강관 용접부의 초음파 비파괴검사

Ultrasonic Nondestructive Testing for Welded Steel Pipes

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요　약

강관 등과 같이 곡면을 이루는 구조물 용접부의 내부 결함을 검출하기 위한 기법을 제안하였다. 인공 결함을 만들어 초음파 비파괴검사를 행하고, 곡면의 표면 거리(Y_S)를 계산하여 실측한 참값(Y_T)과 비교해 보았다. 제안된 방법으로 계산한 값이 참값에 대하여 1%이하의 오차 범위에 들어오므로 강관 용접부의 내부 결함 검사에 응용될 수 있다.

Key words : Curved Steel Structure, Ultrasonic Testing, Nondestructive Testing

1. Introduction

Constructed facilities such as bridges, chemical plants and steel houses should take safety inspection periodically[1]. The safety inspection has many technical methods, destructive or non-destructive. For convenience, non-destructive testing methods are preferred. The ultrasonic testing method is one of the non-destructive testing technologies.For ultrasonic testing, we need a flaw detector having a screen monitor, standard testing blocks and probes. The probes are ultrasonic transducers transmitting and receiving ultrasonic waves by piezoelectric element(s)[2]. Welded pipes may have flaws in welded parts. The surfaces of the pipes are not flat, so there has been many calibration method for testing curved surfaces[3]. However, these are not easy for field engineers. In this paper, an easy method for detecting flaws in welded steel pipes is proposed.

2. Calculation

The surfaces of the welded pipes are not flat as shown in Fig. 1 Fig. 2 shows typical ultrasonic testing direction on curved surface.

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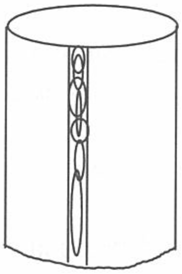

Fig. 1. A welded pipe.

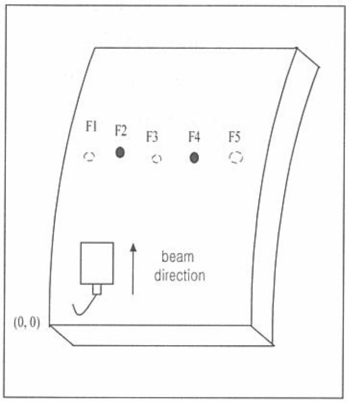

Fig. 2. Ultrasonic testing direction on curved surface.

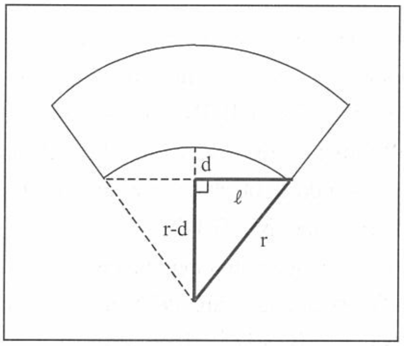

Fig. 3. Curvature radius(r) of the curved surface.

Radius of the curved surface can be calculated using Fig. 3 and eq. (1).

$$r^2 = \ell^2 + (r-d)^2$$
$$\therefore\ r = \frac{\ell^2 + d^2}{2d} \qquad (1)$$

Fig. 4 shows the ultrasonic echoes from the surface and flaw. In this figure W is a beam distance.

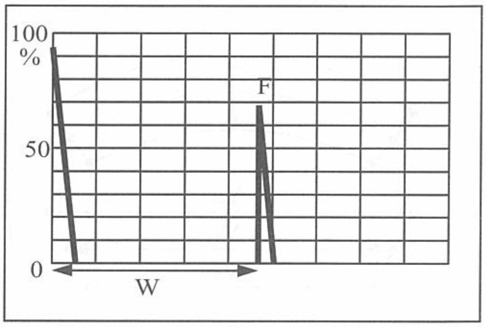

Fig. 4. Ultrasonic echoes from the surface and flaw.

Surface distance between the flaws and transducers can be calculated as below. Fig. 5 shows beam distance (W) and surface distance (Y) for flat specimen.

$$Y = W \cdot \sin\theta \qquad (2)$$

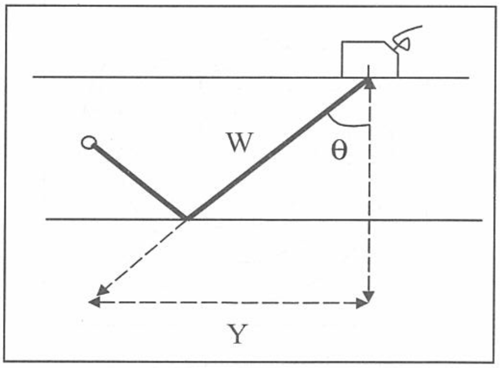

Fig. 5. Beam distance (W) and surface distance (Y) for flat specimen.

However, surfaces of the welded pipes are not flat. Welded pipes have curved surfaces. Distance between the flaws and transducers along the curved surfaces (Y_s) are needed for inspection reports. Let us suppose that you bend a flat specimen, the surface distance (Y)

will be changed into inner surface distance (Y_{in}), neutral distance (Y_o) and outer surface distance (Y_s) as shown in Fig 6.

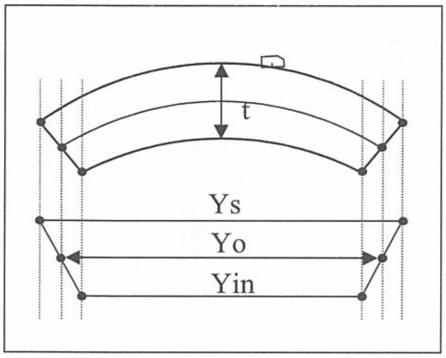

Fig. 6. Comparison of surface distances.

Fig 7 shows that three circles have same center. Let us assume that the neutral distance is same as flat surface distance. This assumption is reasonable for blocks bended a little[(4)].

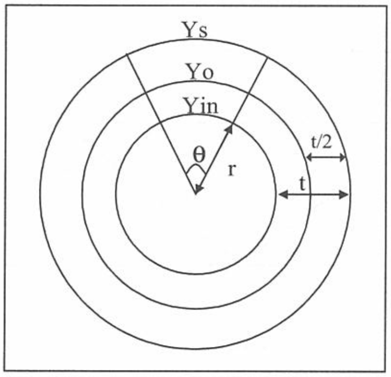

Fig. 7. Three circles have same center.

Then the outer distance (Y_s) can be calculated using calibration coefficient(K) as below.

$$\frac{Y_s}{Y_o} = \frac{2\pi(r+t)\frac{\theta}{2\pi}}{2\pi(r+\frac{t}{2})\frac{\theta}{2\pi}} \quad (3)$$

$$\therefore\ Y_s = \frac{2(r+t)}{(2r+t)} Y_o = KY_o$$

After measuring beam distance (W), neutral distance (Y_o) can be calculated using eq. (2). Then outer distance (Y_s) can be calculated from the neutral distance (Y_o) using eq. (3).

3. Experimental procedure

Before ultrasonic testing, l and d values in Fig. 3 is measured. Curvature radius (r) is calculated from the l and d values using eq. (1).

A 45° or 61° angle beam probes(4 MHz) were prepared as shown in Fig. 8.

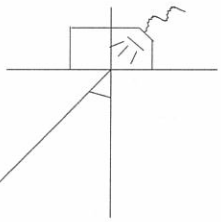

Fig. 8. An ultrasonic testing probe having refraction angle 45° or 61°.

Hole positions were measured by digital ultrasonic testers (Krautkramer USN 52R, Panametrics Epoch-II-B) and an analog tester (Krautkramer USK 7S) with STB-A1 and IIW Type 1 standard blocks according to the codes KS-B-0817 and KS-B-0896[(5-8)].

Before ultrasonic testing, beam injection point and refraction angle are calibrated according to the code KS-B-0817[(9)]. Test block has five drill holes. Three holes are at inner surface and two holes are located at the outer surface as shown in Fig. 2. Neutral distances (Y_o) are obtained from the measured beam distances (W) using eq. (2) and Fig. 5. Then out distances (Y_s) of five holes are obtained from the neutral distances (Y_o) using eq. (3). After measuring real out distances by flexible ruler, two out distance values are compared.

4. Results and discussion

Table 1 shows that calibration coefficient is 1.04 which is calculated by eq. (3). The error rates tested by 45° probe are less than ± 1 % as shown in Table 2. Therefore this simple method is available for detecting flaws in curved surface such as welded steel pipes. The average error rates by 61° probes are 3.76 % as shown in Table 3. Echo signal could not be distinguished when 70° probe was used. As the refraction angles of the probes increase, the errors increase.

Table 1. Dimensions of testing blocks and calibration coefficient [unit : mm]

l	d	radius	thickness	calibration coefficient
135	44	229.1	19	1.04

5. Conclusions

The error rates tested by 45° probe are less than ± 1 %. Therefore this simple method is available for detecting flaws in welded steel pipes having curved surfaces. As the refraction angles increase, the errors increase. Proper angle of the transducers is 45° in this case. For clear conclusion, more blocks having various curvatures should be tested.

Table 2. Comparison of the calculated (Y_S) and true values (Y_T) tested by 45° probes for the block A. [unit : mm]

distances / holes	W (beam distance)	Y_o (neutral distance using eq. 2)	Y_s (calculated out distance using eq. 3)	Y_T (true out distance)	$\|\Delta Y\|$	$\frac{\|\Delta Y\|}{Y}\times 100$ (%)
F_1(out), 1skip	55	38.89	40.45	40.5	0.05	0.12
F_2(out), 1skip	55	38.89	40.45	41.0	0.55	1.34
F_3(in), 1.5skip	81	57.28	59.57	60.0	0.43	0.72
F_4(in), 1.5skip	83	58.69	61.04	61.5	0.46	0.75
F_5(in), 1.5skip	81	57.28	59.57	59.5	0.07	0.12
average					0.31	0.61

Table 3. Comparison of the calculated (Y_S) and true values (Y_T) tested by 61° probes for the block A. [unit : mm]

distances / holes	W (beam distance)	Y_c (neutral distance using eq. 2)	Y_s (calculated out distance using eq. 3)	Y_T (true out distance)	$\|\Delta Y\|$	$\frac{\|\Delta Y\|}{Y}\times 100$ (%)
F_1(out), 1skip	76	66.47	69.13	71.5	2.37	3.31
F_2(out), 1skip	80	69.97	72.77	71.0	1.77	2.49
F_3(in), 0.5skip	48	41.98	43.66	41.5	2.16	5.20
F_4(in), 0.5skip	48	41.98	43.66	43.0	0.66	1.53
F_5(in), 0.5skip	51	44.61	46.39	49.5	3.11	6.28
average					2.01	3.76

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