A Reinforcement Plate for Partially Thinned Pressure Vessel Designed to Measure the Thickness of Vessel Wall Applying Ultrasonic Technique

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1. Introduction

In order to determine the wall thickness of pressure vessel at the design stage, ASME Code Sec. VIII Div. 1 Rules for Construction of Pressure Vessels [1] UG-27 is normally used. In UG-27 the maximum allowable stress of vessel material is used as the reference strength. Therefore, the wall thickness of pressure vessel, designed and fabricated in accordance with UG-27 with the material properties introduce in ASME Sec. II Part D, is very conservative.

It is very hard to preserve the wall thickness of the vessel because of the erosion or corrosion as time goes by. Therefore, the wall thicknesses of heaters in power plants are periodically measured using ultrasonic test. If the integrity of the wall thickness is estimated not to secure, the reinforcement plate is welled on the thinned area of the vessel. The overlay weld of the reinforcement plate on the thinned vessel is normally the fillet welding.

As shown by the references [2-4], the reinforcement plate with adequate thickness does its role very well before the vessel wall is perforated due to thinning. However, the integrity of shell cannot insure because the weldment is directly applied by the shell side pressure to after the vessel wall is perforated. Therefore, it is needed to measure the thickness of thinned area under the reinforcement plate continuously for preserving integrity and planning the fabrication of replacement vessel.

It is impossible to apply the ultrasonic thickness measurement technique after the reinforcement plate is welded on the shell. In this paper new reinforcement plate, which makes it possible to measure the wall thickness under the reinforcement plate applying the ultrasonic technique, is introduced.

2. Methods and Results

2.1 Maximum Stress at the Weldment after Opening

In order to determine whether the vessel has structural integrity, the average maximum stress along the weldment not in reinforcement plate is compared to the allowable stress of weld material in this part. Figure 1 shows the plate geometry and stresses in the weldment. The average tensile stress and shear stress are

$$\sigma_{avg} = \frac{abP}{2w_b(a+b+2w_b)} \tag{1}$$

$$\tau_{avg} = \frac{abP}{2t(a+b)} \tag{2}$$

Principal stress is

$$\sigma_{\max} = \frac{\sigma_{avg}}{2} + \sqrt{\left(\frac{\sigma_{avg}}{2}\right)^2 + \tau_{avg}^{\;2}} \tag{3}$$

If the average maximum stress along the weldment is smaller than the allowable stress of weld material, it can be said that the vessel has structural integrity. Unfortunately, the allowable stress considering the welding efficiency is 45% of that of welding material because the radiographic test cannot be conducted in the site.

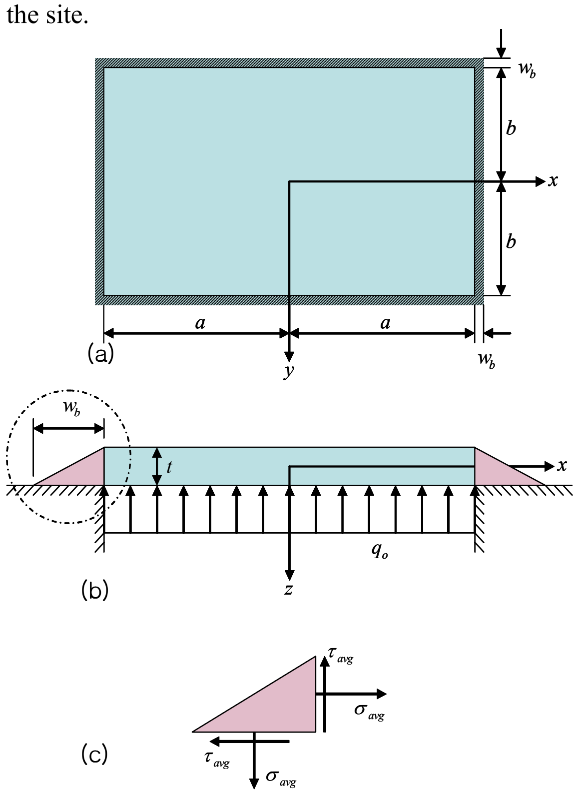


Fig. 1. (a) Reinforcement Plate and welding Bead Geometries, (b) Load Acting on the Plate, (c) average stresses along the weldment

2.2 Measuring Wall Thickness Applying UT

The wall thicknesses of pressure vessels in power plants are periodically measured using ultrasonic test. If the integrity of the wall thickness is estimated not to secure, the reinforcement plate is welled on the thinned area of the vessel as shown by Figs. 2 and 3. It is impossible to apply the ultrasonic thickness measurement technique after the reinforcement plate is welded on the shell because the ultrasonic beam cannot transmit to the vessel wall through the air layer between the reinforcement plate and vessel wall as shown by Fig. 4(a). However, if there exists the couplant layer between the reinforcement plate and vessel wall, the ultrasonic beam can transmit to the inner surface through the couplant layer.

New reinforcement plate illustrated by Fig. 5 has been developed paying attention to the fact explained above paragraph. The plate has a couplant room, a injection hole and a discharging hole. The couplant room holds the couplant during the ultrasonic test. The injection hole should be located in the lowest position and the air discharging hole should be located in the highest position in the plate. The hole positions help the complete fill-up without air pockets which are the barriers to the ultrasonic beam.

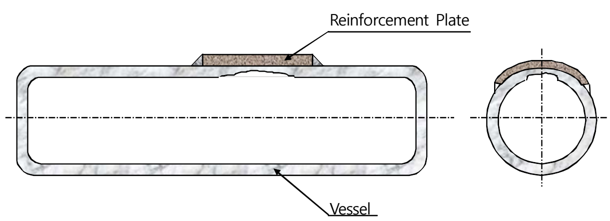
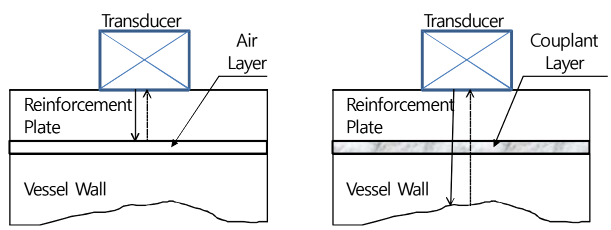


Fig. 2. Reinforcement plate welded on the thinned area of the vessel

Fig. 3. Sectional Geometry of Reinforcement Plate



(a) (b)

Fig. 4. Behavior of Ultrasonic Wave in the Reinforcement Plate on the Vessel Wall (a) with air layer, (b) with Couplant Layer

Referring Fig. 6, the thickness of the thinned vessel with new reinforcement plate is given by following equation:

$$t_3 = t_1 \frac{T_3}{T_1} \tag{7}$$

The couplant shall be removed from the couplant room after the measurement.

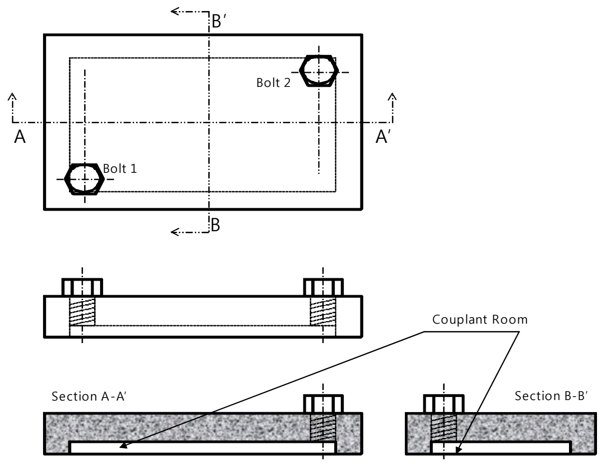


Fig. 5. New-Type Reinforcement Plate with Couplant Room

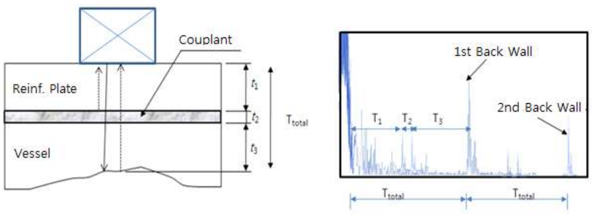


Fig. 6. Ultrasonic Signal of the Thinned Vessel with new reinforcement Plate

3. Conclusions

A method to evaluate the structural integrity of a fillet weldment for the reinforcement plate welded on a pressure vessel is introduced in this paper. Moreover, new reinforcement plate, which makes it possible to measure the wall thickness of pressure vessels under the reinforcement plate applying the ultrasonic technique, is introduced.

REFERENCES

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