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Corrosion Waste Impact on Ship Girder Strength Through Life Cycle

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ABSTRACT: The paper deals with analyzing corrosion waste impact on ship girder strength through the life cycle. Evaluation of corrosion impact on ship strength is important because in some loading cases the ships are in overloaded condition. It is assumed that corrosion wear varies from 0 to 60%. Reduction of their transverse strength in combination of bad weather or sudden storms leads to cargo lost, ship damage and loss of human lives. Strength and plating elements bending capacity are evaluated by ship midsection model development and compared with the same for a new building ship. Helped by the relation between permissible and actual bending moment, plate bending efficiency is evaluated. Ultimate ship girder strength in cases with corrosion waste of more than 30% is evaluated too.

1 INTRODUCTION

The ship's life cycle is a complex process consisting of different stages and processes similar to those in human life. The main milestones in the ship's life cycle can be highlighted in design, building, exploitation, and recycling. The exploitation period continues the longest. Normally, this period is about 20–25 years, but nowadays, taking into account economic conditions, COVID-19, wars, etc., the exploitation period is increased by up to 30 years. Through the ship's life cycle, she is subjected to different processes, forces, and loads. The corrosion process of the ship's hull is unavoidable. The corrosion process reduces ship girder strength and working capacity. Therefore, the study of its impact on ship characteristics is important.

A computer simulation of ultimate girder strength degradation by corrosion and fatigue is done in [3]. There is a developed system for solving practical corrosion and fatigue problems. The system was tested on a double bottom tanker. Results shown indicate fatigue crack and corrosion repair.

The review of the ultimate strength assessment of aging and damaged ship structures is presented in [7]. In this work, attention is paid to the ultimate strength of plates, girders, and the entire ship's hull subjected to corrosion, fatigue, cracking, and damage. The ultimate load capacity of the ship's hull is also studied.

The authors of [6] studied pitting corrosion waste assessment on the hull girder ultimate strength by incremental-iterative methods. They compared the hull girder's ultimate strength combined with pitting corrosion and relevant values from the rule's net scantling. The final result is that the incremental-iterative method is useful for new vessel design and monitoring of aging ships. An incrementally iterative method for determining ultimate strength is used in [8].

In some cases, corrosion waste appears as a result of erosion. This effect is common under suction pipes in ballast tanks after cavitation impact. The pitting corrosion is clearly expressed and affects bottom plates in the vicinity. This problem is studied in [4].

Modern methodology for 3D model strength analysis of corrosion impact on ship hull characteristics is presented in [2]. In this work, authors identify the corrosion impact on the VLCC hull. The strength analysis was done over three cargo holds. They investigated that after 15 years after corrosion, waste plate thickness is reduced about 10%. Based on problem study so far, it is necessary to analyze ship girder strength bending and ultimate strength through studies.

Corrosion waste impacts the weld joints of a ship's hull. In some cases, the corrosion in welding seams reaches 1-2mm per year. The main welding seam corrosion is near to the heat-affected zone and the fusion line [5]. The welding seam and joint degradation and wearness leads to the reduction of ship girder integrity and caused the loss of ships, human lives and cargoes. Corrosion impact on welding joints turns them into a stress concentrator. The stress concentrator is the primary crack and deformation source which impacts hull girder strength negatively.

2 SHIP MIDSHIP MODEL DESCRIPTION

The analysis of a ship's hull corrosion waste during her life cycle is done by model development of a mid ship section of a 6000 t DW general cargo ship, one box hold with BV software, MARS 2000. The ship's main dimensions are shown in table1.

Table 1. Model main dimension

Item	Dimension
Length, m	106.60
Breadth, m	16.00
Depth, m	9.17
Block coefficient	0.721
Sailing area	unrestricted

Mid ship topology is shown on fig.1.

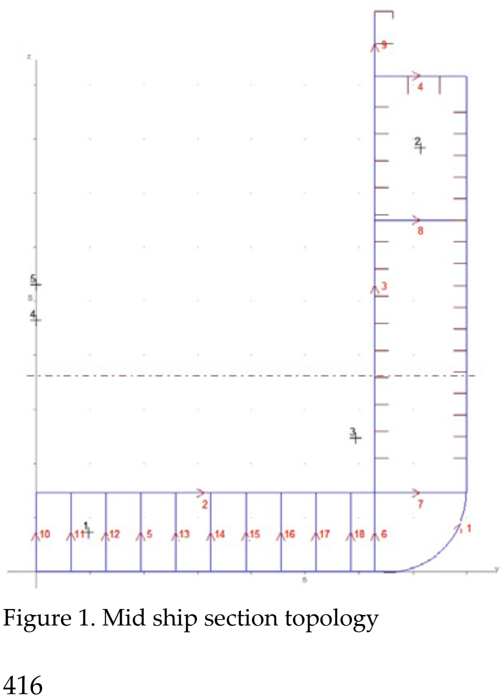

Figure 1. Mid ship section topology

The ship has a double bottom and an inner side. Double bottom height is 1450mm, the inner side breath is 1500mm., cargo hold is designed for container carry. The topology of the mid ship section is designed for production and designed for repair.

In the design stages of a ship, structural elements are envisaged for corrosion addition. Corrosion, in addition to every structural element, is different. The values vary from 1.00 for elements exposed in seawater to 2.00 for the hopper wells for dredging ships[1] .

3 ANALYZE OF CORROSION WASTE ON SHIP HULL PLATING

Corrosion waste is simulated by reducing the shell plating, double bottom, inner side and main deck plating thickness from different percent from 0 after ship delivery to ship owner to 60% after more than 25 years of exploitation.

Helped by developing models, the loading capacity of hull girder strength and its elements are evaluated. Changing of loading efficiency of every plate element from mid ship section is evaluated by permissible and actual σ_x. The gross thickness of a plate element is a study object because they participate in hull girder strength evaluation. The plate names are shown in table2.

Table 2. Plates location in ship hull

Item	Location
s1	horizontal keel
s6	bilge plating
s9	shell plating at 3500mm ab. BL
s10	shell plating at 5000mm ab. BL
s11	shell plating at 6500mm ab. BL
s12	shear strake
s13	double bottom plating
s20	inner side at 4500mm ab. BL
s21	inner side at 6000mm ab. BL
s22	inner side at 7500 mm ab. BL

In the analysis, it is traced what is happening with to ship's hull subjected to corrosion waste. It is assumed that the corrosion waste in early life cycle periods is not so intensive, while after 25 years old its actions are increased. To study the process, it is used the relation between permissible σ_x and the actual same.

$$\sigma_r = \frac{\sigma x_{permissible}}{\sigma x_{actual}}$$

The permissible σ_x is 175 N/mm^2 for all sections. It is selected by the material properties of the ship's steel hull. For all sections, St 2530 is used, with Young modulus 206000.00 N/mm^2 which is most used in shipbuilding and ship repair. The actual σ_x depends on plate location in the ship hull, thickness and applied load in areas. Bending moments for the original section are shown on table 3.

Table 3. Bending moments

	Hogging, kNm	Sagging, kNm
SWBM, d	163886	-135563
VWBM,d	201019	-229369

SWBM,d- design still water bending moment, kNm;
VWBM,d- design vertical bending moment, kNm;

Horizontal keel on the bottom, bilge and side plating up to 5000mm ab. base line are subjected mainly to hydrostatic pressure, while shear strake of dynamic forces are permanent. Double bottom plating and inner side plating are subjected to cargo and ballast water forces. Intensive corrosion of waste on the inner side plates is a danger to cargo water tightness. When the wing ballast tank is full and the pumps continue to pump in ballast, inner side plates are subjected to over pressure and lead to the crack appearance. The same situation with double bottom plating with intensive corrosion waste. In fig.2, the relationship is shown between the permissible and the actual σ_x of the ship's hull girder.

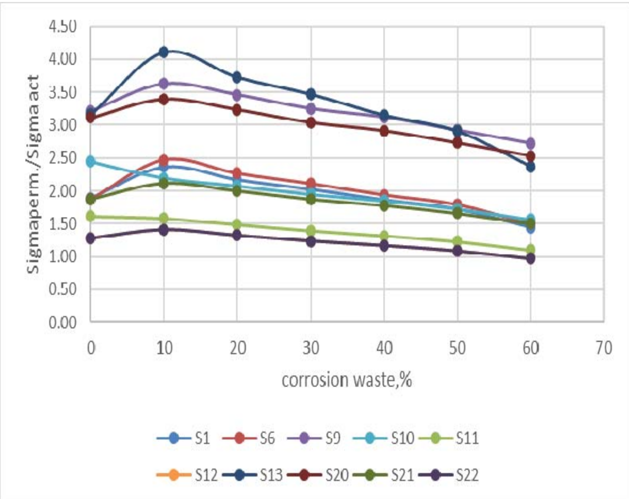

Figure 2. Relation between permissible and actual σ_x via corrosion waste

The value of the relation between permissible and actual σ_x varies from 1.00 to about 4.00. The maximum value is 10% corrosion waste in all cases. Clearly sharply outlined three plate groups. First is the double bottom, inner side and shell plating group with a relation between the permissible and actual σ_x between 2.80 and 4.20. This plating group is near to the base line and the neutral axe. The neutral axe position is at 3.7m above base line. The second plating group is double bottom, horizontal keel and shell plating up to 3500mm above base line. In this group, σ_r is in the range from 1.50 to 2.5. Interesting in this group is that the elements that are near and far away form a neutral axe and base line. The value of the original condition of the ship hull, without corrosion wastes in shell plating at 5000mm above base line, is higher than other elements. This is because in this are is located void space, the ballast tank is not up to main deck. The same is the situation with the same plate at 6500mm above base line. The third plating group consists of shell plating at 6500mm above base line and the inner side at 7500mm above base line. Their σ_r vary from 1.00 to 1.50.

Continuing in time, corrosion waste reduces plate thickness to values which are necessary to be replaced with a new one with thickness equal to a original or greater. Corrosion waste at plate elements is highly expressed in plating elements in comparison to profile elements like bulb profile, L-profile, etc. Reduce plate thickness, reduce mechanical properties of hull girder strength, and she has become a danger for the environment from one side and for crew and cargo from the other side.

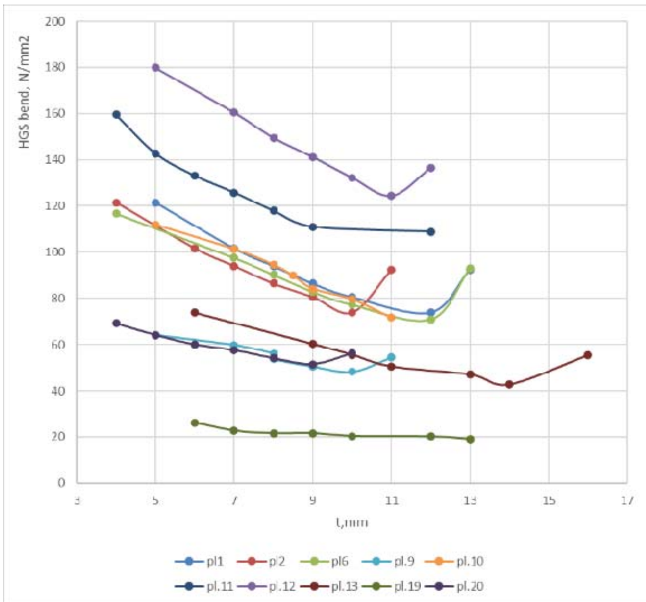

Figure 3. HGS bending via plate thickness

Hull girder strength bending of gross plate thickness is shown in fig.3. The results are shown that in the original plate thickness, which point is located on the right in fig.3, is the nominal value of bending. After that, a lead point with a lower value a which corresponds to 10% corrosion waste. From this point, upward bending values increase your values.

In cases with maximum plate waste hull girder strength bending values have the highest values. This is an argument for section modulus and ultimate strength check- out. Section modulus on deck with corrosion waste is equal and more than 50% is reduced by about 6-7%. The ultimate strength in navigation condition in a sagging condition is about 13% higher than without corrosion waste, fig. 4 and fig.5.

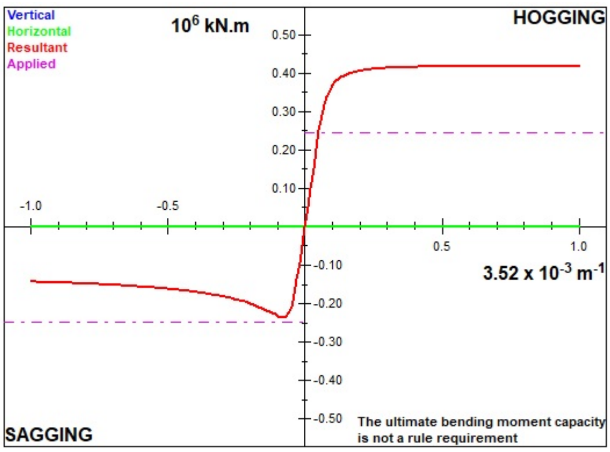

Figure 4. Ultimate ship strength at 50% corrosion waste

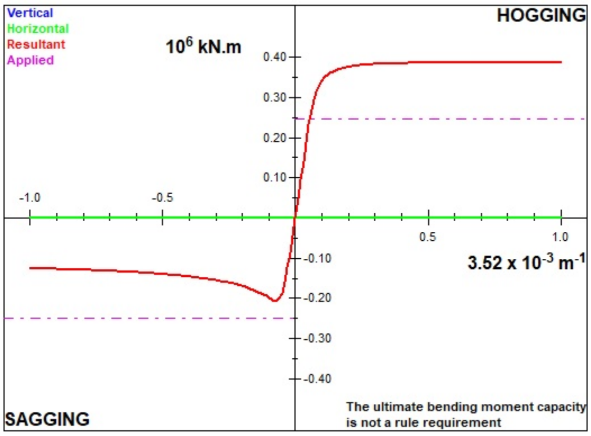

Figure 5. Ultimate strength at 60% corrosion waste

4 CONCLUSIONS

The paper analyzes corrosion waste on ship hull plating during its life cycle. Based on developed models, corrosion waste is simulated with a percentage value from 0 to 60%. Corrosion impact on plate element bending is evaluated by the relationship between permissible and actual bending relationships. Ultimate hull girder strength is evaluated too.

As for the bending capacity of plate elements in a ship's hull, it has been investigated that with corrosion impact, increasing bending capacity is reduced, but in 10% corrosion, waste bending capacity is heightened than without corrosion, in original hull condition. In the analyzed case, the value of σ_r is from 1.00 to 4.50, based on the fact that there are three groups of plate elements.

The situation with hull girder bending is different. At 10%, corrosion waste obtained a lower value of gross thickness bending in compared than without corrosion waste. After that, upward bending values extremely increased your values.

Corrosion waste impact on section modulus and ultimate girder strength. Intensive corrosion waste of more than 25% reduces section modulus on deck by about 6% and ultimate strength is about 13% higher than normal hull condition.

Future work of the study is to evaluate corrosion impact on profile elements subjected to passive corrosion and bottom plating strength in docking periods with floating docks and cradles.

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