Influence of Microdamage Metal of Energy Long Working Objects on Acoustic and Magnetic Characteristics

Nikolay V Ababkov, Alexander N Smirnov

T.F. Gorbachev Kuzbass State Technical University, 28 str. Vesennyaya, Kemerovo, 650000

E-mail: n.ababkov@rambler.ru

Abstract: The samples of damaged metal steam pipes are studied by acoustic and magnetic methods in the paper. In particular, there are studied sample without damage, samples with creep cracks and samples of with microdamage. All samples were made of 12H1MF steel and have different operating time. A graph of acoustic and magnetic characteristics of the operating time and score of microdamage are constructed. A values of acoustic and magnetic characteristics, corresponding to the maximum, defective score of micro steam pipes of metal specimens made of steel 12H1MF are established.

Introduction

In the process of operating elements of technical devices of hazardous industrial facilities (TDOPO) of the energy industry, a number of problems arise that can lead to man-made disasters and human casualties. First and foremost, this is due to the fact that most of the equipment (85-90%) has developed its resource and needs a complete or partial replacement. However, the current state of the economy in the heat and power industry does not allow achieving the set goals. Therefore, the issue of developing new, effective technologies, methods and methods for assessing the operability and restoration of the resource of the elements of technical devices becomes very urgent. And to ensure the safe operation of critical structures, the concept based on “prediction and prevention” instead of the old concept of “detection and elimination” [1] is becoming increasingly widespread.

The object of the research of this article are direct sections with welded joints of the main steam pipelines, bends of the steam-through pipes from the output collectors of the convective superheater of the IV stage to the steam chamber of the boiler, made of 12Kh1MF steel and which were operated at different power stations and the Kemerovo region heat and power plant (Fig. 1).
Fig. 1. Type of test samples of bends of steam-through pipes from the output collectors of the convective superheater of the IV stage into the boiler's steam chamber; size Ø133.0 × 17.0:

- \(a\) – after 230 000 hours of operation;
- \(b\) – after 182 621 h of operation

For the material under investigation, destruction by the creep mechanism is characteristic. According to this mechanism, the destruction of metal occurs due to the gradual accumulation of micropores, which in the subsequent develop into microcracks. The presence of micropores in the volume of the metal is called microdamage [1]. Microdamage is assessed on a point scale in accordance with Annexes G and A of the OST 34-70-960-96. An image of the structure of 12H1MF steel with various microdamage points is shown in Fig. 2, \(a\) and \(b\).

Fig. 2. Structure of steel 12H1MF with different microdamages, × 500:

- \(a\) – point In according to Appendix A of the OST 34-70-960-96 (microdamage by optical methods are not detected);
- \(b\) – point 6-7 by Appendix G OST 34-70-960-96

To detect defects, various test methods are used that fall into two large groups [2]: destructive and non-destructive research methods.

Destructive testing methods include tensile tests, impact tests, carbide analysis and metallographic tests [9, 11]. The main drawback of the above methods is that to conduct the experiment it is necessary to disable the equipment, and to stop, therefore, the production.

Therefore, in order to detect defects in production conditions and without failure of equipment, various methods of nondestructive testing are used.

At present, the sensitivity of devices of traditional methods of nondestructive testing makes it possible to detect microdamage only from 4 points. To detect microdamages of 1, 2 and 3 points, it is necessary to use instruments with greater sensitivity.

One of the most promising methods for monitoring the state of the metal of welded joints, the base metal and the detection of discontinuities is currently considered an acoustic method [10, 12, 13]. Earlier, the authors of [5-8] established that the spectral-acoustic control method is a sensitive method for
estimating local fields of internal stresses and microstructure parameters (dislocation density, curvature-torsion of the crystal lattice, etc.). In addition, the acoustic characteristics are related to the mechanical properties of the materials. This allows us to judge the mechanical properties of the material. The authors of [5-8] proposed complex criteria for the degree of metal damage in relative units.

**Method of experimental research**

The authors carried out studies of the state of metal samples, straight sections with welded joints of the main steam pipelines, bends of the steam-through pipes from the output collectors of the convective superheater of the IV stage to the steam-collecting chamber of the boiler, made of 12H1MF steel and which were operated at different power stations and the Kemerovo region heat and power plant (table).

**General characteristics of the test samples**

| № i/o | Object | Parameters of Exploitation | Grain value | Point of microdamage | Defects |
|-------|--------|----------------------------|-------------|----------------------|---------|
| 1.    | Straight section with welded joint No. 23 of thread "A" of the main steam pipeline of Block 1; Ø325.0 × 43.0 | $T = 545 \, ^\circ C$, $P = 140 \, \text{kgf/cm}^2$ Working time: 342 820 h. | №8 | Ip (not detected) | None |
| 2.    | Bent portion No. 16 of the steam-through pipe from the output collectors of the convective superheater of the IV stage into the steam-collecting chamber of the boiler No. 5; Ø133.0 × 17.0 | $T = 555 \, ^\circ C$, $P = 140 \, \text{kgf/cm}^2$ Working time: 182 621 h. | №8 | 6-7 | Crack on the outer surface of 50 mm long, blind, depth 6.5-7.0 mm |
| 3.    | Bent and straight section of bend with welded joint of the boiler steam duct st. №10; Ø325.0 × 24.0 | $T = 540 \, ^\circ C$, $P = 140 \, \text{kgf/cm}^2$ Working time: 175 354 h. | №8 | Ip (not detected) | None |
| 4.    | Bent portion of the steam-through pipe No. 6 from the output collectors of the convective superheater of the IV stage into the steam chamber of the boiler; 133.0 × 17.0 | $T = 555 \, ^\circ C$, $P = 140 \, \text{kgf/cm}^2$ Working time: 230 000 h. | №7 | 6-7 | Crack on the outer surface of 140 mm |
| 5.    | Bend of the steam-through-pipe from the output collectors of the convective superheater of the IV stage into the steam chamber of the boiler; 133.0 × 17.0 | $T = 555 \, ^\circ C$, $P = 140 \, \text{kgf/cm}^2$ Without work | №1 | Ip (not detected) | None |

The study was carried out using the ASTRON measuring and computing complex and the INTROSCAN metal stress and structure analyzer. Precise measurements of the propagation time (delays) and the ratio of the amplitude of ultrasonic pulses (attenuation coefficient) propagating in the material of
the object under study (ASTRON) with the help of a 4 MHz surface acoustic wave sensor, as well as the intensity of magnetic noise (INTROSCAN) were made. To do this, control zones were prepared on the surface of the samples. After that, measurements were made of the above parameters, with the location of the sensors along and along the rivers relative to the central axis of the bends and steam lines.

**Results and its discussion**

The results of measurements of the acoustic and magnetic characteristics, as well as their dependences on the time taken and the microdamage score, are shown in Fig. 3 and 4. Analysis of the obtained graphs (Fig. 3) makes it possible to judge the absence of any dependencies between acoustic and magnetic characteristics and operating time. At the same time, there are clear relationships between the acoustic and magnetic characteristics and the point of microdamage.

![Graph 3](image3.png)

Fig. 3. Dependences of the values of the intensity of magnetic noise – IMN, b / in (1) and the delay time of surface acoustic waves – R, ns (2)

![Graph 4](image4.png)

Fig. 4. Dependences of the values of the delay time of surface acoustic waves – R, ns (1) and the intensity of magnetic noise – IMN, d/q in (2) from the point of microdamage

Thus, the spectral-acoustic and magnetic noise control methods can be used for evaluation of micro metal continuously operating FEC objects.

**Conclusions**

1. A study of metal samples of damaged steam pipelines by acoustic and magnetic methods was carried out. The sample is not damaged, samples with creep cracks and samples from the detected microdamage.
2. Established values of acoustic and magnetic characteristics corresponding to the maximum, the defective point of microdamages steampipes metal specimens made of steel 12H1MF. Spectral-acoustic
and magneto-noise control methods can be used to assess the microdamage of metal of long-term operating facilities of the fuel and energy complex.

The work was supported by the RNF grant agreement №14-09-00724 and Russian President's grant for young candidates, MK-1341.2017.8.

References
[1] Criteria for the evaluation of the technical state of the long-lived metal of HPP equipment based on acoustic structuroscopy / Smirnov A. N., Ababkov N. V., Muravev V. V., Folmer S. V. // Russian Journal of Nondestructive Testing. 2015. Т. 51. 2. p. 94-100.
[2] Aleshin, N. P. Fizicheskiye metody nerazrushayushchego kontrolya svarnykh soyedineniy: Uchebnoye posobiye. M.: Mashinostroyeniye, 2006. 368 p.; In Russian.
[3] Makhutov N.A., Gadenin M.M. Tekhnicheskaya diagnostika ostatochnogo resursa i bezopasnosti. M.: Spektr, 2011. 185 p.; In Russian.
[4] Bugai, N. V. Working capacity and durability of metal power equipment [Text] / N. V. Bugai, T. G. Berezina, I. I. Truin. M., Energoatomizdat, 1994. 272 p.; In Russian.
[5] Substructure, grain boundaries, and microcracks in long-operating metal / Smirnov A. N., Kozlov E. V., Koneva N. A., Popova N. A. // Metal Science and Heat Treatment. 2005. Т. 47. 3-4. p. 155-161.
[6] Dolzhanskij, P. R. Kontrol' nadezhnosti metallja objektov kotlonadzora: sprav. posobie. – M.: Nedra, 1985. – 263 p.
[7] Kontrol' metallja v jenergetike / pod. red. V. G. Borisova [i dr.], Kiev : Tehnika, 1980. 134 p.
[8] Mitenkov, F.M. O novom metode kontrolja povrezhdzamosti materialja oborudovanija JAGEU i apparatno-programmnih sredstvah dija ee realizacii / Mitenkov F.M., Uglov A.L., Pichkov S.N., Popcov V.M. // Problemy mashinovedeniya i nadezhnosti mashin, 1998. 3. p.3–9.
[9] Ivanov, JU. F. Gradientnye strukturo-fazovye sostojanija, formirujushhiesja v stali 08H18N10T pri mnogociklovoj ustalosti do razrushenija / JU.F. Ivanov, V.E. Gromov, S.V. Gorbunov i dr. // Fizika metallov i metallovedenie. 2011. Т. 112. 1. p. 85–93.
[10] Analysis of acoustic and physical-mechanical parameters Of Cr-Mo-Va steel in the vicinity of the crack / Smirnov A., Logov A., Ababkov N. // AIP Conference Proceedings 2. "Advanced Materials in Technology and Construction, AMTC 2015: Proceedings of the II All-Russian Scientific Conference of Young Scientists "Advanced Materials in Technology and Construction"" 2016. Ch. 020009.
[11] V.P. Gagauz, et al., Structure, Phase Composition and Mechanical properties of Thick Welded Joints [in Russian]. Novokuznetsk: SibGIU, 2008. 150 p.
[12] Miroshin I. V. Otsenka vzaimosvyazezy parametrov mekhanicheskogo sostoyaniya metallja s signalami akusticheskoy emissii / I. V. Miroshin, O. A. Ostanin // Uprochnyayushchiye tehnologii i pokrytiya. 2006. 2. p. 44-50.
[13] Blyumenshteyn, V. Yu. Issledovaniye vliyanija istori nagruzheniya na signaly akusticheskoy emissii (AE) / V. Yu. Blyumenshteyn, A. A. Krechetov, I. V. Miroshin i dr. // Fundamental'nye i priladnyye problemy tekhniki i tehnologiy. 2005. 4. p. 54-57.