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COMMITTEE V.5

NAVAL VESSEL DESIGN

COMMITTEE MANDATE

Concern for structural design methods for naval vessels including uncertainties in modelling techniques. Particular attention shall be given to those aspects that characterise naval vessel design such as blast loading, vulnerability analysis, specialised naval structures and others, as appropriate.

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1. DISCUSSION

1.1 Official Discussion by P. Jelle Keuning

1.1.1 Introduction

It is an honor and a pleasure to contribute to the ISSC symposium as discusser on the Committee V.5 report on Naval Design. Admitted, to be granted that honor has surprised me a little, given the fact that my experience in this field is somewhat “dated”. My main involvement was during my work at the Materiel Directorate of the Royal Netherlands Navy at the Department for Naval Construction, where my responsibilities included also structures and survivability. During that period I also had the pleasure of chairing the NATO Subgroup on Ship Survivability.[1]

However, in 2000 I moved to the position of director for research and development of the Ministry of Defense. This ended my direct involvement in naval ship design, but being responsible for the policy and planning of the S&T activities of the Ministry of Defense, I was still able to follow it “from a distance”. So, you will appreciate that my contribution as discusser will be mainly based on my experience gained during that early period of involvement in “Ship Combat Survivability”. And this not from a “scientists” perspective, but from the “MoD/RNlNavy” perspective.

Because the report is very extensive and carries a lot of information, it is impossible to discuss the entire content in my contribution. So I request your understanding that I will only address a few points.

1.1.2 General

The initiative taken by the ISSC to address Naval Ship Design via its Committee V.5 is much welcomed. From my perspective, creating the possibility for the community of researchers on this topic to exchange views and information is a valuable contribution to the enhancement of the expertise base. I have noted that already since 2006 the Committee V.5 has produced several reports related to naval ship design. And I would like to congratulate the ISSC for being able to construct such an experienced and highly qualified Committee.

I would also like to complement the Committee with their report. It is a very interesting and instructive overview of many items to be considered. The report forms a valued contribution on the topic, because it elaborates on a wide range of relevant issues to take into account when designing a naval ship. And as such is the living proof of the complexity of naval ship design.

However allow me also the following general observation. To my understanding it is the overall objective of the ISSC and her subordinate Committees reports to present and discuss a “state of affairs” on the topic under consideration, making a knowledgeable assessment of this and subsequently identify and/or recommend areas for future research. The present report could potentially have gained even more on impact on the design of naval ships if this approach would have been pursued more rigorously. On several issues an excellent overview is given, but the opportunity is not used to subsequently enrich these findings with a discussion nor followed by recommendations for follow-on R&T activities.

I fully support the stated objective of the committee for the present report, being to address the differences between naval vessels and commercial vessels. It is of prime importance that the structural designer is fully aware of these differences and takes the subsequent implications into account.

The stated quote in the report from ANEP 77 (Naval Ship Code) is in that respect very true and relevant. I would however like to add to this another quote, derived from the NATO ANEP 43 (on Ship Combat Survivability) stating[2]:

> *“The fundamental difference between civil and military use is that the performance requirements of the combatant requires survivability/vulnerability capabilities to fight hurt”*

This is to my opinion an arguably more demanding difference between a civil and naval ship. A naval vessel has to be designed to be able to still execute (part of) its mission also when weapon effects have been endured. The report addresses most of these military loadings, like blast, fragments, fire, UNDEX, etc., and its impact on the structural design of the naval ship. Pending on the specific capabilities required, this certainly results in much more demanding design requirements than usual for merchant ships.

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[1] Not only standardization and interoperability issues were addressed, but also R&D topics like development of development of design tool, full scale experiments, design aspects etc.

[2] ANEP 43 is a NATO document, classified “NATO Confidential”, and as such not available to a broader audience. The quote is from an unclassified Annex of ANEP 43.

I am certain that the Committee agrees that the capability of fighting hurt is a distinctive difference and must be explicitly included into the considerations when assessing the (structural) design of naval vessels. One could argue that, the most tangible design impact of "fighting hurt" is nowadays focused on system design and system lay-out, and that most of its impact on the structural design is in damage containment measures and in many cases not on issues like ultimate strength, shock resistance of the hull structure etc. which are (implicitly) considered to be already more or less adequately covered by the "inherent" abilities of the structure. It would be interesting to learn from the Committee what their opinion is in this respect.

It would also be interesting to learn from the Committee what their opinion is on residual strength after sustaining weapon inflicted damage in this respect. And in combination to this, how the Committee appreciates the case of damaged stability within this context. This is not included in the report; however it is a requirement for naval ships, with implications both on the design and operation, and as such an ongoing research topic for several MoD's. I am interested to learn the views of the Committee if structural design implications for this are to be taken in consideration and if so, how these should be addressed and which research efforts would still be required.

1.1.3 Naval Class Rules developments

Naval (structural) design has been given new attention due to the introduction of naval class rules by the Classification Societies. In the past structural design specifications were covered by (more or less) dedicated rules under the authority of the navies (owner). The involvement of the class societies has supported the introduction of the generic trend towards the "appliance of commercial standards as much as possible" in naval design. Main drivers for this new approach are generally speaking new procurement philosophies, efficiency and costs incentives.

It is well noted that these rules are becoming more and more available and applied in naval ship design. And the Committee is complimented with addressing this extensively in their report. The report gives a good overview of the developments of Naval Class Rules by the Classification Societies.

From this it is interesting to observe the several approaches that apparently seem to be followed by the different societies. Broadly speaking I learned there are two approaches to be distinguished:

- The rules cover these requirements, and define different levels by class notations.
- The rules are based on Military (Owner) based requirements and the CS do the compliance verification only.

With respect to the military operation hull strength aspects there seems to be almost consensus, the majority follows the first approach of class rules coverage. However, when dealing with the military hull performance scenarios (related to weapon impact) there is a clear distinction in two groups. The report does not elaborate on the implications and / or (dis)advantages of these two different approaches.

In order to stimulate the discussion on the implications, allow me to table a statement on this issue and, in doing so, invite the Committee to give their views.

> *"The preferred option should be to leave it to the owner to specify the requirements and to the Classification Society to ascertain (and maintain) the compliance."*

For this I would offer the following considerations.

The survivability requirements form an important part of the overall staff (operational/performance) requirements for any military capability. As such, they form one element in a broader set of operational requirements, which have to be overall balanced. Also in many cases (parts of) these specific requirements are classified. This all favors the specification by the owner.

The compliance will be ascertained by making (extensive) use of simulations codes. The report rightly gives a good overview of the state of the art of these codes for the different loads to be considered. It also addresses the importance of validation of these codes. This validation of codes is a very important quality assurance aspect for the design, but one that in the vulnerability domain is extremely difficult and costly to achieve. At this moment I am inclined to assume that this is still very much in the domain of the defense S&T community. One could argue that when the rules become more commonly applied the class societies are well positioned to play an positive role in this respect. If not now, than possibly in the future?

Following these considerations, the statement supports the approach followed by ABS and DNV. I would be very interested in the views of the Committee on this.

The policy of Class Ruling seems to be “commercial standards unless proven otherwise”. In that respect it is informative to note the reports statement that in most cases the societies publish a complete set of naval rules, however the general parts are copied from the commercial rule book. This raises a point of attention (not addressed in the report) of the possible risks associated with mixing commercial rules with military standards. In former studies the point was raised that caution should be exercised as the consequences of mixing standards may not be understood (overseen) to the full extent. Because rules are also based on data gained from (long-term) operational experiences, effort must be undertaken to assess the possible impacts of the (very) different operational usage between civil and military ships. This mixture may result in unforeseen incompatibility between the two with possible degradation in overall performance.

I do appreciate that this point is probably at the very heart of the efforts of producing naval rules by the societies, and I assume that over the last decade this issue has generated sufficient attention in the research community. It would be very interesting to learn the Committee views on this matter. Do they consider this issue of mixing is properly understood and addressed or do they recommend further attention and research into this matter. For example many of the general structural design aspects also influence vulnerability, for example material specifications (including steel quality), structural details, welding specs, stiffener type , quality control, etc.

1.1.4 Military Loads

The underwater effects chapter in the report describes both the primary elements of the loading by torpedo’s and mines, as the structural response associated to this loading. To be followed by a description of state of affairs (advances) in the numerical modelling. Within the context of this report, the chapter offers an excellent oversight of the underwater explosions (UNDEX) effects complexity. Also the inclusion of the results on the study on “Ship shock tests versus simulations” is illuminating and instructive.

Allow me the following observations related to UNDEX.

It is not self-evident if the discussion in the report focusses on the structural response, directly related to structural design issues, or if it also includes the simulation of the “shock environment” within the ship, which is of enormous importance for the shock hardening of the on board systems. Although these items are of course very closely linked (two sides of the same coin) it could very well imply that for both sides not all elements in the shock loading are equally important. And as such how inaccuracies in the modelling may influence the applicability of the different codes for predicting both sides of the coin. I would argue that in most cases the emphasis during the design is biased toward the “shock-environment” issue giving the shock loading of on board systems rather than shock hardening the hull structure. Could the Committee elaborate somewhat more if it considers the numerical modelling discussion equally relevant for both applications?

The recommendations derived from the study on “ship shock tests versus simulations” are well taken, but do deserve some further elaboration on some issues.

For example, the use for pre-test predictions is indeed considered to be of great value and a point well taken. However, I would be interested in the Committee’s views on the third recommendation related to the use for the extrapolation of the test results to charge geometries other than the used charge geometry. This because the UNDEX threat is normally not related to one specific charge geometry, and equal Shock Factors can be achieved by very different charge geometries. Would other charge geometries be considered to be equally well covered by the test results?

Close proximity explosions become an increasing concern, for which adequate simulations tools would be much welcomed. It is for that reason much appreciated that in the report attention is also given to this threat. The report state that good correlation has been achieved between numerical tests and experimental results related to hull deflection related to underwater dynamic loading. Given the complexity of the loadings associated with FLOATEX, I assume that further work is still necessary to be able to assess the threat in its full complexity.

Finally I would like to echo the Committee conclusion concerning the need of full scale validation. The Committee places in its conclusions proper emphasis on the importance of full scale experiments, considered to be necessary for appropriate validation of the simulation codes. As mentioned earlier, the use of the simulation codes for design and evaluation purposes depends heavily on the reliability of the outcome. Because these full scale experiments are sparse because of cost and environmental issues, I agree that there still exists a great demand for full scale experiments to enable simulation codes validation. Given its nature, I would argue that international cooperation could be a great enabler for this type of experiments. It is for that reason that I would be interested in the views of the Committee if it shares this pledge and how they appreciate the feasibility for international cooperation in this field.

1.1.5 Naval Specific Structure Design

This chapter gives an extensive overview on many naval vessel specific design items. In its conclusions the Committee is fully aware of the trend to increased flexibility requirements leading to more modular design approach. This trend in naval ship design and possible implications is fully endorsed.

For my contribution related to this chapter I would like to restrict myself to two elements.

In the past hardening the structure against blast, fragments and fire was performed without much attention on the "synergetic effects" with can be associated to these loadings, all originating from the same threat. This could result in an unbalanced outcome for the protective design measures taken. The appreciation of this situation has led to the awareness that more S&T attention should be paid to these synergetic effects in designing damage containment measures in naval ship design. I would be interested in the Committee views on the desirability and direction of this S&T effort.

Ballistic protection is in present ships due to the increase of terrorist threats an increasing concern. The solution is often found in both the development of new materials with enhanced properties and in the wider usage of armor steel. In order to mitigate the weight implications, armor steel development has enabled the usage as load carrying structural element also in more highly loaded parts of the ship structure. Is in the opinion of the Committee this aspect sufficiently addressed? Or should further developments be encouraged?

1.1.6 High speed naval craft

The report concludes correctly that the interest in high speed craft will continue to grow. The increased interest in littoral waters has led to more attention to smaller platforms within the navies and directing the research interest to these ships also for the ISSC community seems appropriate.

The report gives an extensive overview of the developments over the years in high speed craft development for naval applications, and the many (structural) issues that are at play, many of which are both relevant to civil and naval ships.

In addition to these important points mentioned in the report, I would like to raise the issue of the subsequently new challenges that arise for these type of ships when used in a naval application, e.g. for achieving adequate vulnerability reduction.[3] Vulnerability reduction measures and ship size are often conflicting. This is especially true for the high speed craft, which cannot readily accommodate weight penalties imposed by protective measures. The report rightly states that lightweight developments have a considerable momentum and impact on high speed craft. However I would argue that, although the Committee report addresses many important issues related to high speed craft, it does not explicitly identify the introduction of vulnerability requirements on these type of craft as an issue that may require new solutions to existing ones already in use for larger ships. So I would be interested in the Committee views on possible R&T topics to be pursued related to this. Possible issues could include to my opinion light weight protective measures (armor), damage containment measures, residual strength considerations etc.

1.1.7 Benchmark studies

Benchmarking is especially important in an area where validation opportunities using experiments are very limited. For that reason alone already the Committee is congratulated by bringing it up.

Although this is for that reason a very generic topic, the chapter focusses on one, very interesting, phenomena. The military threat of whipping due to UNDEX. Because experimental results related to this type of threat are scarce, the results derived from this unique experiment on whipping using a ship model are much welcomed and can be of great interest to the S&T community. Regretfully the Committee was not yet in the position to discuss the test results, so the report contained only the description of the test set-up.

In addition, I would offer a recommendation on another benchmark studies for the Committee to consider. This related to the naval rules by Classification Societies. Would it not be of great interest and practical value to investigate the feasibility of a "benchmark" exercise to compare the structural design outcome between the different Class Societies naval rules executed on a given design and set of staff requirements? Or is this simply too ambitious?

1.1.8 Conclusion

Related to the overall conclusions and recommendations, I would only endeavor to identify one element, which to my opinion deserves additional attention and recommendation.

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[3] Because these ships are frequently put into the role of "first responder" vulnerability requirements are considered appropriate, for instance protection measures for the crew.

The Committee, being congratulated with their very extensive coverage of the subject of naval design in the perspective of difference between civil and military applications, could to my opinion recommend one additional topic, which deserves further improvements and associated R&T efforts.

This relates to the usage of composites as a structural material. Both in civil and naval ships there is trend towards an increased application and an even bigger ambition for application. So, much can already be learned from the progress made and lessons learned in civil and military applications. The report is not very extensive on this topic.

The appliance in conjunction to performance when sustaining military loading is however still appreciated as a challenge. This is, as always, also closely related to the costs implications.

Although much effort is already put in this area, I would consider this an topic where more S&T is necessary to enable a wider application. Maybe an topic for future reports?

2. REPLY BY COMMITTEE

2.1 Reply to the Official Discusser Jelle Keuning

2.1.1 Introduction

The Committee would like to thank Jelle Keuning for his considered discussion and response to our committee report.

2.1.2 General

It is correctly observed that a discussion on the findings in the report is limited and we hope to clarify this in our response.The committee view the discussers report as a valuable addition to our committee's report and agrees fully with the quote from ANEP 43 that the capability of fighting hurt is a distinctive difference between most naval and commercial ships.

2.1.3 Naval Class Rules developments

We are happy to see that the Discusser to a large degree agrees with the committee's findings and views.He highlights two areas that raise principal questions on the use of classification rules for naval ships:

- The Class Societies approach to military loads
- Mixing of Commercial rules and military standards

In the case of the Class Societies approach to military loads, the Owner/Navy specifies the performance characteristics of the vessel and the Class Society handles the safety aspects (in a broad sense).

The question is: where to draw the line between performance and safety? Military survivability requirements involve performance and safety. The preferred approach should be to leave it to the Owner to specify the military requirements and to the Class Society to ascertain (and maintain) the compliance.

In the case of mixing of Commercial rules and military standards, the question is whether this is properly understood and addressed? The issue is probably understood, but perhaps not fully addressed. There is still a way to go before Class Societies and Navies have a coherent view on this.

Until there is a common view and transparent standards, the mixing of commercial and military standards is a dangerous sport.

2.1.4 Military Loads

The discussors comments on chapter 3 are generally supportive of the committee report. He is correct that both global structural response to UNDEX as well as the local response and impact on equipment are equally important. The methods described in this chapter can be used to assess the impact on inboard systems; however, of most interest may be the more simplified numerical approaches implemented by navies in their standards. Whilst review of these techniques would be of interest for inclusion in a future committee report, it is believed to be difficult to achieve in a comprehensive manner due to the classified nature of most of the publications on this subject.

In relation to the subsequent operability of equipment post shock event it is unlikely that this can be conclusively demonstrated without a physical test such as 'air-guns'.

With respect to Mr. Keuning's mention of International cooperation in full scale experiments, it is known that such tests have been undertaken by navies. However, due to the classified nature of the target vessel (even if a legacy vessel) and often the detonating charge type and stand-off distance, it is unlikely that such data will be widely available for verification purposes.

2.1.5 Naval Specific Structure Design

The Discussers points are well received regarding synergetic effects of blast and fragmentation on naval vessel structure. Specifically tying in his concluding remarks requesting further investigation of composites as structural design material for naval vessels, we believe more R&D should be performed regarding synergetic effects on materials other than steel. The progressive failure effects of blast, fragment and fire on naval ship designs of alternative materials as well as comparative results to steel would be most welcomed. We would also encourage the investigation of design techniques and systems to mitigate these effects in future studies.

We thank the Official Discusser for raising the issue of residual strength after weapon inflicted damage. In current methods weapon damage in idealised by using damage spheres and removal of the complete structure. In the residual strength calculation weapon effects such as blast overpressure, fragmentation and fire loading are not assessed. Damage stability is assessed by damage templates. Due to the separation and differences between the damage cases for structural strength and stability, it could be argued that the approach does not necessarily lead to the most optimum structural definition and better synergy could be achieved. We are aware of some effort in combining the structural and stability aspects of survivability but not yet available in the open literature.

2.1.6 High speed naval craft

We agree that the topic of vulnerability requirements for high speed craft may require new innovative approaches to address the vital characteristics of naval designs for high speed craft. Smaller high speed vessels may sacrifice some of the more traditional vulnerability attributes but may have decreased susceptibility through evasiveness and stealth. These craft need to be considered in an overarching survivability context including susceptibility and vulnerability.

2.1.7 Benchmark studies

We regret that the benchmarking results on whipping due to UNDEX were not timely available to be included in the Main Report Annex.

The suggestion for a benchmark study on the different naval rules is a good one. In the ISSC 2009 report such a benchmark with a naval rule comparison on a mid-ship section was described but only global hull strength was assessed for normal military operations. The general conclusion was that the results of all the rule sets are remarkably similar and show that each approach reflect sound physical principles. It would still be interesting to compare several Rule sets to a structure with the goal of addressing the entire hull girder design and optimization. This will allow better insight to just where the approaches differ.

2.1.8 Conclusion

The committee would again like to thank Jelle for his efforts and insightful comments. He has recognized areas which needed further clarification by this committee, and many of which ultimately need greater attention by the research community, hopefully in future ISSC committee mandates.