On the Irregularity of Joint Aperture for Butt-Weld Prepared by Manual Flame-Planing

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1. Connecting with the study on the causes of residual stresses in welded plate, the irregularity of sectional area of joint aperture beveled by manual flame-planing is measured just before the welding operation, and discussed statistically.

It is generally recognized that the amount of transverse shrinkage of welded plates is much affected by heat supplied from electrodes. When the edges of plates are beveled by manual flame-planing, the sectional area of joint aperture varies considerably from section to section along its length; and to fill up the apperture by manual welding, heat supplied in each layer of weld may follow this irregularity.

In Fig. 1, a result of a measurement on the variation of aperture and that of heat supplied during the weld of first layer is shown. (Heat supplied in unit length of the joint is considered to be proportional to the weld time per its length. The points indicate the mean values over ten centimeter length of the joint.) It is seen from the result that the following of heat with the aperture is rather good but the amplitude of the former is much enlarged compared with that of the latter. The transverse shrinkage of plates on and near the weld line may then varies along the joint and causes the residual stresses after completing the weld of each layer.

2. In this note the variation of aperture are measured about many samples of 2.5 meter length picked up from the seams and butts in actual ships on the stocks, and analysed by Noguchi's Harmonic Analyser. The results obtained are shown in Table 1. The length of each sample is determined as long as possible to avoid the effects of the start and end points of gas cutting operations, and may be sufficiently long to analyse the problems because the contribution of the variation of aperture of larger wave length than few meters to the residual stresses of the present type is small.

3. We now consider the flame-planing process as one stochastic time process, and imagine that the sectional area at the point x along the cutting path happens to be $\boldsymbol{f}(x)$ which is represented by Fourier series for range $0 < x < L$, $(L = 2.5\,\mathrm{m})$,

$$\boldsymbol{f}(x) = \boldsymbol{a}_0 + \sum_{n=1}^{\infty}(\boldsymbol{a}_n \sin \omega_n x + \boldsymbol{b}_n \cos \omega_n x) \tag{1}$$

$$\left.\begin{aligned} \omega_n &= \frac{2\pi n}{L} \\ \boldsymbol{a}_0 &= \frac{1}{L}\int_0^L \boldsymbol{f}(x)\,dx \\ \boldsymbol{a}_n &= \frac{2}{L}\int_0^L \boldsymbol{f}(x)\,\sin \omega_n x\,dx \end{aligned}\right\} \tag{2}$$

$$b_n = \frac{2}{L}\int_0^L f(x)\cos\omega_n x\,dx$$

where a_0 is the mean value of sectional area over the range $0 < x < L$, and may be omitted in the following discussions by the above mentioned reasons. Denoting δ^2 the mean spuare of $f(x)$, we have

$$\delta^2 = \frac{1}{2}\sum_{n=1}^{\infty}(\overline{a_n^2} + \overline{b_n^2}) \tag{3}$$

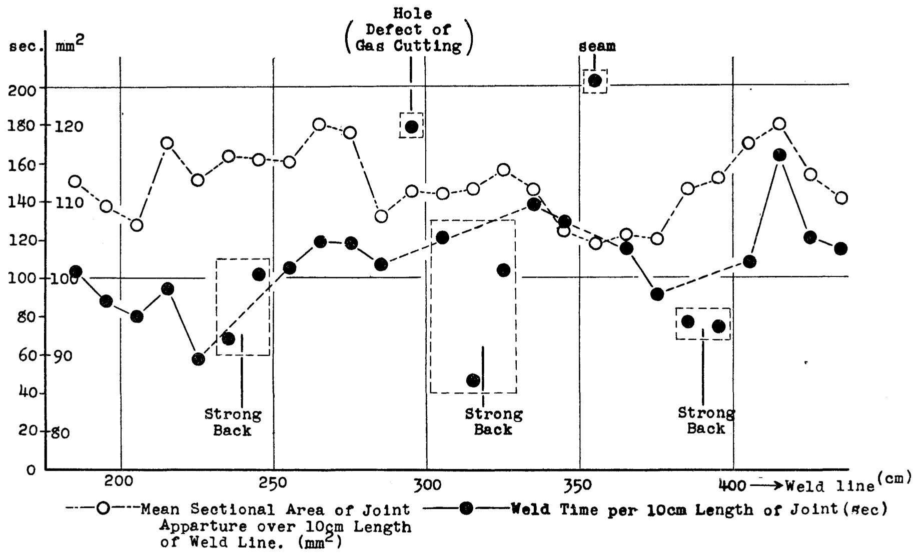

Fig.1. Comparison of the Variation of Sectional Area of Joint Apparture for Butt Weld and of Weld Time Along Its Length.

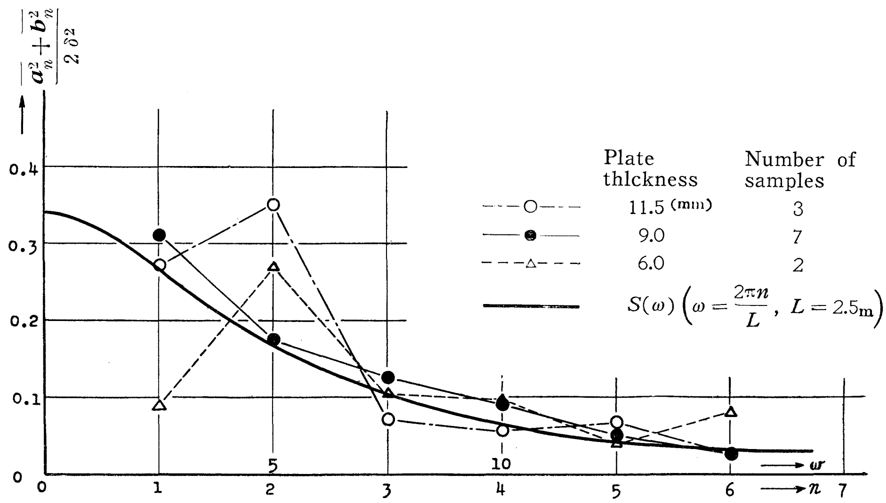

Fig.2. Normalized Spectrum Density of the Variation of Joint Aperture

where bar shows the sample mean. The values of $(\boldsymbol{a}_n^2+\boldsymbol{b}_n^2)/2\,\delta^2$ calculated from Table 1 are plotted in figure 2. From this we may infer that the normalized spectrum density of $\{\boldsymbol{f}(x)\}$ can be represented by, irrespective of the thickness of plates, as

$$S(\omega)=\frac{2}{\pi}\frac{4.85}{(4.85)^2+\omega^2}, \quad \left(\omega=\frac{2\pi n}{L}\right) \tag{4}$$

which is shown by a full line in the figure. The autocorrelation coefficient $\rho(x)$ is then

$$\rho(x)=\int_0^\infty S(\omega)\cos\omega x\,d\omega=e^{-4.85x} \tag{5}$$

The variation of the heat supplied may mainly depend on the spectrum $S(\omega)$, but its higher components should be modified by considering the high temperature plasticity of plate during the weld, the ability of the welding operator, and so forth. If we know the critical value of ω, we can have the mean amplitude and the mean frequency of the variation of joint aperture participated in the residual stresses. It is left in the later measurements.

The results in this note are based on the Reports of West Japan Committee of Ship Structure. The writer is largely indebted to Dr. Y. Watanabe, the chief of Committee, in his kind guidance.

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TABLE I. The results of Fourier Analysis of each sample in mm².

Plate Thickness	Sample	δ	n	a_n	b_n
9 mm	I	6 1	1	0.24	0.76
			2	−1.58	0.75
			3	3.40	−3.38
			4	−0.61	0.63
			5	1.58	3.34
			6	−0.59	−0.25
	II	4.1	1	3.82	0.50
			2	0.37	0.89
			3	1.19	0.75
			4	1.05	−0.30
			5	−0.27	0.72
			6	0.77	0.17
	III	9.0	1	2.02	9.52
			2	−6.63	2.54
			3	−5.23	1.07
			4	−4.04	0.05
			5	−2.96	1.40
			6	−2.55	−0.57
	IV	8.5	1	3.92	3.70
			2	−7.75	1.23
			3	−4 40	1.23
			4	−3.23	0.71
			5	1.08	−0.65
			6	−0.91	−0.16
	V	10.6	1	1.03	4.84
			2	−4.12	−1.71
			3	−3.90	−2.01
			4	−5.32	0.47
			5	−1.62	−2.74
			6	−0.73	−0.93
	VI	9.4	1	6.98	5.12
			2	−3.26	−3.24
			3	2.05	−0.47
			4	−1.89	3.98
			5	1.77	−1.26
			6	−2.06	−1.97
	VII	7.0	1	−5.16	−4.28
			2	−1.06	1.10
			3	−3.85	−1.88
			4	1.80	2.32
			5	1.21	1.47
			6	−0.01	0.62
11.5 mm	I	6.2	1	4.01	2.08
			2	−3.06	2.63
			3	−0.04	0.14
			4	3.33	1.11
			5	1.64	1.42
			6	−0.37	0.07
	II	8.6	1	−6.30	0.24
			2	3.88	7.31
			3	−0.27	−3.47
			4	0.09	−0.49
			5	1.52	2.27
			6	−2.13	−0.76
	III	6.3	1	0.46	4.62
			2	−4.62	1.34
			3	−1.25	−3.06
			4	1.65	−1.32
			5	−2.32	1.55
			6	0.77	−0.59
6 mm	I	3.8	1	−1.56	−0.76
			2	−1.74	−2.21
			3	−1.29	0.48
			4	−1.59	−1.15
			5	−0.66	0.96
			6	−0.83	−0.02
	II	4.5	1	0.96	−1.60
			2	1.64	2.72
			3	2.26	0.07
			4	1.33	1.06
			5	−0.73	−1.07
			6	1.56	1.52