The Identification of Nanoscale Structures According to a Parameters of Acoustic Structuroscopy Method

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Abstract. The fractography of a destroyed steam turbine rotor is studied by acoustic structuroscopy method. The structural-phase state of the metal of the destroyed rotor of a steam turbine is studied using the methods of electron microscopy. It was established that in the areas of control, where the values of the acoustic characteristics have significant differences from the rest of the metal, detected nanocrystalline structure. The possibility of determining the structure of the nanoscale metal by acoustic structuroscopy is shown.

INTRODUCTION

The destruction of the steam turbine rotor № 2 PVS JSC "Zapadno-sibirskiy metallurgicheskiy kombinat" as a result of an accident occurred after 194 000 hours of operation. This destruction occurred in the perpendicular relative to the longitudinal axis of the rotor section, the transition from the diameter of 295 mm (15 steps) to the diameter of 280 mm (16 steps). The source of the break is stress concentrator in the area of the keyway of the rotor stage 15 (Fig. 1). Type of fracture surfaces shows the character of fatigue fracture. The turbine type VKV-22-90 made on Nevsky Machine-Building Plant named after V.I. Lenin in 1963 [1].

Fig. 1. General view of the fracture surface of the rotor
MATERIAL AND METHODS OF STUDY

The disc for research of the destroyed rotor was cut (sample) parallel to the fracture surface thickness ~ 50 mm. Places cutting thin sections of the disc is determined by acoustic methods, including spectral-acoustic (Rayleigh waves by scanning the surface of the opposite fracture), and an end disk longitudinal waves along the entire circumference [1].

The surface of the sample for research by spectral-acoustic method (CPI "Astron") [2, 3] is divided into zones as rectangles (Fig. 2 a).

![Fig. 2](image)

a) b)

Fig. 2. The scheme and measurement results of the acoustic and magnetic characteristics of the surface of fracture the investigated sample:
   a - measurement scheme; b - the results of measurements

RESULTS AND THEIR DISCUSSIONS

After carrying out measurement the following picture of the distribution of acoustic characteristics relative to the cross section of the rotor has received. The highest values of the deviations of the measured characteristics detected in the areas of scan 2, 9-11 and 35-37. Also, significant deviations from the average value found in zones 1, 3, 12-16, 26-29, 38-42, 52 and 61-63 (Fig. 2b) [4, 5].

Further, four sites have been chosen with the acoustic characteristics significantly different from the rest of the metal disc (sample). Metalphysical researches conducted in five different areas of the sample on the surface of the opposite fracture and at a distance of 0.5 mm from the fracture. Schematically, the position of these areas relative to the fracture surface is shown in Fig. 3 [1].

It was found that steam turbine rotors made of steel 40H2N2MA (GOST 4543-71). The analysis is performed on optical-emission spectrometer «Q4 Tasman» [1].

X-ray diffraction analysis (XDA), diffraction and transmission electron microscopy on thin foils (TEM) is used in the paper. Research by using the X-ray analysis was performed at room temperature.
on a DRON-7 [6]. Electron microscopic studies were carried out on a transmission electron microscope EM-125 (without the goniometer). The electron microscope was set to a high resolution, at an accelerating voltage of 125 kV. Working increase in the column of the microscope was × 25,000. Determining the sizes and volume fraction of the phases present in the material carried by the images confirmed by microdiffraction paintings and dark-field images obtained in the reflexes of the respective phases [7].

As studies have shown, the basis of all of the samples is α-phase. Its volume fraction at any point of the product is at least 95%. α-phase - a solid solution of both the interstitial elements (C, N etc.) and substitution elements (Mn, Cr, Si, etc.) in α-Fe with a BCC crystal lattice. The basic units take, first of all, the iron atoms, as well as substitution elements, the internodes (mainly tetrahedral internodes) is partially occupied by carbon atoms. X-ray diffraction pattern obtained from different samples are identical.

Crystal lattice parameters α-phase at all points in samples studied are shown in Table. The same table shows the phase composition, microdistortions and sizes coherent scattering areas (CSA), obtained by X-ray diffraction analysis (XDA). As can be seen from Table, at any point in the product crystal lattice parameter is 0.2872±0.0002 nm, ie, slightly higher than the lattice parameter of pure α-Fe. The crystal lattice parameter α-Fe is 0.2866 nm. This means that although α-phase and consists essentially of α-Fe, but in the solid solution except for the substitution elements (Mn, Cr, Ni, Mo, Si) and is also an interstitial element - carbon.

Electron microscopic researches have shown that regardless of research place the main phase component (matrix) investigated steel is α-phase. Morphologically α-phase in different samples are generally present in the form of: 1) a bainite (least defect of the material); 2) a fragmented α-phase with anisotropic fragments; 3) fragmented α-isotropic phase with fragments and 4) a nanocrystalline structure.
The data X-ray diffraction analysis

| Sample number | The phase composition | Crystal lattice parameters, $\alpha$-Fe, $\alpha$, nm | Microdistortions, $\Delta d/d$ | Size CSA $P$, nm |
|---------------|-----------------------|-----------------------------------------------------|-------------------------------|-----------------|
| № 3          | $\alpha$-Fe           | 0.28705                                             | 0.0005                        | 50              |
| № 1-1        | $\alpha$-Fe           | 0.28700                                             | 0.0022                        | >100            |
| № 1-2        | $\alpha$-Fe           | 0.28702                                             | 0.0014                        | 56              |
| № 2-1        | $\alpha$-Fe           | 0.28720                                             | 0.0018                        | >100            |
| № 2-2        | $\alpha$-Fe           | 0.28710                                             | 0.0010                        | 75              |
| № 4-1        | $\alpha$-Fe           | 0.28700                                             | 0.0020                        | >100            |
| № 4-2        | $\alpha$-Fe           | 0.28706                                             | 0.0010                        | 92.5            |
| № 5-1        | $\alpha$-Fe           | 0.28734                                             | 0.0010                        | 90              |
| № 5-2        | $\alpha$-Fe           | 0.28734                                             | 0.0005                        | 50              |

The nanocrystalline structure is not present in all the investigated points of the product. Microdiffraction pattern is a ring. Example electron microscopic image and microdiffraction pattern shown in Fig. 4.

![Electron-microscopic image](Image)

**Fig. 4. Nanocrystalline structure. Electron-microscopic image**
CONCLUSION

Acoustic structurescopy - it's the definition of composition, grain size, hardness, anisotropy properties of impurities in the material by using of acoustic methods of nondestructive testing.

Electron microscopic study were subject only those areas in which the performance of acoustic characteristics significantly different from the rest of the metal disc. It follows that the parameters of acoustic structurescopy can judge about the presence of nanosized structure metal.

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