Safety of bulk carriers - prime concern of the maritime community

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ABSTRACT

Further to the severe damages which occurred in the recent years on bulk carriers, the paper addresses the improvements which are envisaged to enhance the safety of bulk carriers and to avoid re-occurrence of such casualties.

First, a summary of the main causes of the damages is given, through examination of the results of investigations carried out by regulatory bodies.

Various actions have been undertaken by national and international authorities and by Classification Societies, through IACS or individually. In a second part, the paper examines some of these actions, emphasizing how they will improve the safety.

It is well known that many factors influence the safety of ships, among which the design, maintenance and operation are the most significant ones. Each of these factors is examined in the paper, with emphasis given to the extent of amendments introduced in the IMO and Bureau Veritas regulations:

- amendments to Bureau Veritas rules for the design and construction of bulk carriers are summed up,

- the maintenance is recognized as a key factor of ship safety. Actions have been undertaken by IMO and IACS to ensure that hull structure remains permanently under satisfactory conditions. Main topics of these new regulations are discussed and their consequences on the design and operation of bulk carriers are studied.

- the ship operation is also questioned as a parameter which influences significantly the ship safety. The paper addresses proposals to improve the knowledge of the structural behaviour during loading and unloading operations thanks to the fitting on board of monitoring systems.

In conclusion, the paper emphasizes the prompt reaction of the maritime community (shipbuilders, shipowners, operators, classification societies, flag states...) to find and implement appropriate counter measures towards the recent casualties of bulk carriers.
GENERAL

The statistics established by various international bodies made evidence, for the last twenty years, of a decreasing rate of ship casualties and ship losses, as shown in Figure 1.

![Figure 1 Worldwide vessel loss rate for commercial ships (Source: Data from Lloyd's Casualty Reports)](image)

Unfortunately, in the recent years, an unacceptable increase in the number of bulk carrier casualties was reported, since more than 40 bulk/combination carriers have been damaged or lost together with almost 300 crewmen missing.

This number of lives lost and structural failures reached an unacceptable level for the maritime community for whom the safety of life at sea has always been of prime concern and led all the involved actors - IMO, Governments, classification societies individually or through the International Association of Classification Societies (IACS), shipowners, operators, shipbuilders, underwriters - to react promptly towards this situation.

Preliminary investigation of the possible causes for these losses, showed that the damages occurred on ships of about 19 years old carrying iron ore in most of the cases and that the capsizing was generally consecutive to the flooding of one or more holds.

However, prior to taking positive measures with respect to the design, construction and operation of bulk carriers, it was necessary to have a good understanding of the situation in determining the possible scenarios for these casualties.

Conclusions of these investigations are given in the first part of the paper while the second part details the actions undertaken by the maritime community to improve the situation and avoid the re-occurrence of such casualties.

CONTRIBUTING FACTORS TO HULL STRUCTURAL DAMAGES

Examination of the records of hull structural damages occurring on bulk carriers in service shows that types of damages depend on the age of ships:
- for ships of less than 10 years of age, the damages are local and mainly caused by structural discontinuities or stress concentrations,

- for ships of more than 10 years of age, damages concern larger structural members, such as:
  . transverse web frames,
  . cargo hold main frames and their end connections,
  . transverse bulkheads,
  . side shell,
  . hatch corners, hatch coamings and hatch covers.

Examples of some of the damages which contributed to the recent bulk carriers casualties, are described hereafter more precisely.

Topside tanks
They are intended for the carriage of ballast and are generally protected against corrosion by coating and/or cathodic protection.

However, once the coating protection begins to break down, corrosion occurs in highly stressed areas, accelerating the initiation and propagation of cracks:

. the connection of longitudinals to transverse web frames is particularly sensitive to corrosion cracking, leading to the buckling of longitudinals which are no more efficiently supported in way of the transverse web frames and, consequently, to the reduction of the hull girder longitudinal strength.
In addition, corrosion cracking of the sloped longitudinal bulkhead plating may lead to water leakage into the cargo holds.

. the lower part of topside tanks is bounded by a longitudinal plate on which the cargo hold main frames are bracketed. Continuity of these brackets is ensured within topside tanks as shown in Figure 2.

![Figure 2](image_url)

Corrosion in area A may initiate and accelerate the propagation of cracks at the upper end of cargo hold main frames.
larger damages in topside tanks may be explained by the development of overall and local corrosion leading to the buckling and cracking of the corroded structural members.

Strength deck - Hatch covers
The strength deck areas where risks of cracking exist are well-known; they are:
- hatch corners,
- hatch coamings,
- upper deck strips between hatchways.

All these areas are exposed to weather conditions and, consequently, are to be properly protected and maintained against corrosion. The consequences of corrosion associated to crack initiation in highly stressed areas of hatch corners or hatch coamings may lead to major deck cracking.

Generally, upper deck strips have reduced scantlings in comparison with the strength deck, thus reducing their resistance to compressive loads. Where buckling of upper deck strips occurs, the increase in deformations of hatchways under wave torsional loads may cause:
- the loss of weathertightness of hatch covers, particularly at the fore end of cargo holds,
- the flooding of cargo holds, and finally
- the loss of ship stability.

As far as securing devices and weathertightness of hatch covers are concerned, their damage may lead to the flooding of holds in heavy sea conditions and, consequently, to the loss of ship stability.

Side shell framing
More severe side shell damages have been reported, such as:
- cracks and buckling of side shell frames,
- cracks at the lower end of hold frames, and
- large cracks in side shell plating between topside and hopper tanks.

Thorough investigations have been undertaken to explain the causes of these damages which seem due to high and accelerate rates of corrosion. This mechanism of corrosion of cargo hold main frames may be explained as follows:
- main frame connections to the side shell and end bracket connections to the hopper and topside tanks are subjected to local wastage caused by corrosive cargoes such as high sulphur coal.
- due to the difference between the inner and outer temperature, the cargo moisture condenses. The condensation creates a down stream of acid water, mainly at the connection of main frames to the side shell and at the bracket web connection to the hopper. The corrosion pattern is shown in Figure 3 and, in particular, webs of main frames corrode twice quicker than the side shell plating.
Cracks occur in many cases at the bracket toes and develop rapidly into the hold frames. Where one or several hold frames are detached from the side shell which looses its supports, cracking of the side shell plating develops, as shown in Figure 4, and leads to the flooding of the damaged hold:

**Figure 3**

Transverse watertight bulkheads
As for side shell main frames, the transverse watertight bulkheads may be subjected to high rates of corrosion.

Consequently, where cargo holds are flooded and though watertight bulkheads are designed to withstand such loads, buckling and cracking of highly stressed corroded corrugations occur and the development of buckling deformations may lead to total collapse of the bulkhead.

**Figure 4**

Fore and aft transition zones
Discontinuities between the framing system of the cargo holds and fore and aft regions may explain structural failures observed in those areas.
Contributing factors to hull damages and ship losses
Examination of damaged ships enabled to identify the various factors which contributed, either alone or jointly, to both structural damages and ship losses:

- age of vessels (average age of damaged ships was 18 years approximately and two ships were less than 10 years of age),
- design: low level of structural redundancy, difficulties to survey upper parts of holds in large sized ships, improper design of structural details, etc.,
- poor workmanship,
- ship’s structure condition: unrepaired cracks, insufficient cleaning of holds hiding possible cracks, etc.,
- extreme weather conditions,
- corrosion of the cargo hold main frames and their end connections,
- corrosion of corrugated transverse bulkheads,
- corrosion in uncoated ballast capacities,
- fatigue cracking of end connections of main frames, which may be accelerated for structures made of higher tensile steel, all the more as the fatigue properties of welded structures are not improved with increased yield stress,
- sloshing phenomena in partly flooded holds,
- corrosive action of cargoes such as high sulphur coals or high temperature cargoes,
- cargo characteristics: cargo temperature during loading, moisture content, etc.,
- liquefaction phenomenon due to high moisture content of the cargo, i.e. the cargo reaching a viscous fluid state slides to one side in one roll way and does not return at the other roll way leading to permanent heel,
- loading operations at terminals: high loading rates may lead to overstressing of the structure if the sequences of loading are not perfectly controlled, pattern loading, trimming procedures, etc.,
- unloading operations: cargo handling treatment (heavy grabs, bulldozers, pneumatic hammers, etc.) may damage the mainframes and transverse bulkheads, increasing their vulnerability to corrosion and buckling.

In examining these various causes, the process of events leading to the loss of bulk carriers may be explained as follows:

- ingress of water into one hold either through side shell damage or through damaged hatch cover,
- collapse of transverse bulkheads bounding the flooded hold,
- increase of the hull girder bending moment leading to the collapse of the hull girder,
- shift of cargo first in flooded holds and in other holds, leading to the capsizing of the ship.

Based on these considerations, IMO, Classification Societies either through IACS or individually, decided to revise their rules and regulations for the design, construction, maintenance and operation of bulk carriers.

INTERNATIONAL MARITIME ORGANIZATION (IMO) ACTIONS

During its 17th Assembly held in November 1991, IMO discussed and adopted a very important resolution about the safety of bulk carriers. The Maritime Safety Committee was requested to study urgently the document and to issue and implement detailed requirements on:

- structural integrity,
- effects of corrosion,
- inspections and surveys.
Prior to the conclusions of MSC study, IMO urged IACS to develop survey and maintenance requirements for ships carrying solid bulk cargoes and issued interim measures to improve the safety of bulk carriers, including in particular:

- immediate close-up survey of the welded attachment of the side shell frames in selected cargo holds,
- close-up examination of the entire framing system of the number one cargo hold, plus an internal examination of all remaining cargo holds including close-up examination of a minimum of twenty-five percent of the framing system in each cargo hold, at each special and intermediate survey following special survey number one,
- gaugings of shell plating, associated framing and end connections at each special classification survey and intermediate survey,
- introduction in the operation and loading manuals of the permissible shear forces and bending moments during loading and unloading operations in port as well as the transit conditions.

Concerning the last point, IMO DE 36 discussed extensively the need for a recommendation to fit hull monitoring devices to bulk carriers. As an answer to this recommendation, Bureau Veritas is considering the development of such an equipment as explained in paragraph 6.2.

CLASSIFICATION SOCIETIES (IACS) ACTIONS

The first step of Classification Societies investigations was to call the attention of owners and operators to the condition in which their ships were operated. Simultaneously, occasional surveys and analyses of reported damage were carried out and enquiries were made with owners and crews.

A Working Party on Hull Damages (WP/HD) was created in 1991 within the International Association of Classification Societies to appraise hull damages of bulk carriers with a view to issuing unified amendments to the Rules of all IACS members in order to restore confidence in bulk carriers and improve their safety.

In that respect, IACS WP/HD took two important decisions:

- creation of a hull damage database,
- adoption of an unified requirement on enhanced surveys.

Hull Damage Database

IACS WP/HD decided to set up a system to collect and disseminate through member societies information on major hull damages.

This Early Warning Scheme (EWS) which is formally implemented since January, 1993, aims at keeping all the IACS members informed of damages occurring on ships in service, so that they can immediately take the counter measures to prevent re-occurrence of such damages.

To that end, WP/HD decided to establish standard data sheets for reporting significant hull damages and repairs which will be exchanged between the societies.

All these data will be permanently reviewed by the WP/HD which will issue recommendations or requirements on the basis of the results of these analyses.
Enhanced surveys for bulk carriers
In consideration of IMO MSC 60 report, IACS developed an unified requirement for the survey of bulk carriers (UR Z10.2) which was offered as a Guideline in relation to Resolution A713(17). The IACS proposal was examined at IMO MSC 61 meeting on December 7, 1992, and accepted by the working group subject to few amendments.

These Guidelines should normally be submitted and adopted by the 18th IMO Assembly of October/November in view to be enforced in June 1995.

However, Bureau Veritas as the other IACS members will apply this unified requirement as from 1st of July 1993.
Main points of the unified requirement UR Z10.2 may be summarized as follows :
. a dry docking survey will be part of the special survey,
. extent of special, intermediate and annual surveys has been strengthened, depending on the age of the ship and, in particular, of the condition of the coating,
. thickness measurements are defined more precisely and are to be carried out by certified companies,
. documentation giving the ship’s history (design, repairs, survey reports, condition evaluation report) has to be placed and maintained on board.

As a result of these requirements, it is necessary that adequate means of access be provided to safely permit the close-up inspection of the maximum possible amount of structure.

Various means of access may be envisaged, such as :
. portable ladders, provided that means of securing the ladder be fitted,
. cranes with telescopic arm fitted with a basket,
. permanent clamps,
. permanent plugs enabling to lift a platform,
. video camera.

Corrosion protection of ballast tanks and cargo holds
As indicated above, corrosion is one of the most significant factor which contributes to damages, not only in ballast tanks but also in cargo holds.

Consequently, IACS adopted in 1990 and 1992 two unified requirements, UR Z8 and Z9, which require the corrosion protection of spaces intended for the carriage of salt water and of cargo hold areas more prone to corrosion, ie side shell and its framing and transverse bulkheads.

Guidelines for surveys and assessment of structural condition
The IACS Council mandated the WP/HD to develop internal guidelines for perusal by IACS member societies ship Surveyors when assessing the structural condition of bulk carriers.

Based on experience gained in the recent years, these guidelines will give the necessary information to Surveyors to carry out proper surveys :
. how to prepare the survey,
. where to look,
. what to look for,
. how to repair in case of damage.
BUREAU VERITAS ACTIONS

Complying with its own chart of independency, Bureau Veritas decided to carry out its own studies:

. to re-appraise the adequacy of its rules, based on the results of its research works,
. to inform BV Surveyors on the sensitive structural areas which have to be specially examined during surveys,
. to inform all the shipowners/operators having bulk carriers classed to its Register, about the seriousness of the situation and about the urgency to carry out, at the earliest, close-up surveys of holds and hopper and topside tanks.

The attention was drawn to the catastrophic consequences of uncontrolled loading/unloading sequences, to the damages induced to the structure by unloading devices and to the corrosion action of some cargoes. In particular, a special programme for additional surveys for all the 'CAPESIZE' ship’s type of more than 12 years of age has been set up.

Bureau Veritas research studies aimed at answering the following question:

. Do Bureau Veritas rules for scantlings of web frames and transverse bulkheads take properly into account the types of damages which occurred on bulk carriers?

To that end, following calculations were performed:

. finite element analyses of hold structures of various bulk carriers to assess more precisely the stresses in the critical areas, ie main frames and transverse bulkheads,
. parametric calculations to appraise the influence on the main frames scantlings of:
  - the size of hopper tanks,
  - the length of holds,
  - the torsional strength of hopper tanks.

Results of these studies will enable to issue in September, 1993, revised rules applicable to bulk carriers.

Simultaneously, Bureau Veritas which considers that operating conditions of ships are one of the key parameters to improve the safety of bulk carriers, created in December 1991 a relevant Ad Hoc Group within its Technical Committee.

Results of this Ad Hoc Group have been used to improve the rules on the following items:

. loading/unloading procedures,
. structural loads,
. structural details,
. stress monitoring,
. means of access,
. improvement of surveys.

SHIPOWNERS AND OPERATORS ACTIONS

Conditions in which bulk carriers are operated have been frequently questioned as one of the causes for casualties. Designers are not well informed how ships are operated and, on the contrary, operators are not aware of the basic assumptions which govern the design.
In this respect, many shipowners and operators of bulk carriers expressed their concern for the development of operational guidelines which aim at improving the safety of bulk carriers.

Among the operational matters discussed within our working group on bulk carriers, it appeared that it was necessary to draw attention of the crew on the limitations of the structural design and to provide them with efficient means to control the loading and unloading operations, as they may lead to over-stressing the hull structure.

**Monitoring of weight in cargo holds**

The maximum permissible weight in cargo holds is a leading factor in the design of overall and local structure of bulk carriers:

. the still water bending moment is significantly influenced by an increase of weight in cargo holds. As an example, for a bulk carrier with 7 holds, an error of 10 per cent in the weight of a mid cargo hold may lead to an increase of the theoretical maximum still water bending moment, as given in the loading manual, from 30 to 40 per cent,

. sequences of loading may be theoretically controlled in advance but, in more than than 50 per cent of the cases actual sequences do not correspond to the foreseen ones,

. rates of loading, up to 16000 tons per hour, are such that the crew is generally quite unable to control the actual loading of holds and to ensure that the permissible weight in cargo holds is not exceeded.

Among the existing means (loading manual, loading calculator, monitoring systems) to control the loading operations, the use of hull monitoring devices, as recommended by IMO, seems to be a proper answer to the problem.

For example, the system SAFENAV, developed in 1984 by Bureau Veritas to control the behaviour at sea of ships (motions, accelerations, pressures...) may be envisaged to monitor the weight in cargo holds by measuring the hull girder bending stresses during the loading or unloading operations.

Adaptation of SAFENAV to this particular application is under development within the Society, which needs that the following problems be solved prior to envisaging its use on board of bulk carriers:

. measured stresses are to be the hull girder stresses. In particular influence of thermal stresses is to be eliminated,

. fore and aft draughts are to be measured precisely.

Whether the feasibility of the system is demonstrated, it will be necessary to develop a computer programme enabling to calculate, on a continuous basis, the weight in cargo holds from the information given by the strain gauges.

**CONCLUSION**

Today's evidence is that Bureau Veritas cannot improve alone the bulk carriers safety. The only efficient way is to strengthen cooperation between all parties: shipbuilders, owners, operators, port authorities, flag states and Bureau Veritas.

Thanks to its own researches to improve the appraisal of scantlings and to cooperation with owners and shipbuilders, Bureau Veritas will contribute to design more reliable structures.
Bureau Veritas together with the other IACS members may act through Governments and IMO to implement ad hoc technical requirements for the bulk carriers.

On owner/operator side, it has to be emphasized that suitable operation of ships is the key to prevent major damages.

The future International Safety Management Code will certainly help shipowners to improve the quality and the efficiency of their services.

Loading terminals should take due consideration to the Code for Safe Practice of Solid Bulk Cargoes.

For all actors, the successful way for building and operating safe ships is surely "to prevent the risks" and to manage "Quality".