KC#386

Stress Concentration around Hatch Corner of Bulk Carrier

1. Simplified Fillet Shoulder Model of Hatch Corner

When evaluating a stress concentration around hatch corner of bulk carrier subject to the longitudinal stress due to vertical hull girder bending moment, that is illustrated in Fig.1(a), the shaded area in cross deck is the area where the longitudinal stress is not worked. Therefore, in order to evaluate the stress concentration around hatch corner of bulk carrier, the simplified fillet shoulder model shown in Fig.1(b) can be used.

The height of fillet shoulder depend on the degree of disturbance of longitudinal stress flow occurred due to the structural discontinuity around hatch corner.

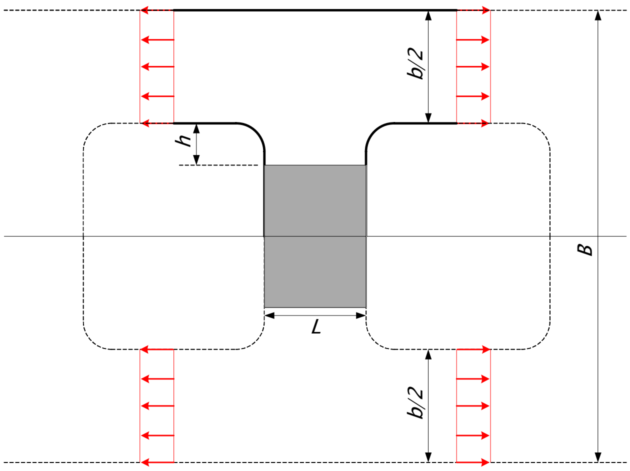

Fig. 1(a) Hatch Opening of Bulk Carrier

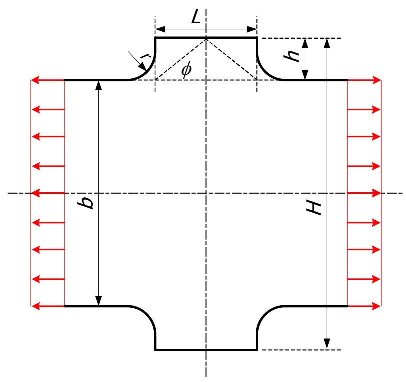

Fig. 1(b) Simplified Fillet Shoulder Model

2. Stress Concentration Factor

2.1 Experimental Formula

The stress concentration factor for the stepped flat tension bar with fillet shoulder was given by Heywood [Heywood, R. B., “Photo-elasticity for Designers”, Pergamon, New York, 1969] as below.

$$\alpha = 1 + \left(\frac{b}{2.8H - 2b} \frac{H-b}{2r} \right)^{0.65} = 1 + \left(\frac{b}{5.6h + 0.8b} \frac{h}{r} \right)^{0.65} = 1 + \left(\frac{b}{2.8L\tan\phi + 0.8b} \frac{L\tan\phi}{2r} \right)^{0.65}$$

The above formula can be applied in evaluating the stress concentration factor to the nominal hull girder vertical bending stress which acts on the ship’s side part of upper deck. The above formula gives the stress concentration factor for the hatch corner of circular arc shape. Although an elliptic arc shape is often used to decrease stress concentration in the actual design, there are no analytical nor experimental results regarding on the stress concentration for the fillet shoulder with elliptic arc shape.

Here, following simple correction factor for the elliptic arc shape is assumed. This correction factor gives the ratio of stress concentration for the tension of an infinite width thin element with an elliptic hole to that with a circular hole. In this equation, r_a denotes the radius in major axis and r_b denotes the radius in minor axis. This correction factor can be applied to the stress concentration factor for the fillet shoulder with circular arc shape of radius r_a.

$$f_c = \frac{1}{3} + \frac{2r_b}{3r_a}$$

2.2 Disturbance of stress flow

As shown in Fig. 1(a), the disturbance of longitudinal stress flow is occurred at the opening corner due to the structural discontinuity around hatch corner. This disturbance of stress flow causes stress concentration and the degree of stress concentration depends on the angle of disturbed stress flow 'ϕ' and the length of shoulder. According to the photoelasticity experimental results, it is said that the angle of disturbed stress flow was about 10 to 30 degree. According to the results of FE analysis of bulk carrier made by NK, the angles of disturbed stress flow around hatch corner were about 15 to 30 degree as shown in Table 1.

Table 1 Angle of disturbed stress flow to the longitudinal direction

Location	Angle to the longl. Direction.
Opening at mid part	16.5 ～ 28.9
Foremost opening	23.0

2.3 Shape of Hatch Opening of Bulk Carrier

The degree of stress concentration at hatch corner is also depending on the shape of hatch opening on the upper deck. Table 2 shows the results of the survey of existing bulk carriers.

According to the Table 2, the ratio of 'H' to 'b' is about 1.1 to 1.3. And the ratio of 'r_a' to 'b' is about 0.05 to 0.07.

Table 2 Shape of Hatch Opening of Typical Bulk Carriers

S. No.	Lpp	B	Length	Width	L	b	H(15)	H(20)	H(25)	H(30)	major r	minor r
BC1	179.80	31.00	20.80	17.60	8.00	13.40	15.54	16.31	17.13	18.02	0.90	0.45
BC2	185.00	32.26	20.47	18.60	8.90	13.66	16.04	16.90	17.81	18.80		
BC3	215.00	32.20	17.85	14.58	7.65	17.62	19.67	20.40	21.19	22.04	1.22	0.61
BC4	279.00	45.00	16.32	20.16	10.56	24.84	27.67	28.68	29.76	30.94		
BC5	279.00	45.00	14.72	21.00	11.04	24.00	26.96	28.02	29.15	30.37	1.36	0.78
BC6	279.20	45.00	15.47	20.00	10.01	25.00	27.68	28.64	29.67	30.78		
BC7	290.20	50.00	15.76	23.40	10.84	26.60	29.50	30.54	31.65	32.86		

2.4 Examples of Stress Concentration Factor

Figure 2(a) and 2(b) show the results of evaluated stress concentration factor for the hatch corner where a circular arc shape and an elliptic arc shape are applied respectively. In these figures, $x = r_a/b$ and $p = H/b$.

When an elliptic arc shape is applied to the hatch corner, the stress concentration becomes sufficiently small.

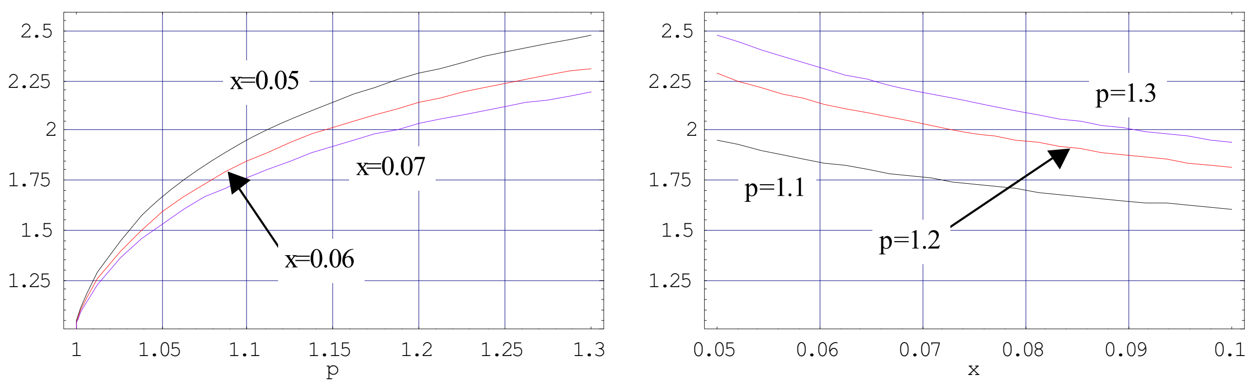

Fig. 2(a) Stress Concentration Factor when the Corner is Circular Arc Shape

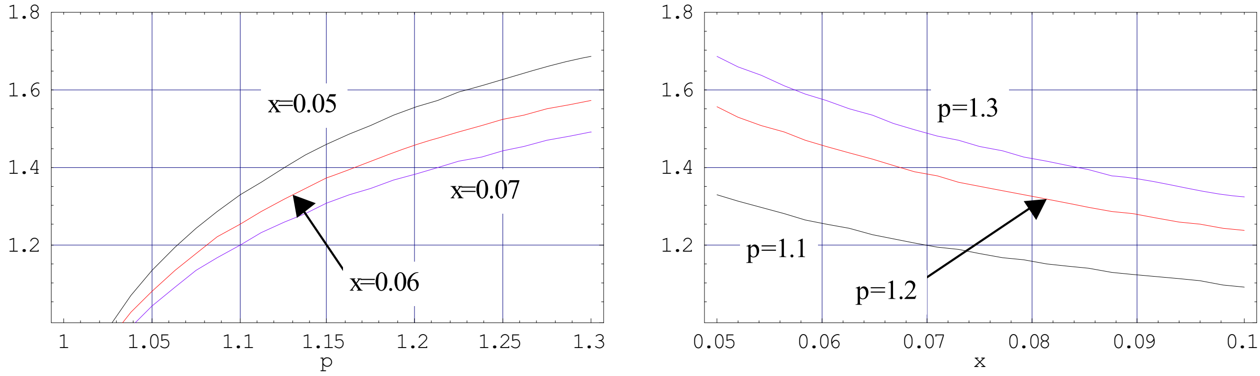

Fig. 2(b) Stress Concentration Factor when the Corner is Elliptic Arc Shape

3. Proposed Formula of Stress Concentration Factor

The stress concentration factor for the hatch corner is proposed as below.

$$\alpha = \max\left[1.0,\quad \frac{r_a + 2r_b}{3r_a}\cdot\left\{1+\left(\frac{b}{1.23L+0.8b}\,\frac{0.22L}{r_a}\right)^{0.65}\right\}\right]$$

where r_a ; radius in major axis

r_b ; radius in minor axis (if the shape of corner is a circular arc, r_b is to be equal to r_a)

L ; length of cross deck

b ; distance from the edge of hatch opening to the ship's side