An Evaluation Method for the Structural Integrity of a Fillet Welded Plate on a Partially Thinned Pressure Vessel Wall

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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.

An evaluation method for structural integrity of an reinforcement plate welded on a partially thinned pressure vessel is introduced in this paper. Because the reinforcement plate acts as an reinforcement before the original vessel wall has opening and the reinforcement plate acts as vessel wall, two different evaluation methods are needed.

2. Analysis

2.1 Assumption

2.1.1 Uniform Thinning

Generally, the cross-section of thinned vessel wall can be idealized as a eccentric circle with outer wall and inner wall. However, it is treated as a concentric circle, which means uniform thinning, in this paper because maximum stress of the non-uniform thinning vessel is similar to that of a uniform thinning as shown by Fig. 1.

2.1.2 Plate Theory

Pressure vessels are normally cylindrical shell. Therefore, a shell theory should be applied to the pressure vessels for an accurate analysis. However, a plate theory can be applied to the reinforcement plate if the plate is small compared to the vessel. In this paper the reinforcement plate is treated as a plate except the case applying UG-27.

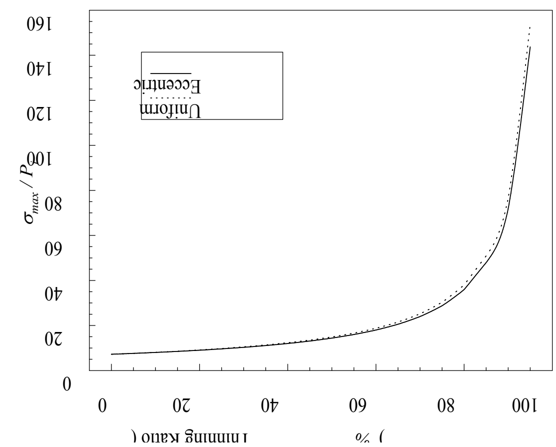

Fig. 1 Maximum stresses for the thinning ratio

2.2 Before Opening

2.2.1 ASME Sec. VIII Div.1 UG-27

The minimum thickness of vessel with internal pressure is given by UG-27.

$$t = \frac{PR}{SE - 0.6P} \qquad (1)$$

where, P is design pressure, R is inner diameter of vessel, S is maximum allowable stress, E is joint effectiveness(see ASME Sec. VIII Div. 1 UW-12). The pressure vessel has the structural integrity by UG-27 if the thickness composed of the current wall thickness of vessel and that of reinforcement plate.

2.2.2 Structural Integrity due to Local Thinning

The internal pressure acts to the reinforcement plate carrying by thinned vessel wall presses as local thinning progressed. The area contacted to the reinforcement plate should be determined by engineering sense.

It is very hard and complicated to calculate the stress of a plate with fixed edges. As shown by reference 3, maximum stress, which is occurred at the fixed boundary, is independent to the material properties of fixed plate. Therefore, the equation and values in the reference 3 can be used if the maximum stress is needed.

$$\sigma_{\max} = \frac{6M_{\max}}{t^2}$$

$$= \frac{6\gamma P}{t^2} \tag{2}$$

where, γ is values of Table 1 and P is the multiplication value of the contact area and design pressure

Table 1 Values of γ

b/a	1.0	1.2	1.4	1.6	1.8	2.0	∞
γ	-0.1257	-0.1490	-0.1604	-0.1651	-0.1667	-0.1674	-0.1680

2.3 After Opening

2.3.1 Pressure Vessel with the same thickness of Reinforcement Plate

As assumed previously, the vessel thinned eccentrically can be treated as the vessel thinned uniformly with the minimum thickness of the vessel thinned eccentrically. In this case, the structural integrity of the vessel should be determined by comparing the average stress applied to the reinforcement plate to the allowable stress of plate material. The average stress is

$$\sigma_{avg} = \frac{PR_m}{t}, \tag{3}$$

where, P is the design pressure, R_m is mean radius, t is the thickness of the vessel. If the average stress is smaller than the allowable stress, it can be said that the pressure vessel has the structural integrity.

2.3.2 Comparing Average Maximum Stress to Strength

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 2 shows the plate geometry and stresses in the weldment. The average tensile stress and shear stress are

$$\sigma_{avg} = \frac{abP}{4w_b(a+b+w_b)} \tag{4}$$

$$\tau_{avg} = \frac{abP}{2t(a+b)} \tag{5}$$

Principal stress is

$$\sigma_{max} = \frac{\sigma_{avg}}{2} + \sqrt{\left(\frac{\sigma_{avg}}{2}\right)^2 + \tau_{avg}^{\ 2}} \tag{6}$$

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.

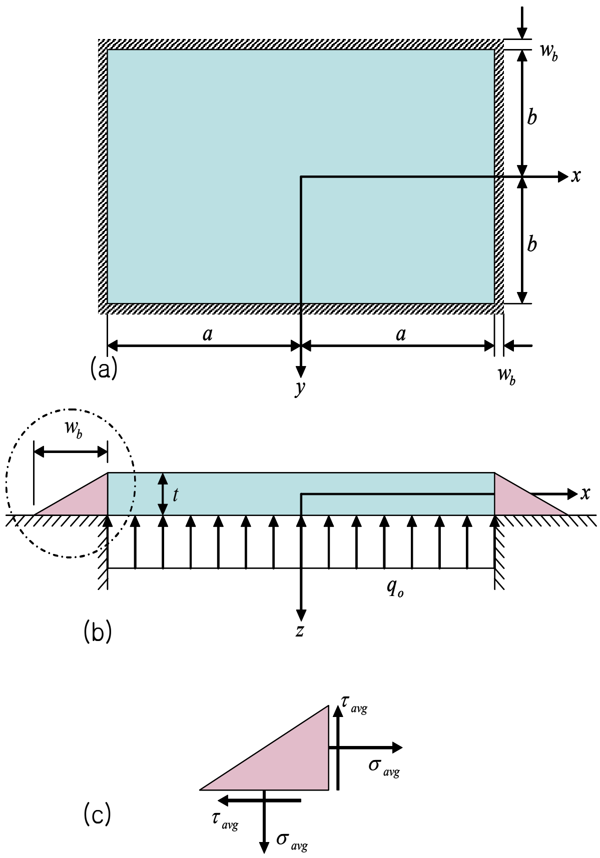

Fig. 2 (a) Reinforcement Plate and welding Bead Geometries, (b) Load Acting on the Plate, (c) average stresses along the weldment

3. Conclusion

A method to evaluate the structural integrity of a reinforcement plate welded on a pressure vessel is introduced in this paper. The thickness of the reinforcement plate should be determined considering every calculations introduced in this paper.

REFERENCES

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