.48	m
m :	15,632	kg
$Φ_D$:	50.00	deg

국립 목포해양대학교
MOKPO NATIONAL MARITIME UNIVERSITY
Marine Design and Production Systems Lab.
S/W Registration No : C-2013-000969
Contact : dkoh@mmu.ac.kr

Fig. 7. Stability assessment tool test configuration screenshot.



국립 목포해양대학교
MOKPO NATIONAL MARITIME UNIVERSITY
Marine Design and Production Systems Lab.
S/W Registration No : C-2014-017259
Contact : dkoh@mmu.ac.kr

STABILITY ASSEMENT
due to Rolling in Beam Waves and Wind (ISO 12217)

Results Summary

V_D :	15.251	m^3
v_W :	28	m/s
M_W :	35,261.48	N·m
$Φ_R$:	26.31	deg
$Φ_V$:	93.84	deg
$Φ_{A2}$:	50.00	deg
A_1 :	30,666	N·m·rad
A_2 :	41,052	N·m·rad
A_2/A_1 :	1.339	-

Righting Moment Curve Plot

Fig. 8. Screenshot of stability assessment tool results with respect to wave- and wind-induced beam rolling.

(1) Gathering and preparing similar ship data was significantly more time expensive as compared to existing methods. However, as the design process proceeded, the utility of the gathered data outweighed the time cost.

(2) Using the statistical data analysis tool and the principal dimensions estimation tool developed in the initial design stage allowed for a significant amount of the information required by the 3-Test to be created in accordance with international standards.

(3) When design changes were made, the two aforementioned tools allowed for systematic, integrated management of design variables.

(4) The preliminary information defined by the two aforementioned tools was used in the stability assessment tool, a process that subsequently facilitated the performance of the stability assessment to a greater degree than that of existing methods.

(5) When the design information obtained by using the developed tools was used in combination with the CAD model, the 3-Test could be performed more effectively, and the overall design process could be systematically managed.

5. Conclusion

Preparing for certification approval for certifications such as CE RCD necessitates consideration of a vast number of complex items to be prepared during ship design. Particularly, in the case of leisure craft shipyards, the scale of the facilities is relatively small and there are often not many design specialists on staff; these circumstances make it difficult to verify the results of the design process.

In this research, the yacht design process was improved such that buoyancy and stability assessments could be systematically evaluated from the early design stages. To do this, we defined and presented the preliminary information required for the assessments, in addition to developing design support tools that are able to systematically validate the assessments in accordance with international standards. Furthermore, the improved design process presented in this research was applied to the design of an actual yacht to demonstrate its effectiveness. We believe that if the design process proposed in this research is used, it can offer a more effective and systematic design certification preparation environment as compared to existing methods. In the future, further studies will be concentrated on that the support tools are integrated with 3D CAD models.

Acknowledgment

This study was financially supported by Mokpo National Maritime University, 2015 year.

References

[1] ISO(2002a), International Organization for Standardization, ISO 12217-1 : Small craft - Stability and buoyancy

assessment and categorization - Part 1: Non-sailing boats of hull length greater than or equal to 6 m, ISO, Switzerland.

[2] ISO(2002b), International Organization for Standardization, ISO 8666 : Small craft – Principal data, ISO, Switzerland.

[3] Kim, D. Y., C. W. Lee, D. K. Lee and D. K. Oh(2014), Characteristics of a CFRP Cruiser's Windage Area by Stability Assessment, Journal of the Korean Society of Marine Environment & Safety, Vol. 20, No. 6, pp. 774-780.

[4] Lee, C. W., D. J. Yum and D. K. Oh(2013), A Study on Design Variables for Automated Design Review according to ISO 12217 on Early Design Stage of Pleasure Yachts, Proceedings of KAOST(Jeju).

[5] RINA(2011), Registro Italiano Navale, VERIFICATION CHECKLIST IN ACCORDANCE WITH THE STANDARD EN ISO 12217-1 and AMENDMENT 1:2009 - STABILITY AND BUOYANCY ASSESSMENT AND CATEGORIZATION: NON SAILING BOATS OF 6 METRES LENGTH OF HULL AND OVER, RINA, Italy.

[6] RINA(2013), Registro Italiano Navale, Rules for the Classification of Pleasure Yacht Part B Hull and Stability, Imago Media, Italy.

Received : 2017. 02. 28.
Revised : 2017. 03. 24.
Accepted : 2017. 05. 29.

Appendix 1. Items for tests, calculations and requirements of offset-load test and downflooding according to ISO 12217-1

Item		Design Category	Demand value		
Downflooding	Downflooding openings	A, B	1. Have all appropriate downflooding openings been identified? 2. Do all closing appliances satisfy ISO 12216? 3. Opening type appliances are not fitted below 0.2m above waterline unless they comply with ISO 9093 or ISO 9094? 4. Are all openings fitted with closing appliances? (Except openings for ventilation and engine combustion)		
	Downflooding height ($h_{D(R)}$)	A, B	Using figure	Basic (requirement)	Using figure ($L_H/17$)
				Reduced value for small openings	If combined clear area(mm^2) < $50L_H^2$[at within the aft $L_H^{1/4}$] (Basic×0.75)
			by annex A		A : 0.5 ~ 1.41 B : 0.4 ~ 1.41
	Downflooding angle ($\phi_{D(R)}$)	A	> ϕ_O + 25° or 30°		use whichever is the greater (if ratio of m_{LDC}/m_{MOC} > 1.15, m_{LDC} & m_{MOC} assessed)
		B	> ϕ_O + 15° or 25°		
Offset-load test	Offset-load heel angle ($\phi_{O(R)}$)	A, B	$< 10 + \frac{(24 - L_H)^3}{600}$		

- ISO 12216 : Windows, portlights, hatches, deadlights and doors-Strength and watertightness requirements
- ISO 9093 : Seacocks and through-hull fittings
- ISO 9094 : Fire protection

Appendix 2. Items for tests, calculations and requirements of resistance to waves and wind according to ISO 12217-1

Item		Design Category	Demand value		
Resistance to waves and wind	Downflooding calculation (ϕ-deg)	A, B	Downflooding angle(ϕ_D) or Angle of vanishing stability (ϕ_V) or 50°, whichever is the least(using annex D)		A_2/A_1>1
	Heeling momentdue to wind (M_W-N·m)	A	$M_W = 0.3A_{LV}\left(\frac{A_{LV}}{L_{WL}} + T\right)\nu_W^2$ A_{LV} : Windage area	V_W = 28m/s	
		B		V_W = 21m/s	
	Assumed roll angle (ϕ_R)	A	25 + 20/V_D	V_D = displacement(m^3)	
		B	20 + 20/V_D		
	Maximum righting moment occurs at a heel angle of 30° (N·m)	A	Case Ⅰ	25kN·m <	
			Case Ⅱ	750/ϕ_{GZMAX} kN·m <	
		B	Case Ⅰ	7kN·m <	
			Case Ⅱ	210/ϕ_{GZMAX} kN·m <	
	Maximum GZ occurs at a heel angle of 30° (m)	A	Case Ⅰ	0.2m <	
			Case Ⅱ	6/ϕ_{GZMAX} m <	
		B	Case Ⅰ	0.2m <	
			Case Ⅱ	6/ϕ_{GZMAX} m <	

- Case Ⅰ: Maximum righting moment occurs at a heel angle of 30° or more
- Case Ⅱ: Maximum righting moment occurs at a heel angle of less than 30°

Appendix 3. Abbreviations

Meaning	Symbol	Unit
Length of hull	L_H	**m**
Length of waterline in the appropriate loading condition	L_{WL}	m
Beam of hull	B_H	m
Draught at the midpoint of L_{WL}	T_M	m
Freeboard amidships at the appropriate loading condition	F_H	m
Mass of the boat in the minimum operating condition	m_{MOC}	kg
Mass of the load to be carried in the minimum operating condition	m_L	kg
Loaded displacement volume	m_{LDC}	kg
Mass of the maximum total load	m_{MTL}	kg
Mass of the light craft condition	m_{LCC}	kg
Displacement volume	V_D	m^3
Plan area of all recesses	A_R	m^2
Nominal sail area	A_S	m^2
Windage area of hull in profile at the appropriate loading condition	A_{LV}	m^2
Calculation wind speed	V_W	m/s
Heeling moment due to wind	M_W	N·m
Downflooding angle	ϕ_D	deg
Heel angle during offset-load test	ϕ_O	deg
Roll angle in a seaway	ϕ_R	deg
Angle of vanishing stability	ϕ_V	deg
Angle of heel at which maximum righting lever occurs	ϕ_{GZmax}	deg
Righting leaver	*GZ*	m
Right moment	RM	N·m