Design of Inspection Method for Control of Gap Dimension Between Reinforcing Ring and Vessel’s Surface

R R Chernyateva

Ufa State Petroleum Technological University, 1, Kosmonavtov st., Ufa, 450062, Russia

Abstract. Discrepancy between real connecting pipe’s unit’s characteristics and unit’s quality rating on base vessel’s nozzle’s reinforcing method analysis is shown. The most common misfit is the dimension of gap between reinforcing ring and vessel’s surface. Nowadays gap’s inspection methods, which are based on taking measurement of gap in one point via signal’s nozzle does not allow to estimate the quality of producing by all the contact surface. For reasoning the currency of new connecting pipe’s gap’s inspection method development finite-element method’s modeling of unit’s stress mode was done. Authors suggested as an alternating inspection method to produce reinforcing rings with two signal nozzles, which allows to estimate gap’s dimension in several points and to increase the objectivity of inspection. Stress mode modeling of reinforcing ring with two nozzles was done. Analysis of modeling results showed, that for inspection gap’s dimension between connecting pipe and vessel inspection method with two nozzles could be used. That allows to take measurement of gap’s dimension in the most loaded areas of vessel.

1. Introduction

Nowadays the main way to reinforce the holes in vessels and facilities used in technological processes in oil refineries and petrochemical enterprises is the installation of a reinforcement (overhead) ring, in accordance with the GOST R 52857.3-2007 and the GOST 24755-89 (ST SEV 1639-88).

The existing technology of assembling and welding of reinforcing rings and the design of this unit are well developed and have extensive experience of use. However, there are questions in the manufacture, which require additional consideration [1, 2]. One of the main questions is the assembly technology and control of the hole reinforcement assembly. The requirements of GOST R 52630-2006 on the limitation of the gap size to 3 mm are not always fulfilled in practice. The gap is controlled with a probe according to the outer diameter of the reinforcing ring [3].

Authors suggested as an alternating inspection method to produce reinforcing rings with two signal nozzles, which allows to estimate gap’s dimension in several points and to increase the objectivity of inspection. Stress mode modeling of reinforcing ring with two nozzles was done. Analysis of modeling results showed, that for inspection gap’s dimension between connecting pipe and vessel inspection method with two nozzles could be used. That allows to take measurement of gap’s dimension in the most loaded areas of vessel [4].

2. Statement of the problem and its solution

Figure 1 shows that the gap between the body and the ring reaches 5 mm. At the same time,
monitoring of this gap for today near the installation of the fitting is practically impossible, and, as a rule, it is not produced. Reducing the gap around the perimeter of the ring is made by clamps, attached to the body of the facility, or, as a rule, by a striking tool, which is also undesirable, and in some cases simply unacceptable in the manufacture of vessels and apparatuses [5].

Avoid incomplete fitting of the overlay ring to the shell in the manufacture of the “fitting with a clamping ring” assembly is rather difficult, due to a number of reasons: deviations during rolling of the overhead ring, especially at large thicknesses, also deflections of rolled shells; impossibility of individually roll one ring under repair conditions at the place of operation of the facility, due to the complex geometry of the body parts, in particular the bottom shape and other reasons [6].

Thus, there is a need to improve the technology of installing the reinforcing ring, as well as the technique of monitoring the gap between the reinforcing ring and the surface of the facility to be reinforced.

To solve these issues, taking into account the studies carried out to assess the stresses of the nozzle arising in the welding node, as well as well-known information on the stress-strain state of the choke assemblies, the following technical solutions were adopted [7–10]:

To reduce the gap between the reinforcing ring and the reinforced surface of the body of the facility, use П-shaped screw clamp mounted on the flange of the fitting;

Control of the gap between the reinforcing ring and the surface to be reinforced is carried out in the most dangerous areas of the nozzle welding unit - in small diameter nozzles, this zone is near the edge of the hole in the diametrical cross-section along the generatrix – in the meridian section (Figure 2). In fittings with a diameter of more than 150 mm, the zone of maximum stress moves to the intersection of the union and the shell in the circumferential section;

The control is carried out through the hole in the ring with the simplest measuring instruments - depth gages, in this case the caliper is examined – with a ruler for measuring depths, the measurement error is 0,05 mm and is acceptable for these purposes.

In view of the fact that one hole is already provided in the reinforcing ring near the perimeter, it is necessary to drill an additional hole in the reinforcing ring, placing it near the fitting, with the condition that it does not enter the welded joint zone.

In this case, it becomes necessary to evaluate the influence of stresses occurring in the body of the facility and the reinforcing ring in the case of a ring weakening by additional holes. Previously, the hole diameter is assumed to be equal to the existing one in the normative documentation, i.e. equal to
10 mm, if necessary, the diameter of the hole can be reduced to 5 mm – the condition under which the measurement can be made using a depth ruler of the caliper SC-1.

Additional holes in the reinforcing ring, arranged to control the size of the gap, cause stress concentration. Given the absence of a standard procedure for calculating the stress state of the device body loaded under such conditions, it was decided to carry out an assessment of the stresses occurring in the body of the apparatus and the reinforcing ring using the ANSYS program.

The design model consists of a shell with a union, a reinforced ring (Figure 3). Geometric parameters of the model:
- Diameter of shell 1 m, thickness 7 mm, length 2.4 m;
- Diameter of the union 100 mm, thickness 5 mm, radius 200 mm;
- Width of reinforcing ring 72 mm, thickness 5 mm;
- The gap between the shell and the reinforcing ring is 3 mm.

Enter material properties. As initial data for solving problems, bilinear properties of the material were specified. In the elastic zone, the modulus of elasticity $e = 2 \times 10^{11}$ Pa, the Poisson's ratio $\nu = 0.3$, the yield strength $210$ MPa, the tangential module $480$ MPa were set.

The geometric model is divided into a grid of finite elements of a given size. In the calculation, volumetric eight-node elements are used, the number of elements along the thickness of the shell, the union and the reinforcing ring near the nozzle welding unit is at least 4 to ensure the accuracy of the results.

Boundary conditions and loads:
Symmetry for the nodes of the model lying in the planes XY, YZ, XZ, i.e. the displacement of the nodes lying in planes in the direction normal to the plane is zero;
In the reinforcing ring, a hole with a diameter of 10 mm is modeled, located in this case near the wall of the nozzle, designed to control the gap in the manufacture of the chimney assembly (Figure 3, c).

The results of the calculations are presented in Figures 4–7.
Figure 4. Distribution of equivalent stresses in the reinforcing ring with a hole near the nozzle, Pa

Figure 5. Distribution of equivalent stresses in the reinforcing ring with a hole in the periphery (the existing version), Pa

Figure 6. Distribution of equivalent stresses in a reinforcing ring with two holes, Pa

For clarity, the graphs of equivalent stresses in the meridional direction (on the inner surface of the ring) are shown in Fig. 7.

Figure 7. The graph of equivalent stresses in reinforcing rings of different designs in the meridional direction.

Stress concentration factor $j$ as known is determinate as ratio of maximum equivalent stresses in specific area with stress raiser to maximum equivalent stresses in the same area without stress raiser. Next results of stress concentration factor $j$ were received:

- For single nozzle near connecting pipe $j = 2.8$;
- For single nozzle near outside edge of the reinforcing ring $j = 2.19$;
- For two nozzles near connecting pipe $j = 2.73$;
- For two nozzles near outside edge of the reinforcing ring $j = 1.89$.

Analysis of received from modeling data showed that the maximum level of stresses in
reinforcing ring appears in the area of reinforcing ring and connecting pipe’s joint in circular cross-section. Thus the level of stresses in presence of nozzle does not exceed the level of allowable stresses, which equals 177x106 pascal for gost 14249-89 design conditions and there is no impact of 10 mm nozzles at distance 47 mm between them on stress level.

Cross-effect of nozzles will appear only in the case of their disposition in immediate proximity according to the peculiarity of reinforcing ring’ loading.

Unit’s stress mode’s analysis showed that in spite of connecting pipe’s unit embodiment regardless of nozzle’s disposition the maximum level of stresses is in meridian vessel’s section (figure 8). The level of stresses in this area does not change. On the base of modeling results received graph of equivalent stresses in vessel (figure 9).

Figure 8. Field of equivalent stresses in vessel’s body on inner surface, Pascal.

Figure 9. Graph of equivalent stresses in vessel’s body on inner surface in meridian cross-section.

3. Conclusions

1 Inspection method on base of using additional nozzle in reinforcing ring could be designed for controlling gap between reinforcing ring and vessel’s surface.

2 Modeling results showed that the level of maximum stresses is not in the area of additional joints in reinforcing ring, but in the area of reinforcing ring’s and pipe’s joint in circular cross-section. Thus in stress concentration zone level of stresses does not exceed the level of allowable stresses.

3 Connecting pipe unit’s stress mode analysis showed that in spite of unit embodiment and nozzle’s dislocation the level of maximum stresses does not change.
References

[1] Konesev S G, Khazieva R T and Kirillov R V 2016 X Dynamics of Systems, Mechanisms and Machines (Dynamics) pp 1–7
[2] Konesev S G, Khazieva R T, Kirillov R V and Konev A A 2017 Journal of Physics: Conference Series (JPCS) 1
[3] Fisher W W, Kelley M E and Lomas J E 2003 Journal of applied behavior analysis 3 387
[4] Usamentiaga R Venegas P Guerediaga J Vega L and López I 2012 Infrared physics & technology 6 pp 491–498
[5] Apisov I V 2014 Electronic scientific journal «Oil and Gas Business» 5 223-237
[6] Kuzavkov V M, Rozinov A Y, Shtaits V V 2005 Russian journal of nondestructive testing 1 pp 39–44
[7] Pimstein P G, Mordina G M, Barabanova L P 2003 Chemical and Petroleum Engineering 4 pp 3–5
[8] Skopinskij V N, Rusanov O A, Nazarov N A 2007 Machine Building and Engineering Education 20 pp 23–33
[9] Sabitov M H and Ponikarov S I 2011 Herald of the Kazan Research university 20 pp 208–212
[10] Cvik L B, Hramenok M A and Shapova M V 2008 Herald of Universities 1 pp 18–24