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SMALL COMMERCIAL FISHING VESSEL STABILITY ANALYSIS WHERE ARE WE NOW? WHERE ARE WE GOING?

John Womack, St. Michaels Ship Design
34600 Warren Road, Pittsville MD 21850
shipsjw@aol.com

SUMMARY

Small commercial fishing vessels are the largest, most diverse, and constantly evolving class of marine vessels in existence. Yet the methods used to evaluate their stability are a one size fits all with little improvement over the many decades since their introduction in the early 1900's. This conflict coupled with significant flaws in the methods used to convey stability guidance to the crews leads to unacceptable risks being taken and fishing vessels and their crews being lost. Improvements are needed in all areas of small commercial fishing vessel analysis; better criteria that reflect the true dynamic environment faced by the crews, better means to convey stability guidance including the current risk of capsize to the crews, and lastly a program to teach stability and how to use the guidance provided.

1. INTRODUCTION

Small commercial fishing vessels, generally less than 150 feet (50 meters) in length, are the most diverse and largest class of marine vessels in existence. There are few common characteristics in hull shape, general arrangements including deckhouses, and fishing methods among the many fisheries worldwide. Even within a particular fishery, many differences in the vessels may exist.

Yet, the stability evaluation methods available today are mostly of a generic one size fits all boats, all seas, and all fishing methods. And the basis for the most common of the standards, the area under the righting arm curve to various angles of heel, is from work done in 1939 for North European coastal traders with little updating in the intervening years. Lastly, if the vessel is less than 79 feet (24 meters), there are no universally accepted stability evaluation methods available.

In part because of this conundrum, the commercial fishing industry is the one of the most dangerous, and deadly, occupations in many countries. Fishers in the United States in 2000 ranked second in deaths per 100,000 workers, right behind timber cutters and well above airline pilots, police, and construction workers. Further, in recent studies by Stephen Roberts of the University of Oxford (Roberts 2002) showed fishers had the most dangerous job in Britain. They were 50 times more likely to have a fatal accident over the last twenty years than the average worker.

Clearly, improving the stability evaluation methods is warranted to further the safety in the commercial fishing industry. But this is only part of the solution required; additional improvements in how a "stability analysis" is performed on a fishing vessel must be done.

This paper will explore the practical issues faced by today's naval architects in doing a satisfactory stability analysis on small commercial fishing boats. First, what are all of the parts required for a satisfactory stability analysis; the stability evaluation methods, the presentation of the stability guidance, and the education of the crews in stability concepts? And secondly, how can those parts be accomplished in a practical fashion; the strengths and weakness of the currently available means and the need for future development?

2. DEFINING WHAT IS A SMALL COMMERCIAL FISHING VESSEL STABILITY ANALYSIS

What is a small commercial fishing vessel stability analysis? It is not just the mathematical calculations done by Naval Architects. A correct stability analysis must also include the presentation of the stability guidance developed to the crews and the teaching of how to correctly use that guidance. This requirement for an integrated process from the technical creators to the end users is the only way to ensure the final goal, the safety of the crews.

Logically, this makes common sense. The best evaluation of a fishing boat's stability by the naval architect is of no value if the resulting stability guidance is not clearly communicated to the crews who must use it. And the best stability guidance is of no value if the crews are not taught how to use it or simply believe it is not correct.

Unfortunately, parts of this process are often lost in the many conflicts occurring in today's fisheries. Cost is always a concern, especially with many fisheries under economic pressure. And the cost comes in two varieties; direct dollars from the additional work done by the naval architect as well as the time spent by the crew not catching fish. And there is always the underlying mistrust between the crews and the naval architects over who best knows how to operate the vessel; those who go to sea or those who have the technical skills (the answer is both).

The end results of better stability guidance are well worth overcoming these conflicts. The additional direct cost increases will be minimal once standard evaluation methods and stability guidance procedures have been developed. And with a comprehensive training program to teach stability to the crews, the underlying mistrusts can be resolved.

3. PROVIDING STABILITY GUIDANCE TO FISHING BOAT CREWS

Currently, the primary means for providing stability operating guidance to small fishing boat crews is the "Stability Letter". These stability letters are generally a simplified version of the traditional "Stability Book" that is generated for large commercial boats. These simplified stability letters have been the preferred means of conveying the critical stability information and boat operating guidance to crews given the simpler configuration of small fishing boats and the lower or non-existent training levels for many of the crews.

For a stability letter to be effective, it must first be understandable to the crews, and second, the crews must believe that the guidance information provided is correct. While the first requirement is fairly obvious, the second requirement is equally important. The best stability letter on the most seaworthy boat in the world is of no value if the crew believes the loading requirements are wrong and ignores the stability guidance. Unfortunately, most forms of the stability letters currently in use are neither readily comprehensible and/or are trusted by the crews (Johnson and Womack 2001).

3.1 KEY AREAS TO IMPROVE STABILITY GUIDANCE

The problems that exist with current types of stability letters used to provide stability to small fishing vessel crews are the principal reason crews are disregarding these letters, either intentionally or because the guidance is incomprehensible, and putting themselves in danger. Fishing boat crews don't have a death wish; they just truly don't understand the potential adverse impacts on their boat's overall stability when they load the boat to make it "feel" better under normal fishing operations (Johnson and Womack 2001).

Since the principal blame for the problems with stability letters lies with the naval architects and marine surveyors who create them, it is they who must find the solutions. But they must understand what the fishermen need and how fishing works in developing the fixes. The solutions for improving stability guidance to small commercial fishing vessel crews are simple.

1. Be written to provide stability guidance, not to dictate the boat's operation.
2. Present the safe loading conditions clearly, both visually and written.
3. Provide some means for conveying the stability levels, i.e. risk of capsizing, associated with each of the loading conditions.
4. Be comprehensible by crews with little or no formal training.
5. Use practical operating restrictions on variable catch limits, etc.
6. Use practical means to allow the crew to check if the boat is loaded correctly.
7. Develop a series of operating guidelines on proper seamanship and boat maintenance suitable for insuring a boat's adequate stability.

In summary, the goal is to provide the captain with practical stability guidance and a way to gauge the risks of capsizing based on loading, weather, and other factors, and let them run their boats.

3.2 PROVIDING RISK BASED STABILITY GUIDANCE BY LOAD MATRIXES

Loading matrixes (see Figure 2 for an example, additional examples to be shown during the Workshop) have been proposed (Johnson and Womack 2001) to meet the goals presented above. The matrixes are easy to use while showing all potential loading conditions on a single page. With catch levels on the left column and various tank and deck loadings across the top and bottom, it is easy for the crew to check if their boat's stability is acceptable.

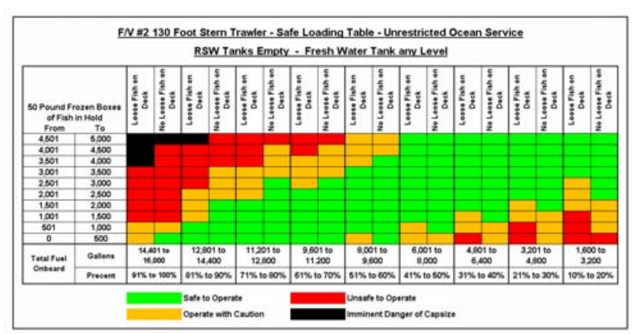

Figure 2: Sample Safe/Unsafe Loading Matrix

These risk based loading matrixes, particularly the color versions, offer many advantages to the crews in safely operating their vessel. First the color gives very quick intuitive indications of the current risk of capsize for any conceivable loading condition. Second, the matrixes allow the crew to plan ahead to ensure adequate stability. With all of the loading conditions on single sheet, the crew can literally plot their trip on the load matrix and adjust loading, ballast, or fuel levels to suit.

This type of loading matrix also has the advantage of putting the operational decisions for the boat back to the captain instead of with the naval architect as current safe/unsafe stability letters do. This approach does require that the captain, vessel owner, and other decision makers must clearly understand the basic concepts of stability in order to select the appropriate risk level, given current and predicted weather conditions and other trip factors.

4. STABILITY GUIDANCE EDUCATION FOR FISHING BOAT CREWS

Assuming the stability letter adequately provides the necessary stability operating guidance, the crews must also believe that the guidance provided is correct so they will follow it. Unfortunately, from many casualties reports in the United States and first hand experience, the crews often ignore stability letters because they believe they, not the Naval Architects, know how to load the boat correctly. (Johnson & Womack 2001, USCG 1999)

The solution is simple; improve the training of basic stability concepts to fishing boat crews so they can better understand and trust their letters. From discussions with fishing boat crews, they are interested in understanding their stability letters. The problem is the creation of the stability letter appears to be a lot of black magic by the naval architect. From moving some weights back and forth on their boat, the architect comes back with a piece of paper on how to load their boat. And often, the stability instructions may run counter to how they believe their boat should be loaded or restricts the maximum allowable catch to levels below what they are carrying now.

To teach stability to fishing boat crews will require explaining fishing boat stability and its complex interactions to crews who generally lack a higher education. Common naval architecture terms used in stability are simply unknown, and often incomprehensible, to the crews. For example, even the basic concept of center of buoyancy, intuitively understood by naval architects, is unknown to many crews. The challenge will be in convincing the crew that the center of buoyancy is a real location that all of the buoyant forces are acting through, not an imaginary point on their boat that the crews may have a hard time conceiving.

The course needs to only teach the basic concepts of stability and the effect of typical fishing operations on a boat's stability. The course should not teach how stability is calculated, that is the responsibility of the naval architect who thoroughly understands all of the nuances of stability.

The primary goals for the proposed stability training course are:

1. Explain what the center of gravity (G) and center of buoyancy (B) are.
2. Show how the relationship between G and B works to keep the vessel upright as it heels.
3. Explain the basic methods of determining if a vessel has adequate stability.
4. Show the effect on a vessel's stability from typical fishing operations.

The basic layout of the stability training course consists of two parts; a written manual and a verbal presentation. The two individual components of the training course will be developed to be mutually supporting. Figures in the written manual would be similar to the displays and models used in the presentation, and concepts demonstrated in the presentation would be in the manual. This will allow crews that have taken the training course to use the written manual as follow-up take-home notes to the verbal presentation.

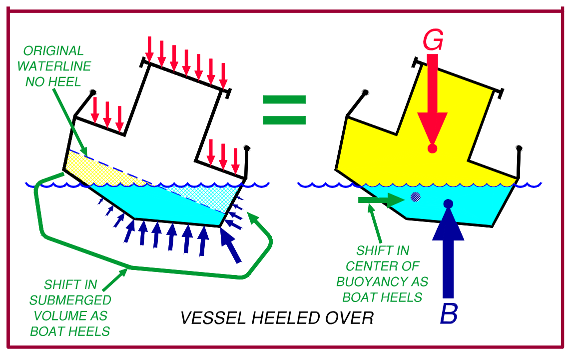

Figure 3: Example Training Manual Figure

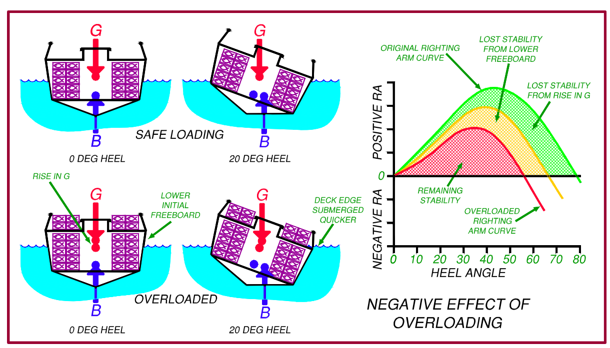

Figure 4: Example Training Manual Figure

The written manual will be developed to be self-explanatory to persons who have some formal education or seamanship training. The figures intended to show the basic stability concepts would be kept simple and structured to appear similar to existing fishing boats designs. It is important to make the figures believable to the crews. If they look similar to their boat, the chances are better the crew will believe the message even when it runs counter to past beliefs. Figure 3 to 5 are examples of the proposed figures (more will be shown during the Workshop).

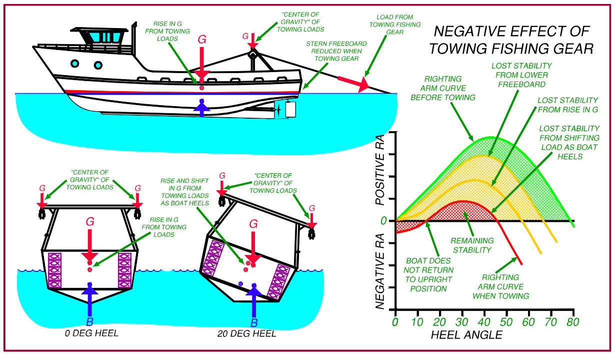

Figure 5: Example Training Manual Figure

The second component of the training course, the verbal presentation, will be developed for both small and large groups. The small group is intended to be an individual fishing boat's crew and owner, with the larger groups being at meetings such as trade shows or National Marine Fisheries Service regional council meetings. The presentation for individual boats will be made easily transportable to allow the presentation to be made onboard, at dockside, or even in the local watering hole. This will allow a naval architect to give the presentation when delivering a stability letter to a boat.

For both presentation sizes, visual displays and static and dynamic demonstration models would be used. The visual displays would be enlarged versions of the training manual figures, posters, slides or computer driven graphics. The models are an important part of the presentation as they allow the crews to see "hands-on" what is happening during typical fishing operations. As an example, the crews can see directly the loss of stability when they boat is overloaded or the negative effects of slack tanks. Actually "capsizing" the model, especially when they believe they have loaded the model to make it safer, is a very convincing training method. (Johnson & Womack 2001)

From practical experience it is important that with presentations for individual vessels, actual graphs of that vessel's righting arms be integrated into the presentation figures. Stability strengths or weakness particular to the subject vessel can be clearly shown.

5. STABILITY EVALUATION METHODS

For small commercial fishing vessels, there are intact and damaged stability evaluation methods currently in wide spread use. These methods, though having shown "adequacy" over time for many vessels, have minimal scientific basis in their creation. They are in use basically because of the lack of other more adequate criteria.

5.1 INTACT STABILITY CRITERIA DEVELOPMENT HISTORY

Intact stability criteria for small commercial fishing vessels are based primarily on evaluating the vessel's static righting arm curve's characteristics. The basis for these criteria comes from Dr. Jaakko Rahola's 1939 doctoral thesis "The Judging of the Stability of Ships and The Determination of the Minimum Amount of Stability" (Rahola 1939). It is from Rahola's work that the current International Maritime Organization (IMO) and United States Coast Guard (USCG) area under the righting area criteria minimum values where obtained. (Francescutto 2002, IMO 1995, USCG 1986)

While a groundbreaking work for its time, the concepts developed have several significant flaws for use with today's small commercial fishing vessels. First, the study was very limited in scope to vessels which "may come to navigate under the conditions prevailing on the lakes and the waters adjacent to our country [Finland]".

Second only 34 vessels covering all types were used in the thesis study, all of which capsized. Of these 34, only 13 vessels were used in the righting arm curve comparisons. And further, of these 13, only 1 was a fishing vessel whose principal characteristics are shown in Table 1. The remainder of the vessels were cargo ships (8), passenger ships (1), military vessels, (1) motor sailing cargo ships (1), and lightships (1). Clearly this study was not representative of fishing vessels to start with. And given the significant differences in today's fishing vessels, no scientific correlation is possible.

Table 1: Fishing Vessels in Rahola's Thesis

F/V Rau III, Whaler - LBP 126 Ft (38.4 m), Beam 26.2 Ft (8.0 m), Depth 15.1Ft (4.6 m), Draft 11.8 Ft (4.61 m)

Further flaws lie with the mythology used by Dr. Rahola to determine what was an adequate, critical, or insufficient righting arm curve from the subject vessels. To quote Dr. Rahola; "When beginning to study the stability arm curve material given more in detail, one immediately observes that the quality of the curves varies very much. One can therefore not apply any systematical method of comparison but must be content with the endeavor to determine for certain stability factors such values as have been judged to be sufficient or not in investigations of accidents that have occurred."

In short, the determination of what was an adequate, critical, or insufficient righting arm curve from the subject vessels was purely subject by a wide range of different accident investigators. This is clearly shown in Figure 6, plots of the subject righting arm curves.

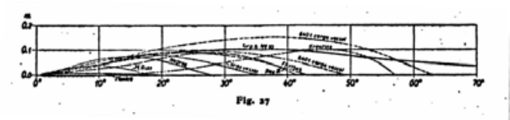

Figure 6A: "Insufficient" Righting Arm Curves

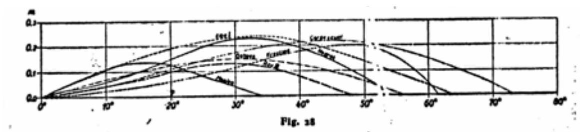

Figure 6B: "Critical" Righting Arm Curves

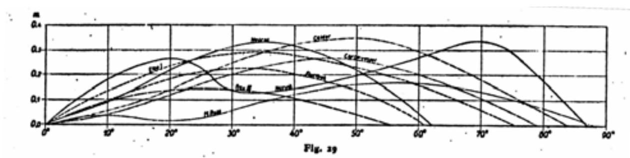

Figure 6C: "Adequate" Righting Arm Curves

Using the adequate righting curves as an example, the opinions of the investigators considered positive ranges of stability from 55° to 88° as adequate. Further differences show in the range of GM, which varies from 0.098 Ft (0.030) m to 4.068 Ft (1.240 m).

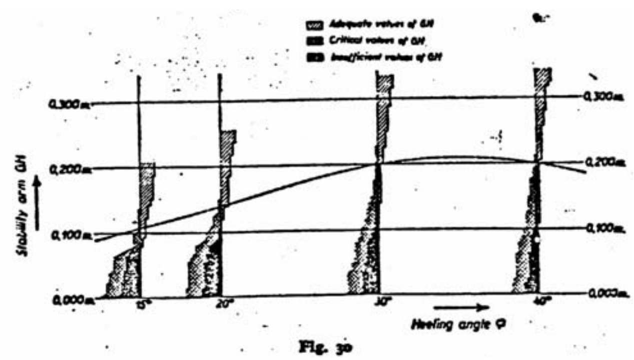

Figure 7: Dr. Rahola's "Comparing Diagram"

From these curves, Dr. Rahola developed the "comparing diagram" shown in Figure 7 to determine his "minimum rule" for adequate stability. The form of the rule was;

1. Minimum RA of 0.46 Ft (0.140 m) at 20° of heel.
2. Minimum RA of 0.66 Ft (0.200 m) at 30° of heel.
4. "Critical Heeling Angle" (Angle of Maximum RA) greater or equal to 35°.

Interestingly, no minimum range of positive stability was specified as a "stability arm curve" of "ordinary form", i.e. typical of the vessels of 1939, meeting the above minimums would have a positive range of stability greater than the minimums established by his research.

Comparing Dr. Rahola's minimum rule with the current IMO Torremolinos Convention Criteria for fishing vessel that is based on his work yields some interesting similarities. Figure 8 shows a typical righting arm derived from Dr. Rahola's minimum rule and Table 2 shows the comparison with the IMO F/V criteria.

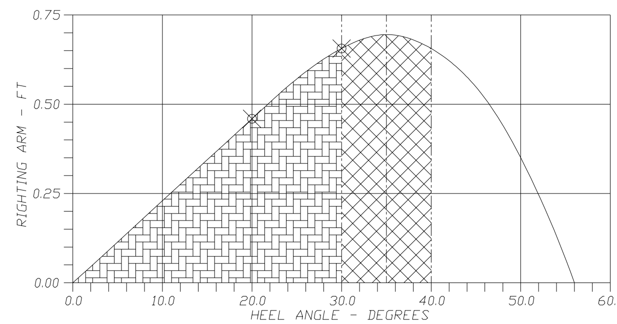

Figure 8: Dr. Rahola's Minimum Rule with Righting Arm Curve of "Ordinary Form"

Table 2: Comparison of Rahola's vs. IMO Stability Criteria

Criteria Requirement	Rahola	IMO
Min Area 0-30° Heel	10.25	10.3
Min Area 30-40° Heel	6.81	5.6
Min Area 0-40° Heel	17.06	16.9
Min RA at 30° Heel	0.66	0.66
Min Heel Angle of Max RA	35	30
Min Initial GM	1.32	1.15

(Note all Units in English - Comparison Only)

The last part of the history of the development of the current static intact stability methods is Dr. Rahola's own comments on his minimum rule which showed amazing foresight into the future. Applicable excepts of his thesis are;

> "The established rule, which is hereinunder (sic) called the minimum rule for the statical (sic) stability, the author does not however wish to propose for general use."
>
> "First of all may be mentioned the unsuitability of the same standard stability arm curve for both large and small vessels."
>
> With respect to his minimum values, "...the values of these stability factors are in all probability sufficient, provided it is not a question of special types of vessels, or exceptionally difficult conditions."

In summary, Dr. Rahola states "A choice of a standard form for the statical (sic) stability curve, so that it would suit both all sizes and types of vessels, thus proves to be an insurmountable difficulty." Yet, today's standards for fishing vessel's are a one size fits all format, a direct contradiction. These contradictions and their consequences can now be explored. (See also Francescutto 2002, Cramer and Tellkamp 2002, Bird and Morrall 1986, Jens and Kobylinski 1982, Cleary 1982 and 1993)

5.2 CURRENT INTACT STABILITY CRITERIA

For vessels 24 m (79 feet) or longer, the primary means for determining the adequacy of a fishing vessel's intact stability is evaluating the characteristics of its static righting arm curve. The principal stability criteria are contained in the IMO 1993 Torremolinos Protocol as previously summarized in Table 2. Various countries have adopted versions of this protocol for their own use. In general, the modifications to the IMO version are the addition of a minimum range of positive stability, typically 60° or more.

These criteria represent a simple one dimensional static evaluation of a complex dynamic situation. To further improve its practicality and account for some dynamic effects on a fishing vessel's stability, additional criteria based on the static righting arm curve have been developed. In general, they involve overlaying a heeling arm that mimics the dynamic effects such as wind, waves, towing fishing gear, or lifting over the side on the static righting arm curve.

William Cleary provides the following insight on how the standards came into being. (Cleary, 2002)
"The criteria were not intended to be representative of fishing vessels. It was for all ships. Sometime in the 1960's it became the basis of European Stability criteria for all ships even though it had a very small foundation. Then it was adopted & modified (increased) for fishing vessels in Europe and has been there by default ever since. The principal reason the Torremolinos Convention failed to 'come into force' was that European boats (and rules based on European or their derivative designs) were so different from Japan's fleet of long slender boats that the 24 m length requirement as a single item was not acceptable to Japan. Japan wanted 24m and 150 Gross tons-a double requirement. When this was not accepted by the rest of the nations, Japan's FV fleet instantly became the world's largest fleet by about 20,000 boats. When Japan did not ratify, the Convention was an automatic non-starter. Japan had hinted at its problem but not made it 'perfectly clear'."

5.3 FLAWS WITHIN THE CURRENT INTACT STABILITY CRITERIA

As previously discussed, there is minimal scientific basis for these criteria, particularly for modern fishing boats. The criteria though having shown through time to provide adequate stability for most classes of vessels under "normal" conditions; fishing vessels are still being lost due to stability problems.. Cases involving pure capsizing without other factors present are quite rare. Generally, additional failures such as downflooding or shifting of cargo have contributed to the loss.

The flaws within the current criteria create several interesting problems for naval architects when analyzing a fishing vessel's stability. In some cases the criteria are actually overly restrictive, which is contributing to losses. In other cases, the criteria are not sufficient to reflect individual stability weaknesses in a vessel. And in all cases for fishing vessels under 79 feet (24 m), no suitable criteria currently exist.

5.4 ADDING VARIABLE WEATHER CONDITIONS

As previously mentioned, the current intact stability criteria are a one size fits all; all sizes, all hull shapes, all fisheries, all sea conditions, all locations. (Spyrou 2002) The intent of the weather criterion was that the vessel's stability should be adequate to survive full ocean storms, even if the vessel works on limited near coastal areas. This may not to appear to be a problem at first glance; the vessels would just have excess stability.

The problem lies in the crew's "feel" of their vessel over time. They learn, and to a certain extent correctly so, that they can "safely" carry more fish in good weather than bad. The conflict occurs when a naval architect must use the existing one size fits all criteria and tell the crew they must carry less fish than they have historically done.

Human nature and the ever present underlying mistrust of naval architects, "what do they know about how to run my boat", have led some crews to ignore their stability guidance and run the vessel "overloaded". Not knowing the true danger they are placing themselves in has lead to the losses when the weathers worsens and the trip conditions suddenly exceed the "normal".

Case in example, the Mid-Atlantic ocean clam fishery, which operates on near coastal trips for a maximum trip length of 32 hours dock to dock. The vessels are further limited to operating in seas less than about 6 feet (2 m) in order to keep the dredge on the bottom. Several vessels have been lost when running "overloaded" and suffered downflooding through open hatches or other openings in the vessel when the weather deteriorated. (USCG 1999, Campbell 2002)

For classes of fishing vessels that operate on limited routes where protected shelter is available in reasonable steaming times, intact stability criteria that reflects less than storm conditions is needed to provide correct stability guidance. While overly conservative stability criteria might not seem to be a major problem, it does lead to the problems noted above and must be corrected.

5.5 ADDING SCALABILITY AND DYNAMIC ANALYSIS METHODS

Current stability criteria are pure static analysis. The vessel is heeled to set points and the forces acting on the vessel calculated. Even the water on deck and severe wind and roll criteria, which are intended to better reflect the true dynamic world, are still a static based calculation.

The real world for small commercial fishing vessels though is a very complex dynamic environment. And the smaller the boat, the more of an effect for the same sea conditions. This is shown by contemplating the effect of 20 foot (6 m) seas on a 1,000 foot (300 m) tanker, a 150 foot (45 m) trawler, or a 50 foot (15 m) offshore lobster boat. Clearly the 20 foot (6 m) seas are no concern for the tanker, minimal concern for the trawler, and significant concern for the lobster boat. The existing stability criteria though do not reflect this conflict due to scalability problems with the Torremolinos area criteria and the lack of true dynamic analysis methods.

Briefly, scalability in vessel stability depends on the square-cubed rule; (Johnson 2001) i.e. the heeling forces, which depend on water and wind impact areas, go up with the square of the dimensions (length by height), but the righting moment which depends on the displacement, goes up with the cube of the dimensions (length by width by draft). For example, when using the IMO Torremolinos area criteria, a vessel twice as large as another has roughly eight times the righting energy as the smaller vessel if both have the same righting arm curve. Yet for the larger vessel the wind impact forces have only increased four times over the smaller vessel. Thus for a given sea condition, bigger is almost always better.

Scalability problems plus the lack of true dynamic analysis methods means current stability criteria do not directly address critical areas such as the danger from excessive rolling, the shipping of water on deck (Francescutto 2001), or broaching, the principal area of concern for smaller vessels. And for fishing vessels less than 79 feet (24 m), these areas are the most critical to its survival. In fact, for these small fishing vessels a dynamic analysis method that evaluates the vessel's response in different seas at different headings may be the best means for developing usable stability guidance. (Johnson and Grochowalski 2002)

5.6 ADDING RISK ASSESSMENT

Another common fault with the current stability criteria for small commercial fishing vessels is the lack of any risk assessment. The criteria are strictly safe/unsafe which is not representative of how fishermen consider the real world. Small fishing vessels generally do not suddenly fall off the stability cliff, i.e. hit broadside by a rogue or extreme breaking wave. A fishing vessel's stability is often lost when an unusual combination of capsizing forces such wind, waves, or fishing loads occurs. (Cramer and Tellkamp, 2002, Umeda and Peters 2002, Dahle and Myrhaug 1995)

As previously discussed in Section 3, providing fishing vessel crews with risk based stability guidance should increase their ability to safely operate their vessels. Knowing their current risk of capsize will allow them to better evaluate current sea conditions. For example, if the seas are "confused", then the crew may elect to increase their stability levels, that is lower the risk of capsize.

By adding risk assessment, the means for creating the green, yellow, and red sections in proposed color risk based loading matrixes would be developed. And given the small size of many fishing vessels, it is critical that the risk of capsize analysis should reflect both static and dynamic methods.

5.7 ADDING CREW MISTAKES

All of the current stability criteria available for small commercial fishing vessels assume the crews operate their vessel correctly; watertight closures secured and good seamanship. In the real world, however, people make honest mistakes, which are not addressed by the current criteria.

The existing damaged stability criteria are for catastrophic events such as collisions or other severe hull breaching. And the residual minimum stability levels proscribed are basically useless unless the event happens in very protected waters. Fortunately these events are few and far between for fishing vessels.

A more prevalent "damage" to a fishing vessel's watertight integrity is watertight doors or hatches being left open. Several examples are the F/V Cape Fear which was lost from flooding through a fish hold hatch that was not fully closed or the F/V Arctic Rose whose loss is possibly due to a watertight door being left open. In both cases, as with most others, the crew was not intentionally endangering their vessel, they likely did not believe there was a risk for the current sea conditions.

The F/V Arctic Rose will be used to illustrate where changes to existing criteria could reflect crew mistakes. The watertight door in question became submerged at about 24 degrees of heel, significantly less than 30 degree breakpoint in the Torremolinos Convention criteria. The door opened into a large main deck processing space, which if flooded with as little as 6 inches (150 mm) of water created such a large free surface effect the a significant loll angle developed. This lolling angle would submerge the door at ever smaller heel angles, likely leading to progressive downflooding and eventual loss of the vessel.

If the artificial 30 degree breakpoint in the Torremolinos Convention criteria were changed to 30 degrees or the angle at which a watertight closure, if advertently left open, would become submerged, whichever is less would help to minimize situations like that on the F/V Arctic Rise.

6. CONCLUSION

By improving all three areas required for providing stability guidance to small commercial fishing vessels; stability criteria, stability letters, and education, we can significantly improve the safety of the crews. New stability criteria need to be developed to reflect today's fishing vessels and the sea conditions they operate in. New means to convey the stability guidance to the crews also need to be developed, particularly the current risk of capsize. And lastly to tie this all together, an integrated program to teach the basic concepts of stability and the crew's effect on stability needs to be developed.

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