DISCUSSION

COMPARISON BETWEEN DIFFERENT SURVIVABILITY MEASURES ON A GENERIC FRIGATE

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COMMENT

Professor D J Andrews FREng, FRINA, RCNC (Vice President)

The authors are to be thanked for publishing results from their Swedish Navy funded work into frigate Survivability. Given the sensitivity of the subject, while there have been a lot of recently published articles on the topic of warship survivability, it is worthwhile to get a view from a navy still considering relatively small warships to be frigates. It is also very helpful to have a set of four "Survivability levels" (at end of Section 2.1) to gauge a design's performance in this regard.

I have several aspects where I seek the authors' clarification: the definition of Survivability used; the practice of naval ship design with respect to the recent adoption of a classification society's "rules"; the lack of architectural definition on the example design; the structural scantlings for the "generic frigate"; the limitation on the results and conclusions:

Survivability: While at Section 2, Equation 2 correctly shows that the inverse of Recoverability needs to be combined with Susceptibility and Vulnerability to give Survivability, this ought to be spelt out in the definition above the equations.

Naval Ship Design Practice: It is considered that at Section 2.2 the comments on the applicability of a classification society's "rules" to naval vessels "set standards…(to) .. a minimum level" is misleading. There is a clear distinction between (commercial) ship rules and (so-called) "naval ship rules". Reference 30 summarises how the UK Ministry of Defence was the first defence department to adopt "naval ship rules" and points out that they differ distinctly in intent and application from their long standing commercial ship equivalents. In essence they are (a) flexible, (b) more advisory than certificates of compliance, and (c) recognise naval operating patterns (including high manning levels) [30].

Architectural Definition: It is surprising if the generic frigate presented has structural definition that there is not the equivalent definition of the ship's internal arrangement presented, especially as it is the above water threat that has been modelled, where the arrangement is considered more significant in assessing Survivability. In an equivalent UCL study the architectural definition was considered to be the key to the assessment of overall survivability (including a numeric assessment of Recoverability [31]. The UCL study also looked at a set of ship design options, including size (destroyer, frigate and corvette) and style (variant frigates with large hull and multihull) as well as two naval auxiliaries to compare combatant and semi-commercial designs [32], and had a comparative assessment of overall Survivability.

Frigate Scantlings: Table 2 provides plating thicknesses. These are questioned as being somewhat light for a 137 m LWL and 3,900 tonne(?) (Deep?) Displacement frigate. It is suggested that hull sides should be nearer 15 mm average and weather deck nearer 12-15 mm with only the superstructure plating looking reasonable?

Results and Conclusions: Conclusions like "(effect of) threat definition"; "avoiding single hit on specific functions" are considered obvious naval ship practice and the comparison with helicopter survivability not useful. It is hard to draw substantial conclusions when the major domain of underwater attack to structural strength lethality has not been addressed. Refs 31 & 32 were careful to avoid generic conclusions without addressing UW threats, since Reference 33 showed the quite different and complex nature of assessing this in a new combatant design, which is clearly a "buoyancy effect" (Section 4.2).

A final question concerns the Discussion remark that it is important to represent "the wiring and piping" (including the connections) and how do the authors believe this could be done effectively the concept phase of a combatant design?

AUTHORS' RESPONSE

First of all we the authors would like to thank **Professor Andrews** for his insightful questions and comments. Below we try to, in relation to the questions and comments, shed some light on the considerations and choices we made when we performed the study and wrote the article.

The frigate used in this study is not related to the Swedish Navy in any way. It is an 'open source' frigate independently developed that was chosen in order to avoid classified information (military as well as commercial). The choice will also allow for examinations and research on the same hull by different researchers all over the world.

We agree with Professor Andrews in that "the inverse of Recoverability needs to be combined with Susceptibility and Vulnerability to give Survivability" should have been more clearly spelt out in the text.

We also agree with Professor Andrews in that there is distinct difference between "naval ship rules" and commercial ship equivalents especially in that "naval ship rules" are flexible, more advisory etc. The Naval ship rules provide standards that increase the survivability of a naval vessel regarding for example demands on separation and redundancy of a ship's general systems such as propulsion and power supply. There is also some difference in how military equipment is handled within the different classification societies. Therefore, it is also important to point out that the "naval ship rules" cover a lesser percentage of the considerations needed in order to perform the design, we have chosen to call this "a minimum level".

The internal arrangement is also here shown to be important. As stated in the article the study only aims to compare differences between the four configurations examined. Therefore, we have focused on presenting the differences between internal arrangements for the four configurations, on a system/ component level.

The basic ship configurations investigated (Configuration 1 and Configuration 2) are chosen to represent a survival level achieved if only civilian considerations are made. The scantlings are therefore based such calculations alone which leads to somewhat light compared to naval ships of the same size.

The results discussed reflect the ship configurations examined and weapons studied. Other conclusions from the differences found should as pointed out not be made.

We are well aware of that also others has pointed out that the vulnerability calculations is sensitive to changes in the threat definition. However, the suggestions for how to deal with this problem are fewer. It is therefore important to start discussing how such uncertainties can be reduced and how remaining uncertainties should be treated such as using the vulnerability to identify the solution with the lowest sensitivity to changes in the threat, i.e. "the robust solution". For further discussions on this topic, i.e. how to deal with uncertainty in security critical decisions, see for example articles by Aven [34] and Liwång [35, 36]. In those articles the links between areas such as technology, concept of operation, tactics and threat modus operandi are central and must all included in the analysis.

Unfortunately "important" does not imply that it always can be done effectively. However, we try point out that survival concepts investigated in the concept phase (such as redundancy) must survive the design and construction phases and actually be reflected down to the last wire or pipe in the ship.

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