9.1 GENERAL CONSIDERATIONS

9.1.4 Corrosion Model

Net thicknesses to be used in fatigue assessment are as follows;

(1) The net thickness of local support members subjected to lateral load is to be obtained by deducting $0.5 \cdot t_C$ from the gross thickness offered.

(2) The net thickness of hull girder section properties is to be obtained by deducting $0.3 \cdot t_C$ [or $0.25 \cdot t_C$] from the gross thickness offered.

(3) The net thickness of all structural members in FE model is to be obtained by deducting $0.5 \cdot t_C$ from the gross thickness offered. The stresses used in the fatigue assessment are to be corrected by multiplying the calculated stress by 0.95.

Technical background of the proposal

Although it is well known that the scatter in corrosion diminution of ship structural members is large, the structural strength can be evaluated according to the model of uniform corrosion condition by the average thickness diminution. The evaluated strength can be regarded as the deterministic value even though the local corrosion diminution is random variable.

The diminution rate of the midship section modulus of a certain ship, whose principal dimensions are L x B x D x Cb = 310.0 x 58.0 x 29.5 x 0.808, was evaluated as shown in Fig. 1.

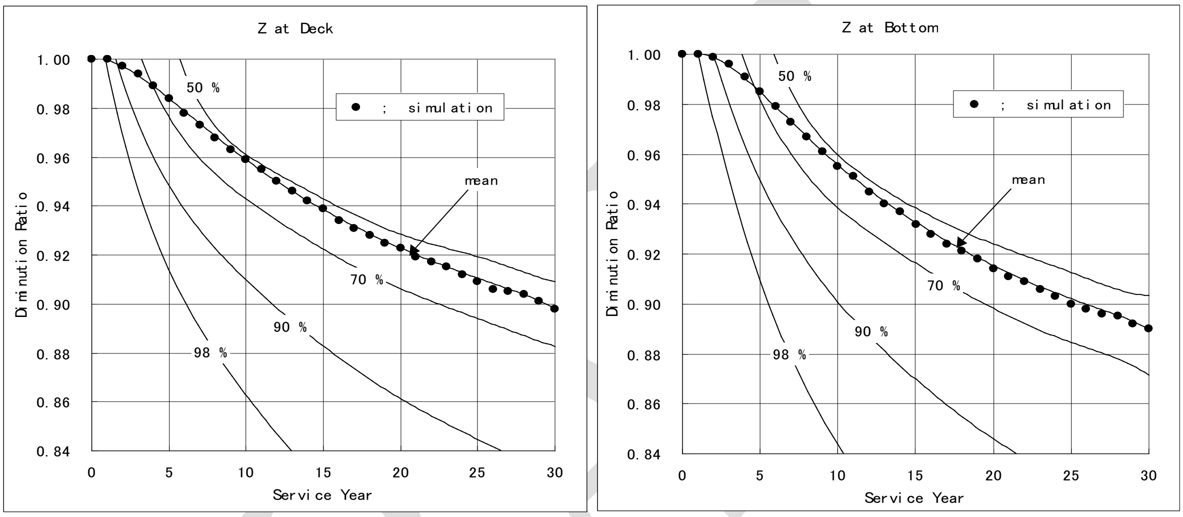

Fig.1 Relation between state of corrosion of each longitudinal strength member and diminution tendency of mid-ship section modulus.

The diminution rates of the midship section modulus were evaluated when assuming that each member was uniformly diminished by the amount of corrosion that the cumulative probability of the diminution becomes 50%, 70%, 90%, and 98% respectively. And the evaluation was made when assuming that each member was uniformly diminished by the average value of the amount of corrosion. Moreover, the generation and the progress of the corrosion of each member were also simulated and the diminution rate of midship section modulus was evaluated. The average value of such an evaluation result of 500 cases is indicated as solid circle in Fig. 1. The difference of the evaluated section modulus by the simulation was about 1.3% in the coefficient of variance even if the maximum. It has been understood that the section modulus diminishes almost deterministically even if the amount of corrosion of each member varies stochastically very much. The result when assuming that each member was uniformly diminished by the average value of the amount of corrosion and the evaluation result by the simulation are almost corresponding.

The corrosion addition of each structural member was established based on the amount of corrosion diminution which corresponds to the 95% cumulative probability at 25 years. The average corrosion diminution is almost equal to the half of this value. Consequently, the strength of the structure aged 25 years can be evaluated by the structural model obtained by deducting half of corrosion addition from the gross thickness.

Fatigue strength is assessed by the fatigue damage accumulated from the beginning of the service. In the early stage of the life, thickness of structural members is hardly diminished. Therefore, fatigue assessment based on the corrosion condition of 25 years gives too conservative results. Fatigue assessment considering the transition of corrosion condition is required.

When the long term stress range distribution follows Weibull distribution, cumulative fatigue damage according to the Miner's law can be calculated as below. The characteristic value of stress range, which increases with the increase of thickness diminution, is the function of time.

$$D = \sum_i \frac{n_i}{N_i} = \sum_i \frac{n_i \Delta\sigma_i^m}{C} = \frac{N_L}{C} \beta(t)^m \Gamma\left[1 + m/\alpha\right] \propto \Delta\sigma(t)^m$$

Then the expected stress range, which gives cumulative fatigue damage same as the fatigue damage considering the transition of corrosion condition, can be obtained as below.

$$\overline{\Delta\sigma} = \left\{ \frac{1}{T} \int_0^T \Delta\sigma(t)^m \, dt \right\}^{1/m}$$

On the other hand, the corrosion condition (amount of corrosion diminution) can be expressed by following equation.

$$d(t) = a(t - t_0)^{1/b}$$

Since the values of parameter in the above equation vary depending on the corrosion environment, some cases of corrosion conditions were assumed to evaluate the effect of corrosion progress on the fatigue strength assessment. In this examination, a certain stiffened panel （$b_p \times t_p + h_w \times t_w + b_f \times t_f = 900 \times 20.5 + 425 \times 11.5 + 150 \times 25$） was used. Target values of corrosion addition were assumed to be from 3mm to 5mm.

The ratios of the amount of expected corrosion diminution which consider the transition of corrosion progress to the corrosion diminution at 25 years were obtained for each condition. And the ratios of the expected stress which gives cumulative fatigue damage same as the fatigue damage considering the transition of corrosion condition to the stress at 25 years were also obtained.

Table 1 The ratios of expected corrosion diminution and the expected stress which consider the transition of corrosion progress to the values at 25 years.

t_C on one side	b	t_0	$\overline{d}/d(25)$	$\overline{Z}/Z(25)$	$\overline{\sigma}/\sigma(25)$
2.5	3	0	0.761	1.085	0.922
		2.5	0.693	1.108	0.902
		5	0.630	1.131	0.884
		7.5	0.556	1.157	0.864
	2	0	0.678	1.114	0.898
		2.5	0.615	1.136	0.880
		5	0.548	1.152	0.868
		7.5	0.478	1.174	0.852
	1	0	0.500	1.169	0.855
		2.5	0.467	1.188	0.842
		5	0.425	1.202	0.832
		7.5	0.371	1.221	0.819
2	3	0	0.761	1.063	0.941
		2.5	0.693	1.081	0.925
		5	0.630	1.097	0.911
		7.5	0.556	1.117	0.896
	2	0	0.678	1.085	0.922
		2.5	0.615	1.101	0.908
		5	0.548	1.119	0.894
		7.5	0.478	1.137	0.880
	1	0	0.500	1.126	0.888
		2.5	0.467	1.140	0.878
		5	0.425	1.151	0.869
		7.5	0.371	1.164	0.859
1.5	3	0	0.761	1.044	0.958
		2.5	0.693	1.056	0.947
		5	0.630	1.070	0.935
		7.5	0.556	1.082	0.925
	2	0	0.678	1.059	0.944
		2.5	0.615	1.071	0.934
		5	0.548	1.083	0.923
		7.5	0.478	1.096	0.913
	1	0	0.500	1.092	0.916
		2.5	0.467	1.098	0.911
		5	0.425	1.105	0.905
		7.5	0.371	1.115	0.897

parameter "a" is determined so as to obtain the target corrosion addition at 25 years

Since the average of evaluated $\overline{d}/d(25)$ is about 0.6, the fatigue assessment of hull girder stress considering the effect of transition of corrosion progress can be assessed based on the net thickness obtained by deducting $0.5 \cdot t_C \times 0.6 = 0.3 \cdot t_C$ from the gross thickness.

On the other hand, it is decided to use a unified corrosion deduction of $0.5 \cdot t_C$ for the strength assessment of yielding and buckling. For the simplicity of work, to use same FE model should be supported. Since this model is the model which represent the corrosion condition at 25 years, the consideration on the effect of transition of corrosion progress is necessary when assessing fatigue strength. For this purpose, the evaluated stress according to this FE model is necessary to be corrected by multiplying it by $\overline{\sigma}/\sigma(25)$. In order to make a conservative assessment, the value of 0.95, which is the maximum value of $\overline{\sigma}/\sigma(25)$, is appropriate to use.

In the case that the subject structure is relatively small such as stiffener end connection, fatigue assessment based on the corrosion condition at 25 years may be appropriate if taking the excessive local corrosion condition into account.