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On the Stiffening of the Edge of the Hole in Orthogonally Aeolotropic Plate with a Circular Hole (stiffened with the coaming plate)*

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As a means of reducing the circumferential stress concentration in plate, the coaming plate is usually introduced around the edge of the hole to supplement the doubling plate. This paper deals with the effect of the coaming plate on the stress distribution in orthogonally aeolotropic plate under uniform tension. That is, we assume the coaming plate is a circular ring and by using the following formula for the edge stress of the plate, namely,

$$\widehat{rr} = P_0 + 2 \sum_{n=1}^{\infty} P_{2n} \cos 2n\beta \quad \text{and} \quad \widehat{r\beta} = 2 \sum_{n=1}^{\infty} S_{2n} \sin 2n\beta$$

the problem can be solved theoretically and simply. In conclusion, the larger the Young's modulus of the coaming plate is, and the greater its height is, and the greater its thickness is, the more the circumferential stress is reduced.

1. Introduction

As a means of reducing the circumferential stress concentration in orthogonally aeolotropic plate with a circular hole, in the preceding report I studied the effect of two crossed bars that have been fitted into a circular hole with the object of stiffening the edge of the hole. This report deals with the effect of the coaming plate, which is usually introduced around the edge of the hole to supplement the doubling plate. In this case, we assume the coaming plate is not a plate, but a circular ring. That is, when the plate with this circular hole is pulled with a uniform tension from infinite distance, we can calculate the stress and displacement around the edge of the hole. And for the coaming plate itself these stresses work on it as the outer load.

So, we can calculate the displacement of the coaming plate from this load.

The displacements that are thus obtained must be equal to the displacements around the edge of the hole of the plate.

Therefore, by equating these displacements, we can solve the unknown constant and our problem can be solved theoretically perfectly.

But this method makes the calculation very

complicated. So, by putting the edge stress $\widehat{rr}$ and $\widehat{r\beta}$ of the plate on the simple form, we can solve it comparatively simply, if we calculate the displacements of the coaming plate from this assumed stress. And the unknown constant, which increases, by assuming these stresses and considering the resultant forces around the edge of the plate, can be solved easily from the relation between the stress function and those resultant forces.

2. Plate

We assume that the orthogonally aeolotropic plate is of infinite size. Like the proceeding report, the fundamental equation is

$$\lambda_1^2 \lambda_2^2 \frac{\partial^4 \chi}{\partial x^4} + (\lambda_1^2 + \lambda_2^2) \frac{\partial^4 \chi}{\partial x^2 \partial y^2} + \frac{\partial^4 \chi}{\partial y^4} = 0 \quad \dots\dots (1)$$

where $\lambda_1^2 \lambda_2^2 \equiv E_x / E_y$, $\lambda_1^2 + \lambda_2^2 \equiv E_x / G_{xy} - 2\nu_x$

E_x, E_y : Young's modulus in x, y -direction of the plate

G_{xy} : Shearing modulus

ν_x : Poisson's ratio in x -direction

General solution of (1) is

$$\chi(x, y) = \frac{-1}{\lambda_1^2 - \lambda_2^2} R \left\{ \frac{F_1(z_1)}{\lambda_1^2} - \frac{F_2(z_2)}{\lambda_2^2} \right\} \dots\dots (2)$$

where $z_j = x + i\lambda_j y \quad (j=1, 2)$

Stress function is

$$F'_j(z_j) = A_j^{(0)} z_j + B_j + \frac{\sum_{n=1}^{\infty} A_j^{(2n-1)}}{z_j^{2n-1}} \quad \dots\dots (3)$$

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Fig. 1

where $A_j^{(0)}$: Real constant
 $B_j, A_j^{(2n-1)}$: Complex constant
 $\zeta_j = e^{\alpha_j + i\beta_j}$

Next,

$$z_j = x + i\lambda_j y = \frac{1}{2} \{ (1 + \lambda_j) \zeta_j + (1 - \lambda_j) \zeta_j^{-1} \} \quad \dots (4)$$

By using the above (4), we make a double change of the co-ordinate, so $\alpha_j = 0$, $\beta_j = \beta$ show the unit circle. Accordingly we consider the hole by the equation $\alpha_j = 0$.

Thus, the stress is

$$\left. \begin{aligned} \widehat{xx} &= \frac{\partial^2 \chi}{\partial y^2} = \frac{1}{\lambda_1^2 - \lambda_2^2} R \{ F_1''(z_1) - F_2''(z_2) \} \\ \widehat{yy} &= \frac{\partial^2 \chi}{\partial x^2} = \frac{-1}{\lambda_1^2 - \lambda_2^2} R \left\{ \frac{F_1''(z_1)}{\lambda_1^2} - \frac{F_2''(z_2)}{\lambda_2^2} \right\} \\ \widehat{xy} &= -\frac{\partial^2 \chi}{\partial x \partial y} = \frac{-1}{\lambda_1^2 - \lambda_2^2} I_m \left\{ \frac{F_1''(z_1)}{\lambda_1} - \frac{F_2''(z_2)}{\lambda_2} \right\} \end{aligned} \right\} \quad \dots (5)$$

$$\left. \begin{aligned} \text{for } n=1, \quad a_1^{(1)} &= \lambda_1^2 (\lambda_1 + \lambda_2) \{ T - (1 - \lambda_2) P_0 - (1 + \lambda_2) (P_2 - S_2) \} \\ a_2^{(1)} &= \lambda_2^2 (\lambda_1 + \lambda_2) \{ T - (1 - \lambda_1) P_0 - (1 + \lambda_1) (P_2 - S_2) \} \\ b_1^{(1)} &= b_2^{(1)} = 0 \\ \text{for } n \geq 2, \quad a_1^{(2n-1)} &= \frac{-1}{2n-1} \lambda_1^2 (\lambda_1 + \lambda_2) \{ (1 - \lambda_2) (P_{2n-2} + S_{2n-2}) + (1 + \lambda_2) (P_{2n} - S_{2n}) \} \\ a_2^{(2n-1)} &= \frac{-1}{2n-1} \lambda_2^2 (\lambda_1 + \lambda_2) \{ (1 - \lambda_1) (P_{2n-2} + S_{2n-2}) + (1 + \lambda_1) (P_{2n} - S_{2n}) \} \\ b_1^{(2n-1)} &= b_2^{(2n-1)} = 0 \end{aligned} \right\} \quad \dots (11)$$

Accordingly, the circumferential stress $\widehat{\beta\beta}$ is

$$\begin{aligned} \widehat{\beta\beta} &= \widehat{xx} + \widehat{yy} - \widehat{rr} \\ &= T - \frac{1}{\lambda_1^2 - \lambda_2^2} \left[(\lambda_1^2 - 1) \left\{ T - (1 - \lambda_2) P_0 - (1 + \lambda_2) (P_2 - S_2) \right\} \frac{\partial_1}{\Delta_1} - (\lambda_2^2 - 1) \left\{ T - (1 - \lambda_1) P_0 \right. \right. \\ &\quad \left. \left. - (1 + \lambda_1) (P_2 - S_2) \right\} \frac{\partial_2}{\Delta_2} - \sum_{n=2}^{\infty} \frac{(\lambda_1^2 - 1)}{\Delta_1} \left\{ (1 - \lambda_2) (P_{2n-2} + S_{2n-2}) + (1 + \lambda_2) (P_{2n} - S_{2n}) \right\} \right. \\ &\quad \left. \times \left\{ \cos 2(n-1)\beta \cdot \partial_1 - \sin 2(n-1)\beta \cdot \epsilon_1 \right\} + \sum_{n=2}^{\infty} \frac{(\lambda_2^2 - 1)}{\Delta_2} \left\{ (1 - \lambda_1) (P_{2n-2} + S_{2n-2}) \right\} \right] \end{aligned}$$

We assume that the uniform tension works on the plate at an infinite distance, so

$$A_1^{(0)} = \lambda_1^2 T, \quad A_2^{(0)} = \lambda_2^2 T \quad \dots (6)$$

And we know the relation between $\widehat{xx}$, $\widehat{yy}$, $\widehat{xy}$ and $\widehat{rr}$, $\widehat{\beta\beta}$, $\widehat{r\beta}$, that is

$$\left. \begin{aligned} 2\widehat{rr} &= \widehat{xx}(1 + \cos 2\beta) + \widehat{yy}(1 - \cos 2\beta) + 2\widehat{xy} \sin 2\beta \\ 2\widehat{\beta\beta} &= \widehat{xx}(1 - \cos 2\beta) + \widehat{yy}(1 + \cos 2\beta) - 2\widehat{xy} \sin 2\beta \\ 2\widehat{r\beta} &= (\widehat{yy} - \widehat{xx}) \sin 2\beta + 2\widehat{xy} \cos 2\beta \end{aligned} \right\} \quad \dots (7)$$

Therefore, we can obtain the edge stress around the hole of the plate from (5) and (7), but these equations are very long and complicated.

So, we assume the edge stress of the hole of the plate is

$$\left. \begin{aligned} \widehat{rr} &= P_0 + 2 \sum_{n=1}^{\infty} P_{2n} \cos 2n\beta \\ \widehat{r\beta} &= 2 \sum_{n=1}^{\infty} S_{2n} \sin 2n\beta \end{aligned} \right\} \quad \dots (8)$$

where, P_0, P_{2n}, S_{2n} : unknown constant

Though we obtain these new unknown constants by referring to (8) and the equation obtained from (5) and (7), we can solve by considering the resultant forces X, Y , in x, y -direction around the hole of the plate. That is,

$$\left. \begin{aligned} X &= \int (\widehat{rr} \cos \beta d\beta - \widehat{r\beta} \sin \beta d\beta) \\ Y &= \int (\widehat{rr} \sin \beta d\beta + \widehat{r\beta} \cos \beta d\beta) \end{aligned} \right\} \quad \dots (9)$$

While, from the stress function

$$\left. \begin{aligned} X &= \frac{\partial \chi}{\partial y} = \frac{1}{\lambda_1^2 - \lambda_2^2} I_m \left\{ \frac{F_1'(z_1)}{\lambda_1} - \frac{F_2'(z_2)}{\lambda_2} \right\} \\ Y &= -\frac{\partial \chi}{\partial x} = \frac{1}{\lambda_1^2 - \lambda_2^2} R \left\{ \frac{F_1'(z_1)}{\lambda_1^2} - \frac{F_2'(z_2)}{\lambda_2^2} \right\} \end{aligned} \right\} \quad \dots (10)$$

Therefore, from (9) and (10)

$$+ (1 + \lambda_1)(P_{2n} - S_{2n}) \{ \cos 2(n-1)\beta \cdot \delta_2 - \sin 2(n-1)\beta \cdot \varepsilon_2 \} \Big] - \{ P_0 + 2 \sum_{n=1}^{\infty} P_{2n} \cos 2n\beta \} \dots\dots\dots (12)$$

where

$$\begin{aligned} \Delta_j &= (\lambda_j^2 + 1) - (\lambda_j^2 - 1) \cos 2\beta \\ \delta_j &= (\lambda_j - 1) - (\lambda_j + 1) \cos 2\beta \\ \varepsilon_j &= (\lambda_j + 1) \sin 2\beta \quad (j=1, 2) \end{aligned}$$

Now, the displacement in x , y -direction u_x , u_y is as follows :

$$\left. \begin{aligned} E_x u_x &= \frac{1}{\lambda_1^2 - \lambda_2^2} R \left\{ \frac{\lambda_1^2 + \nu_x}{\lambda_1^2} F_1'(z_1) - \frac{\lambda_2^2 + \nu_x}{\lambda_2^2} F_2'(z_2) \right\} \\ E_x u_y &= \frac{-1}{\lambda_1^2 - \lambda_2^2} I_m \left\{ \frac{\lambda_2^2 + \nu_x}{\lambda_1} F_1'(z_1) - \frac{\lambda_1^2 + \nu_x}{\lambda_2} F_2'(z_2) \right\} \end{aligned} \right\} \dots\dots\dots (13)$$

And the displacement in r , β -direction u_r , u_β is :

$$\left. \begin{aligned} u_r &= u_x \cos \beta + u_y \sin \beta \\ u_\beta &= -u_x \sin \beta + u_y \cos \beta \end{aligned} \right\} \dots\dots\dots (14)$$

Therefore, substituting (13) in (14)

$$\left. \begin{aligned} u_r &= \frac{1}{2E_x} \left[(1 + \lambda_1 + \lambda_2 - \lambda_1 \lambda_2) T - \{ 2\nu_x - 2\lambda_1 \lambda_2 + (\lambda_1 + \lambda_2)(1 + \lambda_1 \lambda_2) \} P_0 \right. \\ &\quad - (\lambda_1 + \lambda_2)(1 - \lambda_1 \lambda_2)(P_2 - S_2) + \{ (1 + \lambda_1 + \lambda_2 + \lambda_1 \lambda_2) T - (\lambda_1 + \lambda_2)(1 - \lambda_1 \lambda_2) P_0 \\ &\quad + [2\nu_x - 2\lambda_1 \lambda_2 - (\lambda_1 + \lambda_2)(1 + \lambda_1 \lambda_2)](P_2 - S_2) \} \cos 2\beta - \sum_{n=2}^{\infty} \frac{1}{2n-1} \{ [2\nu_x \\ &\quad - 2\lambda_1 \lambda_2 - (\lambda_1 + \lambda_2)(1 + \lambda_1 \lambda_2)](P_{2n-2} + S_{2n-2}) + (\lambda_1 + \lambda_2)(1 + \lambda_1 \lambda_2)(P_{2n} - S_{2n}) \} \\ &\quad \times \cos 2(n-1)\beta - \sum_{n=2}^{\infty} \frac{1}{2n-1} \{ (\lambda_1 + \lambda_2)(1 - \lambda_1 \lambda_2)(P_{2n-2} + S_{2n-2}) + [2\nu_x - 2\lambda_1 \lambda_2 \\ &\quad - (\lambda_1 + \lambda_2)(1 + \lambda_1 \lambda_2)](P_{2n} - S_{2n}) \} \cos 2\beta \Big] \\ u_\beta &= \frac{-1}{2E_x} \left[\{ (1 + \lambda_1 + \lambda_2 + \lambda_1 \lambda_2) T - (\lambda_1 + \lambda_2)(1 - \lambda_1 \lambda_2) P_0 + [2\nu_x - 2\lambda_1 \lambda_2 \right. \\ &\quad - (\lambda_1 + \lambda_2)(1 + \lambda_1 \lambda_2)](P_2 - S_2) \sin 2\beta + \sum_{n=2}^{\infty} \frac{1}{2n-1} \{ [2\nu_x - 2\lambda_1 \lambda_2 \\ &\quad + (\lambda_1 + \lambda_2)(1 + \lambda_1 \lambda_2)](P_{2n-2} + S_{2n-2}) + (\lambda_1 + \lambda_2)(1 - \lambda_1 \lambda_2)(P_{2n} \\ &\quad - S_{2n}) \} \sin 2(n-1)\beta - \sum_{n=2}^{\infty} \frac{1}{2n-1} \{ (\lambda_1 + \lambda_2)(1 - \lambda_1 \lambda_2)(P_{2n-2} + S_{2n-2}) \\ &\quad \left. [2\nu_x - 2\lambda_1 \lambda_2 - (\lambda_1 + \lambda_2)(1 + \lambda_1 \lambda_2)] \times (P_{2n} - S_{2n}) \} \sin 2n\beta \} \right] \end{aligned} \right\} \dots\dots\dots (15)$$

3. Coaming plate

We assume the coaming plate is a circular ring that has the rectangular section—thickness t' , height h —as the effective section. And the radius of the ring is very large in comparison with the thickness t' of the section. Thus, the displacement in r , β -direction on the neutral axis of the ring-section $\bar{u}_r$, $\bar{u}_\beta$ must satisfy the following equation⁽²⁾.

$$\left. \begin{aligned} \frac{d^5 \bar{u}_r}{d\beta^5} + 2 \frac{d^3 \bar{u}_r}{d\beta^3} + \frac{d \bar{u}_r}{d\beta} &= \frac{r^2 t}{EA} \left\{ -\frac{d^2}{d\beta^2} (\widehat{r\beta})_{r=1} + \left(1 + \frac{r^2}{k^2} \right) \frac{d}{d\beta} (\widehat{rr})_{r=1} + \frac{r^2}{k^2} (\widehat{r\beta})_{r=1} \right\} \\ \frac{d^5 \bar{u}_\beta}{d\beta^5} + 2 \frac{d^3 \bar{u}_\beta}{d\beta^3} + \frac{d \bar{u}_\beta}{d\beta} &= \frac{r^2 t}{EA} \left\{ -\frac{d^4}{d\beta^4} (\widehat{r\beta})_{r=1} + \frac{d^3}{d\beta^3} (\widehat{rr})_{r=1} - \frac{r^2}{k^2} \frac{d}{d\beta} (\widehat{rr})_{r=1} - \frac{r^2}{k^2} (\widehat{r\beta})_{r=1} \right\} \end{aligned} \right\} \dots\dots\dots (16)$$

where $(\widehat{rr})_{r=1}$: normal stress of the radius direction of the plate at the base of the ring and the plate

$(\widehat{r\beta})_{r=1}$: shearing stress in the circumferential direction of the plate at the base of the ring and the plate

t : the thickness of the plate

A : effective section area, $A = h \times t'$

k : radius of gyration of area around the neutral axis of the section of the ring

E : Young's modulus of the ring

Substituting (8) in (16)

$$\left. \begin{aligned} \frac{d^5 \bar{u}_r}{d\beta^5} + 2 \frac{d^3 \bar{u}_r}{d\beta^3} + \frac{d\bar{u}_r}{d\beta} &= \frac{r^2 t}{EA} \sum_{n=1}^{\infty} \left\{ \left(8n^2 + 2 \frac{r^2}{k^2} \right) S_{2n} - 4n \left(1 + \frac{r^2}{k^2} \right) P_{2n} \right\} \sin 2n\beta \\ \frac{d^6 \bar{u}_\beta}{d\beta^6} + 2 \frac{d^4 \bar{u}_\beta}{d\beta^4} + \frac{d^2 \bar{u}_\beta}{d\beta^2} &= \frac{r^2 t}{EA} \sum_{n=1}^{\infty} \left\{ 4n \left(4n^2 + \frac{r^2}{k^2} \right) P_{2n} - \left(32n^4 + 2 \frac{r^2}{k^2} \right) S_{2n} \right\} \sin 2n\beta \end{aligned} \right\} \dots\dots\dots (17)$$

This solution is

$$\left. \begin{aligned} \bar{u}_r &= H + (K + L\beta) \sin \beta + (M + N\beta) \cos \beta - \frac{r^2 t}{EA} \sum_{n=1}^{\infty} \frac{1}{2n(4n^2 - 1)} \left\{ \left(8n^2 + 2 \frac{r^2}{k^2} \right) S_{2n} - 4n \left(1 + \frac{r^2}{k^2} \right) P_{2n} \right\} \cos 2n\beta \\ \bar{u}_\beta &= H' + H''\beta + (K' + L'\beta) \sin \beta + (M' + N'\beta) \cos \beta + \frac{r^2 t}{EA} \frac{1}{4n^2(4n^2 - 1)} \left\{ \left(32n^4 + 2 \frac{r^2}{k^2} \right) S_{2n} - 4n \left(4n^2 - \frac{r^2}{k^2} \right) P_{2n} \right\} \sin 2n\beta \end{aligned} \right\} \dots\dots\dots (18)$$

In (18), the displacement is symmetrical, so

$$K = L = M = N = H' = H'' = K' = L' = M' = N' = 0$$

And from the relation with the component of the displacement of the ring and normal stress and shearing stress,

$$\begin{aligned} \frac{d^2 \bar{u}_r}{d\beta^2} + \bar{u}_r + \frac{d^3 \bar{u}_\beta}{d\beta^3} + \frac{d\bar{u}_\beta}{d\beta} &= \frac{r^2 t}{EA} \left\{ (\bar{r}r)_{r=1} + \frac{d}{d\beta} (\bar{r}\beta)_{r=1} \right\} \\ \therefore H &= \frac{r^2 t}{EA} P_0 \dots\dots\dots (19) \end{aligned}$$

Thus, by equating the displacement (18) of the coaming plate, which substitutes these constants equal and the displacement (15) of the hole of the plate, we can solve all the constants and therefore obtain the circumferential stress (12) of the hole of the plate.

F.P.: Furfural-phenol-formaldehyde resin or Pb.
D.S.P.: Double stiffened plate

Fig. 2(a) Distribution of $\hat{\beta}\beta$ for various material E of the coaming plate

4. Numerical calculation

We assume that the orthogonally aeolotropic plate is Eiche, the thickness of the plate $t=0.1$, the radius of the hole $r=1.0$. Now we change variously the quality (E), the height (h) and the thickness (t') of the coaming plate and calculate the circumferential stress $\hat{\beta}\beta$.

Eiche⁽³⁾ is $E_x=58\,200\text{ kg/cm}^2$, $E_y=21\,900\text{ kg/cm}^2$ and $\nu_x=0.33$ ($\nu_y=0.12$). Accordingly, if x -axis is piled up the fibre-direction of the plate, $\lambda_1=1.67$ and $\lambda_2=0.97$.

(1) The equality of coaming plate (E) and at this time $\hat{\beta}\beta$ max of the circumferential stress around the hole of the plate is shown in Table 1

F.P.: Furfural-phenol-formaldehyde resin or Pb.

Fig. 2(b) $\hat{\beta}\beta$ max for various material of the coaming plate

and Fig. 2, in which we assume that the height of the coaming plate $h=0.1$, the thickness of the plate $t=0.1$, that is $\mu=\frac{h}{t}=1$. The thickness of the coaming plate is $t'=0.1$.

(2) The height of the coaming plate h and $\widehat{\beta\beta}_{\max}$ is shown in Table 2 and Fig. 3, in which $t=0.1$, $t'=0.1$ and $E=0.16 \times 10^6 \text{ kg/cm}^2$.

(3) The thickness of the coaming plate t' and $\widehat{\beta\beta}_{\max}$ is shown in Table 3 and Fig. 4. Where $t=0.1$, $h=0.2$ ($\mu=2$) and $E=0.16 \times 10^6 \text{ kg/cm}^2$. Here, we assume r/t' is very large, so $t'=0.30 \sim 1.0$ is not suitable. However, I am calculating in order to discover the general tendency.

5. Conclusion

As a means of reducing the circumferential stress concentration in a plate with a circular hole, we solved the problem in various ways by stiffening the coaming plate. Of course, we assume that the coaming plate and the plate are ideally connected.

Consequently, the conclusion is

(1) The quality of the coaming plate (E)

The larger the Young's modulus of the coaming plate is, the more the circumferential stress is reduced.

(2) The height of the coaming plate (h)

Though the greater the height of the coaming

Fig. 3(a) Distribution of $\widehat{\beta\beta}$ for various height h of the coaming plate

Fig. 4(a) Distribution of $\widehat{\beta\beta}$ for various thickness t' of the coaming plate

Fig. 3(b) $\widehat{\beta\beta}_{\max}$ for various height of the coaming plate

Fig. 4(b) $\widehat{\beta\beta}_{\max}$ for various thickness of the coaming plate

Table 1. The quality of coaming plate (E) and $\hat{\beta}\beta$ max

Quality	Free	Rubber	Eiche	Oak	Furfural-phenol-formaldehyde resin or Pb	Brass	Mild steel	The double stiffened plate
Young's Modulus E kg/cm ²	0	0.0048 $\times 10^6$	0.058 $\times 10^6$	0.12 $\times 10^6$	0.16 $\times 10^6$	0.90 $\times 10^6$	2.10 $\times 10^6$	∞
E/E_s	0	0.082	1.00	2.04	2.75	15.29	36.08	∞
$\hat{\beta}\beta$ max	3.64	3.54	3.21	3.06	2.73	1.24	0.69	0.45

where $h=0.1$, $t=0.1$ ($\mu=h/t=1$), $t'=0.1$

Table 2. The height of the coaming plate h and $\hat{\beta}\beta$ max

The height of the coaming plate $\mu=h/t$	(free) 0	0.10	0.15	0.20	0.30	0.50	1.0	∞ (the double stiffened plate)
$\hat{\beta}\beta$ max	3.64	2.73	2.70	2.54	2.43	1.78	1.56	0.45

where $t=0.1$, $t'=0.1$, $E=0.16 \times 10^6$ kg/cm²

Table 3. The thickness of the coaming plate t' and $\hat{\beta}\beta$ max

The thickness of the coaming plate t'/t	(free) 0	0.05	0.10	0.15	0.20	0.30	0.50	1.0
$\hat{\beta}\beta$ max	3.64	3.00	2.54	2.36	2.22	1.88	1.49	1.26

where $t=0.1$, $h=0.2$ ($\mu=h/t=2$), $E=0.16 \times 10^6$ kg/cm²

plate is, the more the circumferential stress is reduced, when the height is greater than a certain limit (we call this height is the effective height), the degree of reducing of the circumferential stress becomes too loose.

(3) The thickness of the coaming plate (t')

Though the greater the thickness of the coaming plate is the more circumferential stress is reduced, in this case too, there is an effective thickness similar to the above effective height.

According to the result of this numerical

calculation, it will be very satisfactory to make both height and thickness of the coaming plate 1~3 times as much as the thickness of the plate, respectively.

References

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