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X-RAYSTRUCTURAL RESEARCH OF PRODUCTS OF CAVITATIONAL EROSION OF METALS

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S u m m a r y . The results of qualitative and quantitative X-ray phase analysis of products of cavitational erosion of metals surfaces are presented in this article. The obtained data allow to suggest that the main reason of cavitational erosion of metals surfaces in the water is the chemical influence of cavitational environment.
K e y w o r d s : cavitation, erosion, diffractogram, powder sediment.

INTRODUCTION

Cavitational destruction is one of the reasons which causes the intensive wear of equipment: blades of the pumps, surfaces of the pipelines etc. In spite of the problem of cavitational destruction has been analysed for a long time, the mechanism of this phenomenon isn't known till the end so far. That's why the research of the mechanism of this destruction is the actual task, as if the reason of the phenomenon is clear, the destruction of screws of speed vessels, blades of the pumps can be predicted and it'll be possible to prolong their exploitation [1-7].

In the modern works erosion is regarded as the result of periodical load of the surface with spherical waves, generated in the zone of whip of cavitational bubbles and high speed liquid micro streams, which can destroy even super durable materials [8-16].

RESEARCH OBJECT

The results of the research of products of the surface destruction with X-ray structural methods, which allow to determine both the chemical composition of the sediment and its physical condition, that make it possible to find out the mechanism of the destruction of solid surface under ultra-sound cavitation are given in this work. The ultra-sound dispergator UZDN-2T with electrical power of 400 W and frequency of 22 kHz was used for studying the interaction between cavitation and the surface of the attachment.

To study the influence of cavitation on the metals surface the fixed on the magnitostricror attachments from different materials were put down into the 100 ml glass with distilled water. The glass was in the thermostat to prevent heating. The time of ultra-sound processing varied from 15 h till 20 h, after which the liquid was evaporated under the flat temperature, and the sample of abandon powder sediment was made for the X-ray structural analysis. Moreover the control of changing of the attachments mass was made during the process of erosion. The initial mass of the iron attachment was 44,437 g. Its mass after 30 h of ultra-sound cavitation became 43,751 g. The mass decreased on 0,686 g. The initial mass of copper attachment was $50{,}080 \pm 0{,}005$ g, but its mass after 20 hours of cavitational influence became $49{,}612 \pm 0{,}005$ g.

On the fig.1*a*, *b* the photos of the surface of the iron attachment before and after the influence of ultra-sound cavitation are given.

On the fig.2*a*, *b* the photos of the surface of the copper attachment before and after the influence of ultra-sound cavitation are proposed.

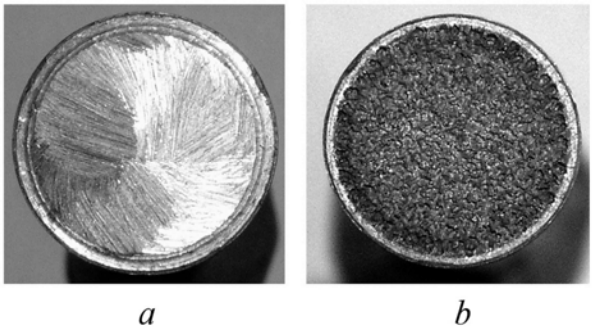

Fig.1. The surface of the iron attachment: *a* – before cavitation; *b* – after 30 hours of the influence of ultra-sound cavitation. The initial mass of the iron attachment - 44,437 g, after 30 h of ultra-sound cavitation– 43,751 g

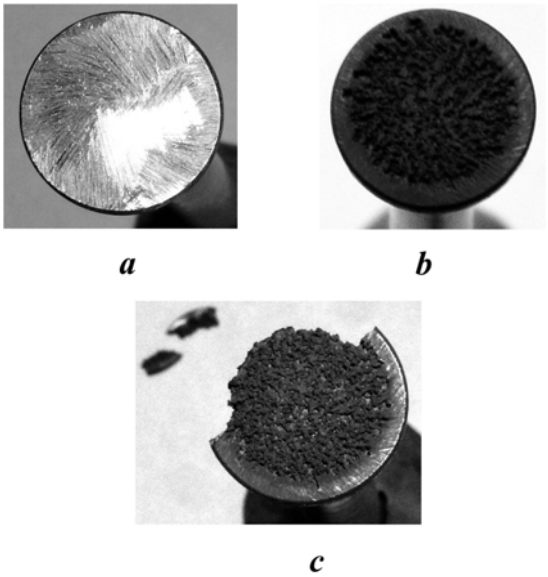

Fig.2. The surface of the copper attachment: *a* – before cavitation; *b* – after 20 h of the influence of ultra-sound cavitation; *c* – after the extra 20 h of the influence of ultra-sound cavitation. The initial mass of the copper attachment – $50{,}080 \pm 0{,}005$ g, after 20 hours of the cavitational influence – $49{,}612 \pm 0{,}005$ g

The powder sediment pressed in side ditches with the inner volume of 10 mm in diameter or 0,5 mm in depth. The side ditches were fixed in the station GP-13 of the goniometer GUR-9 of the X-ray diffractometer DRON-4. Diffractograms of the powder sediment, obtained under the ultra-sound influence on the copper attachment, were taken under the following conditions: the wave length of radiation λ=0,154 nm under the accelerated tension of 29 kV and current of 15 mA. Splits, limited the size of X-ray radiation, for shooting were 0,5×4×0,25 mm. Ni filter was used to filter K_β radiation. The shooting of diffractograms was made in step by step regime: angles $2\theta=10^0$-150^0 with the step of $0{,}1^0$ and the time of exposition of 5 s (fig.3,*b*-1) and 10 s (fig.3, *b*-2). Diffractograms of the powder sediment, obtained under the ultra-sound influence on the iron attachment, were taken under the following conditions: the wave length of radiation λ=0,1936 nm under the accelerated tension of 25 kV and current of 15 mA. Splits, limited the size of X-ray radiation, for shooting were 0,5×4×0,25 mm. Mn filter was used to filter Kβ radiation. The shooting of diffractograms was made in step by step regime: angles $2\theta=6^0$-150^0 with the step of $0{,}1^0$ and the time of exposition of 30 s (fig.3-1) и 20 s (fig.3-2). The initial mass of the iron attachment was – 44,437 g. Its mass after 30 h of ultra-sound cavitation became – 43,751 g. The mass decreased on 0,686 g.

The received diffractograms of the powder sediment, obtained under the ultra-sound influence on the copper attachment are given on the fig.3a,b and on the iron attachment on the fig.4a,b.

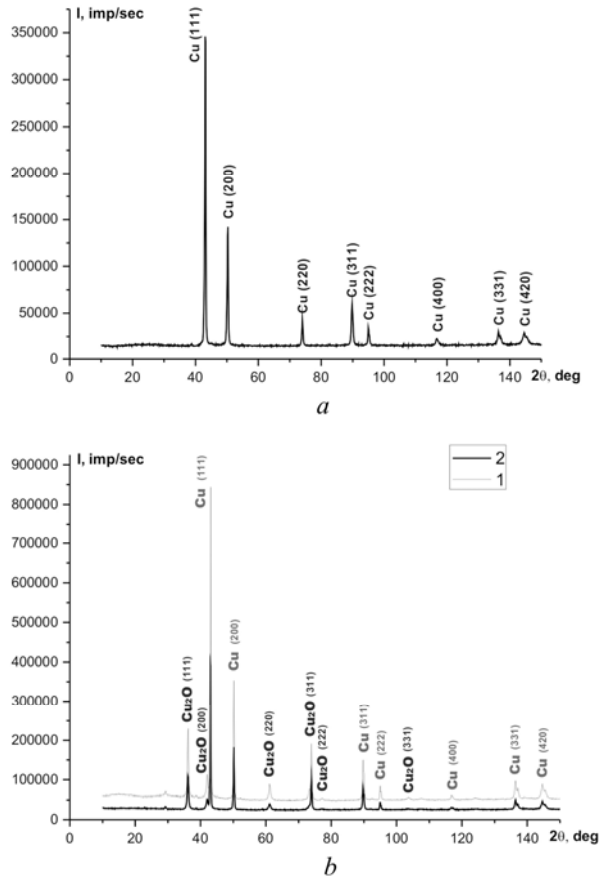

Fig.3. Diffractograms: *a* – copper attachment before cavitation; *b* – powder sediment after cavitation (1 – 20 h of ultra-sound cavitation; 2 – after extra 20 h of ultra-sound cavitation)

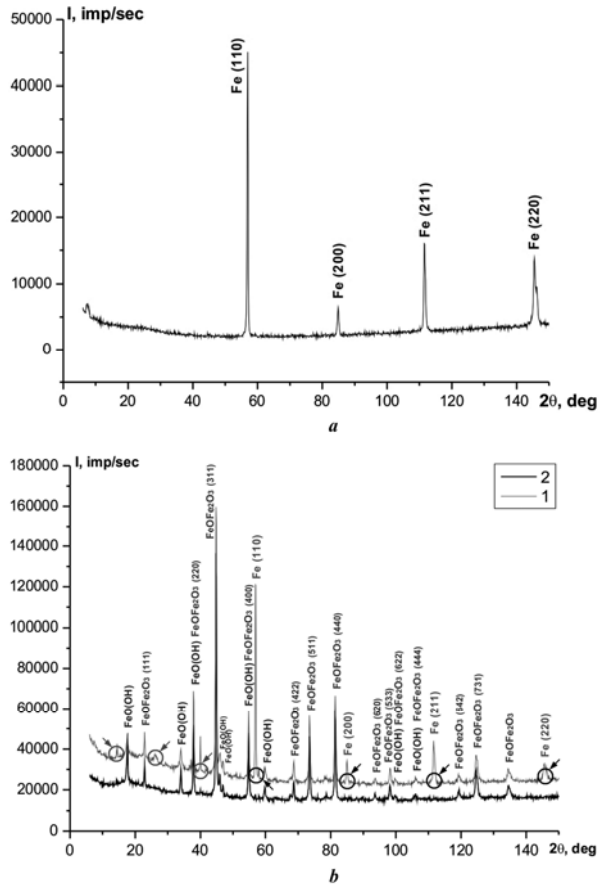

Fig.4. Diffractograms: *a* – diffractograms of the iron attachment before cavitation; *b* –powder sediment after ultra-sound cavitation (1 – 15 hours of cavitation; 2 – extra 15 hours of cavitation). Phase Fe is on the diffractogram 1 (circled), but on the diffractogram 2 phase Fe is absent and unknown reflexes are absent too (first three circles to the left). The initial mass of the iron attachment was – 44,437 g, after 30 h of ultra-sound cavitation it became – 43,751 g

RESULTS

The ratio of integral intensiveness of the reflection *HKL* α-phase (the shooting on the diffractometer with the focus according to Brag-Brentano) is connected with mass shares correlation [17]:

$$\frac{I^{\alpha}_{H_1K_1L_1}}{I^{\alpha}_{H_2K_2L_2}} = k\frac{m_1}{m_2}, \qquad (1)$$

where: $I^{\alpha}_{H_1K_1L_1}$ – the integral intensiveness of the reflection (quantity is equal to the area of the analytical reflex); k – constant for all lines of X-ray grams, which is from the calibration curve; m_1 и m_2 – mass shares of phases.

The reflexes from the surface (111) for Cu_2O and (200) for Cu were chosen as the analytical reflexes. The shooting was made under the following conditions: the wave length of radiation λ=0,154 nm, the accelerated tension 28 kV and current of 15 mA. Splits, limited the size of X-ray radiation, were 0,5×4×0,25 mm. The shooting was made in step by step regime: angles $2\theta = 35^0$-37^0 with the step of $0{,}05^0$ and the time of exposition of 3 s for Cu_2O and angles $2\theta = 49^0$-51^0 with the step of $0{,}05^0$ and the time of exposition of 3 s for Cu. The obtained diffractograms of the analytical reflexes are shown on the fig.5*a,b* [18-20].

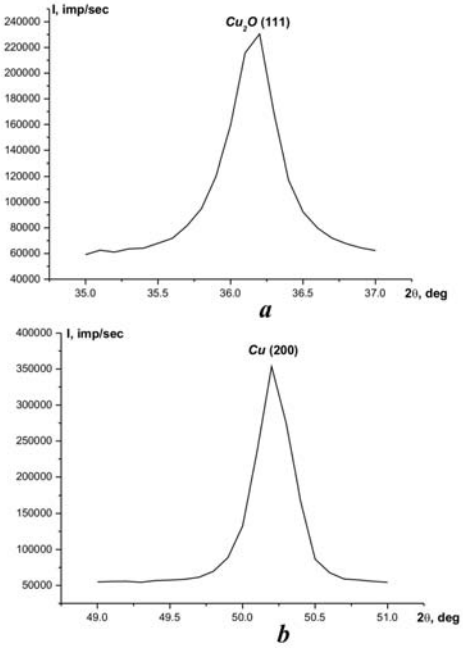

Fig.5. Diffractograms of the analytical reflexes of the powder sediment after 20 hours of ultra-sound cavitation: *a* – Cu_2O (111); *b* – Cu (200)

The results of made calculations have shown that the powder sediment, obtained after 20 h of ultra-sound cavitation, contains: 46,1% Cu_2O and 53,9% Cu, but after extra 20 h of cavitation: 40,8% Cu_2O and 59,2% Cu.

The analysis of defects on widening the lines of diffractograms in the attachment before the cavitational influence and in the products of erosion was carried out further.

It was determined that dispersion and micro tension had the following significances:

- for the copper attachment the dispersion $D = 0{,}12$ μm, micro tension $e = \Delta d/d = 0$;
- for the copper in the sediment the dispersion $D = 0{,}17$ μm, micro tension $e = \Delta d/d = 1{,}5\times10^{-4}$.

These significances show that dispersion, which under the mechanic influence must decrease, in fact increases.

The qualitative X-ray phase analysis of the products of the cavitational erosion was carried out with the help of applied programs IDENT4, XPowder Demo.

The results of the X-ray phase analysis of the products of the cavitational destruction pointed out the existence of the phases: Fe, $FeOFe_2O_3$, FeO (OH), and also the unknown phases.

The quantitative X-ray phase analysis of the powder sediment was made with the calculative method.

The ratio of integral intensiveness of the reflection HKL α-phase is connected with mass correlation (1). k - constant for all lines of X-ray grams, in our case was found with the calculative way as it was impossible to create the sample for the method of calibration curve; m_1 и m_2 - mass shares of phases.

The calculation of integral intensiveness of the reflection for finding the constant k was made according to the formula [15]:

$$I^{\alpha}_{HKL} = k \cdot P\left(\vartheta^{\alpha}_{HKL}\right) \cdot \left(F^2_{HKL}\right) \cdot \frac{1}{2\mu} \cdot p^{\alpha}_{HKL} \cdot \frac{\upsilon_{\alpha}}{\left(V^2_{я}\right)^{\alpha}},$$

where: k – constant for all lines of X-ray grams; $P(\vartheta)$ – angle factor; F_{HKL} – structural factor (taking into consideration the heat multiplier); p_{HKL} – multiplier of repetition; $V^{\alpha}_{я}$ – the volume of a simple cell of α-phase; υ_{α} – volume share of α-phase; μ – coefficient of the linear weakening of the sample.

The results of made calculations have shown that the powder sediment, obtained after 15 h of ultra-sound cavitation, consists of: 3% Fe, 92% $FeOFe_2O_3$ and 5% of unknown phases and FeO (OH).

The qualitative X-ray phase analysis for the powder sediment after extra 15 h of ultra-sound cavitation has pointed out that there are only reflexes of $FeOFe_2O_3$ and FeO (OH) on the diffractogram, but the reflexes of Fe and unknown reflexes are absent.

CONCLUSIONS

All mentioned above allow us to suggest that the main mechanism of the surface destruction under the ultra-sound cavitation is the chemical influence on the metals surface of the cavitational environment.

The distilled water had been replaced by the white spirit for checking up the chemical nature of the surface destruction, but after 20 hours of cavitation the visible signs of erosion on the surface of attachment were not founded.

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РЕНТГЕНОСТРУКТУРНЫЕ ИССЛЕДОВАНИЯ ПРОДУКТОВ КАВИТАЦИОННОЙ ЭРОЗИИ МЕТАЛЛОВ

Владимир Громенко, Сергей Кривоносов, Алексей Снижко

Аннотация. Представлены результаты качественного и количественного рентгенофазового анализа продуктов кавитационной эрозии поверхности металлов. Полученные данные позволяют предположить, что основной причиной кавитационной эрозии поверхности металлов в воде является химическое воздействие кавитирующей среды.

Ключевые слова: кавитация, эрозия, дифрактограмма, порошкообразный осадок.

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