UDC 621.774.09:621.21

Investigation of High-Duty Pipes Surface Condition with the Use of Scanning Electron Microscopy

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Pipes Surface Condition for nuclear energetics is appraised. Reasonability of using scanning electron microscopy, which helps define microscopic defects on the pipes surface and choose the optimal way of pipes production, is shown.

Keywords: PIPE, SURFACE, QUALITY, ROUGHNESS, FRACTURE PATTERN, SCANNING ELECTRON MICROSCOPY

Introduction

Predominant factor of the damage of pipelines and equipment in nuclear energetics is isolated corrosion and one of the main reasons is unsatisfactory quality of surface [1, 2]. Role of technological factors in forming pipes surface condition and the ambiguity of the existing control methods are shown in the papers [3, 4].

Traditionally, while factory testing high-duty pipes from corrosion-resistant steel or alloys, 100% visual inspection, i.e. surface examination, is applied. External surface shall be inspected with the naked eye under the lamp, internal – through the periscope at each end. Tearing, deep scratches, lines and other deep defects that put out wall thickness out of the established negative deviation limits towards nominal dimension cannot be allowed. Less frequently the surface is controlled with the help of selected samples by comparing them with standard samples or by measuring the roughness parameter R_a (center line average profile deviation) with profilograph-profilometer. Besides, the pipes shall be subjected to 100% ultrasonic inspection with setting up the equipment at an artificial line the testing sample with depth 5-10 % of wall thickness.

Results and Discussion

According to the supply condition, depending on the purpose pipes are supplied with the surface after light annealing in a protective atmosphere or vacuum, after chemical engineering processing (etching, electropolishing), after abrasive processing (grinding, polishing with dispersed abrasives, etc.).

Due to the methods of scanning electron microscopy it is possible to evaluate surface quality, predict the stability of pipes adequately under service conditions and choose the optimal way of pipes processing.

The paper is devoted to the research of the pipes internal (working) surface condition that are designed for critical components in nuclear energetics:

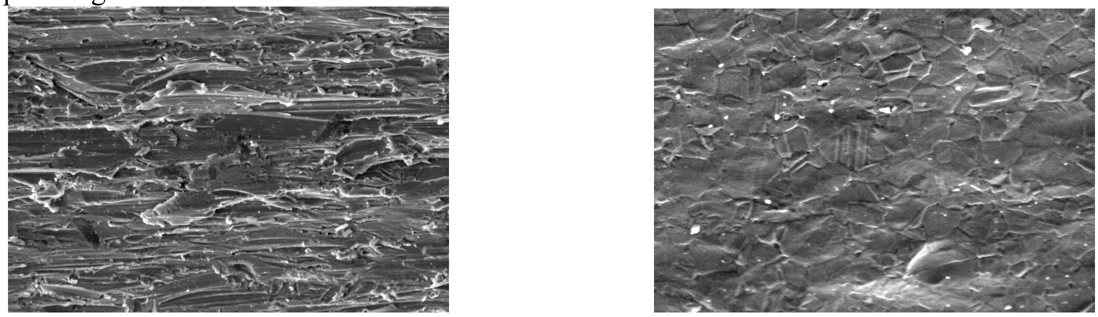
- shells of absorbing elements (SAE) Ø 8,2×0,6 mm of steel 06X18H10T on TU 14-3-219-89 “Highly thin-walled seamless pipes from corrosion-resistant austenitic steels” after electropolishing;
- SAE Ø 8,2×0,6 мм mm of steel 08X18H10T defined in the standard GOST 10498-82 “Highly thin-walled seamless pipes from corrosion-resistant austenitic steels” after dispersed abrasive polishing (crushed sand);
- heat exchanger pipes Ø 19×1 mm of alloy МНЖ 5-1 defined in the standard GOST 17219-79 “Pipes of copper-nickel alloy МНЖ 5-1» after etching.

According to the results of factory inspection, all pipes passed the acceptance test for the compliance with the standard requirements including 100% ultrasonic and visual inspection.

The traditional methods of light microscopy are known to be not effective enough for obtaining high-quality images of curved surfaces.

Additional research was held with the help of scanning electron microscopy and profilometry at SE "SRTI". The surface topography was studied by analyzing the fracture patterns, received on the device “РЭМ-106И” with magnifications of 50 to 5000. The roughness parameter Ra was measured by “Talysurf”. Mantle pipes of the SAE are delivered after light scale-free annealing, etching or electropolishing. It is considered that chemical engineering processing in acid bath as revealing the grain boundaries is not always favourable. However, it was established that because of the grain boundaries opening after vacuum annealing a more relief surface was formed [3, 4]. Therefore, this research is devoted to the study of the pipes surface condition after abrasive and electropolishing.

The analysis of images obtained by "РЭМ" showed that after the abrasive polishing of the inner surface of pipes Ø 8,2×0,6 mm of steel 06X18H10T inhomogeneity with rough relief and microscopic irregularities are observed, which are the result of the abrasive influence (**Figure 1a**).

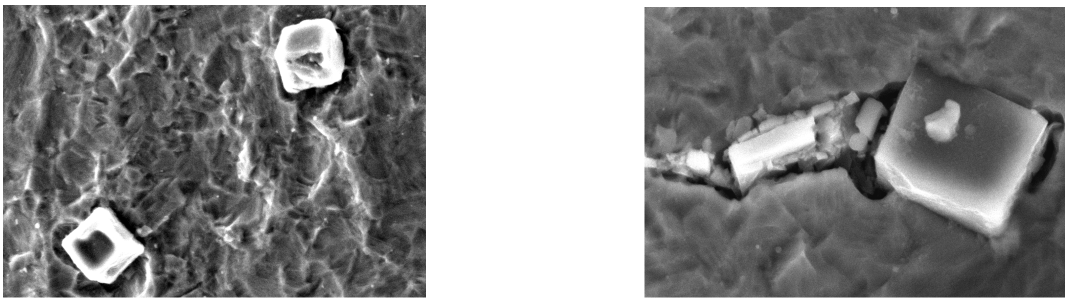


a **b**

Figure 1. Topography of the pipes inner surface Ø 8,2×0,6×4200 mm, ×500: a – steel 08X18H10T, after abrasive polishing (Ra = 0,9–3,5 microns); b – steel 06X18H10T, after electropolishing (Ra = 0,2–0,8 microns).

The roughness R_a is 0,9-3,5 microns. Such surface condition does not provide achievement of the vacuum density when filling the shell with the absorber, e.g. boron carbide. During visual inspection, the inner surface is light or gray, dull, without peculiarities. Besides, after the abrasive polishing the pipes need afterpurification (washing, rubbing or wadding).

As a result of electropolishing the inner surface of pipes Ø 8,2×0,6 mm of steel 06X18H10T is quite homogeneous and smooth. Mostly nonmetallics and grain boundaries are visualized on it (**Figure 1b**). The roughness parameter Ra is 0,2-0,8 microns. The inner surface is light and shiny. Such state of the working surface seems to be more favorable for shells.

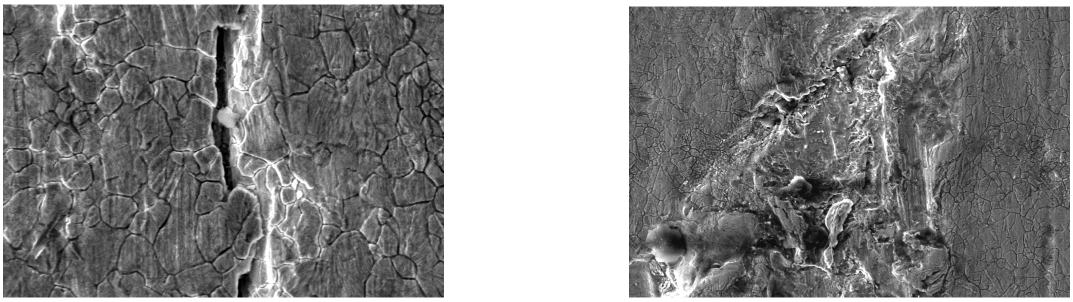


a **b**

Figure 2. Nonmetallic impurities on the pipes inner surface Ø 8,2×0,6 mm of steel 06X18H10T: a – ×1000; b – ×2500

In this case, titanium-stabilized steels 06 ... 08Kh18N10T have in their structure nonmetallic inclusions, in particular, titanium carbonitride, both individual and in the cluster. Opening on the pipes surface, they can be centers of corrosion nucleation. Scanning electron microscopy can detect the presence of the impurities themselves,
their structure, as well as further identify them (**Figure 2**).

The surface of the pipes Ø 19×1 mm of copper-nickel alloy МНЖ 5-1 defined in the standard GOST 17217 must not contain laps, blisters, laminations, deep lines and other defects deeper than 0,1 mm. The images obtained by "РЭМ" showed that there were some microscopic defects on the pipes surface, determined by the way of production. E.g. microcracks, lines, traces of adhering (**Figure 3**). Not exceeding allowable depth norm, such surface defects, will certainly contribute to damage the operation of pipes at nuclear power plants, such as pitting corrosion.



a b

Figure 3. Topography of the pipes inner surface Ø 19×1 mm of МНЖ5-1 alloy: a – ×500; b – ×250

Thus, "РЭМ" allows detecting microscopic or inaccessible for other methods defects, identifying them with the interpretation of the causes of formation, as well as link structure of the metal with the processes occurring on the surface. In view of the investigations pipe shells, standardized Delivery Terms of pipes Ø 8,2×0,6×4200 mm for absorbing inserts dry storage of spent nuclear fuel from Zaporizhzhya NPP were developed, which include the imposition of additional requirements for the delivery and quality of the surface (the norms of roughness, etc.). This document has been approved by the enterprise "Atomenergomash" (Energodar), agreed by NSC "KIPT" and SE "SRTI" and in accordance with it pipe orders are made.

Conclusions

1. The quality of the pipes inner surface of stainless steel 06...08Х18Н10Т and МНЖ5-1 alloy for nuclear energetics was analyzed. It was shown that by using scanning electron microscopy it is possible to diagnose effectively the condition of the surface with microscopic defects, which worsen the service properties of pipes.

2. With the help of "РЭМ" and profilometry the inner surface of pipes Ø 8,2 × 0,6 mm of steel 06 ... 08Kh18N10T after abrasive polishing and electropolishing was compared, what confirmed the clear advantages of the latter. Based on the results, the Delivery Terms of pipes for absorbing inserts dry storage of spent nuclear fuel were developed and approved Terms of delivery tube for absorbing inserts dry storage of spent nuclear fuel.

3. It was recommended to use scanning electron microscopy together with the standard methods of the surface grading while inspecting high-duty pipes. This will help select the best way of producing and processing of pipes as well as predict their behavior under operating conditions with specifying the cause or mechanism of the damage.

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* Published in Russian

Received April 18, 2011

Исследование состояния поверхности труб ответственного назначения с помощью растровой электронной микроскопии

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Выполнена оценка состояния поверхности труб для атомной энергетики. Показана целесообразность пользования растровой электронной микроскопии, которая позволяет распознавать микроскопические дефекты на поверхности труб, и помогает в выборе оптимального способа производства труб.