19th INTERNATIONAL SHIP AND
OFFSHORE STRUCTURES CONGRESS

7–10 SEPTEMBER 2015
CASCAIS, PORTUGAL

VOLUME 3

COMMITTEE IV.1
DESIGN PRINCIPLES AND CRITERIA

COMMITTEE MANDATE

Concern for the general concept of goal orientated design, for the quantification of general sustainability aspects in economic, human and environmental terms and for the development of appropriate procedures for rational life-cycle design of marine structures. Special attention shall be given to the issue of GBS as presently implemented within IMO. Possible differences between the current regulatory framework for ship structures and the design requirements developed for offshore and other marine industries shall be considered.

CONTRIBUTERS

Official Discusser: Toshiro Arima, *Japan*

Floor Discussers: Tetsuo Okada, *Japan*
Robert A. Sielski, *USA*

Reply by Committee:

Chairman: E. Rizzuto, *Italy*
J. Downes, *UK*
M. Radon, *Germany*
G. Egorov, *Ukraine*
Y. Kawamura, *Japan*
S. O'Neil, *The Netherlands*
R. Skjong, *Norway*
A. Teixeira, *Portugal*

CONTENTS

1. DISCUSSION

1.1 Official Discussion by Toshiro Arima

1.1.1 General Comments

According to mandate of Committee IV.1, the Committee has investigated followings by:

- paying special attention to IMO GBS and
- considering possible differences between the current regulatory framework for ship structures and the design requirements developed for offshore and other marine industries.

1. Concern for the general concept of goal orientated design;
2. Concern for the quantification of general sustainability aspects in economic, human and environmental terms; and
3. Concern for the development of appropriate procedures for rational life-cycle design of marine structures.
4. Having reviewed the report of the Committee together with previous ones in 2009 and 2012, I congratulate the Committee and its Chairman Prof. E. Rizzuto for the great success to complete its mandate in a holistic and comprehensive manner.

1.1.2 Specific Comments on section 1

1. With regard to sustainability aspect in an environmental term, ballast water discharges from ships, which are an important vector for the introduction of non-indigenous species into an area and can cause extensive damage to aquatic ecosystems, could be considered as one of the negative implications.
2. If so, how can its costs converted to a monetary unit to consider sustainability evaluation? Are there any papers to deal with this question?
3. When IMO developed FSA, converting human lives into a monetary unit was not accepted and GCAF and NCAF reported in section 2.3 are agreed upon. One of the reasons comes from an ethical problem and it is very difficult at IMO to agree on its coefficient to convert, which could be used globally and worldwide, while it might be possible nationally or non-globally.

In this context, what was discussed on the above-mentioned point in the Committee?

1.1.3 Specific Comments on section 2.2

GCAF and NCAF can be used when the risk under consideration is in ALARP region. In this regard, a paper dealing with a novel method for approximation of FN diagram and setting ALARP borders[1] could be a worth reviewing by the Committee in future. At MSC 95, it was introduced by Japan in MSC 95/INF.10.

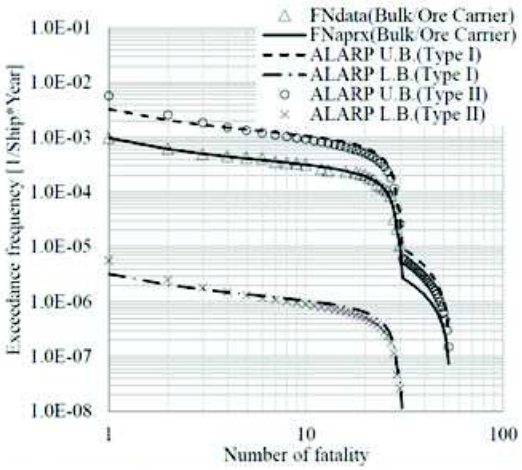


Figure 1. Two types of proposed ALARP border of bulk/ore carriers

1.1.4 Specific Comments on section 5

Concerning regulatory framework for offshore and other marine industries related to the mandate of the Committee, I cannot find review results of Health, safety and environment (HSE), which seems to me very important to understand differences regulatory framework for ship structures and the design requirements developed for offshore and other marine industries.

1.1.5 Specific Comments on section 5.1.1

1. IMO Secretariat advised the Maritime Safety Committee about the implementation of IMO GBS Implementation, i.e. Progress of GBS Initial Verification Audit at MSC 93 (2014) , MSC 94 (2014), MSC 95 (2015), with a view to submitting a final report to MSC 96 to be held in 2016.
2. The GBS audit has been conducted based on GBS Verification Guidelines, i.e. IMO Resolution MSC.296(87), parts of which are beyond the State-of-the-art concerning development of structural rules.
3. Generally speaking, Ships Structural Rules developed by classification societies are empirical but the backgrounds of IACS CSR have been developed and published for more transparency, where rational justification are included as much as possible taking into account of the state-of-the art.
4. It is suggested to review papers reviewing "ship structural regulations" such as Daley (2007) as well as many TB-Reports of CSR-H published by IACS in connection with "Justification" required by GBS verification guidelines.

Justification means providing the supporting data, analysis or other study that demonstrates the adequacy of the methodology, process or requirement.

It should include:

1. basis for the assumptions made;
2. description of the uncertainties associated with them; and
3. any sensitivity analyses carried out.

It includes documented rationale on which the validity of the hypothesis or criteria used in the requirements or calculations are based.

These may be the results of research work, historical data, statistics, etc.

For example, justification of safety factors should describe how the many related assumptions and uncertainties, such as environmental conditions, loads, structural analysis methodology and strength criteria, are accounted for.

Where commentary or data are requested, it is sufficient for such information to be contained in a rule commentary or other supporting documentation.

Daley (2007) [2] reviewed ship structural regulations with a view to aiming at clarifying best practice in regulations.

One is that classification society rules do not appear to have any significant factor of safety against yield at the design point. A second key point is that there is a significant strength reserve, and thus a factor of safety to be found in the plastic capacity of the shell structure. Consequently, it becomes clear that while classification society rules generally result in quite safe structures, different notionally equivalent structures can have quite different capacities, and thus different true factors of safety. The latest developments (e.g. Common Structural Rules) have added considerable complexity to the formulations, but do not appear to have addressed the points being raised here. The new requirements are still based on the traditional elastic section properties.

The plastic reserve is, at least for new construction with proper steel, quite significant and comes with little cost. How to optimize this is still not clear. Unlike elastic response, there is no one measure (such as section modulus) that predicts behavior. This is because plastic behavior is nonlinear and so superposition does not hold. Each structure requires a full nonlinear analysis. A method of assessing and comparing behaviors is needed. A measure, based on the full plastic capacity, would encourage better proportions and more effective steel. This is a direction that could give structures that are both safer and less expensive, and would serve everyone's interests.

1.1.6 Specific Comments on section 5.2

Background of BWMC

1. The danger that bacteria will be carried to a foreign country and an infectious disease will spread with ballast water was pointed out.
2. The concrete measure in IMO starts by concern over the alien aquatic species reported from Canada from MEPC26.
3. At the 18th IMO, "A.774(18) GUIDELINES FOR PREVENTING THE INTRODUCTION OF UNWANTED AQUATIC ORGANISMS AND PATHOGENS FROM SHIPS' BALLASTWATER AND SEDIMENT DISCHARGES" was adopted.
4. At the 20th IMO, "A.868(20) GUIDELINES FOR THE CONTROL AND MANAGEMENT OF SHIPS'BALLAST WATER TO MINIMIZE THE TRANSFER OF HARMFUL AQUATIC ORGANISMS AND PATHOGENS" was adopted.
5. International Convention for the Control and Management of Ship's Ballast water and Sediments, 2004 (adopted on 13th Feb. 2004)

*Outcome of MEPC 66 (Apr 2014***)**

– It was agreed to consider the amendments to the Guidelines for approval of Ballast Water Management Systems (G8) with a view to making them more robust due to a concern that Ballast Water Management Systems approved by IMO in line with G8 Guidelines cannot meet the standards depending on the environmental conditions.

Outcome of MEPC 67 (Oct 2014)

– It was agreed to establish a correspondence group to review G8 Guidelines.
– The MEPC resolution was adopted to clarify that the shipowners that have installed the BWMS type approved by the current G8 Guidelines would not be penalized after the application of the revised G8 Guidelines.

1.1.7 Specific Comments on section 5.4

Operational Stage

SEEMP (Ship Energy Efficiency Management Plan): operational measure that establishes a mechanism to improve the energy efficiency of a ship in a cost-effective manner.

Discussion on the CO_2 reduction scheme using MBM has been stuck.

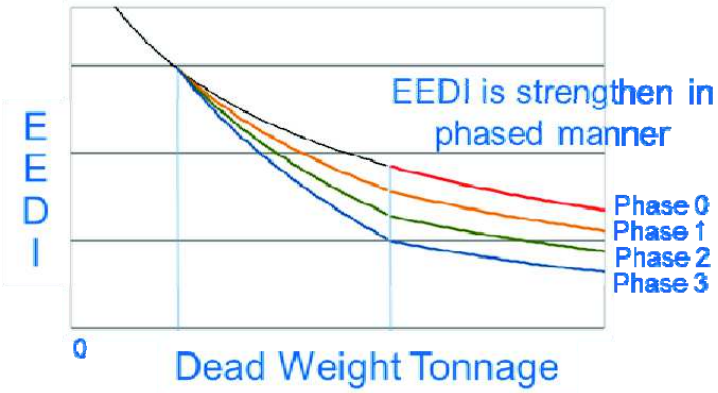
- IMO is considering a new scheme named MRV as intermediate measures between EEDI regulations and Market Based Measures.

Outcome of MEPC 67 (October 2014)

- It was agreed to establish a correspondence group again to further consider the necessary elements for MRV, including "ships to be applied", "data to be submitted" and "purpose of MRV".

Development of EEDI database

Development of EEDI database to data collection for review of EEDI requirement, required by regulation 21.6 of MARPOL Annex VI.



Outcome of MEPC 66 (April 2014)

- The necessary datasets and period for data collection were agreed. Ship type, Ship size (GT or DWT), the sailing date, applicable phase, EEDI limited value, Ship's EEDI, presence/absence of the application of innovative energy saving technology
- It was confirmed that the database would be used only for the review process at IMO and would not be publicized

1.1.8 References

[1] Fujio Kaneko, Toshiro Arima, Koichi Yoshida & Tomohiro Yuzui 2015, On a novel method for approximation of FN diagram and setting ALARP borders, Journal of Marine Science and Technology (JMST), Volume 20, 2015.

[2] Claude Daley, Andrew Kendrick, Mihailo Pavic (2007), New Directions in Ship Structural Regulations, 10th International Symposium on Practical Design of Ships and Other Floating Structures, Houston, Texas, USA.

1.2 Floor and Written Discussions

1.2.1 Tetsuo Okada (Yokohama National University)

Thank you for your valuable presentation on design principles and criteria. I have one question about intellectual property right, and two suggestions on the scope of the work of this committee.

In the current highly competitive industry environment, the concept of intellectual property right is becoming more and more important. Unless intellectual property right is properly protected, huge efforts for technical development in each individual company will not make profit worth the efforts, incentive for research and development will be deteriorated, and progress in technology will slow down.

However, it seems that recent development of rules and regulations tends to be in the direction of jeopardizing intellectual property right. For example, IMO adopted Ship Construction File (SCF), a broad range of technical documents, to be made available to the ship owner and the classification society throughout the vessel's life. The rules of classification societies are becoming more and more complicated and detailed, reflecting advanced design methods developed by leading companies, resulting in the situation that newcomers can use classification rules as design tools. All these trends may have made it more difficult for the original technology developers to protect their know-hows from disseminating into the industries.

In this circumstance, I consider that more discussion is necessary with regard to the ideal concept of rules, functional or prescriptive. Performance based functional rules will promote development of rational alternative designs, which will be prohibited under prescriptive rules. It will also be beneficial for protection of intellectual property right, because design methods will not be disseminated through the rules. I would like to ask the committee's view on this, preferably including comparison with the regulatory situation of other sector of industries, including the offshore industry and the aviation industry.

With regard to the scope of work of this committee, in my opinion, feedback from actual damages of ships and offshore structures is very important for rational development of rules and regulations. Publication of articles dealing with actual damages is encouraged, and it would be beneficial that this committee includes review of those articles in the next term.

Secondly, current rules require considerable amount of finite element analysis, making ship design work more and more demanding. On the other hand, rule formulae of scantlings tend to be very simple, and in many cases only deals with regular structural arrangement. Finite element analysis cannot cover everything, and rule formulae cannot cover everything, therefore, there may be an area, where only empirical formulae without theoretical background are still dominating. In this context, rule formulae reproducing more complex phenomena or irregular structural arrangement would be useful, and research activities in this direction are encouraged.

1.2.2 Robert A. Sielski

Starting at least 30 years ago, interest in reliability-based design methods increased to the point that several ISSC Congresses had specialist committees on the subject of probabilistic methods. Although some committees have discussed reliability, the Design Principles and Criteria have devolved only two pages of thein report on the subject, and the majority of that is on risk-based design.

Can the committee comment on the apparent decline in interest in reliability-based design and why it has not become standard practice today?

On the other hand, with increased interest in risk-based design, does the committee believe that the time has come for a specialist committee on that subject?

2 REPLY BY THE COMMITTEE

2.1 Comments by the OD

The committee is grateful to the Official Discusser Dr. Toshiro Arima for his thoughtful analysis of the report and his suggestions.

2.1.1 General Comments

The committee thanks the Official Discusser for his kind words about the general lay-out of the report.

2.1.2 Specific Comments on section 2

a) Environmental damage induced by ballast water

The problem of ballast water discharge from ships is indeed recognised by the international community and by IMO in particular as a threat to local aquatic ecosystems, which may be attacked and destroyed by non-indigenous species transferred by ballast.

To the knowledge of the Committee, this type of environmental damage has never been quantified in monetary terms, even though many documents describe it in a qualitative way.

It is noted, in addition, that, as for many other types of impact, implications may be very different depending on specific locations. In the case under consideration, the consequences depend very much on the places where ballast water intake and discharge take place. This would further complicate the problem of defining a 'generic' cost (valid worldwide) which should be achieved by average of different situations.

b) Indicators on human life

The Committee reviewed the indicators available to quantify the impact of regulatory requirements on human health. In particular, the report covers two aspects:

- Definitions of indicators allowing, within a cost/benefit analysis, an objective measure of the effectiveness of a given requirement.
- Acceptance criteria i.e. (lower) limits for such indicators, beyond which the requirement is to be considered as effective.

For GCAF, NCAF & DALY indicators, limits are expressed explicitly as upper value in $/averted loss (loss = fatality or loss of 1 year of healthy life).

In the case of LQI, the acceptability limit is embedded in the definition of the index: if the LQI increases as a result of the action to be evaluated, the acceptance criterion is satisfied. A limit in terms of cost per loss can be derived from the condition of increase in LQI and used to calibrate CAF or DALY acceptance criteria.

The limit values above recalled should be intended as societal willingness to pay to avert a negative event, not as the price for human life.

It is noted that, according to the definition of LQI, this willingness does depend on geographical location (life expectancy, Gross Domestic Product, % of productive life, all quantities entering the definition of the index, are actually area-dependent). Once again, averaging seems the only way for seeking criteria with worldwide validity.

2.1.3 Specific Comments on section 2.2

The Committee takes note of the recent and interesting paper mentioned by the OD, which raises a debate about the definition and the meaning of limit curves in FN diagrams. The paper was too recent to be covered in the report and will be most probably discussed in the next term.

2.1.4 Specific Comments on section 5 (HSE)

The committee accepts that the regulatory framework for off-shore and other marine sectors was not covered in detail, in particular as regards HSE documents. This was due to lack of expertise/ involvement of the members.

2.1.5 Specific Comments on section 5.1.1

a) GBS Audit

The committee is aware of the progress of the audit process and of the relevant recent documents: MSC 93-5, MSC 94-5 & MSC 95-5-1 (Implementation of the GBS verification audits – Secretariat), which were not specifically included in the review due to the schedule of report preparation.

The key document at the basis of the Audit process: Guidelines for Verification of Conformity with Goal-based Ship Construction Standards for Bulk Carriers and Oil Tankers, IMO Resolution MSC.296(87) adopted on 20 May 2010 actually is again not in the reference list (but it was discussed in the previous report)

b) Justification of Structural Rules

The Committee agrees about the improved transparency of modern Structural Rules issued by Class Societies, based on a clear justification of the requirements, as detailed by the OD in the question. The process has been recently exemplified in the documents produced for the above mentioned Audit process of CSR-H. The technical background documents relevant to CSR-H are referenced in the report.

c) First yielding vs ultimate limit state

The committee notes that the comment arising from the paper cited in the OD discussion points towards the adoption of ultimate limit states in the formulation of structural checks. By considering ultimate limit state, the post-yielding capacity of structures is accounted for. This trend is actually present in recent Rules (e.g. in CSR section about the hull girder Ultimate Strength). It is noted that the adoption of ultimate limit state in structural analyses may also quite easily be connected with a more systematic implementation of Risk Based design criteria (as the consequences of collapse are much more evident and quantifiable than those of first yielding, making more explicit a quantification of risk.

2.1.6 Specific Comments on section 5.2

a) Background of BWMC

The committee takes note of the list of background documents regarding the problem of water ballast and of the recent documents about Water Ballast Management Systems, but notes that these appear to be adjustments to the procedure (not yet into force, as presently the limit of approval of 35% of world tonnage has not yet been reached). Such adjustments do not seem to imply a change in the design principles that were adopted long time ago and were already examined in the previous terms.

2.1.7 Specific Comments on section 5.4

As regards the on-going discussion at IMO about the control of air pollution by means of an increased energy efficiency, the committee notes that the background documents about the SEEMP (Ship Energy Efficiency Management Plan) and the EEDI (Energy Efficiency Design Index) have been discussed by previous reports.

Recent documents from MEPC66 (April 2014) and MEPC67 (Oct. 2014) cover the discussion about the items to be included in the development of the EEDI database and a reconsideration of the road map for the control of ship emissions. A more gradual approach is envisaged, with monitoring, reporting and verification (MRV) of emissions as a first step, further efficiency measures for existing ships, and market based measures (MBM) in the mid-to-long term.

The committee is aware of such recent developments, but notes that they did not imply any major change in the founding principles of the IMO strategy on the subject and for this reason they were not explicitly recalled in the report.

2.2 Floor and Written Discussions

Many thanks to the Discussers for their written and oral comments and question raised. In the following the answers from the Committee, organized by Discusser and subject.

2.2.1 Comments by Prof. Tetsuo Okada (Yokohama National University)

a) Intellectual property

The subject of the protection of intellectual property is certainly very important in relation to the technology progress, in the sense that a proper revenue must be available for those who made the effort for achieving a technical advancement. The committee, however, did not cover in the report this aspect, which is felt to be beyond the borders of the mandate.

Taking the opportunity of this stimulating question, it is noted that the one of the main advantages of a sustainability based design, verified within a full probabilistic framework and a proper impact assessment is represented by the transparency of the process. Transparency means that the verification of the achievement of the final goals is not based on proprietary assumptions, but on clear formulation of goals and of procedures for verifying that they are met. This, as remarked by the Discusser, is not against the intellectual property of the designer, who is actually entitled of the burden of proof (as well as of the merit). A different design will require a different proof, which will challenge once more the skills of the designer.

The calibration of a deterministic-type requirement, on the other hand, is again a transparent process, which requires the same skills above recalled. This process, however, puts all the users of the final requirement on the same level, as no particular skills are necessary to apply the check.

This is a common situation in design by rules (where the responsibility of achieving the final goal is taken away from the user of rules, who is called only to verify the fulfilment of simple checks). On the other hand, the drawback of adopting a deterministic check is represented by a larger uncertainty in achieving the goal, which implies the need for a larger degree of conservativeness in the formulations of the check itself. The reward for the skilled designer should be represented by the savings of a direct design as compared to rule based design.

b) Exploitation of accident data

The committee agrees with the importance of databases on accidents and near accidents, which constitute important sources of data for risk analysis. It is also noted that important databases would be those coming from insurance companies, which, however, are proprietary and confidential.

Articles and detailed analyses on single accidents may also be of help, as they can shed light on specific hazards and/or sequences of events generating adverse consequences. On the other hand, this focus on specific analyses should not induce over-evaluation of single events/sequences (which would be against an objective evaluation of risk).

c) formulae reproducing complex phenomena

A further note from the Discusser regards the pray for studies about intermediate situations between simple rules on standard structures and direct analyses on complex structures. This need is seen as a natural implication of the calibration of simplified rules: when calibrating lower level formulations, the uncertainty in results is controlled by narrowing the range of application of the rules, thus requiring the definition of more cases (each one representing a narrower scope for the single formulation). Studies about the actual borders of applicability of rules are necessary and this includes investigations of intermediate situations.

2.2.2 Comments by Robert A. Sielski

The Committee notes that probabilistic methods for Reliability Based Design as well as for Risk Based Design are nowadays quite well established. This does not mean that a probabilistic approach is to be applied in any stage of design, but that it should be adopted in the calibration of simplified design checks (and this is actually occurring progressively). While probabilistic procedures are mature, the identification and evaluation of hazards and consequences (i.e. of the scenarios to which such procedures are to be applied) have evolved considerably. In this respect, a general aim of the report of our committee is to highlight how the concept of risk, which traditionally at IMO is mainly associated to consequences to human beings, should be extended to include also short and long-term consequences for the environment. In this context, the term of design for sustainability has been used in the report to indicate such wider perspective and a major part of the text has been devoted to the analysis of the present implementation of this concept. A similar trend is likely to be followed in the next reports of this committee.