Spend Less, Save More (Lives)

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ABSTRACT

This paper questions whether we should re-direct our efforts to improve safety at sea, suggesting that most research does little to save lives. It promotes the view that we are missing an opportunity for very simple means of assessment that might benefit a wider range of seafarers. Data from the author's own research, principally for the UK's Maritime and Coastguard Agency, is combined with findings of other significant research projects, such as HARDER, as well as the latest casualty reports and investigations, to demonstrate that we have the knowledge to develop excellent tools for safety assessment and guidance.

Keywords: *Stability, safety, criteria, guidance*

1. INTRODUCTION

It is the author's view that many researchers have a tendency to complicate the subject and their findings, and that there is a strong case for taking a much simpler and more pragmatic approach if we really have a desire to improve safety at sea. Stability assessment and regulation are necessary, but they need not be complicated or expensive. This is particularly important for small vessels, where most fatalities occur.

The most effective path to safety though, is through education and the provision of information on the level of safety of a particular operation. Conventional pass/fail criteria and stability information booklets do nothing to provide this, and we await the development through IMO of the Second Generation Criteria to see if they improve that situation. The method proposed here offers practical safety guidance in relation to the size of the vessel and the prevailing seastate.

2. WHERE DOES THE MONEY GO?

It is inevitable that research efforts are concentrated on subjects that attract funding. Government funding is likely to be driven by defence strategy and politics, so is more likely to be available for naval vessels, for issues that attract widespread publicity such as the safety of passenger vessels, or for parts of the industry able to apply significant commercial pressure; typically major shipping companies.

Inspection of the proceedings of STAB2009 reveals that, of the 70 papers, most addressed large ship stability, almost 70% concerned methods of numerical prediction of ship dynamics, and 14% were specific to parametric rolling. There was only one paper that addressed small craft specifically, describing model simulation of fishing vessel casualties.

If we go back a further 15 years to STAB1994 we find that, again, more than half of the papers were on numerical simulations, but there were some differences in the spread of interest. For example, only two papers concentrated on parametric rolling, while 10% addressed the stability and safety of small vessels, predominantly fishing vessels.

On the basis of this very simplistic view, it appears that the majority of our efforts are concentrated on developing ever more reliable methods of predicting the motions of large vessels, and that these efforts are increasing. Research devoted to small vessel safety appears to be decreasing, or perhaps is not presented at these STAB conferences. This reflects what one might expect in view of the most likely sources of funding.

Despite this extensive investment in stability research during the last two decades, much assessment of stability still relies on criteria derived from Rahola's work, published in 1939. Things are changing now, as the IMO is committed to developing a revised Intact Stability Code, and considerable effort is being directed towards it. Whether the revised Code will provide a more reliable assessment of the level of safety remains to be seen, but it is unlikely to be as simple as the current criteria.

3. WHERE ARE THE FATALITIES?

Between 1994 and 2007, the number of lives lost on cargo ships ranged between 100 and 400 per year. This includes deaths from all causes, not just stability related incidents.

Since the Second World War there have been a number of well publicised, major maritime disasters, and inevitably the highest casualty numbers occur when passenger vessels are involved. Most fatalities have been caused by fire, explosion or grounding, with few major accidents caused by loss of stability or buoyancy. Below is a list of those incidents which have resulted in the loss of at least 500 lives as a result of stability or loading deficiencies, since 1945.

Le Joola; an overloaded Senegalese ferry that capsized in rough seas in 2002, with over 1800 lives lost.

Estonia; a Baltic Sea ferry that capsized in 1994, following failure of the bow door, with the loss of almost 1000 lives.

Bukoba; an overloaded passenger ferry that sank on Lake Victoria in1996 with the loss of about 800 lives.

Princess of the Stars; a Philippines ferry that sank in a Typhoon in 2008 with the loss of about 700 lives.

Ramdas; an Indian passenger ship that capsized in 1947 with the loss of 625 lives.

Shamia; a Bangladesh ferry that capsized in a storm on the Meghna river in 1986 with the loss of about 600 lives.

Of these 6 casualties over the past 66 years, the worst four occurred during the last 20 years, and suggest that the carriage of passengers at sea is not getting any safer. Two of those were heavily overloaded vessels however, and no amount of stability research will help vessels that are loaded far beyond their safe design limits.

The investigation into the loss of the Princess of the Stars concluded that the captain made an error of judgment in continuing his voyage into known severe weather, and this perhaps is a case where improved safety guidance might have made a difference.

The loss of the Estonia resulted in tremendous research effort, particularly around Europe, as indeed did the capsize 7 years earlier of the Herald of Free Enterprise, which resulted in the loss of 193 lives. These two incidents demonstrate the influence of public opinion, media coverage and political pressure in encouraging investment in stability research.

In round figures, the statistics suggest an average of around 1000 shipping fatalities per year, which makes it a relatively safe form of transport. This is not the full story though, and we have all seen references to the International Labour Organisation's estimates of a global death toll of 24,000 per year in the fishing industry alone. These don't appear in most shipping statistics. They are predominantly in small vessels in less industrialised countries, but fishing has one of the highest fatality rates in all countries, regardless of the level of sophistication of the local industry. Fifteen years ago in the USA it was believed to be more than 40 times higher than the national occupational average (Petursdottir et al, 2001), and it remained so in 2008. Current UK figures show it to be 115 times higher than for shore based workers. Not all of these deaths are caused by stability and loading incidents, but capsizing and foundering frequently result in the loss of all crew.

4. DOES STAB REPRESENT OUR BEST EFFORTS?

Because of the pressures on academics to publish, the STAB conferences, like so many other scientific fora and journals, attract predominantly academic papers. Academic studies frequently take the form of 3 year post-graduate projects and attract a high level of mathematics or numerical analysis. Typically they lead to further interesting research but have little direct application to industry.

Applied research conducted for industry is more likely to result in practical solutions, but is less likely to appear because it might be confidential, those involved cannot afford the time to prepare papers or participate, and there is little incentive for them to do so. The state of the art in industry therefore is not often represented in engineering conferences, and an example in the field of stability is the successful effort by the Icelandic Maritime Administration to reduce fishing vessel losses by capsize (Viggósson & Bernodsson, 2009). Between 1969 and 2002, 71 vessels capsized with the loss of 129 crew but since 2003 no vessels have capsized. This has been achieved partly by improving the fleet, but also through education and the provision of useful information. The innovative methods they developed could be implemented elsewhere but are not widely known and have not been disseminated at STAB.

5. ARE COLLABORATIVE PROJECTS PRODUCTIVE?

Most of us will have heard the phrase “A camel is a horse designed by committee”. With the contemporary trend for major research funding to be allocated to international collaborative projects, we should be careful to avoid the development of too many camels. Some prominent recent developments have been through many committee stages before the research recommendations are finalised. These recommendations then are discussed, and perhaps adjusted, by national or international regulatory committees, such as IMO.

The reasons for such collaboration are laudable and one can appreciate the hopes of the funding bodies that the best resources will be brought together to find great solutions, but they are not necessarily the most efficient use of research funding.

As consultants who work directly for industry on most of our projects, and occasionally for Governments or other funding bodies on contract research, we have no doubt that we can work most efficiently when we do not need to collaborate or coordinate our work with others. This is not arrogance, or an argument against all collaborative research, because it does have valuable benefits. Rather, it is a belief that we can offer good, practical solutions to problems most efficiently when we are given a clear remit and are left to conduct the technical work with a minimum of administrative effort. We do, of course, discuss specific issues with others when necessary and appropriate.

Two examples of different projects are considered to illustrate this point.

6. THE HARDER PROJECT

A good example of a recent major collaboration was the EU research project HARDER (Harmonisation of Rules and Design Rationale), which involved a consortium of 19 organisations from industry and academia. The project cost €4.5M and included some complex physical modelling on seven vessels. A number of papers have been published which present selected data and findings, for example Tagg & Tuzcu (2002).

A principal finding of that project was that the stability parameter that correlated most closely with wave height to cause capsize was the range of residual stability after damage. The GZmax values also showed reasonable correlation, although they varied with vessel type, and it was concluded that the most useful measure of survivability is a criterion based on the product of the two. Their recommended formula (1) for a survivability factor, s, was adopted by IMO as a basis for the probabilistic damage stability regulations of SOLAS 2009.

$$s = K\left[\frac{GZmax}{0.12} \times \frac{Range}{16}\right]^{\frac{1}{4}} \qquad (1)$$

Where K is a constant, depending on ship type, GZmax is in metres, and Range is the range of positive stability in degrees.

It is unclear from Tagg & Tuzcu (2002) whether the HARDER researchers considered the inclusion of displacement or other ship dimensions to relate ship size to wave height, and thereby make their formula truly non-dimensional. The project concentrated on large ships, and their aim was to develop a method of assessment for certain types of ship, not a method that might be applied to vessels of any size. Notwithstanding that, the authors of that paper apparently believed the formula to be non-dimensional as they state "…..since all factors in the equation are already non-dimensionalized."

The values 0.12 and 16 in their formula were empirically derived values of GZ and range, and the formula therefore appears non-dimensional. The use of a constant value to replace GZ in this way, however, returns the formula to a dimensional form. In practice, for a limited range of vessel sizes and types, GZ curve characteristics tend to be similar because of regulatory or practical design constraints. The formula may be effective for a limited range of vessels, therefore, in the same way as conventional criteria that apply constant minima for all vessels, but it is no more non-dimensional than they are. If very small vessels had been considered it is likely that different constants, or perhaps a different formula, might have been required to fit their test results. Indeed, different values have been recommended to replace the constant 0.12 for ships of different types, such as Ro-Pax ships, where the value 0.25 is more appropriate. This aspect is discussed further in Tsakalakis et al (2009).

It is common for regulations to have different approaches or formulae for different sizes or types of ships, but it presents problems if design trends take new vessels outside the range of those used in the rule development. It would be preferable for truly harmonised standards to be non-dimensional and capable of assessing all vessels with a common formula.

Can a formula that requires significantly different empirical constants, depending on some definition of the ship type, really be regarded as harmonised? When designs develop away from the norm, how do they fit the formula?

Following independent trialling of the method by industry, prior to implementation of SOLAS 2009, some problems with its application were encountered. Vassalos & Jasionowski (2009) described these and concluded "…there is new evidence emerging that indicates gross errors in the derivation of survival factors, demanding swift action by the profession to avert 'embarrassment' on a global scale".

7. MCA RESEARCH PROJECT 509

A project that set out with very different aims but resulted in similar findings was the Maritime & Coastguard Agency's Research

Project 509. The remit was to assess the level of safety provided by the criteria for multihulls in the IMO HSC2000, and compare it with that provided by the criteria for monohulls. It was conducted independently by the Wolfson Unit, with a budget of only 3% of that of the HARDER project. It included model tests on six vessels, in a total of 53 intact and damage configurations (Deakin 2005).

On such a small budget the model tests were somewhat simpler than those in the HARDER project. They were no less valuable and informative however, with over 800 test cases, each conducted at a full range of headings to the waves to determine the vulnerability to capsize.

The problem with model tests of criteria, rather than specific ships, is that the model equally could represent a ship of a different size, at a different scale. Indeed it could represent a ship of any size. Only at one scale would the test condition represent a ship that just complies with the minimum criteria. Scaled to represent a smaller ship it would fail the criteria whilst a larger ship would have stability in excess of the minimum criteria because, although regulatory criteria do not vary with ship size, the GZ values are not non-dimensional. The work highlighted the fact that the level of safety provided by the criteria is dependent on the size of the vessel and the seastate in which it operates. Criteria based on the positive range of stability are the exception to this, because range is a non-dimensional parameter, unlike GZ or the area under the GZ curve.

Whilst it was not the objective, the outcome of the work was a recommendation for a new criterion, or method of estimating the minimum level of safety of a vessel, given its size and stability. As in the HARDER project, it was recognised that vulnerability to capsize depended largely on the residual range of stability but the secondary characteristic was found to be the maximum righting moment, rather than GZmax. A strong relationship was found between the critical wave height and the following combination of residual stability characteristics:

$$\frac{\text{Range}\sqrt{\text{RMmax}}}{\text{B}} \tag{2}$$

Where Range is the range of positive residual stability in degrees, RMmax is the maximum residual righting moment in tonne.metres, and B is the beam of the vessel in metres.

This differs from the parameters used in most conventional stability criteria because it includes displacement in the righting moment term, which is beneficial, and beam, which is not. Although wide beam provides good initial stability, if two vessels of different beams have similar stability characteristics, the one with the wider beam generally will be more vulnerable to capsize.

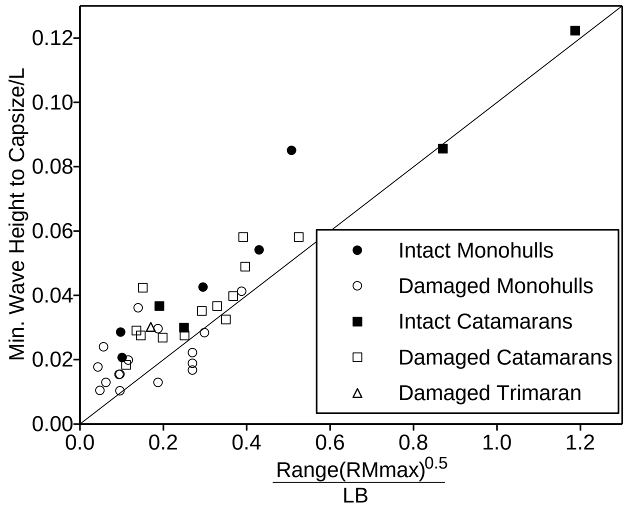

Figure 1 Relationship between stability and the minimum wave height to capsize from Research Project 509.

Figure 1 presents a summary of the model test capsize data, and demonstrates that the critical wave height appears to be independent of hull shape or damage configuration. The data have been made non-dimensional using the overall length to normalise both axes. Any model or ship capsize data can be compared on this graph.

The line on the graph represents the simplest formula that provides an effective fit to the data. It was proposed as a method of estimating the critical wave height and is defined as:

$$\text{Critical Wave Height} = \frac{\text{Range}\sqrt{\text{RM max}}}{10\text{B}} \quad (3)$$

To address safety in a seastate, it was proposed that the critical significant height be defined as:

$$\text{Critical Sig. Height} = \frac{\text{Range}\sqrt{\text{RM max}}}{20\text{B}} \quad (4)$$

Since these formulae are derived from the non-dimensional relationship, they offer a truly harmonised means of estimating capsize vulnerability, with no reference to vessel type or variation of constants. They do not pretend to offer a prediction of when a capsize might occur, merely a limit within which a vessel can expect to be safe from capsize. When operating beyond that limit a vessel may be vulnerable to capsize, although the probability of capsize may not be high.

When the formula was developed, early in 2005, it was based on these limited model test data. Subsequent analysis of other model tests, including those of the HARDER project, and documented ship capsizes has provided additional support for it (Deakin 2010). Figure 2 presents the evidence collected to date, all of which supports this simple formula.

Some casualty data lie on the proposed line, while others are substantially above it. The latter is to be expected in general because the line is an attempt to estimate the minimum wave height to capsize, for the worst possible heading and wave frequency. Most model tests are not designed to identify this case, and we cannot assume that ship capsizes occur in the worst possible circumstances. Indeed, if the ship is under control, the crew generally make an effort to select a heading that they perceive to be relatively safe.

The latest additions to our casualty database have come from a recent investigation into the loss of the fishing vessel Trident in 1974, and are identified on Figure 2. The investigation concluded that the vessel capsized as a result of wave action and its stability therefore was inadequate for operation in that seastate (Young, 2011). For the casualty, the seastate obviously is an estimate. For the model test, the stability was not exactly the same as that of the ship, so the point lies at a different x-ordinate, but from the actual wave height time history it has been possible to determine the wave height that caused the capsize (MARIN, 2008). This result represents the lowest seastate in which capsize occurred in the model tests, but tests were not conducted in lower seastates, so it may not represent the minimum possible wave height to cause capsize, which the line on the graph aims to represent.

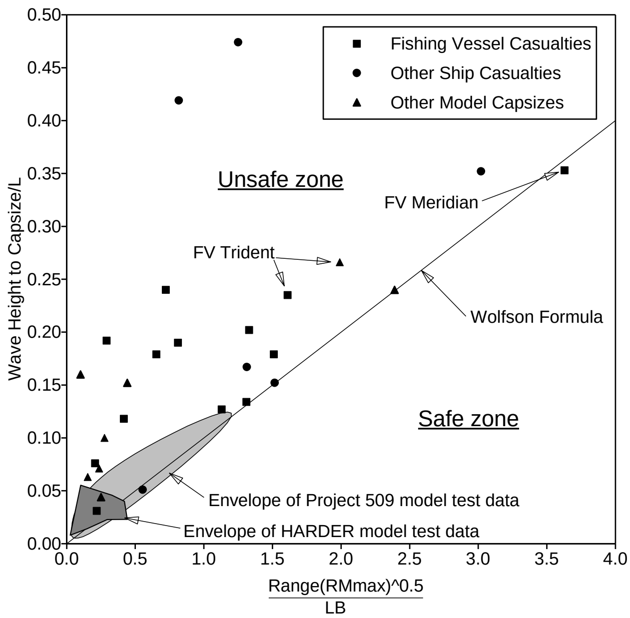

Figure 2 Correlation of casualty and model data with the proposed formula.

8. APPLICATIONS OF THE RESEARCH

The application of the HARDER project remains isolated to damage stability assessment of specific types of large vessels, as prescribed in the SOLAS requirements agreed at IMO.

There it should provide a valuable tool to help prevent loss of life, particularly when applied to passenger ships, and in time we may know whether it is a successful tool. Its adoption perhaps was inevitable, given the financial and political commitment to its development and the prominence of the organisations involved, but it is very sad that it appears to have no application to smaller vessels.

The Wolfson Unit's formula can be applied to any size and type of vessel. In the current climate it may be seen as too simplistic for adoption by IMO but, in the author's view, simplicity can be a strength. Regardless of its regulatory application, it is worthy of consideration as a basis for preliminary design assessment or, more importantly, for operational safety guidance.

An example where regulations proved inadequate but guidance might have been of value was Meridian, identified on Figure 2. This fishing vessel capsized while on guard duty in the North Sea in 2006 with the loss of all four crew. It had stability characteristics well in excess of the IMO minimum criteria, but was in severe weather with waves up to about 8 metres, and was only 22.7m long. With such good stability, its loss came as a surprise to the accident investigators, but safety guidance based on a formula such as this might have warned the crew, as the weather worsened, that they were operating with marginal safety.

The formula was used in the development of simple safety guidance for fishermen, as presented at STAB2006 (Deakin 2006). By considering the anticipated loading and lifting cases, the maximum recommended seastates can be determined to inform operational decisions. This is the most important and valuable development, and worthy of wider application.

The concept was further simplified for application to small boats without any stability information. The method provides approximate safety guidance based on the length and beam of a boat, by relating the residual freeboard to the seastate. Three safety zones are defined, and are displayed on a single page Stability Notice which can be posted in the wheelhouse:

Green: “Safe” in all but extreme seastates

Amber: “Low level of safety” and should be restricted to low seastates

Red: “Unsafe, and danger of capsize” unless restricted to calm conditions and with extreme caution.

The seastate boundaries are defined by their significant height, Hs, in relation to boat size.

Green/amber $$Hs_{amber} = \sqrt{1+0.4LOA} - 1 \quad (5)$$

Amber/red $$Hs_{red} = \left(Hs_{amber}\right)/2 \quad (6)$$

For vessels with no stability data the recommended minimum residual freeboards, F, that correspond to these seastates are:

<u>Decked boats</u>

Green/amber $$F_{amber} = \frac{B}{L}\left(Hs_{amber}\right) \quad (7)$$

Amber/red $$F_{red} = \left(F_{amber}\right)/2 \quad (8)$$

<u>Undecked boats</u>

Amber/red $$F_{red} = \frac{2.6B}{L}\left(Hs_{red}\right) \quad (9)$$

All units are metres. These formulae can be applied in a few minutes by anyone capable of using a tape measure and calculator, and might help to raise the safety awareness of those using small craft. They were derived using data for UK fishing vessels, for which they were harmonised with the IMO criteria, but the author believes that they can be applied much more widely, to many types of craft. This is just one method, and perhaps requires greater validation and development for wider application, but illustrates that practical solutions can be found without great expense.

Figure 3 FV Aleyna, photographed in 2006. She capsized in 2008 while fishing as a beam trawler.

The photograph in Figure 3 was taken in 2006. It shows a vessel of 14 metres which operated with very low freeboard for many years. Superimposed on the photograph is a freeboard guidance mark proposed as a means of relating the safety guidance directly to the vessel, for all to see. The mark spans the freeboards from “green” at the bottom to “red” at the top, as defined by equations (7) and (8). It is clear that, even when rigged as a stern trawler, and when upright, the vessel was operating predominantly in the amber or red safety zones. In 2007 it was rigged with heavier beam trawling gear and the safety margins would have been even smaller, but the heeling moments would have been much greater. The vessel capsized while trawling in 2008.

These marks are not intended to have any regulatory purpose, but to ensure that the owner, crew, their wives and indeed the whole community, become familiar with the level of safety of a vessel and its limitations. They may help in raising safety awareness generally.

9. OUR RESPONSIBILITIES

In an ideal world, naval architects would take responsibility to make ships as safe as possible. We know how to make ships safer, but safety always comes at a cost. In practice, therefore, naval architects must find a compromise between safety and the cost of the ship, or the economics of its operation. Invariably they design the vessel to the regulatory minima, because that gives the most economical solution with acceptable safety. Traditionally, regulations and stability information booklets have done nothing to provide safety guidance to the master of a ship. They give the operator the confidence to go to sea in the belief that the ship is safe if operated within the specified range of loading conditions. It may not be safe though, particularly if it is a small vessel in big seas.

We should all take responsibility for the safety of seafarers and passengers by developing and promoting the use of practical methods of assessing the level of safety of a ship in a range of seastates. We should be honest about the limiting seastates in which a ship might remain safe from capsize.

Regulators have the greatest responsibility, but too often they are intimidated by industrial and political pressure. In the UK, for example, the proposal to provide small fishing vessels with the safety information and freeboard guidance marks as described above was opposed by the MCA, the UK's Government safety agency. Their argument was that it might reduce the market value of vessels with particularly low freeboard and make them difficult to insure.

As researchers, we should be honest about the value of our work in improving safety of lives at sea. Valuable resources are invested in stability research every year, but most of it is of no value to the majority of seafarers. We can strive for accurate capsize simulation, but capsize prediction is not a precise science. Can we do more to improve safety statistics? The author believes that we can, and looking beyond the limitations of STAB is important.

10. CONCLUSION

We all hope that funding for stability research will continue to be forthcoming. We should use what we learn to improve safety for all, by developing formulae like (3) or (4). These offer an honest means of safety assessment that takes account of size and seastate, and can be used to provide simple operational guidance.

We should put pressure on Governments to introduce requirements for simple safety guidance information, not complex regulation.

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