Technical Background on Corrosion Addition

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Introduction

The IACS Unified Requirements for strength criteria of structures such as double bottom and bulkheads of single side skin bulk carriers have adopted the "Net Scantling Approach" in which the gross scantling is obtained by adding the net scantling obtained from the structural strength requirement to the thickness diminution due to corrosion. In using the net scantling approach, the following terminology is used.

Net thickness: the thickness required solely based on the structural strength aspect which is the minimum scantling that must be kept throughout the service life of the ship

Wastage allowance: the value of thickness diminution due to corrosion expected during the service life of the ship obtained by statistical analysis based on the thickness measurement data of ships and the steel renewal criteria which ensure that the net thickness is kept throughout the service life of the ship.

Corrosion additions: the value is obtained from Wastage allowance by adding to the thickness diminution predicted till the next thickness measurement.

In order to introduce this Net Scantling Approach to the hull structural rules, at first, we have to have an accurate grasp of the real thickness diminution. For this, corrosion process from occurrence through propagation were investigated on extensive thickness measurement data, and a corrosion process model was developed based on probabilistic theory thus estimating the thickness diminution of structural members. Based on this, a guideline on corrosion addition for bulk carriers and tankers was developed and was submitted to the IACS Working party on strength (WP/S). The philosophy of Net scantling approach and the corrosion addition values are adapted in the draft IACS Common structural rules for bulk carriers and tankers. This paper describes on how to determine the corrosion addition, how to apply the corrosion addition and how to treat the wastage allowance.

1. Corrosion addition

1.1 Determination of corrosion addition

The corrosion addition was determined by the following procedure (details can be found in the technical paper published in ClassNK Technical Bulletin, Vol.21, 2003, pp 55-71).

(1) Gather about 600,000 thickness measurement data sampled from single hull tankers and single side skin bulk carriers of age 5 to 27 years.

(2) Select the thickness measurement data of single hull tankers complying with MARPOL 73/78 Convention and with no coating of structural members in cargo oil tanks and of bulk carriers with coated structural members in cargo holds required by the existing IACS UR.

(3) Develop a corrosion propagation model to simulate the realistic corrosion phenomenon based on probabilistic theory and identify the necessary parameters for each structural member using the thickness measurement data.

(4) Estimate the corrosion diminution at the cumulative probability of 95% for 20 years using the corrosion propagation model.

(5) Sort out the corrosive environment to which each structural member is exposed and calculate the amount of corrosion of each corrosive environment using the estimated corrosion diminution of each structural member.

(6) Corrosion addition is determined based on the environment to which each structural member is exposed.

However, the average scrapping age of ships is about 25 years, and the design life of ships is proposed as 25 years by the submission paper on "Goal Based Standard" MSC/78/6/2 of IMO. Therefore the estimation period of corrosion diminution is changed to 25 years from 20 years. Moreover, in the real corrosion phenomena, scatter of thickness diminution depends on the maintenance condition of the individual ship rather than the thickness measurement of each structural member as shown in Figure 1.

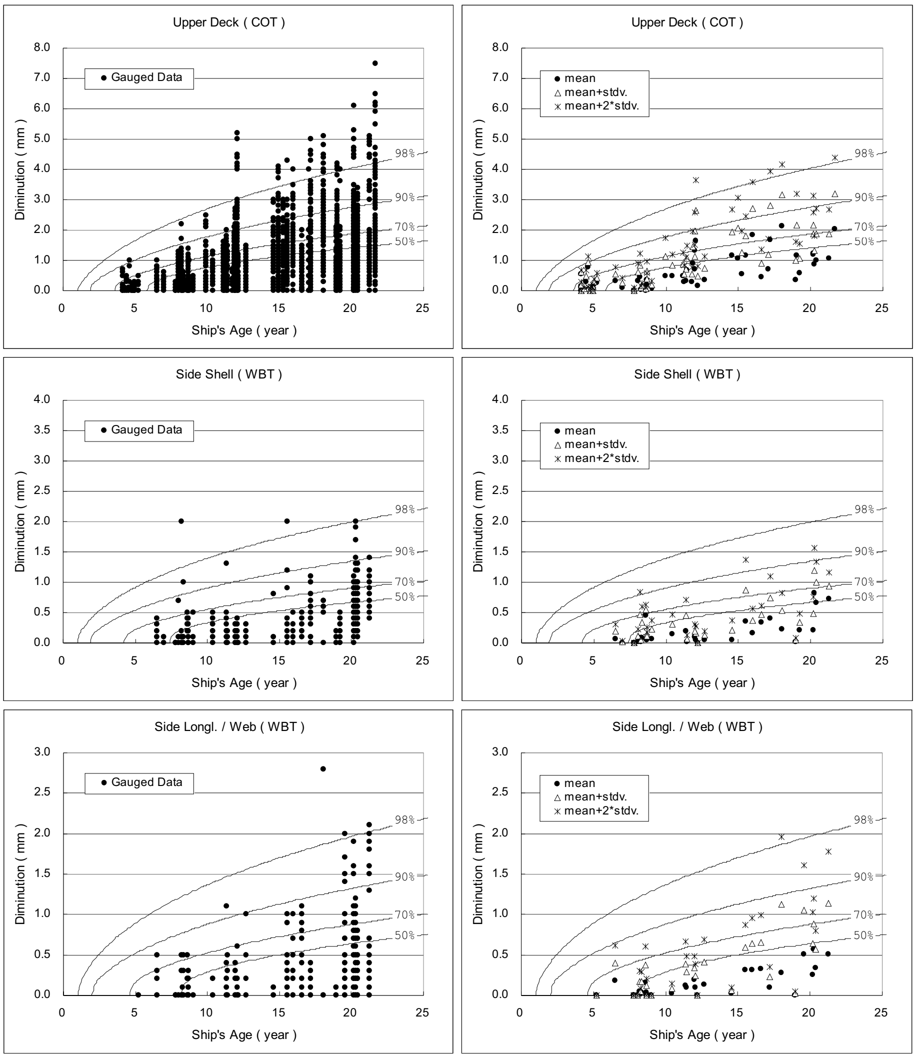

Figure 1 Statistical analysis of thickness measurement data of structural members of tankers

The conclusions drawn from the figure are:

(1) The mean value of thickness diminution of upper deck plating that is exposed to severe corrosive environment exceeds the estimated value at the cumulative probability of 70% in seven ships among 75 ships. And the “mean + 2 times standard deviation” value exceeds the estimated value at the cumulative probability of 98% in only 5 ships.

(2) The ”mean + 2 times standard deviations” value of side shell plating and structural members in ballast water tanks the environment of which is less corrosive than upper deck exceeds the estimated value at the cumulative probability of 98% in none and 1 ship, respectively.

(3) The individual mean value of thickness measurement for most of the ships is lower than the estimated value at the cumulative probability of 50%.

(4) The thickness measurement data of structural members other than upper deck plating, side shell plating and internals of ballast water tank also have similar tendencies as in item (2).

These conclusions show that, except for a small number of ships with poor maintenance, steel renewal is not required if structural members have sufficient corrosion additions according to the estimated corrosion value at the cumulative probability of 90% for 25 years. Therefore the corrosion additions are determined based on the estimated corrosion at the cumulative probability of 90% for 25 years.

Tables 1 and 2 show the estimated corrosion at the cumulative probability of 90% for 25 years for structural members of tankers and bulk carriers respectively.

Table 1 The estimated corrosion for structural members of tankers Unit mm

Structural Member	COT	WBT
Upper Deck Plate	2.93	2.19
Side Shell Plate	1.90	1.79
Bottom Plate	4.05	3.15
Longl. Bhd. Plate	1.92	2.00
Trans. Bhd. Plate	2.35	2.34
Deck Longl.	1.94	1.81
Deck Trans. Web / Face	2.07 / 2.36	1.90 / 2.73
Horizontal Girder Web / Face	2.03 / 2.89	1.90 / 2.77
Cross Tie Web / Face	1.84 / 1.90	1.69 / 1.81
L. Bhd. Longl. Web / Face	1.85 / 1.87	1.68 / 1.71
L. Bhd. Trans. Web / Face	2.50 / 1.93	1.48 / 1.94
Side Longl. Web / Face	1.85 / 1.87	1.68 / 1.71
Side Trans. Web / Face	1.99 / 2.01	2.36 / 2.00
Bottom Trans. Web / Face	2.41 / 1.94	1.38 / 1.74
Bottom Longl. Web / Face	1.88 / 1.90	1.73 / 1.74

Table 2 The estimated corrosion for structural members of bulk carriers Unit mm

Structural Member	Position	Cargo Hold		Ballast Hold	
		DW<50,000	50,000≤DW	DW<50,000	50,000≤DW
Bhd. Plate	Lower	1.98	4.35	2.06*	3.28
	Middle	1.98	4.17	2.06*	4.62
	Upper	1.82	4.40	1.92*	3.14
Hold Frame	Lower	2.42	3.99	2.42*	2.93
	Middle	2.42	3.80	2.42*	2.85
	Upper	1.92	3.49	3.62*	3.45
Lower Stool		2.09	5.50	3.68*	5.53
		DW<50000		50000≤DW	
Upper Deck Plate		3.82		3.66	
Hatch Coaming		1.71		2.79	
Bottom Plate		*		1.92	
Side Shell Plate		*		2.91	
Inner Bottom Plate		3.29		4.86	
Sloped Plate in TST		1.78		2.95	
Sloped Plate in BHT		2.06		3.83	
Floor		*		2.27	
Girder		*		2.34	
Longl. in DBT & BHT		*		2.17	
Longl. in TST		*		3.12	
Trans. Ring in BHT		*		2.39	
Trans. Ring in TST		*		3.40	

*: indicates that the estimated value is unreliable or estimation is not possible due to the lack of thickness measurement data or the data is taken from ships of similar age.

Further to the above considerations, corrosion addition of structural members in fuel oil tanks, fresh water tanks and their boundaries are also evaluated so that corrosion addition can be specified for all structural members of the ship. The results are summarized below:

1.1.1 Keel plate and bottom shell plating

In the current class rules, the keel plate is required to have a thickness 1.0 or 2.0 mm above the adjacent bottom plating thickness. This was provided based on the assumption that the keel plate corrodes faster as it is difficult to paint the keel block due to docking blocks in the dry dock. However, this effect could not be observed from the corrosion analysis mentioned above, though the thickness measurement data of keel plate is also included in the bottom plating. Gathering 684 thickness measurement data for bottom plating and 103 data for keel plate of general cargo ships and bulk carriers of age of 14 to 24 years, statistical values like the maximum diminution value, average diminution value, etc are investigated. Figure 2 shows the result of the investigation which clearly indicates that thickness diminution of keel plate is not different from that of bottom plating.

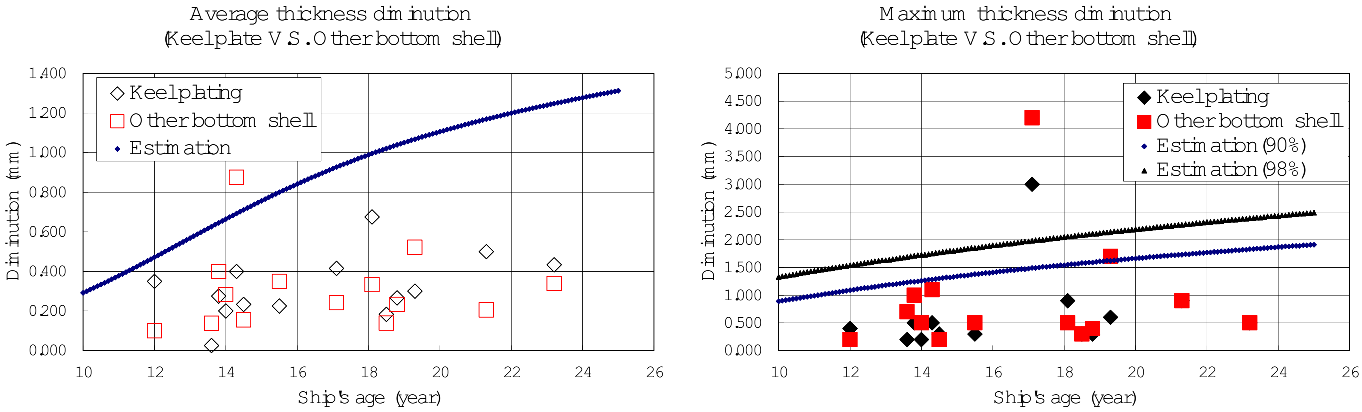

Figure 2 Thickness diminution of keel plate and bottom plating

1.1.2 Thickness diminution of structural members in fuel oil tanks (FOTs) and their boundaries

Structural members in FOTs are generally examined visually for corrosion at periodical surveys, and thickness measurement is dispensed with if the condition is found satisfactory. Therefore, thickness measurement data of structural members in FOTs or lubricated oil tanks are very limited. About 320 thickness measurement data of three general cargo ships of age 12 to 20 years were collected from among the massive thickness measurement data. The maximum diminution was 0.6mm at about 20 years and the average diminution was 0.3mm. A simple extrapolation to 25 years gives the maximum diminution of 1.0mm. From this result, the value for corrosive environment in such oil tanks is considered to be 0.5mm for one side which is the same for void space as given in Table 3.

On the other hand, the boundaries of FOTs, especially the boundary plate between FOT with heated fuel oil and water ballast tank (WBT), have heavier corrosion than those within the tanks. In order to confirm this inference from the thickness measurement data, about 360 thickness measurement data from ten ships of age 12 to 20 years are sampled. A maximum value of 2.7mm, an average value of 1.0mm and a 90-percentile value of 2.4mm at about 20 years are obtained from the statistical analysis of the data. The sampled data are of the boundaries between FOT and WBT within double bottom. This result is shown in Figure 3.

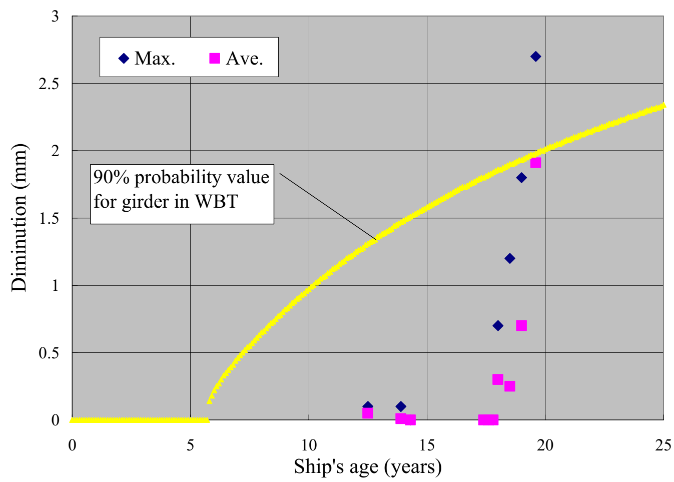

Figure 3 The thickness diminution of boundaries of FOT loaded with heated oil

An extrapolation to 25 years using this result gives the 90-percentile value of 2.9mm. The value of corrosion addition on one side in WBT is given as 1.2mm from Table 3 and 0.5mm in FOT from the result mentioned above. Therefore, the corrosion value of 1.2mm due to heated fuel oil effect is obtained by reducing 1.2mm for WBT and 0.5mm for FOT from 2.9. This effect is limited to the boundaries between FOTs and WBTs and does not appear in other boundaries such as bottom plate that is always cooled down by seawater.

1.1.3 Fresh water tanks (FWTs)

Similar to FOTs, thickness measurement of structural members in fresh water tanks is also seldom carried out, and therefore the thickness measurement data of structural members in FWT is very limited. From the sampling of 22 thickness measurement data of three ships of age 12 to 18 years, the maximum diminution was found to be 0.4mm, and the average was 0.1mm at about 18 years. Therefore, the value of corrosive environment in FWTs is considered to be 0.5mm.

1.1.4 Lower bracket of hold frame

Thickness measurement data of hold frames is classed into 3 categories; upper part, middle part and lower part. Thickness measurement data of the lower part and upper part of hold frame include the data of both webplate and faceplate of frames and their bracket. However, lower brackets of ships of deadweight 50,000 tons and above are considered to be more corroded than lower part of hold frame because stress on the lower bracket is higher than that on the webplate and faceplate of lower part of hold frame. This effect is considered as the additional corrosion effect for lower brackets.

1.1.5 Classification of bulk carriers

Corrosion phenomenon of structural members in cargo holds of bulk carriers strongly depends on the kind of loaded cargo. The kind of cargo is closely related to the deadweight of the ship; ships of deadweight 50,000 tons and above mainly load iron ore and/or coal, and ships of deadweight under 50,000 tons mainly load cargo other than iron ore and coal. However, since the kind of loaded cargo is more related to the ship's length than ship's deadweight, the bulk carriers are classed into 2 categories corresponding to their length; ships of length 200 m and above, and ships under 200m in length.

On the other hand, IACS Unified Requirements S25 (UR/S25) regarding harmonized notations and design loading condition has been adopted in 2002. In this UR, bulk carriers having length of 150m or above are classed into 3 categories with notation BC-A, BC-B and BC-C. Corresponding to this classification of bulk carriers, the draft guideline for corrosion addition of bulk carriers and tankers submitted to IACS WP/S specifies that bulk carriers classed into BC-A and BC-B ships mainly carry iron ore and/or coal, and BC-C ships and ships of length under 150m mainly carry cargo other than iron ore and coal.

Further, ballast hold for all bulk carriers is used both as ballast hold and cargo hold. Since thickness diminution of structural members in ballast hold is smaller than that of cargo hold, corrosion addition of structural members in cargo hold is applied to that in the ballast hold.

Based on these results, the corrosion value of each corrosion environment for double hull tankers and bulk carriers is given in Table 3. The corrosion addition is obtained by summing up the values given in Table 3 corresponding to the environment on the two sides of the structural member plus reserved corrosion margin (0.5mm). This corrosion addition value is corresponding to the value obtained by mean + 2 times standard deviations at 25 years.

In this case, rounding operation to the nearest 0.5mm could not be accepted. This is because the corrosion value is derived based on the corrosive environment corresponding to actual corrosion phenomenon, and rounding off of this figure may result in too large or small value. Therefore, the corrosion addition should be expressed in 0.1 mm increments without rounding off.

Table 3 The corrosion value for different corrosive environments (the values are given for one side of the structural member)

Corrosive environment			Corrosion value (mm)	Applicable structural member
Main environment		Additional factor		
In COT			1.1	Structural member other than those mentioned below
		High temperature	1.1 + 0.5	Deck plating
		High stress	1.1 + 0.3	Faceplates of girders and transverses
		Pitting effect	1.1 + 1.6	Inner bottom plating
In WBT	Topside tank	High temperature	1.7	Structural member other than those mentioned below
		High stress	1.7 + 0.3	Faceplates of girders and transverses
	Other than above		1.2	Structural member other than that mentioned below
		High stress	1.2 + 0.3	Faceplates of girders and transverses
In cargo hold of BC-A and BC-B ships	Upper part	Members not between cargo holds	1.8	Hold frame and inner side skin plating
		Boundary between cargo holds	2.0	Transverse bulkhead
	Middle and lower parts	Members not between cargo holds	1.8 + 0.2	Hold frame and inner side skin plating
		Lower bracket	1.8 + 0.2 + 0.3	Lower bracket
		Boundary between cargo holds	2.0 + 0.2	Transverse bulkhead
		Horizontal member	1.8 + 0.2 + 1.7	Inner bottom plate, sloping plate of bilge hopper tank
		Slant plate of lower stool	2.0 + 0.2 + 2.2	Slant plate of lower stool
In cargo hold of BC-C ships or ships of length below 150m	Upper part	Members not between cargo holds	1.0	Hold frame and inner side skin plating
		Boundary between cargo holds	1.0	Transverse bulkhead
	Middle part and lower part	Members not between cargo holds	1.0 + 0.2	Hold frame and inner side skin plating
		Boundary between cargo holds	1.0 + 0.2	Transverse bulkhead
		Horizontal member	1.0 + 0.2 + 1.2	Inner bottom plate, sloping plate of bilge hopper tank
		Slant plate of lower stool	1.0 + 0.2 + 1.0	Slant plate of lower stool
Atmosphere		Horizontal	1.7	Exposed upper deck plating
		Vertical	1.0	Side shell plating and hatch coaming
Sea water			1.0	Side shell and bottom shell plating
FOT			0.5	Internal members in FOT
		Boundary between FOT and WBT	1.7	Tight girders and floors between FOT and WBT
Void spaces, FWT			0.5	Internals in such spaces

1.2 Application of corrosion addition

1.2.1 Corrosion addition for local strength members

Corrosion addition is applied to the local strength member according to the definition of net scantling approach. That is, the necessary minimum scantling of a structural member $t_{gross\_required}$ is given by adding the necessary scantling from the strength point of view t_{Net} and corrosion addition t_{CA}. This is obvious from the basic assumption of local strength assessment.

Generally, the necessary scantling from the strength point of view t_{Net} given by the scantling formula is expressed in increments of 0.1mm by rounding off the two decimal places to the nearest single digit. Also the corrosion addition t_{CA} is expressed in increments of 0.1mm as mentioned above. Therefore, the necessary minimum scantling of a structural member $t_{gross\_required}$ is also expressed in increments of 0.1mm.

Though current classification rules for hull structure do not allow the actual scantling to be less than that obtained from the rule formula, conventionally classification societies may accept a smaller scantling expressed in increments of 0.5mm obtained by rounding off to the nearest 0.5 mm that may correspond to the nominal thickness of rolled steels which comes in increments of 0.5mm. This is possible because $t_{gross\_required}$ is considered to have sufficient safety margin including corrosion, and hence the safety margin compensates for the reduction in scantling due to rounding down in the current rules. However, in the net scantling approach, such a rounding down will result in the reduction in values of t_{Net} or t_{CA} which is not appropriate. As the solution, the following 3 approaches may be adapted in the new structural rules.

(1) $t_{gross\_required}$ is expressed in intervals of 0.1mm and rounding down is not accepted.

(2) $t_{gross\_required}$ is rounded up to the nearest higher 0.5mm unit

(3) Both t_{Net} and t_{CA} are rounded up to the nearest 0.5mm unit

Since the approach specified in above (1) is in terms of 0.1mm unit, it will require a great deal to order, produce, and control rolled steels and it will be likely that the problem of minus tolerance of thickness of rolled steels is brought to the scantling requirements. On the other hand, the approach (2) or (3) is not likely to have the above problem. Furthermore, the approach (3) results in scantlings 0.25mm greater than that specified in (2). The designers and some owners may not welcome the approach (3) because of the weight increase due to the addition of 0.25mm on an average, but some owners may welcome this due to the merit of increased wastage allowance. Since the proposed corrosion addition is sufficient to minimize the steel renewal of structural members for a ship which is properly maintained, approach (2) is considered to be an optimal one.

1.2.2 Corrosion addition for global strength members

The strength assessment of major load carrying structural members such as transverse girders is carried out considering the mutual interaction of such members covering a wide extent of the structure rather than using simplified scantling formula such as for a local strength member. Generally, finite element analysis (FEA) is widely used for the strength assessment of such structures. In FEA, a wide extent of the structure is modeled in order to consider the mutual interaction of primary supporting members and the structural response of the whole structure when the loads act on them is obtained. In this case, when the thickness diminution of one structural component is uniformly reached its corrosion addition value, it is most unlikely that the rest of the structure also has reached its corrosion addition value from the viewpoint of probabilistic theory. Normally, corroded areas and less corroded areas are scattered in the structure at random. The structural response in the corroded condition mentioned above is considered equivalent to that in uniformly corroded condition with average diminution. In this case, it is necessary to consider the average corrosion value of all the structural members, but it is a complicated task to prepare the average corrosion value of each structural member that has a different corrosion addition value. The average corrosion value is nearly equal to half the corrosion addition of each structural member. Therefore, half the corrosion addition value is applied to the structural strength analysis of primary supporting members in using the FEA. Hence the actual structural model for FEA is prepared by reducing half the corrosion addition value from the original scantling in the drawings, and strength assessment is carried out. Hull girder strength assessment and ultimate strength assessment for hull girder when a ship is regarded as a simple girder are also carried out in the same manner.

When assessing the buckling strength of panel elements of shell plating and web plate of primary supporting members, the stress acting on the panel element estimated from the result of the FEA is used.

However, critical buckling stress of the panel element is calculated using the scantling obtained by reducing the full corrosion addition from the original scantling because the panel element is regarded as a local strength member.

1.2.3 Corrosion addition for fatigue strength assessment

Fatigue strength of structural members can be assessed by the cumulative damage estimated against the cyclic loads encountered by the ship during her design life. The scantling of the structural member varies from no thickness diminution at the initial stage to thickness diminution equal to the corrosion addition at the end of the design life. However, it is not practical and is very difficult to consider the diminution of the scantling which varies over time in fatigue strength assessment. Therefore fatigue assessment considering the corrosion effect is generally used instead of considering the actual scantling diminution. In this case, it is necessary to consider many coefficients of corrosion effect for every corrosive environment because the corrosion effect depends on the environment to which structural members are exposed. Thus this method is also seemed to be impractical. Assuming that the thickness diminution is zero prior to service and thickness diminution reaches full corrosion addition at the ship's design life, the average diminution can be half the corrosion addition through the ship's design life. Therefore, half the corrosion addition can be applied for fatigue strength assessment.

2 Wastage allowance in the current rules and the net scantling approach

2.1 Wastage allowance for the local strength member

The current classification rules give scantlings that are necessary to prevent structural damage mainly based on extensive experience, but it is not clear what is the actual scantling that is sufficient enough. Further the lower acceptable level of structural strength due to corrosion is also not clear. Surveys of the ships in service have been carried out by experienced surveyors using specified wastage allowance set as a percentage of original thickness based on experience. For that reason, the chances of causing serious problems due to corrosion are very limited.

For example, in the case where the thickness diminution limit of the upper deck plate is 20% of the original thickness at the midship region and the thickness of the whole upper plate is worn out about 20% of the original thickness, the section modulus of the transverse section also reaches 80% of the original. And this case is never accepted from the viewpoint on longitudinal strength of hull girder in the current rules. Therefore wastage allowance criteria for the transverse section modulus are defined in the current classification rules to ensure sufficient hull girder strength. The more critical criteria among the two wastage allowance criteria mentioned above are applied in actual survey of ships in service. For the example case mentioned above, wastage allowance is 10% diminution of the original thickness. The wastage allowance criteria from a similar point of view are also applied to the bottom plates which contribute to the longitudinal strength of hull girder. In case of inner bottom plating, since it is close to the neutral axis of transverse section, the wastage allowance is set as about 20% of the original thickness. Considering the example of a Cape size bulk carrier with deck plating 38mm, inner bottom plating 25mm, and bottom plating 20mm, the wastage allowance and proposed corrosion addition mentioned above is given in Table 4.

Table 4 Current Wastage allowance and proposed corrosion addition

	Original thickness t	Wastage allowance from the viewpoint of local strength	Wastage allowance from the viewpoint of longitudinal strength	Proposed wastage allowance	Proposed corrosion addition
Upper deck plating	38mm	8.6mm (20% *t + 1mm)	3.8mm	3.5mm	3.9mm
Inner bottom plating	25mm	6.0mm (20% *t + 1mm)	5.0mm	5.0mm	5.4mm
Bottom plating	20mm	5.0mm (20% *t + 1mm)	2.0mm	2.5mm	2.7mm

In can be concluded that the proposed wastage allowance is approximately equal to the current actual wastage allowance criteria applied in actual survey. Therefore, the proposed wastage allowance and corrosion addition provide a sufficient value considering the actual wastage allowance in the new structural rule based on the net scantling approach

2.2 Wastage allowance for the global strength member

As mentioned before, the global strength of structural members is assessed using scantlings obtained by reducing half the corrosion addition from the original scantling. The result of hull girder strength assessment considering this approach is given in Figure 4 which shows that the transverse section modulus considering half the corrosion addition is nearly equal to 90% of the original value, which can be the wastage limit from the viewpoint of longitudinal strength. Thus the strength assessment of global structural members considering half the corrosion addition implies the strength assessment of structural members whose scantlings reach their wastage limit. In this case, since some structural members are assumed to reach the wastage limit from the viewpoint of local strength, the wastage limit of structural members is dealt with in the same manner as the local strength member. However, the actual wastage limit from the viewpoint of longitudinal strength is judged based on the actual thickness measurement data. Therefore, the treatment of the wastage allowance of global structural members mentioned above depends on accurate thickness measurement.

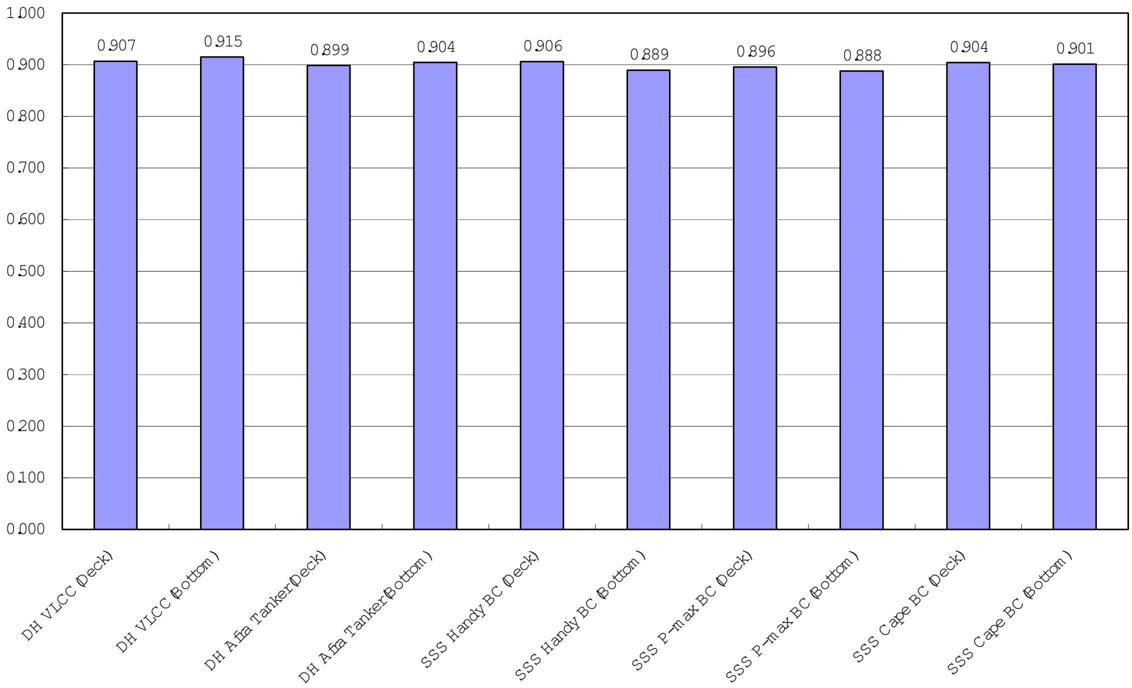

Figure 4 Transverse section modulus considering half the corrosion addition

In using FEA for the strength assessment of global structures such as structures within the cargo hold region, half the corrosion addition is taken as the average thickness diminution. Full corrosion addition is considered for buckling strength assessment. Therefore, the wastage allowance of structural members whose scantling is determined by FEA is also the same as the wastage allowance for local strength member.

3 Conclusions

The conventional method based on the corrosion rate obtained by dividing the thickness diminution by the elapsed years cannot explain the actual corrosion phenomenon of structural members. However the corrosion progress process model newly developed based on the probabilistic theory can explain the actual corrosion phenomenon. This is because the probabilistic parameters of the corrosion process model are identified by using more than half a million thickness measurement data sampled considering coated ballast tanks and cargo holds, uncoated cargo oil tanks, and maintenance condition of individual ships.

The conclusions of this study can be summarized as follows:

(1) The estimation period of corrosion diminution is 25 years which is the average age of scrapped ships.

(2) The estimated corrosion at the cumulative probability of 90% gives a sufficient level because the

thickness diminution of most of the structural members of ships that are properly maintained does not exceed the estimated corrosion values during their life.

(3) Based on the estimated corrosion, the wastage allowance is defined which minimizes the steel renewal of structural members during the ship's design life as given the following formula.

$t_{wastage\_allowance} = roundup_{0.5}(t_{CA} + t_{c2})$

This wastage allowance is close to the actual current criteria on wastage allowance applied in the survey of ships in service.

(4) The wastage allowance is defined for each side of the structural member as the corrosive environment to which each side is exposed may be different. The total corrosion addition t_{CA} is obtained by adding the corrosion addition value of one side t_{C1} and that of the other side t_{C2} plus 0.5mm taken as $t_{reserve}$, which are expressed in increments of 0.1mm. Where $t_{reserve}$ (=0.5mm) is the thickness in reserve to account for anticipated maximum thickness diminution t hat may occur during the assumed inspection intervals of 2.5 years after the thickness measurement. Then corrosion addition value is nearly equal to the estimated corrosion diminution taking into account the 2 standard deviation at 25 years.

(5) The scantling of a structural member consists of two necessary minimum components as follows: One is t_{Net} which is the net scantling required from the structural strength viewpoint that should be kept throughout the design life of the ship. The other is the corrosion addition t_{CA} which corresponds to the estimated thickness diminution during the design life of the ship plus $t_{reserve}$. The estimation of rational corrosion addition makes the introduction of the net scantling approach to the new structural rules.

(6) The required scantling of local structural members $t_{gross\_offered}$ is obtained by the following formula.

$t_{gross\_required} = roundup_{0.5}(t_{Net} + t_{CA})$

It is preferable that $t_{gross\_required}$ is rounded up to the nearest higher 0.5mm.

(7) Transverse section modulus considering half the corrosion addition is about 90% of the original value which corresponds to the wastage allowance from the viewpoint of hull girder longitudinal strength. Wastage allowance for global structural members can be obtained using the same formulation as for local structural members.

(8) Global strength members such as those contributing to the hull girder strength can be assessed by FEA considering half the corrosion addition.

(9) Fatigue strength of structural details can be assessed considering half the corrosion addition as a mean thickness diminution during the design life of ships.