A new era of fishing vessel safety emerges

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ABSTRACT

Commercial fishing is one of the least safe activities taking place within the EU and the worldwide community today. Several accidents and fatalities have been recorded over the past years stemming from various causes related to the operation, design of the vessels and severe weather conditions. This paper describes the background while attempting to elucidate and assess the impact of a new damage stability recovery system for new and existing fishing vessels, leading to high levels of survivability in the damaged condition. Highly expanded foam is injected in the most vulnerable compartments, rendering the whole ship a lifeboat. One case study is presented to provide the requisite evidence.

Keywords: *Fishing vessel; Safety; Damaged Stability, Risk, Survivability, DSRS*

1. INTRODUCTION

The safety problem of fishing vessels is a major issue across Europe and the rest of the world. Although, attempts to resolve the problem are taking place, the problem of damage stability is one that has yet to be solved as catastrophic accidents continue to happen, leading to societally unacceptable consequences.

The extent of the problem is further highlighted with the aid of the following statistics:

- Each year there is an average of 24,000 fatalities and 24 million non-fatal accidents.
- The fishing fatality rate is estimated at 80 deaths/100,000 individuals per annum, which is 79 times higher than the overall occupational fatality rate.
- In the period 2011-2015, almost 1,368 fishing vessels have been involved in 4,620 maritime accidents.
- It is estimated that there are 4 million fishing vessels operated globally, 1.3 million decked vessels and 2.7 million un-decked vessels; about 15 million people are employed aboard fishing vessels and about 98% of these people work on vessels less than 24m in length.
- In 2017, the total European fishing fleet has reached 183,104 vessels. (FAO, 2016)
- 5k and 10k fishing vessel newbuildings are expected in Europe and worldwide, respectively, within the next 8 years.
- The risk of a fishing-related accident in EU waters is 2.4 times greater than the average of all EU industry sectors.

Out of all the recorded accidents over 60% involve trawlers, whilst 15% dredgers (EMSA, 2015). The most critical location of the main casualties is the engine room as shown in Figure 1 .

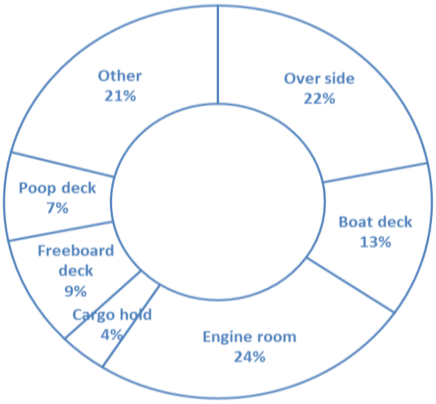

Figure 1: Main Casualty Areas in Fishing Vessel Accidents

Post-accident analyses have indicated that the main causes relate to ship stability and the influence of adverse weather conditions (Vassalos,

2006) . Particularly, the vessel is operated close to its stability limits in following / quartering to beam seas, where the waves adversely affect its dynamic stability. Also, fishing vessels are erroneously overloaded, in particular with heavy loads (fishing apparatus) in the ship superstructures; Doors or hatches left open, causing water ingress in case of green water on the stern deck and finally fishing gear suddenly becoming hooked on the sea bottom, etc. cause large scale water ingress.

Many attempts to develop warning systems and guidelines have repeatedly failed over the years. Traditionally, design/passive measures have been the only means to achieve damage stability enhancement in a measurable way (SOLAS 2009, Ch. II-1). However, limited choice for passive protection creates inertia and safety stagnation. Operational/active systems , instead, would enable the maritime industry to draw from a wealth of experiential or technological fund of knowledge to reduce the highly unacceptable loss of life. All the above points to the need for a foolproof approach to increase the resilience of the fishing vessels to capsize whether in intact or damaged condition. This paper paves the way in this direction by providing the background and rationale for such a framework and by introducing an alternative system for damage stability enhancement that involves injecting highly expandable foam in the compartment(s) undergoing flooding during the initial post-accident flooding phase.This leads to enhancing damage stability and survivability of fishing vessels well beyond the design levels in the most cost-effective way currently available.

2. DAMAGE STABILITY RECOVERY SYSTEM (DSRS)

System description

The Damage Stability Recovery System (DSRS) (Paterson, et al., 2016) focuses on compartments prone to high risk as a last line of defence against large scale flooding. The working principle of the proposed system is simple: when a vessel is subjected to a critical damage, stability is recovered through the reduction of floodable volume within the vessel’s high risk compartment(s). This is achieved by rapidly distributing fast setting, high expansion foam to the protected compartment(s) resulting in a multitude of positive effects that enhance stability, floatability and watertight integrity. Lost buoyancy is minimised whilst free surface effects are eliminated, floodwater is contained and KG is reduced.

The system consists of a fixed supply of foam resin and hardener agents, each stored within a stainless steel container. Both containers are connected to a piping network for distribution to the protected compartment(s). A gauging and sampling pipe on each tank allows the tanks to be gauged and for periodical samples of each component to be extracted for testing. Tank ventilation is enabled through a ventilation line equipped with a non-return valve and vacuum relief is offered by a secondary ventilation line also equipped with a non-return valve.

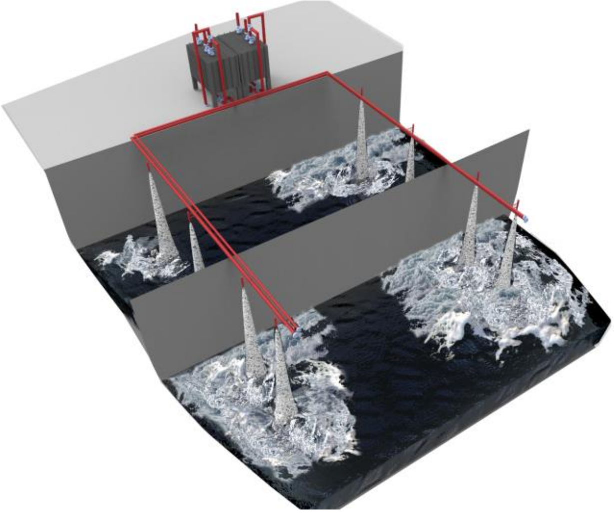

Figure 2: DSRS Graphical Representation

Two electrically driven internal gear pumps, located on the resin and hardener lines respectively, are used to deliver both foam components to a number of mixing nozzles located within the protected compartment. Each pump may be operated from the main or emergency electrical supply and must be started by manual means either remotely from the bridge control console or from their local switches. Both resin and hardener lines have re-circulation loops whereby the pumps can be used to circulate each component periodically. This enables faster foam deployment as it removes the requirement for pump-priming while also allowing the pumps to be tested when necessary.

Figure 3: DSRS Graphical Representation

Within the protected compartment(s) the resin and hardener lines divide into both port and starboard side branches for uniform filling of the space. Each branch contains a number of static mixing nozzles where resin and hardener components are mixed to form a homogeneous solution. The interaction of the two components produces a chemical reaction that enables the in situ production of foam.

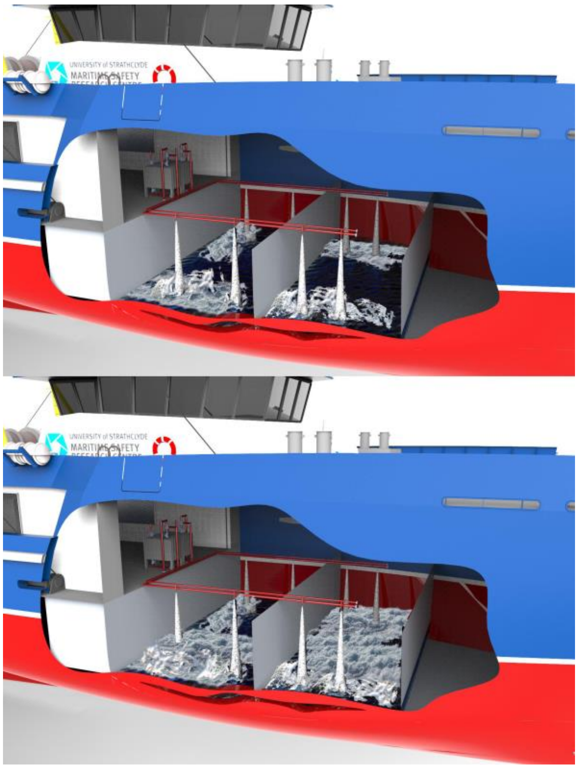

Figure 4: DSRS Graphical Representation

The system is interfaced and can be controlled from the Safety Management System (SMS) coupled with a Decision Support System (DSS), which in the event of a collision or grounding incident will provide the master with an advised course of action based on the extent of flooding, damage location and condition of the vessel. This is facilitated by a water ingress detection system with sensors located in the protected compartment and also within adjacent compartments both fore and aft of the protected space in order to cover damage lengths extending up to in most cases three compartment damage.

Finally, the foam compound meets all the environmental and health criteria, it is not harmful to humans, it is non-flammable and its release does not pose any danger to the crew on-board or the environment.

3. ADOPTED METHODOLOGY

Overview

One fishing vessel has been investigated with a view to assess the effectiveness of the proposed Damaged Stability Recovery System (DSRS) as a risk reduction technology. The study has been conducted with the aid of the probabilistic approach to damage stability (SOLAS 2009) as a means of establishing the initial level of flooding risk associated with the vessel. The effects of the DSRS have then been modelled in order to assess the risk reduction afforded by the system.

DSRS implementation & modelling

In order to ascertain the impact of the proposed system on vessel safety, the overall (collision) flooding risk level associated with the vessel had to first be identified, namely:

$$Collision\ Flooding\ Risk_{total} = 1 - A \qquad (1)$$

This provides a benchmark from which to gauge any improvement on the vessel safety afforded by the DSRS. In order to ensure the system is applied in the most efficient manner, it was reasoned that the compartment(s) protected by the system should be those which contributed maximally to the risk. As such, a risk profile of the vessel was created in order to aid in the identification of design vulnerabilities. This then provided the foundation from which a risk-informed decision could be made with regards to the compartment(s) that should be protected by the system while also highlighting the circumstances under which this protection is necessary.

The results from the probabilistic damage stability assessment afforded a straightforward way of determining the vessel risk profile by firstly considering the local risk associated with each damage scenario, as provided by equation 2 below.

$$Collision\ Risk_{local} = p_i \cdot (1 - s_i) \qquad (2)$$

These local risk values could then be mapped along the vessel according to damage centre in order to form the risk profile as depicted for an example in Figure 5.

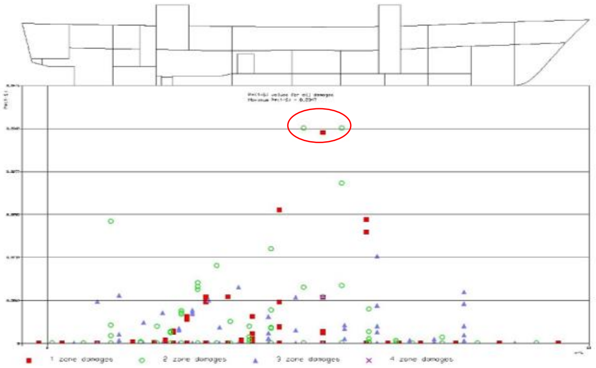

Figure 5: Example Case, Local Risk Profile

In the above risk profile, risk is plotted on the vertical axis and the damage position along the horizontal. Differing lengths of damage, as measured by multiples of adjacent zones, are distinguished by marker type and colour. This enables the identification of safety critical design areas, hence opportunities where safety could be improved most significantly and efficiently. Three cases in particular, circled in Figure 5 are identified as large risk contributors. As such, it can be reasoned that the DSRS would be best applied in the protection of one or both compartments, which give rise to this risk in the most efficient way.

The effects of the DSRS system were modelled through alterations to the permeability of the protected compartment(s) to account for the presence of the foam. The required volume of foam in each case was taken as the minimum volume required, ensuring the fishing vessel survived the most demanding high risk damage scenario (s).

4. CASE STUDY

Vessel overview

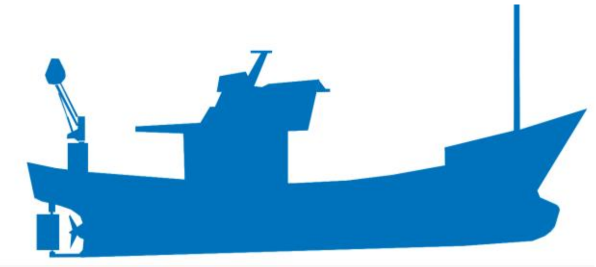

Figure 6: Vessel Profile

The vessel is an example of a typical fishing vessel operating within UK coastal waters. It is operated by 15 crew members with the provision of cabins for overnight sail. Also, it is subdivided into 8 watertight compartments and it is not equipped with life boats due to coastal operation. The principal particulars are provided in Table 1 below along with the vessel's profile in Figure 6.

Table 1: Main particulars

Displacement (t)	392.6
Length overall (m)	30.80
Length B. P. (m)	29.58
Draught MLD (m)	3.230
Breadth (m)	6.840
Depth (m)	6.40
Crew number	15
Gross Tonnage	230

Stability Assessment

Even though SOLAS 2009 does not apply to this type of vessels, it is an instrument that facilitates a whole-vessel vulnerability to (collision) flooding. In addition, it leads to a risk level estimation that offers a reference and a means of comparison with other similar vessels. Stability assessment is conducted in an iterative manner; the first, to identify compartments susceptible to high risk, whilst the rest to evaluate progressively the effects of the DSRS.

A total of 320 damage case scenarios are generated and assessed utilising the main three loading conditions in accordance with the SOLAS 2009 framework, namely the light service, partial and deepest subdivision draughts, which combine to form a theoretical draught range/distribution for a given vessel.

Table 2: Loading conditions

	Draught (m)	GM (m)	Displ(t)
Light (DL)	2.280	0.308	233.3
Partial (DP)	2.740	0.215	306
Deepest (DS)	3.230	0.374	390

The damage stability assessment results can be found in Table 3 along with the vessel's initial local risk profile in Figure 7.

Table 3: Initial damage stability results

Required Index	0.673
Adl	0.558
Adp	0.541
Ads	0.711
Attained Index	0.612
Risk (1-A)	0.388

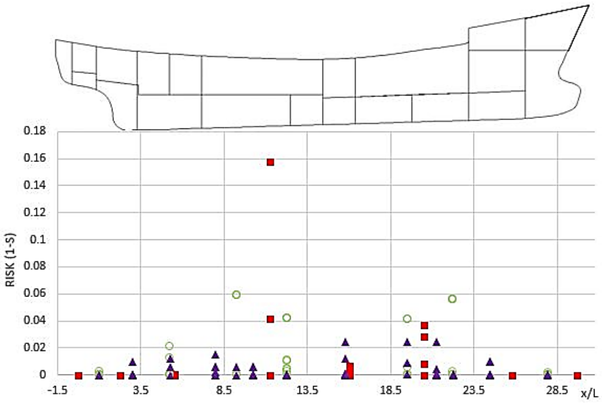

Figure 7: Initial local risk profile

It is apparent from the results that the vessel's risk profile reveals several vulnerabilities. The maximum local risk recorded is $P \times (1 - S)$ =0.16 for damage cases centrered close to the engine room. Two cases are identified as the largest risk contributors and therefore deemed appropriate for protection by the system. The first comprises the engine room, aft crew cabins and two centralised vivariums. In the second case, the fishing store compartment deteriorates safety and can instigate potential large scale flooding.

The total volume of foam required in these cases was identified as that required to mitigate the risk stemming from three compartment damages equating to 170 m^3 expanded volume. The expansion ratio of the foam is considered to be 50, thus the raw foam volume required is 3.4 m^3. Yet, the total weight of the system consisting of the primary and auxiliary components is estimated to be 9.1 tonnes.

The damage stability performance was then re-assessed following a permeability change to all the critical compartments to account for the effects of the foam. The new stability assessment results are provided in Table 4 below.

Table 4: Final damage stability results

Adl	0.92
Adp	0.97
Ads	0.98
Attained Index	0.96
Risk (1-A)	0.04
DA	36%
DR	90%

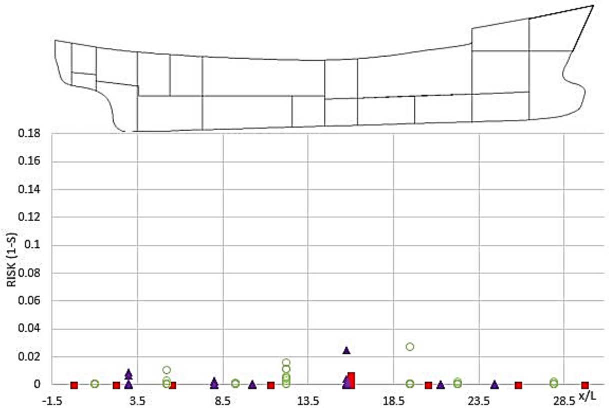

Figure 8: Final local risk profile

As presented in Figure 8, the maximum local risk has been significantly decreased to $P \times (1 - S) = 0.026$. The increase in the Attained index ensued from the implementation of the DSRS is 36%, whereas, the capsizing risk has been almost eradicated. In addition, the risk stemming from all three compartment damages has been eradicated for all potential damage case scenarios along the length of the vessel. This is an exceptional improvement in the damage stability of the vessel, accentuating the vital role of the DSRS.

Furthermore, the effect of the DSRS in decreasing the vessel's required GM limit curve is assessed, demonstrating further the improvements afforded. As it is displayed in Figure 9, in terms of damage stability alone, the new derived limiting GM curve compared to the original limiting GM curve yields a decrease of approximately 79% for the partial subdivision draught and around 55% for the deepest draught respectively. This can be translated into substantial contribution to the safety of the vessel.

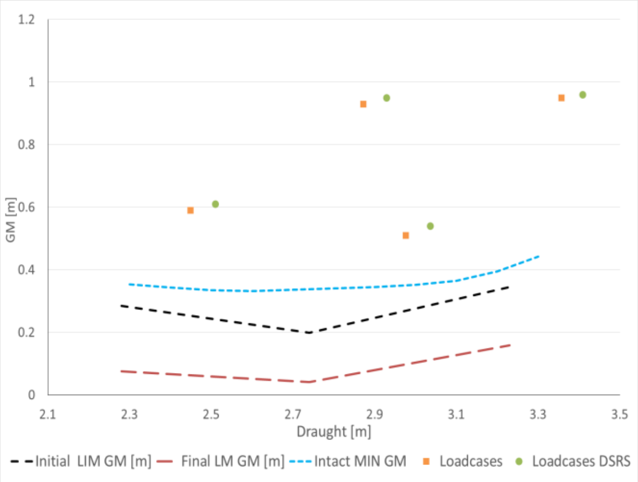

Figure 9: GM (m) for intact and damage stability

Intact stability is paramount for small vessels and therefore it is necessary to account for the change imposed by the additional weight of the system. As it is apparent from Figure 9, four different load cases have been assessed. The difference in the GM and draught can be justified purely by the increase in the weight. The effects of this change on the load case GM margin ranges from 2% to 17% reduction. Finally, the vessel complies with all fishing vessel intact stability criteria as outlined within IMO's resolution A749-4.2.

Importantly and expectedly, intact stability requirements for small vessels dominates over damage stability requirements with regards to limiting GM . This vulnerability of small fishing vessels is well known. Fisshing vessels, in general, are susceptable to parametric roll and broaching but these are not covered by any legislation and criteria. Studies (Gonzales et al, 2014) have shown that vessels with Froude number higher than 0.3 have a high tendency to these effects.

5. CONCLUSIONS

The Potential influence of the DSRS is indeed manifold. It has been identified as a non-intrusive cost-effective and very flexible solution to the damage stability problem of fishing vessels that does not interfere with the existing characteristics of the vessel or its functionality altogether, enabling the vessel to remain competitive whilst being safe.

Such improvement in safety represents a significant step-change, one that holds great promise for both new buildings and existing fishing vessels and with the potential to raise international and domestic safety standards, saving thousands of lives.

The use of an active system marks an important paradigm shift in the damage stability standards. The significant enhancement of damage stability levels, ushers in a new era of 3-compartment standard vessels.

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