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Strength of upstream and downstream chambers, collectors, heat exchange tubes of gas aerial cooler apparatus, and assessment of life extension

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Strength of upstream and downstream chambers, collectors, heat exchange tubes of gas aerial cooler apparatus, and assessment of life extension

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Abstract. The gas aerial cooler apparatus (ACA) were characterized. These ACA serves for cooling the service gas. The analysis of engineering documentation was carried out in order to establish the range of amenable to control parameters of the engineering status, to carry out the recognition of failures (if ever) and damages that could led to a failure. The applied method of acoustic emission (AE) yielded total and direct information on the defect growth (hazard rate) in materials of operational facilities. The AE control might be used as a determinative procedure for the selection of criteria needed for assessing the status of diverse structures as well as for release to continued operation the production facilities (with providing a necessary level of safety during the enterprise operation) because the AE control enables to detect a fault at early stage of its growth. By applying the AE method for elaboration of a control of specific objectives, complicated problems related to generation of elastic waves from growing cracks and their transformation during propagation up to sensors were successively resolved.

1. Introduction

Degradation of stressed solids is a complicated process [1-3]. To investigate the process, its trends, specific stages, stage succession in the defect growth (hazard rate), and to consider the specificity of material and exploitation of the ACA object, various methods were applied [4-7]. The control was exercised by the following devices: ultrasonic finger gage BULAT 1M, hardness meter 54–359M, ultrasonic crack detector 1214 EXPERT (Serial No 205125); however, the conclusion on the condition of the object was issued only after application of the AE method. The following procedure of non-destructive inspection were used for assessment of the state of basic metal and for metal of welded seams [8-10]: visual and dimension control (VIC); acoustic emission testing (AET); ultrasonic thickness measurement (UTM); measurement of hardness (MH); liquid penetrant test (LPT) with an option to substitution for magnetic particle test (MPT); ultrasonic control (USC). With the purpose of the destruction forecasting in blanket elements, it is essential to study and analyze the dependence of the activity and amplitude of AE signals on the loading time and size of load in the gas ACA system In addition, the possibility and significance of the application of acoustic emission method for diagnosing and assessing the working life (resource) of specific gas ACA systems.

2. Nondestructive inspection procedures

Visual and dimension control (VIC) of the surface of elements of gas ACA, welded seams, and basic material in the heat affected zone is performed in accordance with the RD 03-606-03 with the purpose of detecting the inadmissible surface defects and deviations in relative positions of welded units.

The visual control of the apparatus is aimed to detect the following defects emerged during operation: apparent deformations of elements, pinchers, goffering, violations of integrity of tube finning, cracks, corrosive and erosive wear of welded joints. Thorough attention is looked at seems of welding attachment of outlets and flanges, places of seems crossing, and un finned parts of tubes. Five–ten power lenses are used for inspection. The visual control is performed with considering possible workmanship defects such as notching, collaring, burning through, un welded craters, gas pockets, porosity, grit, shifting, and inter mutual picking of butting parts.

In case if found either locally deformed zones or permanent residual deformation, a measurement of its extension and configuration is performed. When expecting the apparatus, the following items must be established: the conformity of the inspected apparatus with the analysed engineering documentation; the presence of information on the adjustment of the control and measurement instrumentation; working capacity of pressure safety valves and shut-off valves as specified by the safety provisions established in an enterprise owner of the ACA.

Acoustic emission testing (AET) is performed according the acoustic emission testing GOST R 52727-2007 [9], GOST 27655 – 88, PB 03-593-03 [18], RD 03-299-99 [25], RD 03-300-99, MR 1998 with the purpose of detection of growing defects (from AE signals parameters), and in order to determine fields of their possible arrangement and further identification.

In the case of discrepancy of hardness in a Table as well as in the presence of excessive corrosive failures or cracks, and after using the open flame, the metallographic examination is carried out.

Liquid penetrant test (LPT) (with an of a substitution for magnetic particle test (MPT)) of the basic metal and welded joints of elements of the gas ACA is performed in accordance with RD 13-06-2006 (LPT) and RD 13-05-2006 (MPT) with the purpose of detecting the surface defects such as cracks and rolling skins as well as for doubling (confirmation) of the presence of discontinuities detected by the VIC method.

Ultra sonic control (USC) is performed according the GOST 14782 – 86 and OST 28 – 2044 – 83 with the purpose of detecting the internal defects in welded joints as well as after the AE control for a more detailed localization of defective spots that could grow in welded seams and in the basic material of gas ACA elements from both outer and product sides.

The results of the performed in vestigations by each of the described on destructive control procedures are assessed separately in accordance with the methodology [9,10] and drawn up according STO Gazprom 2–2.4–083–2006.

In addition, independence of results of engineering documentation, visual control, and acoustic-emission control, the volume of diagnosing of welded joints is determined. In any case, them and atorycontrol of welded seems by the USC, LPT (MPT) methods is performed in places of repair works or defects found during the visual inspection.

3. Experimental and discussion

At the present time, the most complete and direct information on the growing defects(hazard rate) in materials of operational facilities (Figure 1) might be obtain by the acoustic emission method [1].

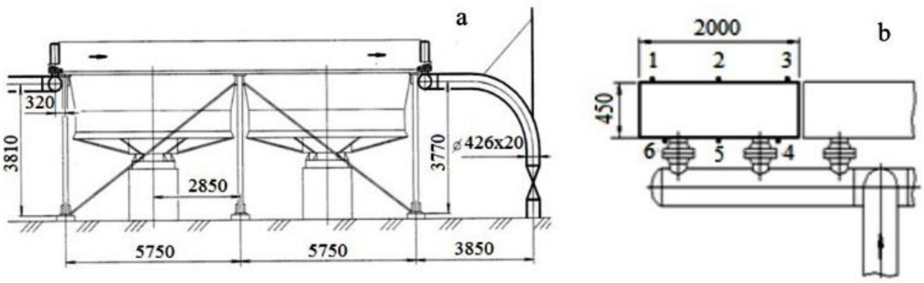

Figure 1. Gas ACA diagram with locations of AE sensors: a) - General view of the gas ACA (dimensions in millimeters, mm); b) - layout of sensors (No 1, 2, 3, 4, 5, 6) when locating AE signals on the input chamber of the gas ACA

The AE control might be used as a determinative procedure for criteria selection needed for the assessment the states of diverse structures as well as for release to further service of production facilities (with providing a necessary level of safety during the enterprise operation) because the AE control enables to detect a fault at early stage of growth [11]. By applying the AE method for the production engineering for controlling specific objectives, complicated problems related to generation of elastic waves from growing cracks and their transformation during propagation up to sensors must be resolved. If the fracture of a loaded solid is a process, one must investigate this process, its principal tends, specific stages, and the succession f stages [12,13] for the purpose of drawing out the predictive signs of macroscopic destruction, and, in the case the growth of defects(hazard rate) in materials of operational facilities[14], one should apply a few methods, however, the conclusion on the condition of the object might be issued only after the application of the AE method (Figure 2).

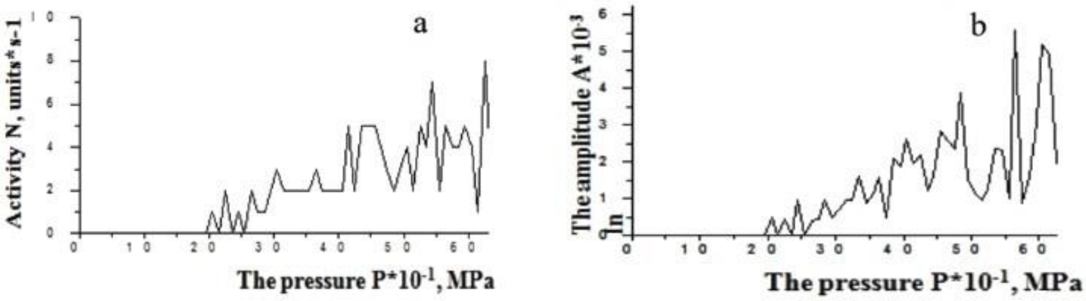

Figure 2. Results of the study of gas ACA "Nadym": a) - graphs of the dependence of AE signals on the load; b) location of AE signals on the gas ACA input chamber.

A defect was detected in the lower circular weld of the gas ACA, No 4 (Figure 3.).

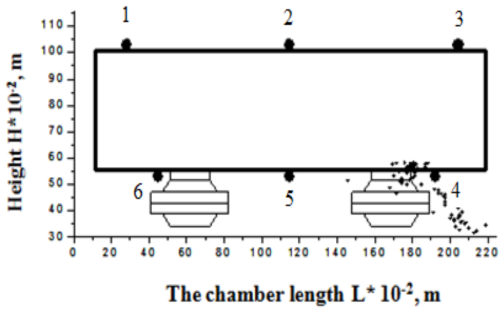

Figure 3. A defect detected in the lower circular weld of the gas ACA, No 4.

The executive summary concerning a further operation use of the apparatus will be issued after the inspection of the gas ACA by the AE method. There were no detected defects in places of welded joints in inspected apparatus No 1, 2, 3, 5, 6, which could hinder the further exploitation.

4. Circular rings, strength calculation according to GOST 14249-89

The calculations were performed with the help of the application program package for the strength calculations of elements of vessels, apparatus, and conduct pipes of PVP Design. The element is a smooth circular ring operating under interior pressure (Figure 4). A hydrostatic shell test. Feed data:

The ring material is 09G2S, specified temperature is T = 20 ºC, specified pressure is P = 8.37 MPa, in side diameter of the ring is D = 3000 mm, the ring wall thickness is S = 60 mm, increase in corrosion C = 3 mm, Technological allowance is C_1 = 0 mm, Safety coefficient of longitudinal weld is $\varphi_p = 1$. Admissible stress is $[\sigma] = 272$ MPa.

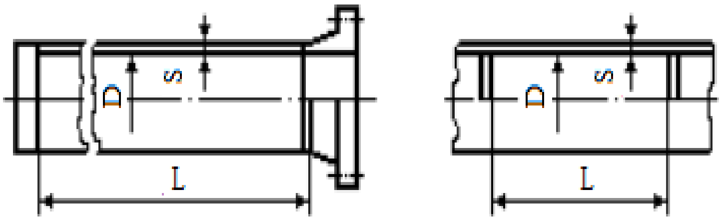

Figure 4. Elements of vessels, apparatus, and conduct pipes of PVP Design.

Calculation data:

$$S_p = \frac{pD}{2[\sigma]-p} = 46.88 \text{ mm} \quad (1)$$

Effective thickness of ring wall under pressure (1).

$$S \geq S_p + C = 49.88 \text{ mm} \quad (2)$$

Effective thickness of ring wall under pressure with allowance (2).

$$[p] = \frac{2[\sigma]\varphi_p(S-C)}{D+(S-C)} = 10.14 \text{ MPa} \quad (3)$$

Permissible internal pressure (3).

The ring satisfied the conditions [15-17] of strength in accordance with requirements of GOST 14249-89

5. Conclusion

It has been found that the signals from the corresponding defects including microcracks appear at the early stage yet. Their growth and location leads, finally, to the macroscopic fracture. The amplitude and spectral analysis of AE signals in dependence on the load and deformation action time let us to determine the predictive signs of the transition to macroscopic fracture. Proceeding from the analysis of kinetic consistency of the fracture of both loaded specimens and a model of conduct pipe, the assessment of the lifetime was carried out. Thereupon, the possibility of the prolongation of a term of safety operation of heat objectives was confirmed.

Results of the performed investigations, as well as their analysis, let us to develop a new methodology of the assessment of the working capacity and extension on service life of heat exchanger equipment belonging to OAO Gazprom, which was approved by the Gazprom headquarters with obtained approval from the supervisory body.

A fit for service evaluation of the apparatus was settled upon results of the AE inspection of the gas ACA apparatus. The minimum permissible values of element thickness were picked up in both with the procedure of determination of the remaining life of the gas ACA operated in gas-compressor stations belonging to the RAO Gazprom and through calculations according SNiP 2.05.06-85. Ad effect was revealed in the lower circular weld of gas ACA (No 4). There were no other defects in metal of welded joints in the investigated ACA apparatus, which could hinder the exploitation of these ones.

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