STUDY OF NON-METALLIC INCLUSIONS IN STEEL USING EDX ANALYSIS

Volodymyr Sukhomlyn[1]
Bohdan Korkh[2]

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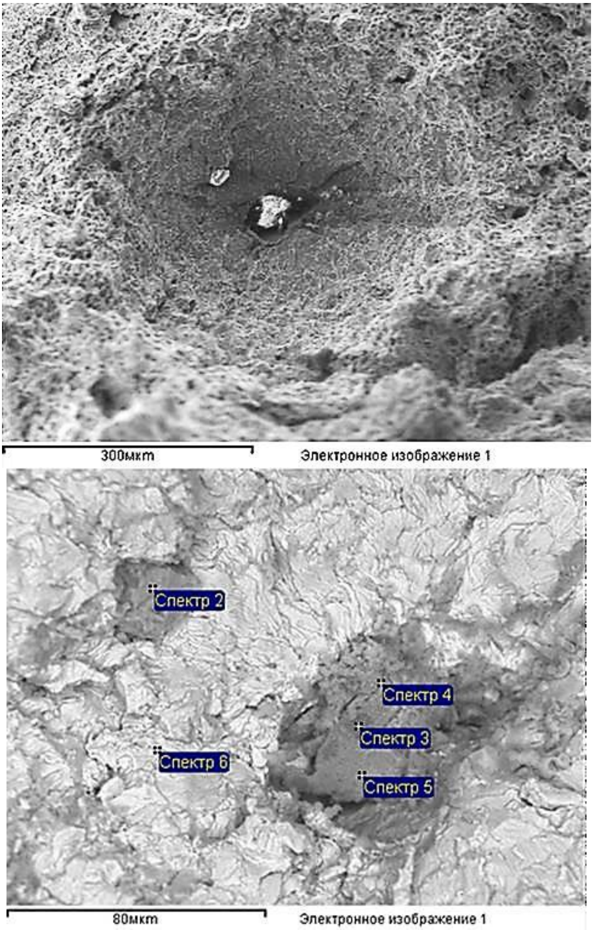
It is known that the mechanical and technological properties of steel depend on non-metallic inclusions, their shape and distribution throughout the metal volume. This theoretical and practical issue is given considerable attention [1, p. 2895]. Modern alloys obtained by metallurgy have high requirements for the quality of steel, so the accuracy and locality of the methods for studying non-metallic inclusions is steadily increasing. These requirements are met by the method of X-ray energy dispersive microanalysis, which is quite effective, and sometimes the only method for solving such issues. In the work, the morphology and chemical (quantitative) composition of non-metallic inclusions were studied using scanning microscopy and spectral X-ray microanalysis. Industrial lots of rolled products with a diameter of 8 mm made of low-carbon steel of standard chemical composition were used as the material for the studies. The structure, microstructure, and fractography of rolled metal samples were studied in laboratory conditions. Microanalysis requires a number of operations, including sampling and preliminary preparation of samples, grinding, polishing and chemical etching of microsections, their viewing and photographing. To observe fine structural details at high magnifications, anodic dissolution (electrolytic polishing) is performed [2, p. 1912]. With the correct choice of the chemical composition of the electrolyte and its operating mode, an atomically smooth surface without damage of external origin is ensured. For factographic studies of tensile samples and structure studies, a scanning electron microscope REM-106 of the Ukrainian enterprise SELMI was used. To perform more complex studies on the identification of non-metallic inclusions and unknown phases, a SUPRA 40WDS device (Carl Zeiss, Germany) was used with an INCAx-sigth X-ray energy-dispersive microanalyzer (Oxford Instruments, Great Britain) with INCA 350 software.

Investigation of the interface formed after mechanical tensile testing of a wire rod with a diameter of 8 mm revealed non-metallic inclusions (Figure 1) which were examined by X-ray energy dispersive microanalysis.

[1] Dnipro State Technical University, Kamianske, Ukraine
[2] Dnipro State Technical University, Kamianske, Ukraine



a *b*

Figure 1. Non-metallic inclusions in rolled: *a* – non-metallic inclusions, *b* – marked locations for obtaining energy dispersive spectra.

The locations from which the X-ray spectra were obtained are marked in Figure 1, *b*. Figure 2 shows an example of "Spectrum 5" from point 5 after computer processing with the INCA 350 software and mathematical complex.

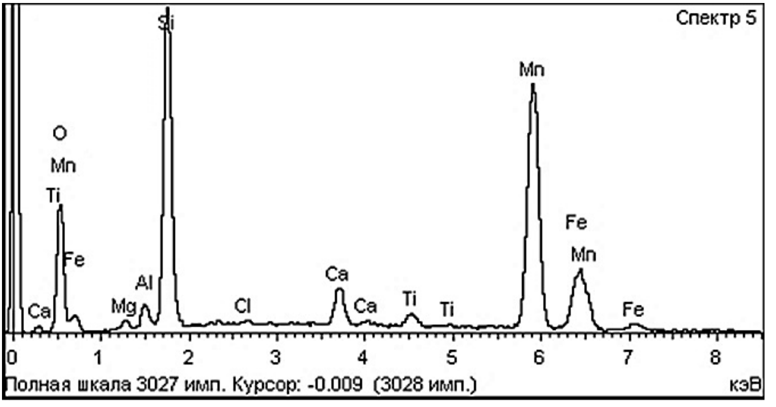


Figure 2. X-ray spectrum from point 5 in Figure 1

The results of decoding all the spectra from Figure 1, *b* are summarized in Table 1. The final analysis of the obtained results leads to the chemical elements that made up the substance that led to the destruction of the steel rod during mechanical tensile tests.

Table 1

Chemical elements in the composition of non-metallic inclusions

Спектр	В стат.	O	Mg	Al	Si	S	Cl	Ca	Mn	Fe	Всього
Сумарний спектр	Так	9.95	0.14	0.27	2.49	0.07	0.32	0.22	2.65	83.50	100.00
Спектр 2	Так	26.44	0.86	1.38	20.52			2.55	35.06	12.19	100.00
Спектр 3	Так	47.49		0.33	39.71		0.40	0.27	1.93	9.87	100.00
Спектр 4	Так	46.20	1.19	1.57	19.03	0.18	0.22	1.68	23.14	6.08	100.00
Спектр 5	Так	21.66	0.74	1.36	19.11		0.23	2.90	43.99	8.73	100.00
Спектр 6	Так				0.27				0.63	99.10	100.00
Макс.		47.49	1.19	1.57	39.71	0.18	0.40	2.90	43.99	99.10	
Мін.		9.95	0.14	0.27	0.27	0.07	0.22	0.22	0.63	6.08	

The software of modern scanning microscopes with attachments for energy dispersive analysis allows obtaining the results of the studies from Table 1 in the form of oxides. This possibility, for X-ray spectral microanalysis, significantly increases the range of important studies. These data are summarized in Table 2.

Table 2

Oxides included in non-metallic inclusions

Елемент	Ваговий %	Атомний %	Сполука %	Формула
Mg K	0.74	0.81	1.23	MgO
Al K	1.20	1.18	2.27	Al2O3
Si K	17.80	16.89	38.08	SiO2
Ca K	2.23	1.48	3.12	CaO
Ti K	0.89	0.50	1.49	TiO2
Mn K	30.94	15.01	39.95	MnO
Fe K	10.77	5.14	13.86	FeO
O K	35.42	58.99		

Conclusions:

1. Scientific results have been obtained on the origin, morphology and chemical composition of non-metallic inclusions in low-carbon steel coils.
2. X-ray spectral microanalysis methods have significant advantages in determining the chemical composition in local volumes of solids.
3. The presence of a maximum on the spectrogram indicates a substance, and the integral intensity serves as a quantitative characteristic of a chemical element.
4. An X-ray spectral microanalyzer allows you to obtain information about a chemical substance from a polished surface, from an etched surface of a cut, or a fracture after mechanical testing.

References:

1. Andre Luiz Vasconcellos da Costa e Silva. Article The effects of non- metallic inclusions onproperties relevant to the performance of steel instructural and mechanical applications. *Jornal of Materials Research and Technology*. 2019. DOI: https://doi.org/10.1016/j.jmrt.2019.01.009

2. Abd El Khalick Mohammad, Danwei Wang. Electrochemical mechanical polishing technology: recent developments and future research and industrial needs. *Int J Adv Manuf Technol* (2016) 86:1909–1924. DOI: https://doi.org/10.1007/s00170-015-8119-6