STIFFENER AS A SPECIAL DESIGN SOLUTION FOR PRESSURE VESSEL REPAIR UKRUTNI PRSTEN KAO POSEBNO KONSTRUKTIVNO REŠENJE ZA SANACIJU POSUDE

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STIFFENER AS A SPECIAL DESIGN SOLUTION FOR PRESSURE VESSEL REPAIR

UKRUTNI PRSTEN KAO POSEBNO KONSTRUKTIVNO REŠENJE ZA SANACIJU POSUDE

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Keywords
- pressure vessel
- stiffener
- welded joints
- repair
- defect

Abstract

The reparation of vessel 970 is shown, since the risk is very high (close to the worst case of both probability and consequence, being the highest). Since the defect location was not suitable for digging out and repair welding, it was decided to make a circumferential stiffener, to reduce the stress acting on the welded joint, so that both the stress intensity factor and net stress are reduced significantly.

Ključne reči
- posuda pod pritiskom
- ukrutni prsten
- zavareni spojevi
- reparatura
- greška

Izvod

Prikazana je popravka posude 970, jer je rizik bio veoma visok, blizu najgoreg slučaja verovatnoće i posledica. Kako položaj greške nije bio pogodan za iskopavanje i reparaturno zavarivanje, odlučeno je da se napravi ukrutni prsten, kako bi se smanjio napon u zavarenom spoju, tako da se i faktor intenziteta napona i neto napon značajno smanjuju.

INTRODUCTION

After long-term operation, defects are found in welded joints in pressure vessel 970, Fig. 1. Given the high price and often the inability to purchase new working parts, there is a need for repairs. As mentioned above, after a long exploitation of the parts, defects are noticed, that can compromise the integrity of the structure.

Figure 1. The pressure vessel 970, before repair.

Repairing the pressure equipment is an efficient solution to many problems, /1/, and requires both practical and theoretical knowledge, especially for pressurized equipment, /2-5/. Nowadays, these repairs are very accurate, thanks to modern non-destructive testing devices and the precise determination of the size and position of defects, /1-5/. Figure 2 shows the pressure vessel 970, with the stiffener as a special repair design solution.

Figure 2. The pressure vessel 970, after repair with stiffener.

INSPECTION OF PRESSURE VESSEL 970

First inspection and testing of pressure vessel 970, as shown in Fig. 1, was performed by NDT methods before the repair with stiffener. Visual testing, magnetic particle testing and ultrasonic method were applied. It is known that ultrasonic testing is mostly used in the testing of pressure equipment, which proves to be the most reliable technique in detecting defects, /1-5/.

Vessels are made of microalloyed steel Nioval 50, with pressure in vessel 970 p = 81 bar; thickness t = 50 mm; and diameter D = 2150 mm. The vessel 970 was inspected by 100 % ultrasonic testing of two vertical and three circular welded joints. Nine unacceptable indications (1.1-1.4, 5.1-5.4 and 5.6), as well as one with an echo height above the registration level (5.5) were detected.

After the final UT testing of the vessel 970, defects 1.4 and 5.6 were found out to be the most dangerous with the following geometry and location:
– defect 1.4; length 35 mm and width / depth 22 mm in the central circular seam, from 28 to 50 mm,
– defect 5.6; length 75 mm and width / depth 20 mm in the central circular seam, from 18 to 38 mm.

Welded joints tested before repair, are shown in Figs. 3 and 4. Figures 5 and 6 show results of NDT testing for indications 1.4 and 5.6.

Figure 3. Tested welded joints (marked by red arrows) on vessel 970, before repair.

SPECIAL DESIGN SOLUTION FOR PRESSURE VESSEL 970

Risk-based analysis has been successfully used in recent years to evaluate possible effects on pressure vessel safety, /6-12/. As for the pressure vessel 970, since the risk was at a very high level, close to the worst case of the probabilities and consequences, and the position was not suitable for the repairer by welding, it was decided to make a stiff ring in order to reduce the stress on the welded joint, so that both the stress intensity factor and the stress acting on the defect 5.6 become significantly reduced.

Figure 4. Tested welded joint 5 on vessel 970, before repair.

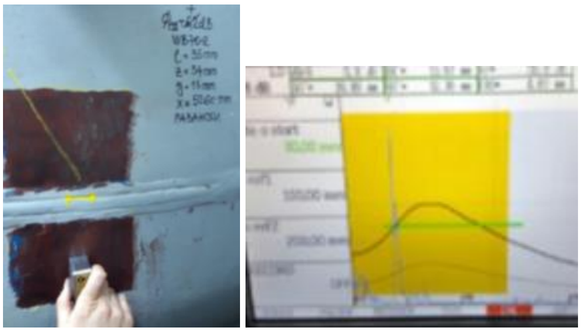

Figure 5. Position and size of defect 1.4 in vessel 970.

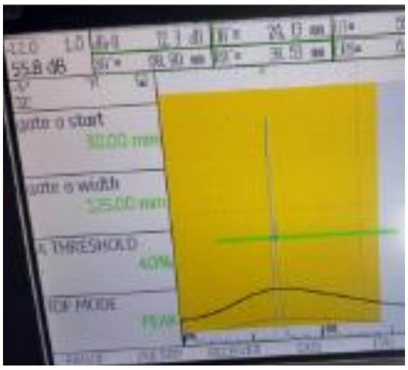

Figure 6. Position and size of defect 5.6 in vessel 970.

The first thing that has been done is the calculation of stresses and strains in the zone of the stiffener, which we shall explain below.

Input data for pressure vessel 970:
– design diameter: Ø 2200 mm,
– length (height): 4485 mm,
– volume: 13 m^3,
– wall thickness: 50 mm,
– pressure: working 7.3-7.7 MPa, design 8.1 MPa.

Calculation of stress and strain of vessel 970 for pressure 8.1 MPa:

$$\sigma_t = pD/2s = 8.1\cdot2100/2\cdot50 = 170.1 \text{ MPa}, \quad (1)$$

$$\sigma_z = pD/4s = 8.1\cdot2100/4\cdot50 = 85.05 \text{ MPa}, \quad (2)$$

$$\sigma_r = p = 8.1 \text{ MPa}, \quad (3)$$

$$\sigma_i = \frac{1}{\sqrt{2}}\sqrt{(\sigma_z - \sigma_y)^2 + \sigma_z^2 + \sigma_y^2} = \frac{\sqrt{3}}{2}\frac{pR}{t} = 147 \text{ MPa}, \quad (4)$$

where: σ_t, σ_z, σ_r are stress components in the circumferential, longitudinal, and radial directions; and σ_i is total stress. Strains are defined by:

$$E\varepsilon_x = \sigma_x - \nu\sigma_z - \nu\sigma_y = -\frac{3}{2}\nu\frac{pR}{t}, \quad (5)$$

$$E\varepsilon_y = \sigma_y - \nu\sigma_z - \nu\sigma_x = \left(1 - \frac{\nu}{2}\right)\frac{pR}{t}, \quad (6)$$

$$E\varepsilon_z = \sigma_z - \nu\sigma_y - \nu\sigma_x = \left(1 - \frac{\nu}{2}\right)\frac{pR}{t}, \quad (7)$$

where: ε_t, ε_z, ε_r are strain components in circumferential, longitudinal and radial directions; $E = 2.1\cdot10^5$ MPa is modulus of elasticity; and $\nu = 0.3$ is Poisson's coefficient.

After the finished calculation, the sheme for installation and assembly of the stiffener on the vessel 970 are made, Figs. 7-9. The first stiffener had 16 plates, the second one 17, all of them are 5×50 mm.

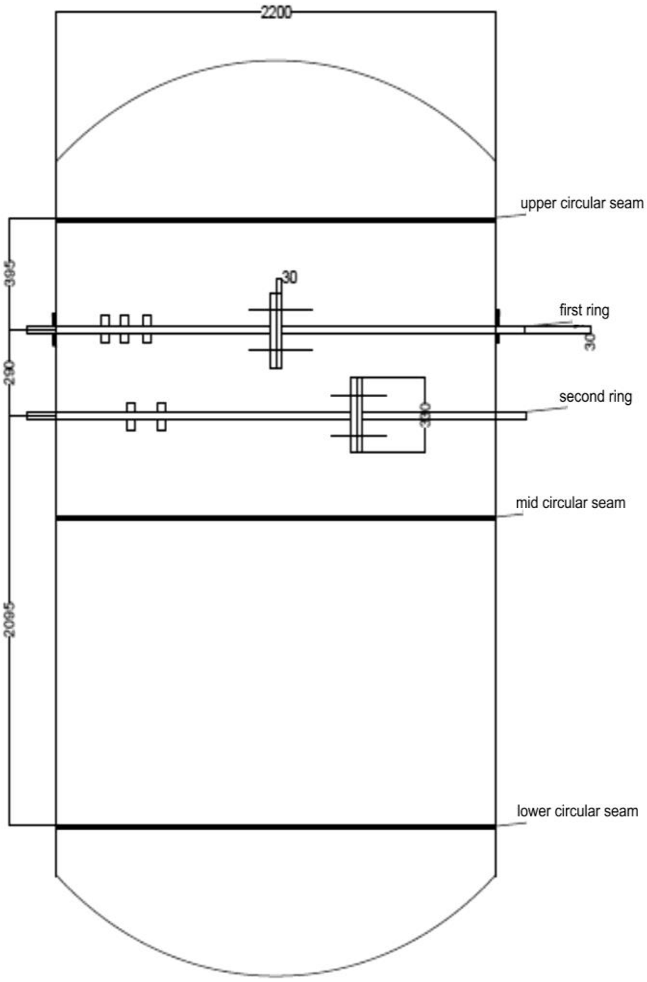

Figure 7. Scheme of vessel 970 reinforcement with outer stiffeners.

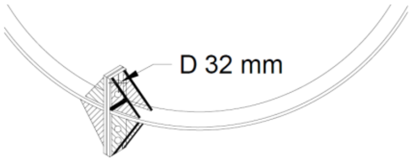

Figure 8. Schematic solution of flange joint for tightening rings.

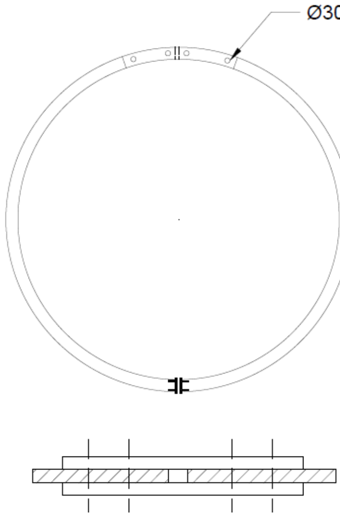

Figure 9. Schematic solution of connecting half of the rings.

After making the plan for the assembly and erection of the stiffener, it was successfully installed on vessel 970. Details are shown in Figs. 10-12.

Figure 10. Details of the two-ring reinforcement solution.

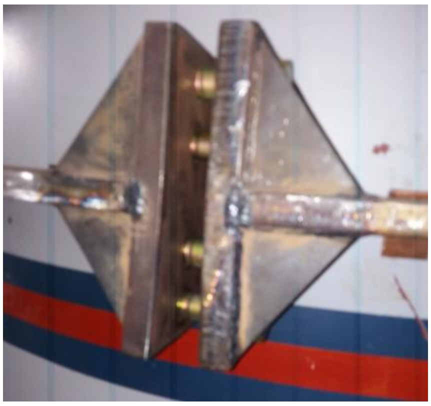

Figure 11. Flange joint details.

Figure 12. Stiffener bonding with 4 screws M30 (class 8.8).

INSPECTION OF PRESURE VESSEL 970 AFTER REPAIR

Only some details of the NDT inspection of vessel 970 after the erection of stiffener is presented. Figure 13 shows details of NDT inspection of vessel 970. It should be noted that after placing the stiff ring, the NDT methods show that the defect on the vessel 970 has not changed.

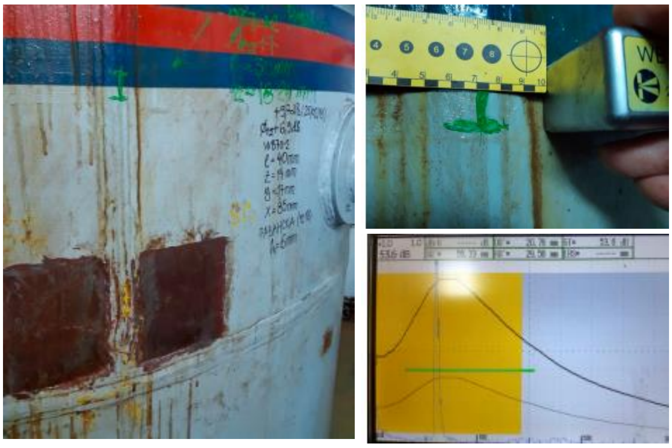

Figure 13. Ultrasonic examination of vessel 970, after repair.

CONCLUSIONS

Defect 5.6 in vessel 970 presents a high risk, but in this case removal by repair welding was not a practical solution, so a special design solution is successfully made in the form of a stiffener to reduce the stress.

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