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AN EXPERIMENTAL EVALUATION OF THE STABILITY CRITERIA OF THE HSC CODE

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ABSTRACT

This paper presents a very brief outline of the findings of a research project to study the levels of safety offered by the stability criteria of the 2000 HSC Code. The objective was to compare the levels of safety provided by the monohull and multihull criteria, and perhaps suggest adjustments to the multihull criteria so that they might provide an equivalent level of safety to those for monohulls. In the event, the research led to suggestions for more widespread changes to the conventional approach to stability assessment.

INTRODUCTION

The 2000 HSC Code includes intact and damage stability criteria for multihulls that have no documented technical basis. The monohull criteria have a longer history in the Code, and resemble those used in other regulations, so they have become accepted as a satisfactory standard.

The UK Maritime and Coastguard Agency (MCA) commissioned the Wolfson Unit to conduct an experimental study, Research Project 509, to evaluate the level of safety offered by the multihull criteria, and compare it with the accepted level of safety provided by the monohull criteria. The principal objective was to provide data to support a submission to IMO if the results indicated that it would be appropriate to revise the Code.

The study comprised tests on passive models, in waves, in a towing tank. The aim was to determine the wave conditions required to capsize a vessel that just complies with the criteria.

The Code criteria are summarised for ease of reference at the end of this paper. The full report to the MCA is available from their web site: www.mcga.gov.uk

1. MODELS

1.1. Selection

Lines plans of models were prepared by the Wolfson Unit, using vessels representative of the world fleet as a basis in each case. Fleet data were used to aid selection of examples spanning the range of forms and sizes, to investigate as many variables as possible within the budgetary limitations. Body plans are presented in Figure 1.

1.2. Construction

The models comprised 2mm thick GRP shells with watertight bulkheads and removable rectangular side panels to represent damage openings. Perspex decks enabled observation of flooded compartments, and to check for leaks.

Some model configurations were tested with simple box superstructures. Monohull 2 represented a ferry with an intact vehicle deck, and the model topsides extended to represent the hull to the deck above.

1.3. Ballasting

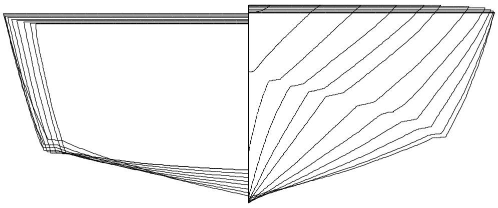
Ballast weights were fixed within intact compartments, on deck or to vertical threaded studs to facilitate adjustment of the VCG. In some cases the high ballast location required to achieve a condition corresponding to Code criteria precluded modelling of representative roll inertias. As the tests progressed this became of little concern because few tests resulted in synchronous rolling, or dynamic events that would be affected significantly by roll inertia. Where roll inertia was important but incorrectly modelled, it is likely that capsize would have occurred in a similar way, but at a different frequency.

Transverse ballast shifts were used to represent heeling moments due to wind, passenger crowding or lifeboat launching, and the desired heel angle was measured with an inclinometer. The range of positive stability was also measured to ensure correlation with the calculated stability. The accuracy of this measurement was within 0.5°.

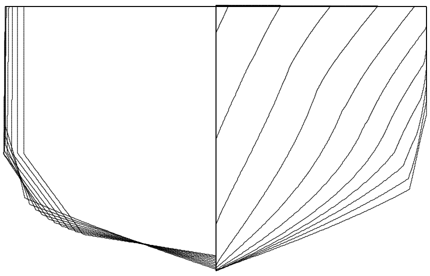
1.4. Stability Calculations

The stability of each test configuration was determined using Wolfson Unit software. The internal volumes were defined, with correct allowance for hull and deck thicknesses, and all stiffeners. The permeability of all compartments was 100% to correspond with the models.

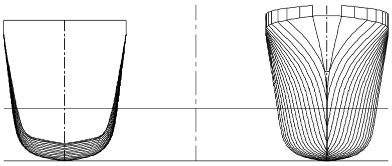
Because the ballast weights were located such that they were not immersed until capsize, it was not necessary to include their volume in the calculations.



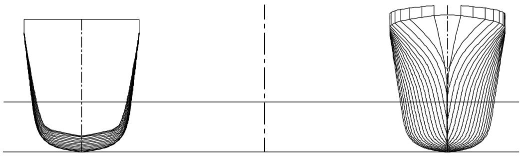
Model M1 – L: 38.8m, B: 9.0m, 1:25 scale



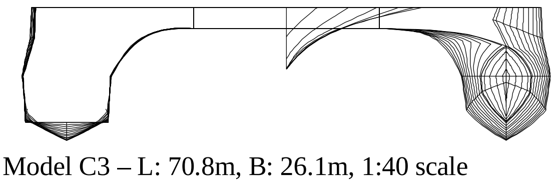
Model M2 – L: 96.0m, B: 17.0m, 1:40 scale



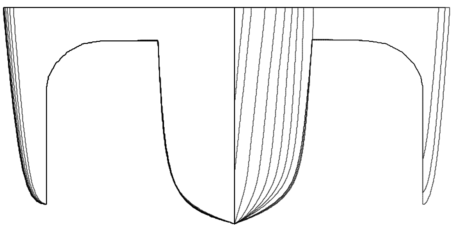
Model C1 – L: 32.7m, B: 8.3m, 1:20 scale



Model C2 – L: 32.7m, B: 11.1m, 1:20 scale



Model C3 – L: 70.8m, B: 26.1m, 1:40 scale



Model T1 – L: 53.0m, B: 12.0m, 1:25 scale

Figure 1: *Body plans of the models*

1.5. Test Configurations

The six models were tested in 53 configurations, with variations in displacement, VCG, damage extent, and initial list. Each was identified by a number, ID1 to ID53.

Table 1 presents a summary of the configurations principal stability characteristics. The latter refer to the residual stability, after the heeling moments were applied, for the full scale vessel. Because the GZ properties listed are residual values, they do not necessarily correspond to the critical criteria values, which may refer to the stability in the absence of moments. Furthermore, the GZareas listed are the total areas for the range of positive stability, rather than the areas addressed by the Code, which may be limited to a smaller range of angles. The table includes references to the critical Code criteria, numbered as in the criteria summary in Table 2.

2. TEST TECHNIQUE

2.1. Test Facility

The tests were conducted in a towing tank 76 metres long by 3.7 metres wide by 1.7 metres deep, equipped with a plunging wedge wavemaker.

2.2. Handling

At the start of each test, the model was located approximately 20 metres from the wavemaker. Its orientation was controlled by hand, with light strings secured to the bow and stern. It was important to ensure that no force was applied to the strings at critical times, otherwise a capsize could be induced. If this occurred the result was ignored and the test repeated.

It was noted that, where the natural drift rate was high, capsize might occur in the initial encounters, but could be avoided if the model were assisted manually until it had established its natural rate of drift. Once this had been recognised, care was taken to ensure that the model was prevented from capsizing during the transition phase at the start of a test. It was considered that this method more closely represented the situation of a vessel drifting freely in a seaway, but it should be noted that an encounter with a severe wash might better be represented by the initial, more onerous, encounters.

With each configuration, tests were carried out at all orientations to the waves, that is, head, bow, beam, quarter and stern seas, with damage towards and away from the oncoming waves.

2.3. Waves

Because of the large number of variables and model configurations, it was not possible within the budgetary constraints to conduct tests of long duration in sea spectra.

ID	Model	Configuration & Damage Extent	Disp. tonne	VCG m	Critical Criterion No.	List deg	GM m	GZmax m	GZArea m.rad	Range deg	Min. Wave to Capsize m
1	M1	Intact	123	4.684	4	5.0	2.37	0.16	0.058	33.5	2.10
2	M1	Intact	123	4.684	4 & 9	10.0	0.73	0.04	0.007	15.3	0.80
3	M1	Intact	200	4.470	Margin	0.0	1.43	0.33	0.162	41.5	
4	M1	Intact	200	4.650	Fails 5	4.9	1.15	0.16	0.061	30.3	3.30
5	M1	Intact	200	4.505	5 & 9	10.0	1.05	0.09	0.028	24.2	1.65
6	M1	23% to 76%	123	4.950	Margin	0.0	0.29	0.13	0.031	26.3	1.10
7	M1	23% to 76%	123	5.012	Margin	10.0	0.27	0.07	0.010	14.2	0.77
8	M1	23% to 76%	123	5.035	2 & 10	13.0	0.57	0.04	0.005	9.8	0.50
9	M1	5% to 35%, superstructure	200	3.799	2	0.0	0.71	0.10	0.029	26.2	
10	M1	5% to 35%, superstructure	200	3.970	Fails 2 & 4	0.0	0.46	0.06	0.014	21.3	
11	M1	5% to 35%, deck intact	200	3.799	2 & 10	6.0	0.47	0.04	0.005	16.4	1.40
12	M1	23% to 76%	200	4.050	Margin	0.0	0.65	0.17	0.047	26.1	
13	M1	23% to 76%, superstructure, deck intact	200	4.130	Margin	0.0	0.59	0.15	0.039	24.7	1.60
14	M1	23% to 76%	200	4.130	Margin	0.0	0.59	0.15	0.039	24.7	
15	M1	23% to 76%, deck intact	200	4.347	2	0.0	0.47	0.10	0.022	21.0	0.73
16	M1	23% to 76%	200	4.347	2	0.0	0.47	0.10	0.022	21.0	0.65
17	M1	23% to 76%, superstructure	200	4.347	2	0.0	0.47	0.10	0.022	21.0	0.86
18	M1	23% to 76%, deck intact	200	4.130	Margin	5.5	0.89	0.08	0.014	16.5	0.50
19	M1	23% to 76%, superstructure, deck intact	200	4.130	Margin	5.5	0.89	0.08	0.014	16.5	1.15
20	M1	23% to 76%, deck intact	200	4.347	2 & 10	6.2	0.62	0.04	0.005	11.7	0.40
21	M1	23% to 76%, superstructure	200	4.347	2 & 10	6.2	0.62	0.04	0.005	11.7	0.60
22	M2	Intact, superstructure	1260	9.277	5 & 9	10.0	1.29	0.07	0.014	16.8	2.74
23	M2	0% to 21%, superstructure	1260	10.110	Margin	0.0	1.02	0.14	0.035	21.7	
24	M2	0% to 21%, superstructure	1260	10.110	Margin	3.8	0.84	0.08	0.014	15.6	1.48
25	M2	0% to 21%, superstructure	1260	10.331	2 & 10	4.6	0.65	0.04	0.005	10.8	1.00
26	M2	21% to 45%, superstructure	1260	9.568	2 & 10	7.5	0.44	0.04	0.006	12.6	2.30
27	M2	45% to 86%, superstructure	1260	10.780	2 & 10	5.1	0.60	0.04	0.004	9.7	1.70
28	C1	Intact	93	6.932	9	10.0	3.55	0.33	0.043	12.2	0.98
29	C1	0% to 31%	93	4.075	8	15.1	3.27	0.23	0.044	17.3	1.15
30	C1	31% to 82%	93	3.887	6	10.0	5.55	1.51	0.670	45.2	
31	C1	100% raking	93	5.760	Fails 7	20.0	6.28	0.23	0.028	11.2	1.20
31a	C1	Intact	170	3.690	Fails 9 & 11	20.0	2.53	0.13	0.015	11.2	1.20
32	C2	Intact	93	8.990	Margin	0.0	11.98	2.33	0.637	29.2	4.00
33	C2	Intact	93	11.000	Margin	0.0	10.14	1.90	0.428	23.7	2.80
34	C2	0% to 31%	93	4.698	Margin	10.0	7.16	0.49	0.113	21.0	1.90
35	C2	0% to 31%	93	5.900	11	10.7	5.16	0.23	0.029	11.5	0.90
36	C2	0% to 31%	93	4.700	Fails 11	13.0	4.58	0.18	0.025	12.1	0.95
37	C2	8% to 31%	93	4.700	Margin	12.0	11.46	0.63	0.122	18.8	1.60
38	C2	8% to 31%	93	4.968	Margin	12.0	11.46	0.61	0.115	17.7	1.30
39	C2	8% to 31%	93	5.236	6	12.0	11.00	0.57	0.100	16.4	1.20
40	C2	8% to 31%	93	6.040	Fails 6	12.0	10.14	0.47	0.071	13.7	0.90
41	C2	24% to 58%	93	6.096	Margin	9.3	13.48	0.76	0.187	22.6	1.90
42	C3	0% to 39%	1100	10.530	Margin	13.8	10.10	0.43	0.066	13.5	
43	C3	14% to 72%	1100	10.530	Fails 8	17.6	11.08	0.79	0.196	22.0	2.30
44	C3	14% to 72%	1100	10.530	Fails 8	20.0	7.98	0.46	0.085	16.4	1.90
45	C3	14% to 72%, superstructure	1100	10.500	Fails 8	21.0	6.68	0.33	0.053	14.1	3.00
46	C3	14% to 72%	1100	10.520	Fails 8	21.8	6.42	0.26	0.035	12.2	1.30
47	T1	Intact	175	5.273	Margin	8.5	1.63	0.55	0.165	31.0	*
48	T1	Intact	300	4.700	4	0.0	0.69	0.39	0.209	63.8	
49	T1	61% to 100%	175	4.439	Margin	0.0	1.60	0.55	0.319	70.6	
50	T1	61% to 100%	175	4.439	Margin	3.6	1.49	0.49	0.231	65.9	
51	T1	61% to 100%	175	4.439	Margin	7.0	0.65	0.43	0.166	38.5	*
52	T1	61% to 100%	300	4.195	Fails 11	10.0	0.42	0.10	0.021	20.0	* 1.60
53	T1	100% sponson raking damage	300	4.700	Margin	8.9	0.71	0.34	0.146	63.5	
53a	T1	Intact	307	4.630	Margin	8.9	0.69	0.33	0.143	63.5	

* Second stability peak

Table 1 *Summary of test configuration*

The nature of the capsize mechanism has a bearing on the probability of encountering waves that will cause the ship to capsize. A ship may require a train of several large waves, of similar period, to roll it to progressively greater angles until it capsizes. Another vessel may require just one such wave to capsize it. The former will be much less likely to capsize in a given sea state than the latter, since the probability of encountering several large waves consecutively is relatively low. In the model tests with regular waves, very few capsizes were due to synchronous rolling, where a gradually increasing roll angle with each successive wave results eventually in a capsize. If it is assumed that capsize is primarily due to encountering a single large wave, and not synchronous rolling, then it follows that it is necessary only to perform tests in regular waves, and to extend the results, using statistics, to allow for a sea state if desired.

Maximum possible wave heights depended on model scale and wave period but, broadly, were of the order 2 metres at 4 seconds period, and 6 metres at 10 seconds, full scale.

2.4. Test Results

The tests yielded capsize data for each model configuration for a matrix of wave heights and periods. Capsize boundary curves were derived as illustrated in Figure 2, and Table 1 presents the minimum wave height required to cause capsize for all configurations. The absence of a value indicates that no capsize occurred in the range of waves available.

2.5. Capsize Mechanism Definitions

A variety of capsize mechanisms were observed and, in some configurations, the mechanism varied for different wave periods. The mechanisms were categorized into the following groups:

- Lack of stability on a wave in head or stern seas.
- Gradually increasing heel to windward in beam seas, sometimes with some rolling.
- Catamarans, capsizing diagonally to leeward in bow seas.
- Increasing roll angles to leeward in beam or bow seas.
- Increasing heel due to water accumulating inside superstructure. With damage to leeward capsize was to leeward, and with damage to windward capsize was to windward.

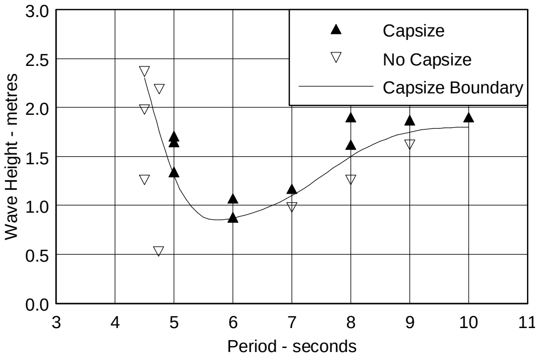


Figure 2 *Capsize data and boundary curve for model configuration ID2*

3. STABILITY PARAMETERS

3.1. Relationships Between Parameters

It has become an accepted convention that stability is assessed against criteria based on the parameters selected by Rahola many years ago. The 2000 HSC Code is no exception, incorporating requirements for GM, GZ, area under the GZ curve, and the angle at which the maximum GZ occurs.

In this project, many of the tests were conducted with initial heel because of asymmetric flooding or an applied moment. In order to make comparisons between those models that were initially upright and those that were heeled, the residual stability curves have been used.

For the GZ curves of the tested models, the relationships between stability parameters were examined. No relationship was found between GM and the other parameters. Although GM is frequently used, via a roll test, to measure stability, and is a useful indicator of changes in the condition of a particular vessel, it is not a reliable measure of stability at large angles. The residual stability of a catamaran illustrates this fact. The GZ curve for a catamaran tends to be virtually linear over a range of angles, until one hull begins to emerge from the water. Applying, or increasing, a heeling moment therefore has the effect of reducing the maximum residual GZ value and area under the curve, without affecting the residual GM value.

Strong trends existed in the variation of GZarea, the total area under the residual stability curve, with GZmax, the peak residual GZ value, but were different for monohulls and multihulls. The closest relationship found was between GZarea and range of stability x GZmax. See Figure 3. The trimarans did not fit the trend closely because their GZ curves had a double peak rather than a simple parabolic form.

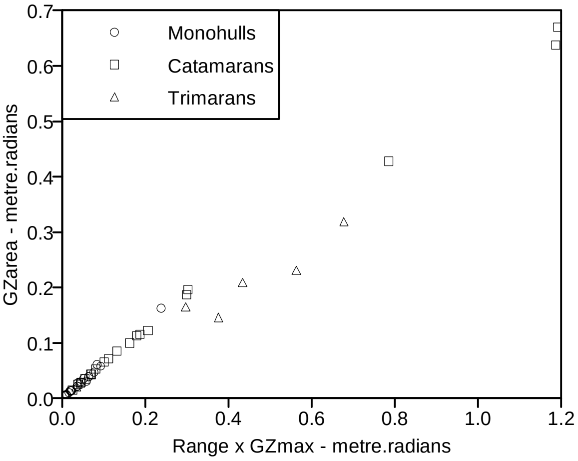


Figure 3 *Relationship between stability parameters*

A similar relationship was found between range of stability and the angle of maximum GZ. One may infer that it may not be necessary to regulate GM, GZmax, angle of GZmax, GZarea and range, because some parameters may be related.

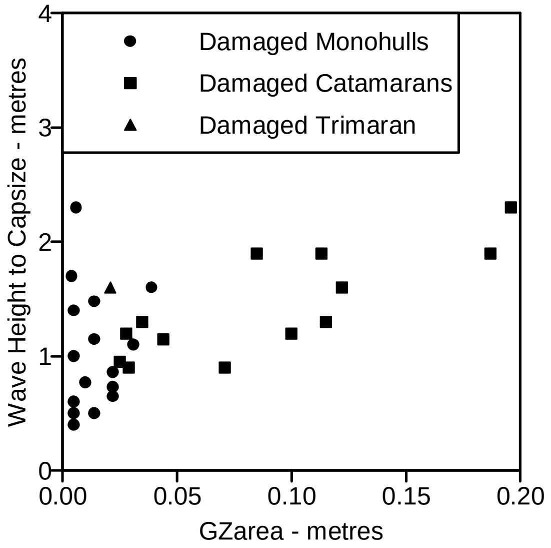


Figure 4 *Variation of wave height to capsize with GZ curve area*

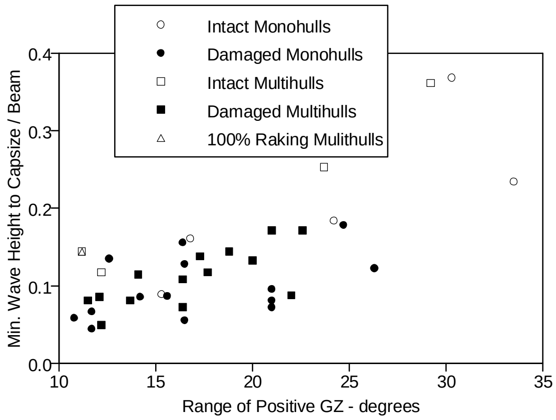


Figure 5 *Variation of wave height to capsize with range of stability*

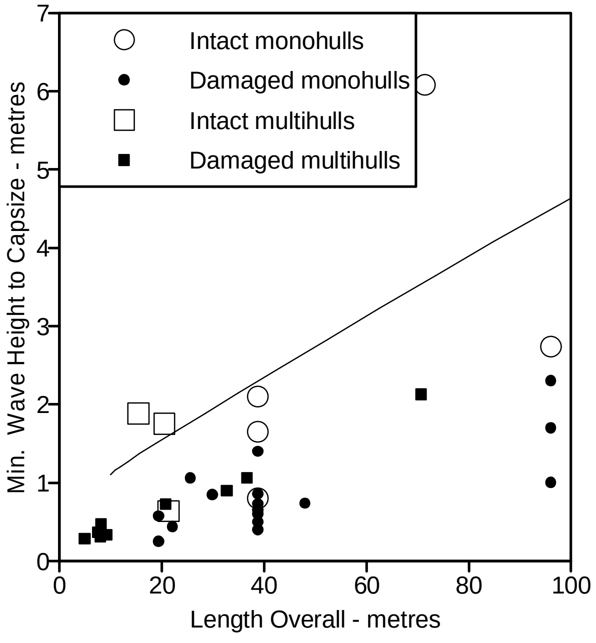


Figure 6 *Test results scaled to represent Code minimum criteria*

3.2. Relationships with Capsize Results

The minimum wave heights required to capsize the models were plotted against GZ parameters. Figure 4 presents one example. Regardless of the stability parameter used, there were no clear trends, although there appeared to be clearly defined diagonal ‘safe’ boundaries, below which no capsizes occurred. This example, for damaged models, shows that the boundaries differed significantly between monohulls and multihulls. Such differences were not found, however, between intact and damaged configurations.

3.3. Effects of Scaling

With increasing ship size, GZ values tend to remain constant because of practical constraints on the design, as well as to comply with regulatory minima. It is not the case that GZ values are non-dimensional.

Whilst the models were based on vessels of a specific size, they could equally represent some other size of vessel at a different scale. The wave heights required to capsize are scaled accordingly, as are the GZ values, but not the range of stability.

By re-scaling the test results in Figure 4 each point generates a line through the origin. The result is a group of radial lines, one of which defines the lower ‘safe’ boundary. It is logical that larger vessels are less vulnerable than small vessels and, in general, one would expect the data points defined by large vessels to lie above the safe boundary. Non-dimensional versions of these plots did not reveal trends.

The exception was for the range of stability, as illustrated in Figure 5. The trend of increasing safety with range is strong, albeit apparently non-linear, on this non-dimensional plot.

Figure 6 presents results scaled such that their stability just complied with the Code criteria. The data are presented in terms of the variation of minimum wave height to capsize with length. In some cases, the models were tested with the stability critical at the nominal scale, and so there are clusters of data points at certain lengths. Where the stability at the nominal scale had a margin, a smaller scale was used to eliminate the margin.

Many of the data points for catamarans are for small vessels, because it was difficult to ballast the catamaran models with stability as low as the minimum requirements.

The trend of increasing wave height with size is clear, as is the scatter due to variations in level of safety, even for individual models. The existing criteria appear to offer similar levels of safety for the different forms, but there is much scatter.

The line on Figure 6 indicates the upper limit of permitted operational seastates for existing HSC. It is worrying that most minimum wave heights to capsize are well below this line, particularly as it is defined by significant wave heights and some waves encountered may be much higher.

4. FACTORS GOVERNING SAFETY

4.1. Residual Stability

It was the residual stability, after the application of any passenger crowding, wind heeling, or other moments, that governed the response of a model to waves. There was no increase in vulnerability with increasing initial angle of heel, provided the residual stability remained adequate. The upright case is not unique. One may consider all vessels, regardless of the asymmetry of flooding or the applied heeling moments, as floating bodies characterised by their residual stability.

If heeling moments are anticipated, the stability in the absence of those moments is not a comprehensive assessment of the safety of the vessel. There are two options for stability assessment. One must either set minimum levels of stability when upright, with suitable margins based on the assumption that all vessels will be subject to similar heeling levers, or set minimum levels of residual stability, having estimated the anticipated heeling levers for the vessel in question.

The 2000 HSC Code adopts different approaches depending on the type of vessel, and there is a potential problem with the method used for monohulls. Consider the curves presented in Figure 7. In the absence of heeling moments, the curve has the required GZ and area, with a maximum GZ occurring at the minimum angle permitted, 15 degrees. If passenger crowding were to heel the vessel to the maximum of 10 degrees, however, the residual stability would be negligible but is not assessed.

4.2. Displacement

Stability is defined by the righting moment, and not by GZ alone. Displacement, therefore, has an influence on safety.

This is illustrated by comparison of the data for models ID 31 and 31a in Table 1. These refer to the same model configuration. Ballast was added to one hull of the intact model. In one case it represented floodwater in a double bottom, as might result from raking damage to the bottom of one hull. In the other case it represented ballast water in the double bottom compartments of one hull, and hence an intact condition with a centre of gravity offset from the centreline. The righting moments were the same, but the different intact displacements result in different GZ values being derived.

4.3. Range of Stability

The test results revealed range of stability to be a very important parameter. Conventional criteria tend to regulate GZmax and GZarea, and exclude the range, but it is unclear whether these are the most appropriate parameters to assess, or whether they have been deemed successful because they provide a reasonable estimate of the range.

4.4. Downflooding Angle

The tests were not designed to address downflooding, and it was clear that many factors, including the location of any opening relative to local superstructure details, would affect the incidence or rate of flooding. When downflooding occurs due to wave action, the resulting reduction in freeboard will increase the downflooding rate. For the same reasons, it is not considered worthwhile for a safety standard such as the HSC Code to attempt detailed assessment of downflooding by wave action. The GZ curve therefore should be terminated at the angle of immersion of a significant opening.

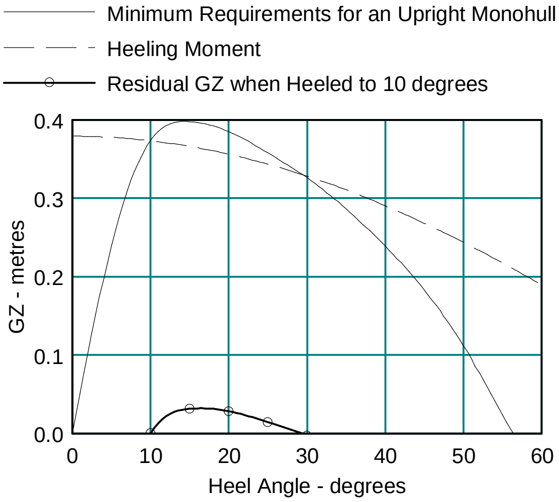


Figure 7 *Stability curve for a monohull that just complies with the Code*

4.5. Passenger Safety

The Code specifies maximum allowable heel angles for damage equilibrium, wind heeling, and passenger crowding. These criteria ensure safety of the passengers but, as these tests have demonstrated, they have no bearing on vessel safety. For this reason these criteria were not included in the derivation of Figure 6.

5. DEVELOPMENT OF AN ALTERNATIVE METHOD OF ASSESSMENT

The results presented in Figure 6 suggest that the Code criteria should all be increased substantially. To do so, however, might have an influence on the design of certain types of craft because, whilst HSC generally operate with good stability margins, it is common to find a small margin with regard to one particular criterion. HSC casualty statistics do not contain records of capsize incidents, and so there is no indication that existing designs are unsafe. Rather than consider such an increase, efforts were concentrated on developing a more rational basis for assessment.

Many attempts were made to manipulate the test data to derive ‘safe boundaries’. The importance of range, righting moment and the size of the vessel in governing the minimum wave height to capsize were recognized and incorporated where possible.

The most successful is presented in Figure 8. A strong linear trend was found, with data for all forms of model configuration collapsing into a single envelope. Furthermore, it is interesting to note that all of the capsize mechanisms described in section 2.5 are distributed, apparently at random, through the envelope.

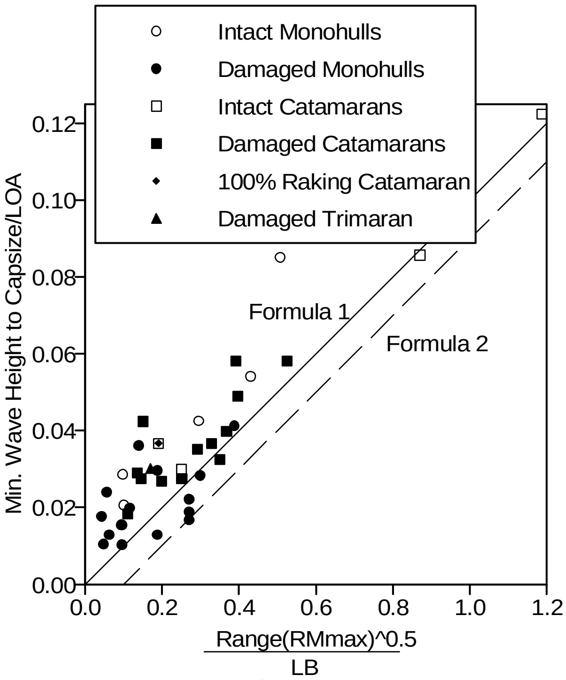


Figure 8 *Variation of non-dimensional wave heights with combined stability parameters*

This combined stability parameter refers to the residual stability with heeling moments applied, and incorporates the range of stability, the maximum righting moment, the length and the beam. The lower importance of the righting moment is recognized by it being raised to a lower power.

The parameter might be used to enable stability assessment to be related to vessel size and the anticipated operational seastate. The lines labelled Formula 1 and 2 represent alternative proposals that might be adopted for this purpose, depending on the level of conservatism required. Formula 1 represents a lower boundary of most data points, with an intercept at the origin and a gradient matching the trend, while Formula 2 bounds all of the data with a line of the same gradient. They are defined as:

$$\text{WaveHeight} = \frac{\text{Range}\sqrt{\text{RMmax}}}{10\text{B}} \qquad \text{Formula 1}$$

$$\text{WaveHeight} = \frac{\text{Range}\sqrt{\text{RMmax}}}{10\text{B}} - \frac{\text{L}}{100} \qquad \text{Formula 2}$$

The selected formula will provide an estimate of the minimum wave height to capsize, and this may be related to the significant wave height for the anticipated operation on the basis of wave statistics. For example, when intact, a vessel might be required to comply with formula 2 with a wave height value of twice the anticipated significant height, while in the damaged state the wave height might be the same as the significant height. Such relaxation of requirements for damaged vessels is used in the existing requirements of the HSC Code, and elsewhere.

6. CONCLUSIONS

The Code criteria do not provide immunity from capsize in typical operational seastates.

Multihulls tend to have a higher level of safety than monohulls as they have greater margins over the Code requirements. This is a reflection on typical vessel parameters and not on the levels of safety provided by the Code.

Critical capsize modes depend on a number of parameters, including wave frequency. They are highly variable and unpredictable.

The minimum wave height required to capsize depends on the size of the vessel relative to the waves, and its stability.

The vulnerability to capsize by wave action is governed by the residual stability in the presence of any heeling moments. Assessment of stability in the absence of such moments does not provide an adequate measure of the level of safety.

The Code criteria for intact monohulls do not address residual stability after passenger crowding. This may lead to very low levels of safety in some cases.

Whilst the form of the vessel and extent of flooding undoubtedly affect response to waves, they affect the vulnerability to capsize only in terms of their effects on the righting moment curve. All configurations may be considered as floating bodies characterised by their residual stability curve.

The vulnerability to capsize depends primarily on the range of residual stability and, to a lesser extent, on the maximum residual righting moment.

Conventional criteria provide a level of safety that has become accepted, but they address parameters that provide approximate measures of the range and maximum righting moment, rather than by addressing them directly.

Conventional criteria set minimum GZ values regardless of the size of the vessel, and therefore incorporate an inherent assumption that larger vessels operate in higher seastates.

Comparison of the levels of safety provided for monohulls and multihulls by the Code is not possible because of the differing parameters assessed, the differing account taken of heeling moments, and the neglect of the effects of size of the vessel relative to the seastate.

A method has been proposed to assess the level of safety on the basis of the size of the vessel relative to the operational seastate, the beam, the range of residual stability and the maximum residual righting moment. A single formula may be applied to all forms of HSC, intact and damaged. The method is believed to be equally applicable to other vessel types.

The method will provide equivalent assessment of different forms of vessel, and may be adjusted to have an appropriate impact on the existing fleet.

Some criteria provide a level of safety for passengers, generally by limiting the residual heel angle under the influence of heeling moments, and should not be confused with those that provide a level of safety against capsizing.

It is hoped that industry will be encouraged to investigate the impact of this method of assessment, for HSC and other types of vessel, for which it is believed to be equally applicable.

		Intact		Side or Bottom Damage		100% Raking Damage		Any Damage, Intermediate Stages
No	Criterion	Monohull	Multihull	Monohull	Multihull	Monohull	Multihull	
1	Minimum GM, m	0.15						
2	Minimum GZ, m	0.2 at 30° or more		0.1				0.05
3	Min. angle of max GZ	15°	10°					
4	Minimum GZ area, m.rad	0.055 + 0.001(30-angle of max GZ) up to angle of max GZ	0.055 x 30/(angle of max GZ or downflooding or 30°) up to angle of max GZ	0.015 to 27° or downflooding		0.015	0.015	0.015
5	Minimum GZ area 30° to 40° or downflooding, m.rad	0.03						
6	Max. inclination angle			10°	10°	20°	20°	
7	Minimum range			15°, or 10° with increased GZ area		15°	15°	7°
With Heeling Moments Applied								
8	Maximum wind heeling angle		10° in gust		15° for pax craft, 20° for cargo craft			
9	Max. passenger crowding angle	10°	10°					
10	Min. residual GZ with wind, pax crowding, or lifeboat launching, m			0.04				
11	Minimum residual GZ area, m.rad		0.028 with wind + gust + pax crowding or turning		0.028 with wind + pax crowding			
12	IMO weather criterion	applicable						

Table 2 Summary of the 2000 HSC Code stability criteria