ACCIDENTAL DAMAGE TEMPLATES (ADTS). A BASIS FOR THE FUTURE OF NAVAL SHIP SAFETY CERTIFICATION?

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ABSTRACT

The stability standard used for United Kingdom (UK) Ministry of Defence (MoD) shipping activities is based upon Sarchin and Goldberg (1962) and it does not distinguish between what can be considered the capability to withstand hostile damage and a minimum level to safeguard against typical merchant shipping accidents. Furthermore there is not a robust link between residual stability and strength following damage. This paper gives discussion of the methodology proposed and assumptions made in order to determine accidental damage extents for naval ships based on experience by merchant ships.

Keywords: *Stability, Damage, Collision, Raking, Paramarine, Safety*

1. INTRODUCTION

Naval Ships are designed to withstand and remain afloat after substantial damage from hostile action. The capability to survive hostile damage will depend on the ship role and the value of the military asset. Generally larger ships tend to be more valuable in terms of a military asset therefore are required to be capable of sustaining larger extents of damage and remain afloat. The stability standard used for UK MoD shipping activities is derived from the Sarchin and Goldberg (1962) paper that outlines Stability and Buoyancy criteria for United States of America (U.S.) Naval Surface Ships. The paper addresses both intact and damage stability with the criteria proposed based on war damage experience, model and full-scale caisson explosion tests and general operating experience.

Currently the UK MoD stability standard does not distinguish between what can be considered the capability to withstand hostile damage and a minimum level to safeguard against typical merchant ship accidents. Naval ships face similar navigation hazards such as collision and grounding as merchant ships, yet the current standard does not distinguish between accidental and hostile damage.

As naval shipping activities are subject to more scrutiny by the public and adopting merchant standards there is a need to define a tolerable level of safety for naval stability in order to benchmark against merchant shipping activities. For naval ships one must attempt to distinguish between hostile and accidental damage, this has led to the following conclusion: Safety is driven by accidental damage whereas capability, which is a cost driver, is driven by hostile damage. It is reasonable to assume that a warship has a comparable probability of accidental damage as a merchant ship therefore a warship should offer the same level of safety as a merchant ship as a minimum.

This paper proposes a method of establishing a safety baseline that demonstrates tolerable levels of safety for naval stability with regards to residual stability and strength through use of the Accidental Damage Templates (ADTs). The ADTs would then provide a common approach towards residual stability and strength analysis.

2. ESTABLISHING A SAFETY BASELINE

In order to provide naval personnel with a level of safety comparative to statutory requirements one may draw the conclusion of adopting SOLAS as the standard however this option is not necessarily suitable nor practicable for a warship. Although SOLAS does address the safety of life at sea and MARPOL conversely the environment it does not address the value of the military asset.

Although direct application of SOLAS is not reasonably practicable using the same damage statistics and following the approach used by IMO would allow a tolerable limit of safety to be defined for naval stability. The SOLAS regulations are based upon statistics collated for the HARDER "Harmonization of rules and design rationale" research project undertaken by a consortium of European industrial, research and academic institutions. The HARDER Project considers two main damage mechanisms, collision damage and raking damage, the statistics consists of some 1851 collision incidents and 930 grounding incidents. Figure 1 displays a plot of HARDER data.

Collision damage is defined as ship to ship damage and raking damage is based on ship to ground/rock damage.

Evidence from the development of IMO regulations has shown that historically SOLAS requirements for Passenger ships have adopted around a 50th percentile of the collision statistics to define damage extents. Therefore one could analyse the HARDER data in the same manner as SOLAS to define a tolerable limit. The intent being to define a tolerable limit that is higher than the SOLAS limit as naval doctrine requires due consideration is given to the value of the military asset. This proposed method has the added benefit of also being able to “demonstrate at least as effective as statute” without the need to adopt SOLAS.

Accounting for naval doctrine, the value of the military asset and to ensure that the consequences of damage to a warship are proportional to the initiating event it is not appropriate to adopt a 50% percentile and that the tolerable level of safety should be based upon the 95th percentile damage extents for both collision and raking damage. For both damage types the statistical plots of cumulative distribution against damage size indicated that the point of diminishing return occurred approximately at the 90th - 95th percentile as shown in Figure 2. Full discussion of the statistical analysis and justification of the tolerable damage extents is presented in Peters (2007).

Figure 1. Non-dimensionalised HARDER Damage data.

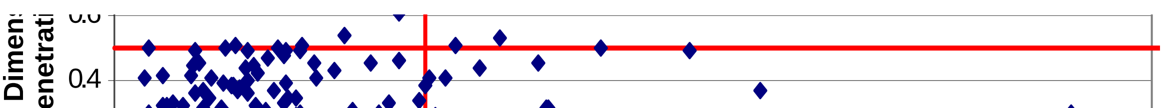

Figure 2 displays a proportional relationship between damage length and cumulative probability up to the 90th - 95th percentile region whereas beyond this region the proportional relationship is no longer true and the damage length increases vastly for a very small increase in cumulative probability. To illustrate the logic of focusing on the point of diminishing return one only needs to study Figure 2 and it is immediately apparent that designing to anything greater than the 95th percentile would not be reasonable or logical. Designing for the 95th percentile results in a 0.15 damage length however designing for the 100th percentile would double the damage extents to a 0.3 damage length. In order to design for anything above the 95th percentile a disproportionate amount of effort is required to protect against a low frequency number of events.

3. DAMAGE SEVERITY

Due to the range of statistical data, it is desirable to ensure that the consequences are proportional to the damage event and therefore, more than one damage templates size is required to represent different severities of damage from a small minor damage to a major significant event. Three damage severities are proposed which represent limited, moderate and significant damage severities.

Limited damage severity is broadly equivalent to SOLAS requirements with a 50% probability of exceedence hence using this template demonstrates SOLAS compliance.

Significant damage severity is based upon a major damage event therefore is based upon the 95th percentile representing the most extreme damage that a naval vessel would be expected to survive.

Moderate damage severity represents damage extents part way between Limited and Significant extents and is based upon the 80th percentile. The moderate severity of damage can be defined as damage that the vessel is able to survive without extensive damage control.

The significant damage severity represents the most onerous damage extents that a ships residual stability and strength will have to capable of withstanding and generally the larger the damage extents the bigger the problem. However it can be the case that smaller damage extents present more challenging stability and structural problems therefore including the moderate and limited severity extents ensure that smaller damage extents do not result in a worse stability or structural condition. Further to this is that compliance with the Limited extents demonstrates an equivalent level with SOLAS.

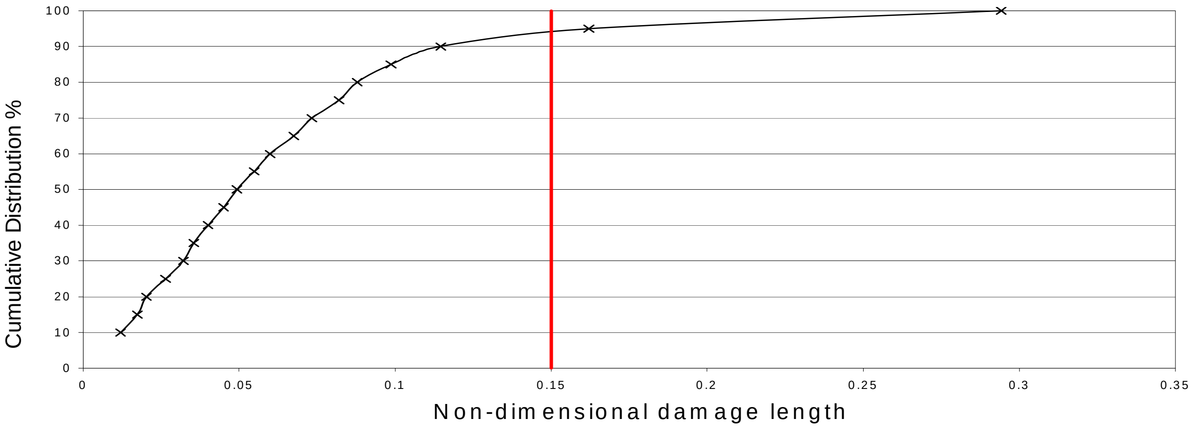

Figure 2. Point of diminishing return occurring approximately at the 90th – 95th percentile.

4. SHIP CLASSIFICATION

It is possible to categorise front line fighting vessels based on the vessel role which the ship is expected to operate in, rather than classification on ship length alone which is the current practise. Categorising the ships on the vessel role allows selection of the characteristic hostile threats from a variety of weapon types that the vessel is expected to survive operating in that role. The proposed categories for classification along with examples of ships within each category are presented in Table 1.

Table 1. Proposed ship classification based on vessel role as opposed to ship length.

Ship Type	**Category**	**Typical Length**
Small Patrol craft	1	30m
MCMV / OPV	2	50m
Frigate / Corvette / LSL / Small fleet tanker	3	120m
Medium Combatant / Logistic Ship / Destroyer	4	150m
Large Combatant / AOR / Tanker	5	200m
Large Carrier	6	275m

For accidental damage extents the advantage of categorising the ships by role and identifying typical ship lengths for each role is that the HARDER statistics can then be analysed in the same manor thus permitting one to determine damage extents for each of the ship categories. Due to the limited number of ship collision statistics for large vessels it was necessary to group together Categories 5 and 6. Similarly due to the lack of raking incidents it was necessary to group Categories 1, 2 and 3 together as one and group Categories 4, 5, 6 together and define raking extents for these two groups.

5. DAMAGE EXTENTS

The proposed collision damage extents that are based upon the 95th percentile analysis of the HARDER data are presented in Table 2. Please note that in all cases L relates to waterline length in metres and B relates to waterline beam in metres.

Table 2. Proposed Collision damage extents.

Cat 1	**Limited**	**Moderate**	**Significant**
Length	0.05L	0.08L	0.22L
Penetration	0.15B	0.25B	0.5B
Height	Full	Full	Full
Cat 2	**Limited**	**Moderate**	**Significant**
Length	0.05L	0.1L	0.22L
Penetration	0.15B	0.35B	0.5B
Height	Full	Full	Full
Cat 3	**Limited**	**Moderate**	**Significant**
Length	0.05L	0.1L	0.15L
Penetration	0.2B	0.2B	0.5B
Height	Full	Full	Full
Cat 4	**Limited**	**Moderate**	**Significant**
Length	0.06L	0.1L	0.15L
Penetration	0.2B	0.4B	0.5B
Height	Full	Full	Full
Cat 5&6	**Limited**	**Moderate**	**Significant**
Length	0.06L	0.1L	0.15L
Penetration	0.15B	0.4B	0.5B
Height	Full	Full	Full

The proposed raking damage extents that are based upon 95th percentile analysis of the HARDER data are is presented in Table 3.

Table 3. Proposed Raking damage extents.

Cat 1,2,3	**Limited**	**Moderate**	**Significant**
Length	0.1L	0.25L	0.5L
Width	0.1B	0.2B	0.25B
Penetration	1m	2m	2m
Cat 4, 5, 6	**Limited**	**Moderate**	**Significant**
Length	0.15L	0.45L	0.72L
Width	0.15B	0.5B	0.75B
Penetration	1m	2m	2m

6. TEMPLATE SHAPE DEVELOPMENT

ADTs were conceived as a method of combining the revised damage extents and ship classification in a common format to permit stability and structural analysis. The design intent being that the ADTs are simple in nature and highly intuitive to use yet still provide an accurate representative of the damage caused by a collision or raking incident. It is desirable that the ADTs can be parametrically scaled to the correct size for the vessel category and damage severity to be analysed. In the future Software integration of the ADTs is planned to permit analysis of residual stability and strength through generation of damage cases.

In attempting to develop the generic shape of the ADTs various research and simulations were undertaken, further to this many photographs were sourced however no conclusive damage shape became evident for either collision or raking damage.

6.1 Collision Damage Template

A generic collision template was modelled by representing the overall damage region with a full height vertical cuboid at the ship side containing a triangular cuboid thus representing a simplified bow penetrating into the side of a vessel as shown in Figure 3. The stability loss resulting from the collision is to extend to the extremities of the rectangular cuboid therefore any compartment in contact with this rectangular cuboid is assumed to be breached and fully flooded.

The structural loss elements of the collision template comprise of three different regions of structural loss. The triangular cuboid represents region C with 100% structural loss for the side shell, decks and any other structure that it encompasses. Region C has the same damage penetration and height as the overall damage extents but the length is only 50% of the overall template length as shown in Figure 3.

The bounding rectangular cuboid that encompassed the remainder of the damage region consist of region A with 50% structural loss for the side shell and supporting structure and region B with 10% structural loss for decks and supporting structure. The approach does not take account of the resistance of the structure to damage e.g. the energy approach, as in general warships have traditionally adopted lighter more efficient structures and now also adopting classification society rules.

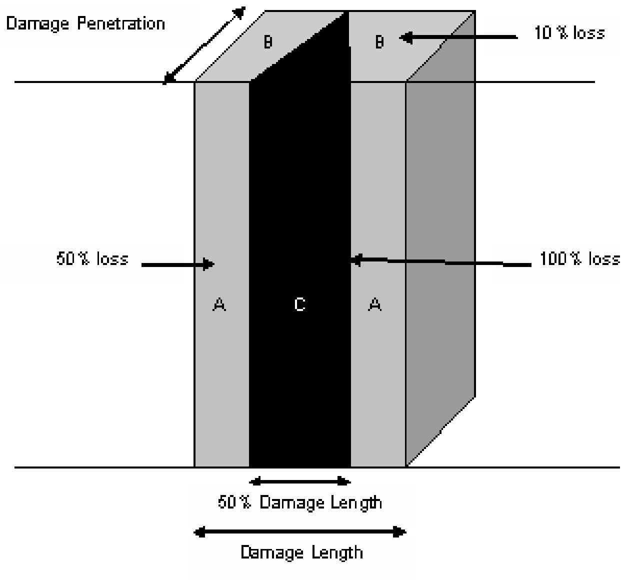

Figure 3. Collision Damage Template.

6.2 Raking Damage Template

The assumption used to model raking damage was that it was caused by a cone shaped rock dragging along the keel of the vessel therefore the resulting damage is representative of an inverted V shape. A rectangular cuboid running parallel to the keel represents the full extents of the damage and within this is a triangular cuboid as displayed in Figure 4. The stability loss resulting from the collision is to extend to the extremities of the rectangular cuboid therefore any compartment in contact with this rectangular cuboid is assumed to be breached and fully flooded.

With the raking template the structural loss elements are slightly different in nature due to the different location and orientation of the template. The triangular cuboid represents region C with 100% structural loss for the keel plating/side shell and other structure that it encompasses. For the raking template region C extends for the overall damage length but the width is only 50% of the overall damage width and only penetrating 75% of the overall penetration depth as shown in Figure 4.

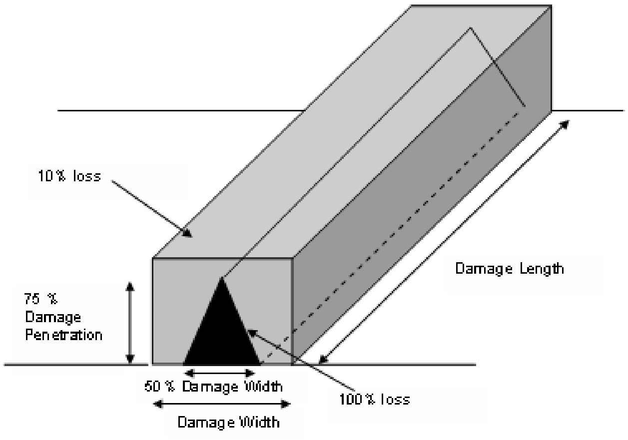

Figure 4. Raking Damage Template.

The bounding rectangular cuboid that encompassed the remainder of the damage region consists of region A with 50% structural loss for the keel plating/side shell and supporting structure and region B with 10% structural loss for bulkheads and supporting structure.

7. CONCLUSIONS

As naval shipping activities are subject to increasing scrutiny by the public there is a need to define a tolerable level of safety for naval stability. The method discussed within this paper proposes that a tolerable level of safety for naval ships will be achieved if they are capable of withstanding damage extents that are based upon the 95th percentile of damage extents as experienced by merchant shipping. This conclusion was drawn through statistical analysis of the HARDER database following the same method that the IMO used in the derivation of SOLAS. The damage extents have been used to define Accidental Damage Templates which form a common method of analysis for residual stability and strength.

8. ACKNOWLEDMENTS

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9. REFERENCES

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