Pragmatic solutions to regulatory problems

Wolfson Unit has been undertaking stability research for the MCA.

Stability is an aspect of naval architecture that continues to attract widespread research, justified because stability accidents carry a relatively high fatality rate. The modern trend is towards increasingly complex numerical simulations or probabilistic methods of assessment, targeting naval or large commercial vessels because that is where the interest behind the research funding lies. Unfortunately, a familiar result of much research is a recommendation for further work to improve predictions or validate them. Another sad fact is that most lives are lost on very small boats, in sectors of the industry where such approaches will never be applicable. The loss of 24,000 fishermen every year, predominantly from the small craft fleets of developing countries, is evidence of that.

The Wolfson Unit has been conducting stability research for the UK Government for 20 years. Much of the work has been aimed at small craft, where simple, pragmatic, solutions to safety are essential, but this approach has also been developed for application in those projects relating to larger vessels. Throughout the projects, the Unit engineers have consistently found that many of the conventional stability criteria address parameters which are not the best measures of safety. Simple alternative formulae have been provided to facilitate safety assessment, regulation, and the provision of information to enhance operational safety, and the projects' objectives have been met without concluding that further research was required, except where a project was specified as the first phase of a study.

A thorough research study was commissioned in 1988. It included collating stability data for yachts and sailing ships, studying documented casualties, wind tunnel testing a variety of rig types to quantify heeling moments and their variation with heel angle, creating a new facility in a wind tunnel where floating models could be subjected to gusts, and installing data acquisition systems on two vessels to gather wind speed and heel angle data over a full sailing season. Two of the principal findings were that the conventional methods of calculating heeling moment and gust response were invalid. It was determined that there is virtually no dynamic response to a gust, because the rise time of a severe gust is similar to the natural period of a quarter of a vessel's roll cycle, and the aerodynamic damping of a sailing rig minimises any dynamic effects of shorter rise times. The Wolfson Unit proposed an entirely new method of assessment, recommended new criteria, and developed a graphical presentation to advise the crew of their level of safety from downflooding or capsizing in a gust or squall. Heeling moments are so dependent on sail shape and sheeting that estimation of maximum moments is unreliable. The method avoids any restrictive regulation of the sail area, and instead provides information to assist the crew in deciding when to shorten sail, using guidance on maximum safe heel angles. The methods and criteria have been adopted by several other national authorities, and the guidance is widely used and respected by crews.

Figure 1. A catamaran during tests with reefed sails.

The earlier capsizing tests had shown that all vessels are vulnerable to capsize in breaking waves of height similar to the vessel beam, and that a large range of stability was the essential characteristic to ensure recovery from capsize. Given the link between beam and wave height, smaller vessels are more likely to encounter dangerous waves, and the minimum range criterion therefore was dependent on size. Externally ballasted yachts have a high level of stability to carry sail effectively, and this gives them adequate safety with regard to other hazards.

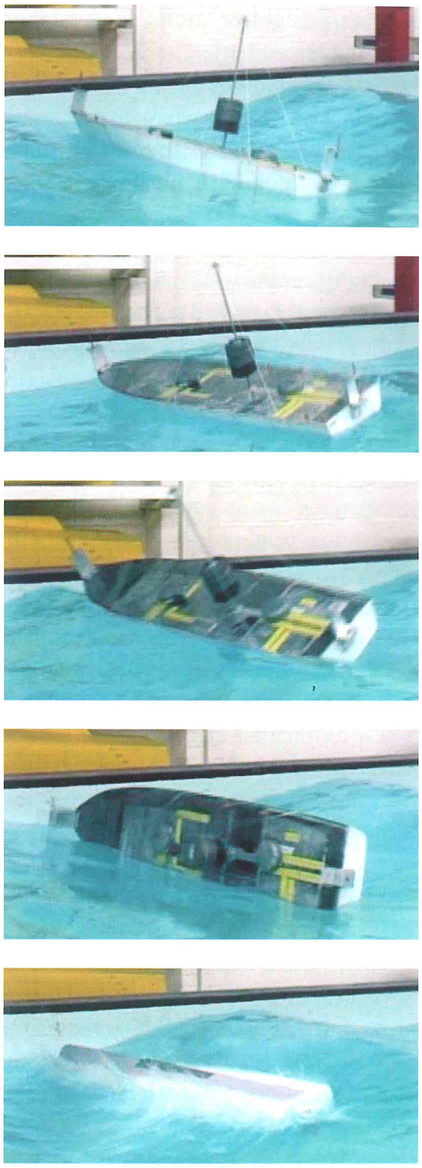

Figure 2. An intact monohull capsizes in moderate waves.

Adjusting methods

In 2006, the MCA commissioned Research Project 534, to determine whether the methods should be adjusted for the largest yachts, now approaching 100m. It was concluded that the existing methods and criteria remained valid, but that there may be instances where a yacht has a very high maximum righting moment in relation to the potential heeling moment, perhaps because of extreme beam or a very small sail plan. In such cases an alternative approach was proposed, which harmonised with the requirements for sailing multihulls.

The safety of sailing multihulls was addressed in 1995 because a number were operating commercially and the methods used to assess them had not been developed in the previous studies. The work identified aspects that were poorly understood, and was followed in 1998/9 by Research Project 427, with tests conducted in the towing tank to investigate vulnerability to capsizing in breaking waves, and pitchpoling. An interesting result was that the range of stability again was important, this time in determining whether capsize occurred following an encounter with a large breaking wave. Wind tunnel tests were conducted to quantify the heeling moments, Figure 1, and a new formula for calculating the heeling moment was developed. This included the deck area, which is neglected in conventional formulae, but has a significant influence on the lift force and its contribution to the heeling moment.

Further work on the wind heeling moments of catamarans was conducted as part of a coordinated group of research projects in support of the IMO review of the 2000 High Speed Craft Code. The work was conducted in phases, as Research Projects 503 and 537. Models of monohull and catamaran ferries, and a systematic series of rectangular blocks, were tested in the wind tunnel to develop improved formulae for wind heeling moment, and its variation with heel angle. As with the sailing multihulls, the deck area and beam of the vessel were found to have a strong influence on the heeling moment, because the vertical lift is a major component. This had been found during tests conducted in 1988 by the Wolfson Unit, acting as sub-contractors in a previous MCA project, and the principal contractors had made some recommendations for adjustment of the method, but they were not adopted. Resulting from the Projects were proposed formulae for heeling moment,

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and its variation with heel angle, based on the profile area, but also dependent on the beam to height ratio.

The IMO weather criterion has been problematic for some ship types, and has been the subject of much research. With the introduction of EC Directive 98/18, all European sea-going domestic passenger vessels will be required to comply, but some UK ferries cannot. In 2007, with Research Project 571, the MCA commissioned the Wolfson Unit to determine the validity of the roll prediction within the criterion, in particular for wide, shallow draught passenger vessels. Five vessels were modelled and subjected to rolling tests in waves representative of those assumed in the weather criterion. A total of 19 configurations were tested and it was clear from the results that the existing criterion does not provide a reliable prediction of the roll angle. The method generally gives an under prediction of roll for vessels of low beam/draught ratio, and an over prediction for those of high beam/draught ratio. Wide, shallow draught vessels therefore are at a disadvantage in the assessment. Researchers in Russia and Italy had proposed adjustments to some factors in the criterion and, while these do not provide reliable estimates, they offer a more consistent correlation with the model test data. It appears that the criterion is flawed in several ways, but it was appreciated that its elimination is unlikely to be acceptable in the short term, and it was recommended that the existing proposals be supported by the UK.

Returning to the HSC Code review,

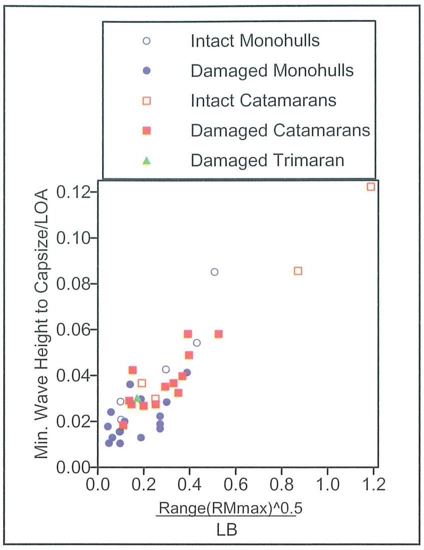


Figure 3. The strong relationship between minimum wave height to capsize, and a proposed stability parameter.

another issue was to address the relative levels of safety provided by the monohull and multihull stability criteria. The former were widely accepted conventional criteria while the latter had no sound technical basis. In Research Project 509, the Wolfson Unit tested two monohulls, three catamarans, and a trimaran, in a range of loading conditions, upright and heeled, intact and damaged, with damage openings towards and away from the waves. The tests were unusual in that the models were ballasted to conditions designed to test the minimum criteria, rather than to test a particular vessel. The models were stationary, but unrestrained, in waves. Tests were conducted at a matrix of frequencies and heights, and at all headings, to determine the minimum wave height required to capsize the model in each case. The large number of variables resulted in a test programme of 800 cases, each of which was tested at all headings.

Rescaling for larger sizes

Whilst a model at a particular scale can be ballasted such that it just complies with the criteria, if it is re-scaled to represent a larger size vessel it will comply with ease because the GZ values will be greater. If the model capsizes in a certain wave height, this has obvious implications for the validity of the fixed criteria in terms of immunity from capsize. The tests therefore verified the simple fact that safety is dependent on vessel size and sea state, parameters which are not incorporated into conventional methods of assessment, and it proved impossible to compare monohull and multihull safety in general, simply on the basis of the HSC Code criteria. Although hypothetical craft could be compared directly, actual multihulls tend to be much safer than monohulls because they tend to have greater margins of stability over the minimum criteria.

The findings were interesting, and demonstrated that conventional criteria are not the best measures of safety. It is the residual stability in the presence of moments such as passenger crowding or wind heeling that governs the safety, but it is the upright stability that is assessed most rigorously. Vulnerability did not appear to be influenced by the form of the vessel, number of hulls, or the existence or extent of damage. All configurations may be considered as floating bodies characterised by their residual stability curve. The vulnerability to capsize is most dependent on the range of positive residual stability and, to a lesser extent, the maximum residual righting moment.

A new method was proposed to assess the level of safety on the basis of these characteristics and the size of the vessel relative to the operational sea state. The single formula developed may be applied to all types of hullform, intact or damaged. It follows, therefore, that it may be applied to all types of ship.

In some cases, the waves in which it was possible to capsize the models were lower than the operational limits of the ferries on which the models were based. The tests represented the dead ship condition, and the worst possible combination of wave period and heading, so there are few full scale casualties for correlation purposes, but those that were found, mostly fishing vessels, appear to validate the method. It has therefore been presented to the IMO for consideration, but it is expected that further validation for a range of vessel types may be required before it can be given full consideration in that forum, and the MCA has invited tenders for Research Project 583, which will address that.

The conventional system of stability assessment discourages fishermen from considering their stability, because they go to sea confident in the knowledge that it complies with the relevant requirements in all operating conditions. Inadequacies of the conventional system are that it does not necessarily address the effects of operational loads or moments, does not address safety in terms of the size of the vessel in relation to the sea state, does not provide practical guidance on varying levels of safety, and does not present information in a simple format. Regulatory boundaries have driven designs in undesirable ways and this was something to be avoided in this work.

The recommendation was for a Stability Notice; a single page of information posted prominently on the vessel, simple enough to be understood and memorised by the crew. It is proposed to provide information that stability is variable, may be inadequate, and is under the control of the fishermen.

The method developed in Project 509, to relate residual stability to safety with regard to vessel size and sea state, was ideal for application to fishing vessels, and was used as the basis for guidance. For a vessel with full stability data, it is quite simple to determine the maximum load, or the maximum lift on a particular towing block or derrick, at which the residual stability is reduced to some particular level. Two levels were proposed; amber, at which the vessel may be described as having a low level of safety, and red, at which there is danger of capsize. In each case, the situation is associated with a maximum recommended sea state. The amber level was aligned with the safety offered by the minimum criteria, and the red level at 50% of that in terms of the maximum sea state. The guidance cannot be precise, but is intended to raise the safety awareness of the crew, assisting them in their decisions on loading and lifting, having regard to the prevailing conditions.

For the smaller vessels, the source of guidance information was more problematic, because the expense of a full stability assessment would not be acceptable politically. The research involved a study of fleet characteristics, and the stability of sample vessels, together with calculations on systematic variations of hullform and loading. The proposed method is for the same information to be provided as for the larger vessels, but basing the guidance on the residual freeboard. Heavily loaded vessels, or those lifting heavy weights over the side, are far more vulnerable to capsize, and this is reflected on the Stability Notice, Figure 4. An additional recommendation was for a freeboard guidance mark to be placed on the vessel's side, indicating the residual freeboards corresponding to the safety zone boundaries. These would have no regulatory purpose, but would enable the crew to relate the stability notice directly to the vessel operation. They would also indicate the relative safety of different vessels, and perhaps increase the safety awareness of a fishing community. The information for the notice can be derived in a few minutes with a calculator, using only the length and beam of the vessel to determine the guidance freeboards and sea states, and might be a valuable tool with which to improve the very low safety levels that occur in some parts of the world. *NA*

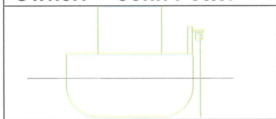
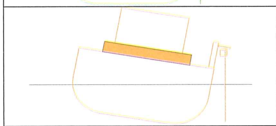
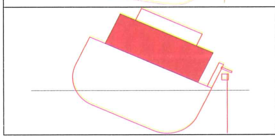
STABILITY NOTICE				
Name: Jolly Polly **No:** AB789 **LOA:** 10.6m **Beam:** 3.85m **Owner:** John Potter	LOADING & HAULER USE	SAFETY GUIDANCE		
		Zone	Minimum Freeboard	Maximum recommended seastate
	Good margin of residual freeboard	Good margin of safety	At least 47cm	
	Loading or hauling reduces minimum freeboard to less than 47cm	Low level of safety	24 to 47 cm	1.3 metres
	Excessive loading or hauling reduces minimum freeboard to less than 24cm	Danger of capsize	Less than 24cm	0.6 metres

Figure 4. Example Stability Notice for a small fishing boat with no stability data.