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REPAIR AND STRUCTURAL INTEGRITY ASSESSMENT OF A LARGE SPHERICAL TANK

POPRAVKA I PROCENA INTEGRITETA VELIKOG SFERNOG REZERVOARA

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Keywords
- repair welding
- large spherical tank
- acoustic emission
- strain gauges

Abstract

Cracks are found during regular periodical NDT (MT and UT) in a large spherical tank, produced in 1974 of low carbon high quality steel of yield strength 385 MPa, similar to A516 Gr.60. Crack length was between 5 and 150 mm, with depth up to 13.8 mm, more than half of vessel thickness (26 mm). Repair was performed in the usual way, by grinding and surface welding. The waterproof testing of the repaired vessel was performed according to standard procedure with additional strain measurements using strain gauges positioned at surface welded regions to assess the vessel structural integrity. Also, acoustic emission was used to follow vessel behaviour during the waterproof test. Since no signal was recorded and strains were linear during the test, it was concluded that the repair was successful, and structural integrity is proved as well.

Ključne reči
- sanacija zavarivanjem
- veliki sferni rezervoar
- akustična emisija
- merne trake

Izvod

Prsline su otkrivene tokom redovnog ispitivanja bez razaranja magnetima i ultrazvukom u velikom sfernom rezervoaru, proizvedenim 1974. od niskougljeničnog visokokvalitetnog čelika sa granicom tečenja 385 MPa, sličnog A516 Gr.60. Dužina prslina je bila između 5 i 150 mm, sa dubinom do 13,8 mm, što je više od polovine debljine posude (26 mm). Popravka je urađena na uobičajen način, brušenjem i navarivanjem. Probno ispitivanje je urađeno po standardnoj proceduri, uz dodatno merenje deformacija mernim trakama radi procene integriteta konstrukcije posude. Takođe, akustična emisija je korišćena za praćenje ponašanja sfernog rezervoara tokom probnog ispitivanja. Pošto nije zabeležen signal AE, a deformacije su bile linearne tokom ispitivanja, zaključeno je da je popravka bila uspešna i da je integritet konstrukcije sfernog rezervoara takođe dokazan.

INTRODUCTION

Tests aimed at assessing the integrity of a pressure vessel are performed on a spherical tank for liquid petroleum gas (LPG marked R-113), Fig. 1. The R-113 spherical tank has been in operation since 1974, which is a sufficient reason to carry out an integrity assessment, bearing in mind that the NDT tests performed during periodical inspection revealed crack-type flaws that were detected by magnetic particle testing and ultrasound. The crack front length ranged from 5 to 150 mm. Unacceptable flaws of the crack type need to be repaired at locations where crack type flaws are detected.

Technical data: volume 600 m^3, LPG medium, working pressure 1.67 MPa, waterproof pressure 2.5 MPa, diameter 10.5 m, and thickness 26 mm.

MATERIALS AND METHODS

The spherical tank is made of low alloyed carbon steel ČSN 11484.1, similar to A516 Gr60, /1-5/, with chemical composition and mechanical properties shown in Tables 1 and 2, in respect, whereas the microstructure is shown in Fig. 2.

Figure 1. LPG spherical tank, designated as R-113.

Table 1. Chemical composition of the ČSN 11484.1 steel.

C	Si	Mn	P	S	Cu	Ni	Cr	Ti
0.19	0.5	1.28	0.025	0.02	0.08	0.05	0.19	0.12

Table 2. Mechanical properties of the ČSN 11484.1 steel.

Yield strength R_e (MPa)	Tensile strength R_m (MPa)	Elongation A (%)	Impact energy at –40°C, KV (J)
385	558	29	93

Manual metal arc welding technique (111) is used with basic electrode EVB Ni, 'Elektrode Jesenice'. The standard designation according to SRPS EN ISO 2560-A is E 50 6 1 Ni B 42 H5, and according to AWS A5.5-96: E 7018-G, /6/.

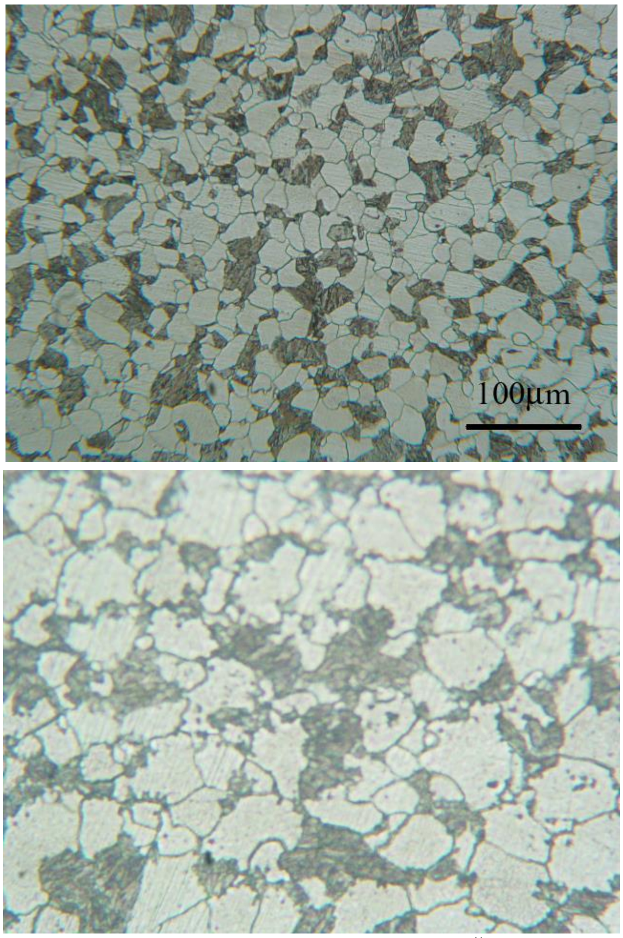

Figure 2. Microstructure of the parent material ČSN 11484.1.

REPARATION AND INTEGRITY ASSESSMENT

Repair of welded joints is defined according to the type and size of defects. Figure 3 shows the location and size of the crack-type defects located on the second (II) radial butt-welded joint, labelled "DEFECT 1" and "DEFECT 2". Both cracks-like defects and their geometry (length and depth) were detected by UT examination. The length of "DEFECT 1" was 28 mm and its depth 13.8 mm, whereas "DEFECT 2" was 18 mm long and 7.3 mm deep. In both cases, the measurement was made from the outside of the spherical tank.

Figure 3. Disposition of DEFECTS 1 and 2

Based on the defect types and depths, repair was carried out in 3 different ways:

If defect depth is less than 1.9 mm, it was removed by grinding, followed by VT and MT examination. In the case that the defect has not been removed completely, the repair was continued by grinding and carried out by welding only after complete removal of defect.

The same procedure was applied for defects up to ½ of wall thickness, expect when they were not completely removed after grinding, when the third option was used.

Repair in the case of defects with depth more than ½ thickness (13 mm) was carried out in the following way: First, the defect was grooved up inside to 2/3 of the thickness and then the test was performed with liquid penetrants. This was followed by welding on the inside. With the completion of the welding work on the inside of the tank, "V" groove was made outside by grinding, assembling an asymmetric "X" joint.

The final dimensions of the polished and prepared zone around the weld metal and the weld itself, as well as the profile of the groove, are shown in Fig. 4.

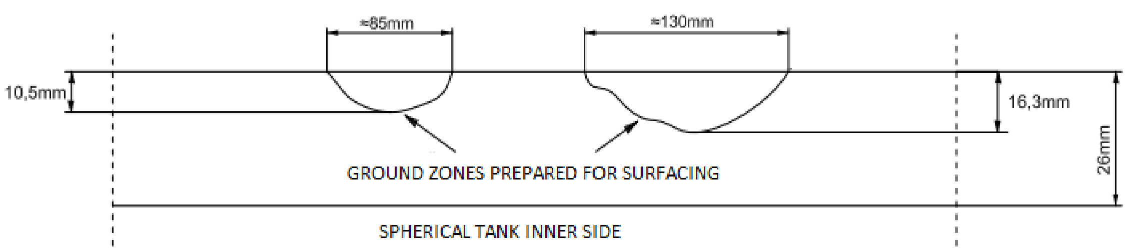

Figure 4. Dimensions of the ground and prepared zones "DEFECT 1" and "DEFECT 2"

Additional tests during the waterproof testing were carried out from the outside using suitable methods, which will not compromise the structural integrity of the spherical tank. To that end, and taking into account the working fluid and working conditions in the spherical tank, as well as the location and orientation of the place where the works and repairs were carried out, these tests were performed using active non-destructive testing methods:

- tensometric methods (strain gauges),
- acoustic emission methods.

In order to determine the stress state in the zones where the repair was carried out (measuring points 2, 3 and 4), and regions without defects (measuring points 1 and 5), strain gauges 10/120 LY 11 were used, as defined in tab. 3. The layout of the strain gauges is shown in Fig. 5. Diagrams pressure vs. strains are shown in Fig. 6.

a)
b)
c)
d)

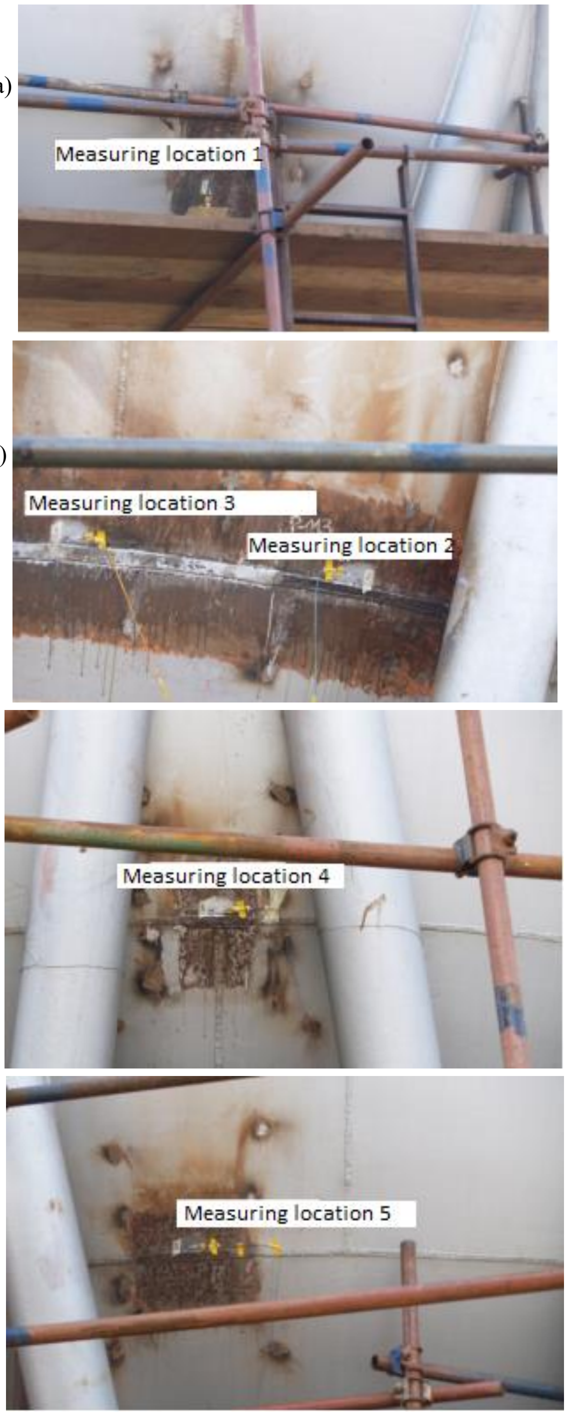

Figure 5. Measuring locations and strain gauges.

Table 3. Measuring locations (ML).

MP 1	Defect free zone close to vertical welded joint V2-3: 5.
MP 2	Repair zone – radial welded joint II - DEFECT 1.
MP 3	Repair zone – radial welded joint II - DEFECT 2.
MP 4	Repair zone – radial welded joint II - DEFECT 3, above vertical welded joint V2-3: 6
MP 5	Defect free zone close to radial welded joint II, 350 mm left from the vertical welded joints B2-3: 4

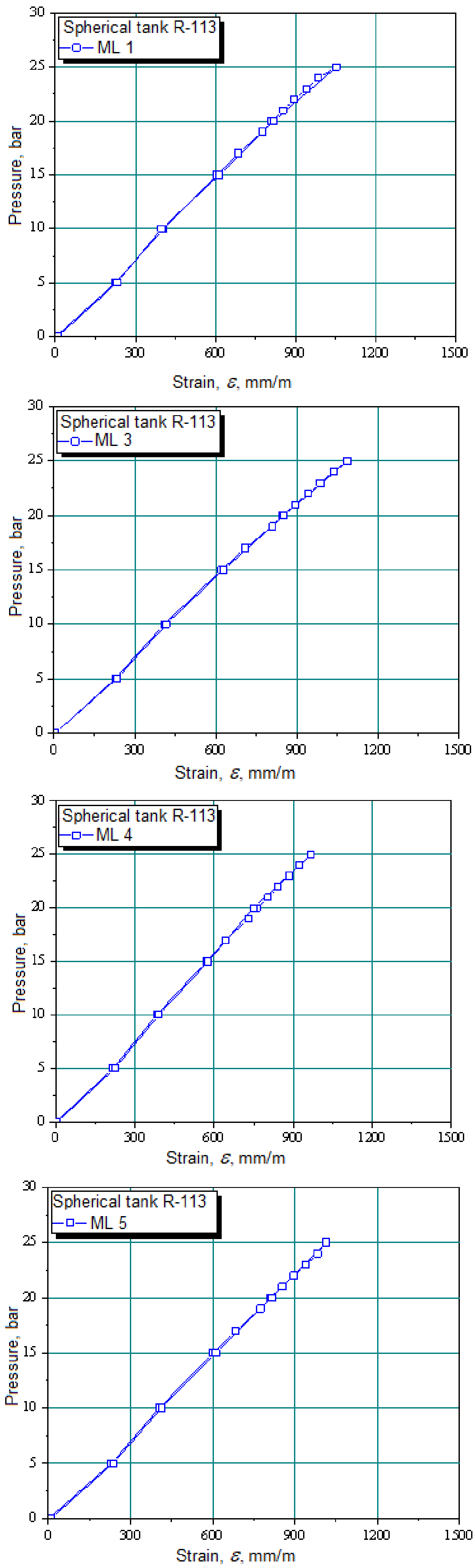

Figure 6. Pressure-strain diagrams for spherical tank R-113.

In addition to strain measurements that indicated elastic behaviour, acoustic emission is performed at the same time during waterproof testing, /7-9/. Processing acoustic emission signals is based on ring down counting. Scheme of this testing is shown in Fig. 7.

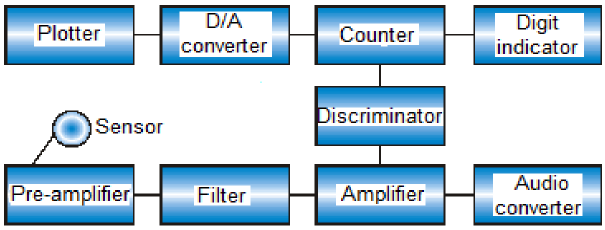

Figure 7. AE testing scheme.

As one can see from Fig. 8, there is no signal in AE indicating that the repair is performed successfully and proving that the structural integrity of the tank is not compromised.

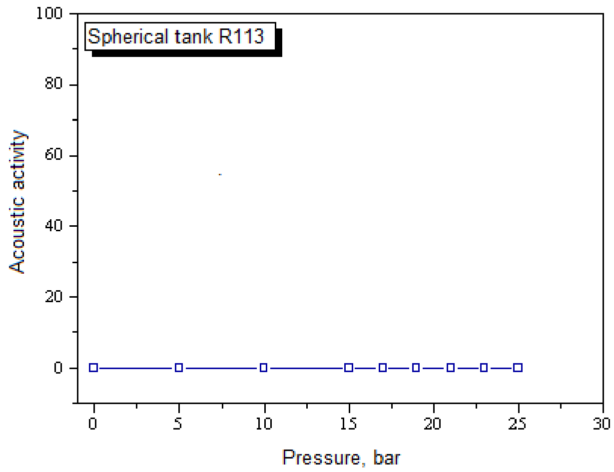

Figure 8. Acoustic activity for various pressure levels.

DISCUSSION - WATERPROOF TESTING

According to the new ASME standard, /10/, proof testing pressure is calculated as:

$$p_i = 1.3 p_r \left(\frac{\sigma_{\max.20}}{\sigma_{\max.pr}} \right),$$

where: p_i is test pressure; p_r is working pressure; $\sigma_{\max.20}$ is maximum allowable stress at room temperature; $\sigma_{\max.pr}$ is maximum allowable stress at the calculated temperature. Based on the available documentation for the spherical LPG tank, maximum allowable stress at both temperatures is the same, 148 MPa, thus the test pressure should be 2.17 MPa (1.3·1.67 MPa).

As already noticed in a couple of references, /11-14/, in order to avoid unwanted consequences, i.e., the possibility of initiation of cracks during proof testing pressure, it is necessary to reduce the test pressure and comply with the latest ASME standard.

CONCLUSIONS

The structural integrity of the repaired spherical LPG tank is proved by waterproof testing, since strain measurements indicate only elastic stresses, whereas AE shows no signals.

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