Key-note address
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Ship Design Rules and Regulations
- An overview of major themes

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Abstract: This paper provides an insight into the ship safety legislation issues relating to ship design that has evolved in recent years, with a brief background on the risk-based approach that the shipping industry has adopted.
It outlines the roles of classification societies in ensuring that the ships are designed, built and maintained in good condition.
It also provides an overview of the development of the Goal-Based Standards and the common Structural Rules. Some critics even suggest that the discussion on the development of the Goal-Based Standards should have taken place some decades ago. Nevertheless, a good degree of progress is being made with participation from the flag states and industry organizations. The goal-based regulatory framework is expected to begin with goal-setting at the top-level, followed by breaking down the goals on the sub-levels. It means that once the Goal-Based Standards are developed, classification societies will develop detailed standards on ship structure and machinery by which the so-determined safety goals are achieved.
Major issues surrounding the development of the Common Structural Rules will be introduced.

Finally, the results of the Maxwave Project are discussed from the ship designer's point of view with the following summary:
- IACS Recommendation No. 34
- Analysis of shipping casualties
- Design parameters such as probability of encounter and return period
- Difference between shipping and offshore industry
- Voluntary reduction of ship speed

1. Introductory remarks

Ladies and Gentlemen,

I would like to thank you for inviting me to take part in this workshop. At the beginning of this year, the final reports of the Maxwave Project were published. The Senior Advisory Panel (SAP) finalized its report with recommendations for ways forward. As the cover note of the SAP report suggests, the Project has found its way to raise awareness of users in various sectors of the Society. Therefore, perhaps this might be a timely occasion on which to look at how the ship safety is addressed both at IMO and IACS and see what they have achieved – and then to look to the challenges ahead. Finally, I will suggest how the findings of the Maxwave Project should be carried forward.

As I understand, the main objective of this section of the workshop is to openly exchange our views and search for the answers to a few fundamental questions:

- First of all, to what extent will the findings of the Maxwave Project influence the shaping of the future ship design practices ?

- The answer to the first question is directly connected to the second issue: are the current ship design practices and ship construction rules, including the classification societies' requirements, adequate to the new times – and if they are, then to what extent? Do they respond to the new needs and are they an effective instrument for preventing and countering any perceived risks which modern ships are subject to.

I hope that this workshop provides an opportunity to understand what other stakeholders do play in their roles and to have an insight over these issues.

2. Roles of classification societies[1]

At the outset, it might be helpful if I were to update you as to what roles classification societies do play, and what is IACS in relation to IMO.
Classification societies have been subjected to much criticism, some constructive and some not. Constructive criticism is always welcome; however, to be truly constructive, it should be based on a full understanding of the roles of the Classification Societies and their considerable contribution to ship safety in the setting and maintaining standards for hull structures and shipboard engineering systems.

IACS Member Societies produce rules for hull structural design and essential shipboard engineering systems and apply them by means of appraisal of the design and survey of the ship and its systems. Additionally, the Societies apply the requirements of the IMO Conventions on behalf of more than 100 Administrations, also by means of design appraisal and survey.

[1] IACS and IMO, the established relationship (JRG Smith J D Rose, IACS, 2001)

Therefore, it is important to have a clear understanding of the separate but related functions of the Societies and the International Maritime Organization (IMO) in producing safety and pollution prevention rules and regulations for ships, and the functions of the Societies in applying them. It highlights the fact that compliance with Classification rules for hull structures and essential shipboard engineering systems is a requirement of the 1974 Safety of Life at Sea Convention (SOLAS 1974)[2].

Each Member of IACS can be defined as a Classification Society having comprehensive classification rules compiled on the basis of sound research and development, a worldwide network of well qualified surveyors' efficient and effective feedback of significant technical data via surveyors' reports and an internationally recognized quality management system. Their classification rules have been in a constant state of evolution and development, in some cases for over 200 years, and have traditionally addressed hull structures and shipboard engineering systems. Complying with these rules will ensure the provision of adequate overall or global strength, together with adequate local strength of individual components. For overall strength, a ship's hull must be capable of withstanding design values of still water and wave induced loads within specified stress criteria. Local strength, to resist modes of buckling, fatigue, yielding or brittle fracture, is obtained by compliance with the rules' material requirements and scantling formulations. In addition, the rules provide for the determination of scantlings of primary members (such as girders, floors, stringers) direct calculation procedures and permissible stress criteria.

A strength of the classification concept is that the societies act as independent bodies, giving an independent assessment of the status of the structure and machinery of a ship.

However, classification societies are not guarantors of safety of life or property at sea or the seaworthiness of a vessel in the sense that they have not full control over how the vessel is operated and maintained in between the periodic surveys. Further, proper and effective construction of the ship lies in the hands of the designer and shipbuilder. Human errors and poor workmanship may occur. Safe operation of a ship for its intended service depends principally upon the shipowner, the shipowner's representatives and the crew who operates and maintain the ship on a day to day business [3].

IMO Conventions, on the other hand, concentrate on other safety issues, such as the computation of load lines and conditions of assignment, stability, security, fire safety, life saving appliances, navigation lights and equipment and radio communication. IMO, as a specialized agency of UN, enables Member States to meet collectively for the purpose of producing international Conventions, instead of producing their own safety and pollution prevention requirements individually and in isolation.

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[2] SOLAS 1974 Reg.II-1/3-1 states that in addition to the requirements contained elsewhere in SOLAS 1974 As amended, ships shall be designed, constructed and maintained in compliance with the structural, mechanical and electrical requirements of a classification society which is recognized by the Administration in accordance with the provisions of regulation XI/1 or with applicable national standards of the Administrations which provides an equivalent level of safety.

[3] classification societies – what they do and do not do (IACS, 2004)

Despite records of achievement by IACS and IMO, regrettably, accidents do occur, no matter how much we seek to make ships built and operate safely. The circumstances that follow any major shipping accidents will inevitably have an impact on the image of the shipping industry as a whole. Therefore, there is a demand for more robust ships that will be safer and more productive for longer.

IACS initiated the Common Structural Rules program in June 2003 to improve transparency in rule making, and clearly define the rule objectives, thereby removing competition among classification societies based on specific rules, nor seeking to optimize steelwork to the detriment of the longevity of the ship. This is a huge step forward in the ship design rule making history where all the technical expertise of the classification societies is combined with the feed back input from the ship owners.

IACS plans to extend common rules approach to other vessel types, with container ships in the list.

The common rules have been developed with goal-based standards (GBS) in mind which are currently being laid down by the IMO. The objective of GBS is that a ship is built in accordance with rules that ensure a safe operating life for a particular type of ship over a specific period in certain prevailing sea conditions. Once such standards are set, classification societies with feedback from ship owners and operators, are to establish common rules to achieve the goals. Therefore, it can be safely said that classification societies would not compete on the necessary minimum scantlings. Instead, focus will be given to service delivery to their customers after the ship is built.

3. Improvements in ship safety legislation

It is often said that more than 80 % of accidents at sea are the results of human errors. It does not mean that for only 20 % of those marine accidents, interest parties other than ships' crew such as the ship designers, owners and regulators are accountable. From the design stage, ships shall be built to withstand the most probable worst damage scenarios in a hostile environment. However, in many instances, improvements in safety have been driven by accidents. This is not a proper way to deal with improving ship safety because decisions are not taken solely on a basis of sound technical analysis. The urgent need to introduce new requirements tailored to address the specific problems overrides.
Following a series of high profile accidents at sea such as Piper Alpha(offshore), Herald of Free Enterprise, Exxon Valdez, Scandinavian Star, and Estonia in 1980-1990s, the shipping industry was called on to adopt a risk-based approach in ship design and operation as other industries had practiced for years[3].

3.1 Risk-based approach

Having recognized a more holistic approach is needed in place of a piece-meal approach, and in response to the call for risk-based approach from various sectors, the IMO, supported by IACS, has introduced a more structural risk analysis process through a now so famous

[3] In an attempt to answer the question "Is safety given sufficient weight in ship design and technology ?", UK House of Lords Science & Technology Committee (Report 2992-92, 2nd report, 1992) recommended that UK should advocate the adoption of performance standards rather than prescriptive standards wherever possible.

"Formal Safety Assessment" procedure, and regulators are encouraged to examine potential areas and introduce appropriate risk reduction measures before a tragedy occurs. A number of FSA studies have been undertaken, with bulk carriers FSA studies heading the list.

Many of classification societies also are moving towards the application of risk methodologies to the establishment of classification rules for both the design and operational maintenance of ships' hulls, machinery and marine structures. This risk-based approach will *supplement* the traditional prescriptive approach, allowing variation from prescriptive rules provided that the system (ship) risks are maintained at acceptable levels [4]

The advantages are: a systematic method is put in place to seek to establish ship safety regulations on the basis of assessment of risks, costs and benefits. Further, this method is characterized by being both rational and systematic, thus generating confidence that regulatory decisions based upon its use should be robust and defensible.

In addition, classification societies introduce a reliability-based method for ship hull structures that can be expressed in a special format such as the Load and Resistance Factor Design (LRFD) format.

All these efforts stem from the shared understanding that changing rules in immediate reaction to casualties prior to discovering main causes is an inadequate way of addressing the ship safety issues, and from the demand of the shipping industry as a whole that ships are to be built more robust and operate more safely.

3.2 Common Structural Rules (CSR)

IACS Joint Tanker & Bulker Project teams are currently developing the new rules under the IMO's "goal-based standards" principles. What this means in practice is that classification societies will agree common structural rules enabling robust tankers and bulkers to be built, fit for purpose and effective and safe operation, to last for a period of 25 years, corresponding to 10^8 wave induced load cycles. Differences in scantlings or longitudinal strength requirements will be removed so that new ships conform to common standards, whichever Classification Societies oversee their construction. Matters of significant importance are as follows:

- The ship's hull girder strength should be sufficient enough to withstand North Atlantic ocean conditions for 25 years (25 year return period). The North Atlantic is regarded as the most severe. The 25-year significant wave height is equal ca. 16.0m which corresponds to ca.31.0 m individual wave height.;
- Net Thickness Approach (as opposed to gross scantling approach)

  The net scantling approach (.i.e. excluding nominal design corrosion margins) is intended to ensure that, with protective coating and good maintenance, the minimum global and local strength requirements to resist all the failure modes will be met over the ship's intended service life.

  Under the older rules, the corrosion margin is given as a percentage figure of steel plate thickness but the new rules will give an absolute minimum figure corrosion margin.
- Fatigue assessment and fatigue details catalogue

[4] MSC 72/16, Decision parameters including risk acceptance criteria, Norway, 2000

Survey procedures – renewal criteria for explicit wastage allowances. Similarly to the net thickness approach, the fatigue life of structural details is based on a 25 years unrestricted service at the North Atlantic sea conditions.

This initiative utilizes in the best way the combined experience and know-how of all IACS members.

To fill the gap between design appraisal and survey during construction, IACS is, in parallel, developing a standard procedure for survey and inspection during new building construction.

3.3 Goal-Based Standards(GBS)

Based on a proposal by The Bahamas and Greece, the IMO Council agreed to include the development of Goal-Based Standards for shipbuilding into its Strategic Plan[5].

The basic principles of the proposed goal-based regulatory framework, as shown in Fig.1, are:

- The goal-based standards should represent the top tiers of the framework, against which the ship safety should be verified both at design and construction stages, and during ship operation.
- The goals are not intended to set prescriptive requirements or to give specific solutions. However, they should be clear, demonstrable, verifiable and long-standing and capable of adapting to changes in technology.
- The goals should be achieved either by compliance with published technical standards or by means of alternative solutions providing an equivalent level of safety;
- The requirements developed and applied by national Administrations or Classification Societies acting as Recognized Organizations should be capable of demonstrating compliance with the goal-based standards.

[5] IMO Strategic Plan (MSC 78/6/2, February 2004)

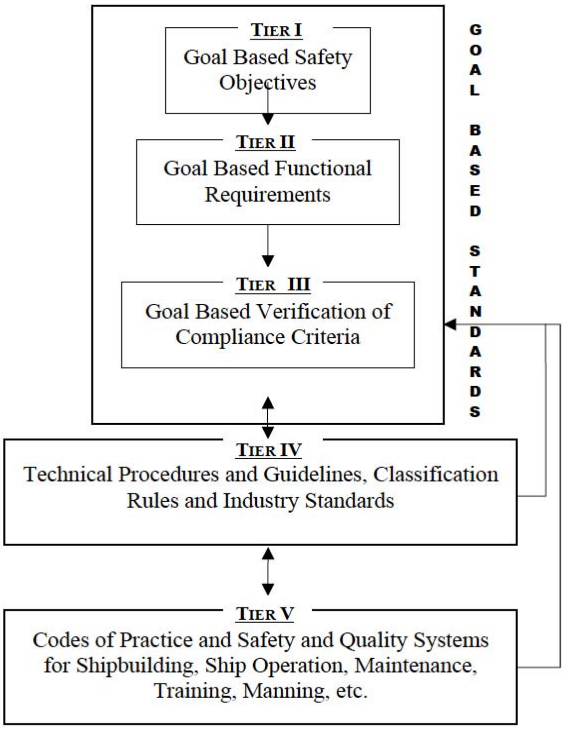

Figure 1. Goal-Based Regulatory Framework[6]

The mechanism by which the goal-based standards will be put in place are as follows:

- IMO sets the goals;
- IACS develops classification rules and regulations that meet the so-determined goals;
- Industry, including IACS, develops detailed guidelines and recommendations for wide application in practice.

It should be, however, noted that even at the time of this writing, IMO members governments and non-governmental organizations are voicing their views on how the discussion on GBS shall be carried forward. Though IMO is currently focusing its attention on the GBS for the design and construction of new ships, the scope of application of the GBS will soon be extended to cover quality and uniformity on how ships are to be surveyed during construction, another important aspect of ship safety prior to the delivery of the ship.

Figure 2 is an example showing how the classification rules would stand under the IMO's goal-based standards.

[6] MSC 78/6/2, Goal-Based Standards, The Bahamas, Greece and IACS, 2004

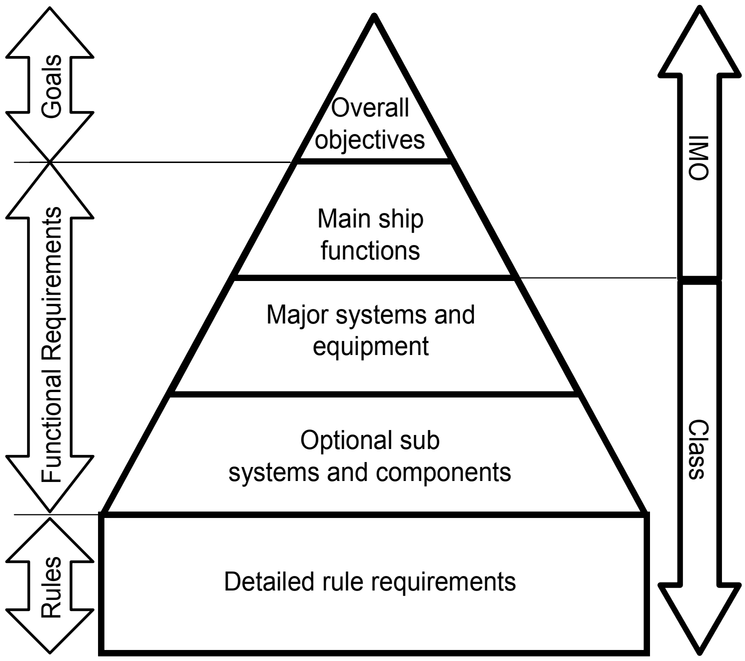

Figure 2. GBS and class rules

4. Freak Waves

4.1 General

Waves which influence the behavior of ships at sea exhibit a notably random behavior in nature. For engineering purpose, waves need to be described by probabilistic models.
One of the important tasks in ship design is the estimation of an extreme design wave from the recorded wave data. In other words, a good degree of understanding of the random seas enables designers to predict ship motions, wave-induced forces, bending moments of ships and dynamic pressures at sea, or, more generally speaking, prognosticate wave loads. These engineering disciplines are well established in naval architect, ocean engineering, offshore engineering and coastal engineering.

IACS standard wave data [7]is applied as a standard probability of sea states for long-term prediction, while wave data for representative worldwide trading routes can be applied, using the Global Wave Statistics, North Pacific wave data and Walden's North Atlantic wave data. It recommends the Bretschiender or two parameter Pierson-Moskowitz spectrum for the North Atlantic which includes the most important factors in ship design: significant wave height and wave directional spectrum.
For the purpose of ship design, information is needed not only on the severity of sea states that the ship is expected to encounter during her life time (e.g. 25 years), but also on the frequency of occurrence of sea conditions, the former being most commonly represented by significant wave eight and the latter being important for fatigue analysis.
IACS Recommendation, by its definition, is of recommendatory nature. IACS Members are not bound by it, however, it provides at least guidance as to the use of wave data, determination of return period (RP) and probability of exceedance.

[7] IACS Recommendation No. 34 – Standard Wave Data, 2001

4.2 Freak Waves

Notably, Draper. L suggested two aspects of freak waves[8], which were followed by other researchers (M.Ochi, R. Dean, etc) to continue using the term “freak waves” and develop a theory for application to a real ocean wave spectrum.

At this stage, no authoritative definition of “freak waves” which represents the observed abnormal waves such as the New Year Draupner wave yet exists. Even the terms for such waves vary ! The commonly used criteria to define freak waves, Hmax/Hs > 2.0, a ratio between maximum wave height and significant wave height, is still challenged due to its shortcomings in representing the full spectrum of the surrounding sea states.

Even if it is the correct definition of a freak event, the question of highly non-linear lifetime maximum responses of a ship to freak waves has to be addressed with caution.

It is noted that recent advances in wave generation and measurement techniques have led researchers and oceanographers to investigate the existence of the so-called “freak waves” and their physical/statistical characteristics. “Maxwave” project was a most recent collaborative research program.

Careful follow-up of the researches in the Maxwave project makes of impressive findings[9]:

- Traditionally, this type of waves have been observed only occasionally under unexpected condition. However, by virtue of an advance mode of measurement and data analysis techniques, the occurrence of freak waves has been analyzed and measured.
- Better understanding of the mechanism generating such waves was gained.
- Most importantly, the analysis of shipping casualties is expected to lead to the development of a mechanism by which shipmasters will be alerted of an occurrence of freak waves, so as to enable them to take precautionary actions.

With respect to the areas of future study as a result of the Maxwave project, I wish to add the following comments:

- The design practice is moving towards a more consistent probabilistic approach, for example, extremes are determined for a given return period (e.g expected lifetime of the structure). In order to consider the effect of freak waves in ship design, the probability of occurrence and also the probability of a ship encountering such waves need to be quantified. This involves a rigorous analysis of shipping casualty database. It is not unusual that the lack of casualty data, or more precisely speaking, lack of information on the core causes of the reported casualties, can lead to a misleading or unfounded conclusion. Therefore, a degree of accuracy in data analysis in dealing with uncertainty needs to be assured and the process needs be made transparent.

  The findings of the Maxwave Project indicate that freak waves, due to their extreme steepness, normally last for very short periods before breaking. Hence, the probability of a ship or platform meeting such waves is even significantly lower than the probability that these waves occur in the ocean.

[8] Draper.L, freak ocean waves, 1964
[9] Maxwave Senior Advisory Panel (SAP) report, 2004

Further, shape of freak wave profiles both in space and time including their kinematics and ship responses to freak waves should be analyzed and be well documented.

- A distinction is to be made between ship structures and offshore structures.

  Offshore structures normally operate at fixed locations and often require a unique design. Unlike offshore platforms, ships have forward speed. The methods applied for wave load calculations are different between ships and offshore structures. Master' practice to adapt ship, course and heading to extreme environmental conditions need to be taken into account. Offshore structures cannot actively avoid heavy weather in the same manner as shipmasters do[10].

  In that sense, it is very encouraging to see that the Maxwave Work Package.8 reported that Manual of Marine Met services could provide additional information on abnormal waves in the list of potential parameters for warning. A software tool in support of the master's decision-making under abnormal wave conditions has also been shown in various occasions[11].

- The validity of a non-linear wave theory and mathematical model for freak waves developed in the Maxwave Project should be verified, i.e. how well the prediction of the theory agrees with the actual measurements. I believe that this is an area for further research as one of recommendations of the Maxwave project.

5. Concluding remarks

With 95% of world trade dependent upon maritime transportation in one form or another, a massive increase in shipping transportation may occur over the next 25 years[12].
Whether this prediction is accurate or not remains outside of the scope of this workshop. However, these figures compel us to an ever increasing need to ensure that ships are built to the highest standards and operate safely for their intended life-time.

Now, challenges lie ahead. It is important to note that whatever level of quantifiable risk we deem acceptable today will without doubt be declared unsatisfactory by the media and public once that level is exceeded in an accident involving a catastrophic consequences. Though our responsibility is to learn from the incident and find a means of preventing it from happening again, it is equally important to bring the risk-based safety standards to practice as a means of addressing the ship safety from a much broader perspective.

In addition, new knowledge gained from the advanced technology shall be fed into the design rules whenever found necessary.

I hope that the updates on the current major themes in the shipping industry that I have provided will assist you in the application to your own fields of interest. Finally, it is

[10] The classification rules presuppose that the ship will be operated and maintained by a competent and adequately trained crew. Together with the making timely and precise decisions to change the ship's heading, the magnitude of voluntary speed reductions in extreme sea-states has been part of the art of seamanship.
[11] Shipboard Routing Assistance (H. Rathje(GL), Design & Operation for Freak Waves, 2003, London)
[12] US Department of State, Blue Water Project, 2003

encouraging to see that the scientific researches on the freak waves continue and have entered into a Post-Maxwave phase with more tailored research objectives.

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