Stress-Deformed Condition at Different Angle of Scratch Inclination on Flat Cover of Hatch-Blade

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Abstract. Defects of mechanical origin are quite often found on the structural elements of the devices of the production facilities of the fuel and energy complex. One of the most common mechanical defects is scratches and hairlines on the outer surface of the structural elements. The current regulatory and technical documentation establishes standards for the rejection of defects of various types, which provide for the decommissioning of objects with unacceptable defects for repair or subsequent dismantling. However, in most cases, mechanical defects such as scratches are within acceptable sizes and do not have a decisive effect on the life, reliability and safe operation of vessels and apparatus. However, the presence of such defects can change the stress-strain state of the object to a more unfavorable side, and therefore accelerate the process of accumulating damage at points of concentration of increased stresses. Subsequently, places with a concentration of increased voltages under certain operating conditions can be sources of premature destruction of the element and failure of the object as a whole. Therefore, the actual work is the simulation of the stress-strain state of the flat manhole cover with a scratch, having a different arrangement. In this work, the stress-strain state of the flat manhole cover is examined depending on the location of the scratch on it at a different angle relative to the vertical axis of symmetry of the cover.

1 Introduction

Installation of vessels and apparatus of oil and gas industries is associated with formation of different level of defects in the material of various elements of the technical device. Also, various defects can be formed during storage and transportation of objects. The predominant part of these defects are mechanical defects - hairlines, scratches, balls, dents and others. For some of the defects of this type, for example, dents, regulatory and technical documents, strict requirements for dimensions are defined, the excess of which entails the rejection of the element where this dent is located. Scratches generally do not have a significant impact on the operational reliability of the equipment due to the fact that their width and depth, as a rule, does not have a defining parameter in terms of life and safe operation. In the current norms of rejection of structural elements of vessels and devices, there are no rejection dimensions of scratches, as well as a description of their most

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unfavorable locations on the external surface of structural elements from the point of view of emerging places of increased stresses and a change in the stressed-deformed state (SDS) of the element [1-4]. However, the presence of scratches, especially on small structural elements, can have a significant impact on SDS, due to its geometric dimensions relative to the surface area of the element. In such cases, even a scratch of small sizes can significantly change the SDS of the element, thereby determining the reliability of the entire apparatus as a whole [5-8]. Therefore, the actual work is the assessment of the SDS of the flat manhole cover depending on the length and location of the scratch on it at different angles relative to the vertical axis of symmetry of the cover under the influence of technological workloads [9-10].

2 Research Methodology

To estimate the SDS of the flat manhole cover of the apparatus, depending on the angle of the scratch relative to the central part of the lid, under the influence of operational parameters, the manhole of the apparatus of one of the oil and gas industries was selected. The device is operated at operating pressure $P = 2.0$ MPa and operating temperature $t = 20$ °C. The material of the manhole and its cover is high-quality carbon steel 10. The hatch has the following technical characteristics: size of a branch pipe of the union 472×18 mm; flange of connector is flat welded with thickness $s = 18$ mm; thickness of flat cover $s = 10$ mm; outer diameter of flat cover $D = 510$ mm; cover is equipped with 20 holes $\varnothing 18$ mm for bolted connections.

In the process of modeling, the licensed software complex "KOMPAS-3D" was used with the APM FEM system integrated into it for solving engineering and research problems. At the first stage, a hatch-eye model was built in the COMPAS-3D program [11-15]. Then, using the APM FEM strength analysis system, which is part of the COMPASS-3D program package, loads such as: pressure and temperature were applied; fasteners are installed. Then the scratch was simulated with different inclination angle on the flat cover relative to its vertical axis of symmetry. The scratch is an extended linear plane defect with sharp vertices. The length of the scratch was $L = 50$ mm, width $B = 1$ mm, depth $H = 1$ mm. The shape of the scratch with the geometric dimensions is shown in Figure 1. The locations of the scratch on the flat cover of the manhole with a different angle of inclination relative to the vertical axis of symmetry of the cover for estimating SDS are sketched in Figure 2. One sharp tip of the scratch comes from the center of the flat cover. The angles of inclination were taken in increments of 15° : 0° , 15° , 30° , 45° , 60° , 75° and 90° .

Fig. 1. Scratch shape with geometric dimensions

Fig. 2. Location of scratch on flat cover of manhole with different angle of inclination relative to vertical axis of symmetry of cover for SDS assessment

3 Research results and discussion

At the first stage of research, a SDS assessment of the flat cover without scratching was carried out. Results of calculation of SDS of flat manhole cover without scratch are shown in Figure 3.

Fig. 3. Results of calculation of SDS of flat manhole cover without scratch

Analyzing the result shown in Figure 3, we can say that the maximum stresses are 76.59 MPa and are concentrated in an area close to the bolted circle of the flat manhole cover. Moreover, the distribution zone of maximum stresses is uneven.

Next, the SDS of the flat cover with the different angle of the scratch on the flat cover of the manhole with respect to the central part of the cover according to Figure 2 was evaluated. Results of SDS calculation are given in Figures 4-10.

Fig. 4. Results of calculation of VAT of flat manhole cover with scratch on with inclination angle 0° relative to vertical axis of symmetry

Figure 4 shows that the maximum stresses are concentrated in the scratch area and reach 121.8 MPa, which is 1.6 times the value of the maximum stresses without scratching on the surface of the flat cover.

Fig. 5. Results of SDS calculation of flat manhole cover with scratch with inclination angle 15° relative to vertical axis of symmetry

Figure 5 shows that when the scratch is placed at an angle 15°, the maximum stresses are already 134 MPa. This is 12 MPa more than for the scenario when placing a scratch on a flat manhole cover with an angle of inclination of 0° and 1.75 times higher than the value of maximum stresses without scratching on the surface of the flat cover.

Fig. 6. Results of SDS calculation of flat manhole cover with scratch with inclination angle 30° relative to vertical axis of symmetry

Analyzing Figure 6, it can be seen that when the scratch is placed at an angle 30°, the maximum stresses are 157.6 MPa. This is 23.6 MPa more than for the scenario when placing a scratch on a flat manhole cover with an angle of inclination and 2 times higher than the value of maximum stresses without scratching on the surface of the flat cover.

Fig. 7. Results of SDS calculation of flat manhole cover with scratch with inclination angle 45° relative to vertical axis of symmetry

Analyzing Figure 7, it can be seen that when the scratch is placed at an angle 45° compared to the position at an angle 30°, the maximum stresses are reduced and amount to 131.2 MPa.

Fig. 8. Results of SDS calculation of flat manhole cover with scratch with inclination angle 60° relative to vertical axis of symmetry

Fig. 9. Results of SDS calculation of flat manhole cover with scratch with inclination angle 75° relative to vertical axis of symmetry

Fig. 10. Results of VAT calculation of flat manhole cover with scratch with inclination angle 90° relative to vertical axis of symmetry

4 Conclusions

Based on the results of the SDS simulation of the flat manhole cover with a scratch of length $L = 50$ mm depth $H = 1$ mm and width $B = 2$ mm and with a different angle of its inclination relative to the vertical axis of symmetry of the cover when exposed to pressure $P = 2$ MPa and temperature $t = 20$ °C, the following conclusions can be drawn:

- It has been established that the value of the angle of inclination of the scratch relative to the vertical axis of symmetry of the cover affects the SDS of the flat cover of the hatch-eye in terms of maximum stresses. During technical diagnostics, to assess the actual technical condition, it is necessary to take into account the angle of the scratch, if any;
- It is shown that the maximum stresses occur in the flat cover when the scratch is arranged at an angle of 30° relative to the vertical axis of symmetry of the cover and is 157.6 MPa;
- It has been found that large values of maximum operating stresses are observed in cases where the scratch is located at sharper angles relative to the vertical axis of symmetry of the cover, namely 15° , 30° and 45° .

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