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DIAGNOSIS OF LONGITUDINAL WELDED JOINTS OF TUBES BY THE METHOD OF MAGNETOELASTIC ACOUSTIC EMISSION

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Summary. *The microstructure of the steel 19H and 17H1S pipes after long-term operation is investigated. Dependence of the magnetoelastic acoustic emission signals characteristic change on the structure of different areas of the welded joint is determined. The effect of residual stresses after welding on the change of the signals amplitude sum of magnetoelastic acoustic emission has been investigated.*
Key words: *magnetoelastic acoustic emission, pipeline, welded joints, microstructure, residual stresses.*

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Statement of the problem. The safe operation of pipelines is foremost provided while controlling the oil and gas pipelines operating efficiency as well as their supporting system and their diagnosis investigations. Special attention should be paid to the welded joints (WJ), as they have some peculiarities, such as WJ cross-section structural inhomogeneity, accumulation of the non-metal inclusions in the metal weld, availability of the residual stresses after welding, initiation of hot and cold cracks while WJ forming [1]. In the case of long-term operation these characteristics being affected by the transported substances, change of the operation pressures and the environmental conditions can cause the initiation of microcracks and result in the material fracture.

Analysis of the available results of investigations. The method of magnetoelastic acoustic emission (MAE), which is based on the signals excitation by the external magnetic field, which initiates the jump-like displacement of the magnetic domain walls (the Barkhausen effect) [2, 3], is efficient for the local diagnosis of the welded ferromagnetic structural elements. These processes are special at the threshold of some defects or their accumulations, where sufficient changes of the material domain structure occur being affected by the plastic deformations, stresses or hydrogen.

In the papers [4, 5] the dependence of the material magnetic properties on the change of the stress-strain state of the investigated object, different modes of the thermal treatment, change of the chemical composition of the metal and improvement of its hardness has been analysed. Every of the mentioned above features is available while joining by welding. The main problems after the WJ crystallization are those dealing with different microstructure in all its areas and additional stresses caused by the high temperature effect.

The advantages of the MAE method for the investigation of the welded structure stress state in comparison with the conventional diagnosis methods are those, that requirements as to the surface preliminary work, creation of the additional loading closing or change of the operation regime of the element being under investigation, are not stated.

The Objective of the paper. To investigate the microstructure of the longitudinal welded joints material for the oil-pipelines made of 19Г steel and gas-pipelines made of 17Г1С steel of 1020mm diameter, 10mm wall thickness after 48 and 39 years of operation correspondingly, to determine the effect of the metal structure of different WJ areas and residual stresses in the pipeline fragment on the MAE signals characteristics.

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Method of investigations. The pipes metal microstructure was investigated in their diametric cross-section using prismatic 10×30×60mm specimens cut out from the pipeline area with the longitudinal welding. The specimens were polished and pickled by the 2% solution of the nitric acid. Optical microscope NU-2. was applied. The effect of the structure inhomogeneity in different WJ pipeline areas on the MAE signals characteristics were studied on the 240×10×3mm specimens cut out from three main areas of the longitudinal WJ (Fig. 1). Magneto-acoustic information system MAE-3Л designed for the extracting and processing of the MAE signals was used [6]. The specimens were remagnetized with the help of the attached electromagnet (AEM) with the 1260 coil copper wire on each electro wire support. The induction amplitude of the magnetic field in the specimen was measured taking advantage of the 300 turn coil under the active resistance 14 Ω. The effect of residual stresses was investigated on the pipeline fragment with the longitudinal welded joint. Relaxing annealing was used to eliminate the stresses.

Result of investigations and their analysis. Having performed the metalographic investigations, it was determined, that the investigated materials belong to the type of ferrite-perlite steels (Fig. 1). The structure of the oil-pipeline weld seam (Fig. 1c) is specifield by the greater dispersion than in the base metal (Fig. 1a), which is characterized by some band-like structure caused by rolling. The basis of heat treatment zone (HAZ) is the over-heated area with the coarse-grained ferrite-perlite structure and available ferrite (Fig. 1b).

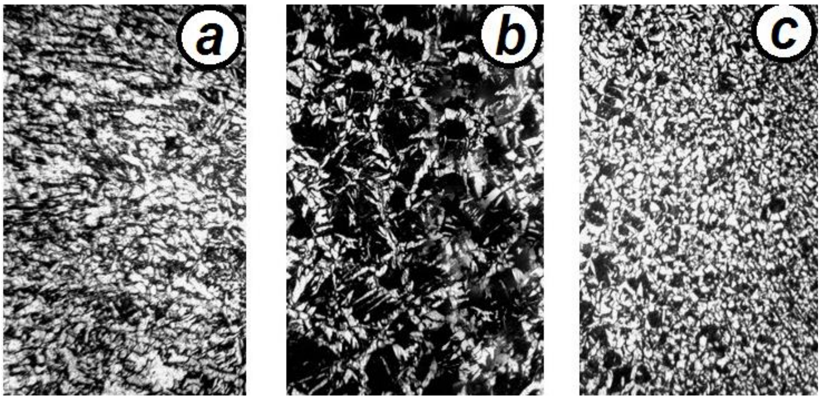


Figure 1. Microstructure of 19Г steel welded joint (×100):
a – base metal, b – heat treatment zone, c – seam metal

Taking into account one type of the investigated steels the microstructure of the gas-pipeline welded joint is similar according to the dispersion degree and the ratio of the ferrite and perlite content (Fig. 2).

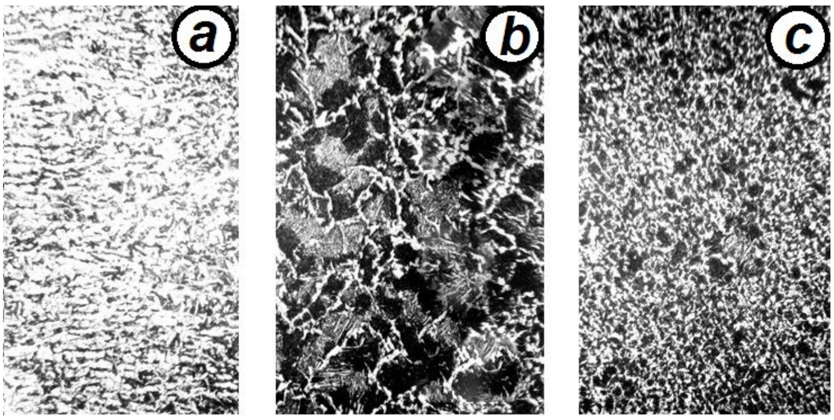
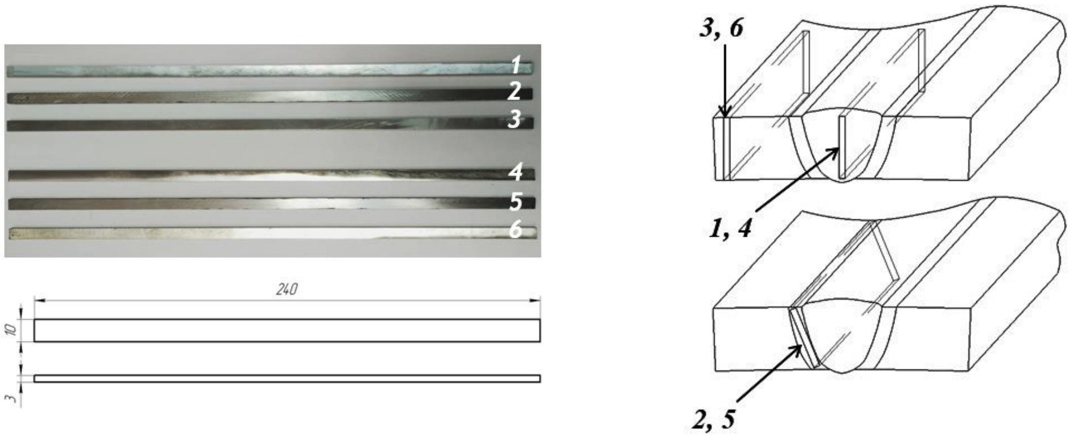


Figure 2. Microstructure of 17Г1С steel welded joint (×100):
a – base metal, b – heat treatment zone c – metal seam

The authors of the papers [2, 3] analyzed the effect of different microstructure features on the material domain structure, that is why, taking into account the WJ cross-section structural inhomogeneity, some experimental investigations have been carried out to determine dependencies in the specimens from different WJ areas using the MAE method of investigation. In Fig. 3 general view of specimens and their cut-out points are presented.



a *b*

Figure 3. General view of the investigated samples and their sizes (a) and cut-out points from the fragment of pipes with longitudinal weld joint (b): 1, 4 – metal seam, 2, 5 – heat treatment zone, 3, 6 – base metal

From the dependences obtained from the experimental results the difference between the amplitudes sum of the MAE signal ΣA_i for the specimens cut out from the three main areas of the oil (Fig. 4) and gas pipelines (Fig. 5) welded joints.

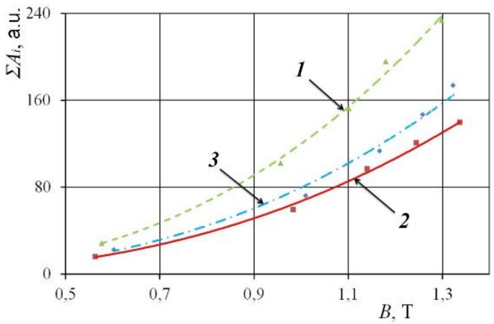


Figure 4. Dependence of the amplitudes sum of the MAE signal on amplitudes of magnetic field induction *B* in specimens from different zones of weld joint of 19Г steel:
1 – seam metal, 2 – heat treatment zone,
3 – base metal

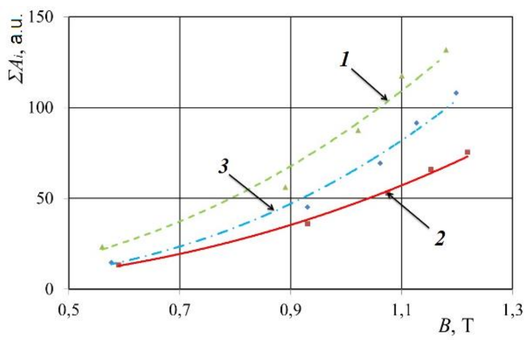


Figure 5. Dependence of the amplitudes sum of the MAE signal on amplitudes of magnetic field induction *B* in specimens from different zones of weld joint of 17Г1С steel:
1 – weld joint, 2 – heat treatment zone,
3 – base metal

According to the literature data [7 – 10] the 90˚ domain walls being the main MAE source are located along the grain boundaries. Thus, when the other factors in the metal structure of the higher dispersion degree and, correspondingly, greater total boundary length are not available, the number of the MAE signal will be increased, and as a result of it the amplitude sum.

Under the constant induction amplitude of the remagnetized field *B* the greatest values of the amplitude sum ΣA_i are found for the specimens of the welded joint (Fig. 4, 5, curve 1). In the specimens of the HAZ the lowest values ΣA_i are fixed (Fig. 4, 5, curve 3). It is caused by structural transformations in the ferromagnet because of the high temperatures while welding, which result in the change of the domain structure of the material [3].

The process of forming the welded joints is specified by such peculiarities: specific shape of joints and seams, available stress concentrators, stress state inhomogeneity, mechanical properties inhomogeneity, appearance of technological defects and sufficient residual stress while welding. It was decided to investigate the possibility to find the residual stresses degree in WJ taking advantage the MAE method at the long-term operation structures, the main pipelines with the longitudinal welds in particular. In Fig. 6 the scheme of the experiment is presented. The HEM was moved perpendicular to the 50mm pitch weld seam axis under constant induction *B* (0,3 T) in the magnetic wire cross-section and the change of the amplitudes sum of the MAE signals by the acoustic emission transformer.

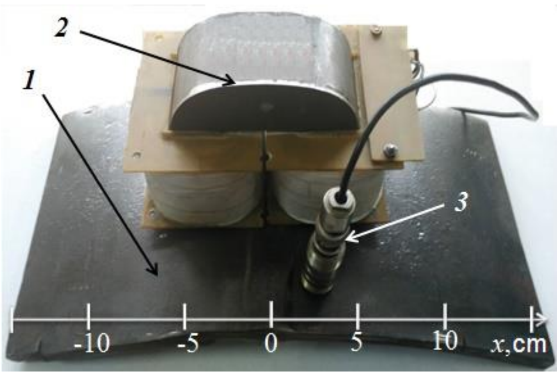


Figure 6. General view of the study plate with welded joints: 1 – investigated plate, 2 – AEM, 3 – acoustic emission transducer. Dimensions of the plate: 300 × 150 × 10 mm

To eliminate the residual stresses the relaxing annealing was performed at the temperature T = 500 – 550 ˚C during 2 hours and the plate together with the furnace were cooled.

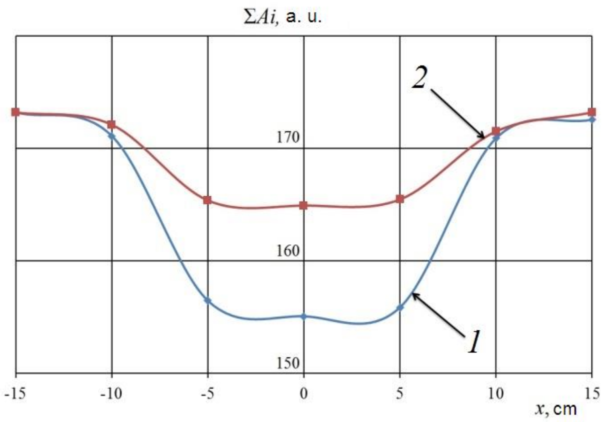


Figure 7. Change of the amplitudes sum of the MAE signals from the position of the NEM on the plate with a welded joint of 19Г steel (the axis of the joint coincides with the axis of the ordinate):
1 – plate in the output (stressed) state,
2 – after annealing

In Fig. 7 the dependence of the amplitudes sum of the MAE signals on the NEM position on the investigated specimen with the residual stresses (curve 1) and after its elimination (curve 2). As it is seen from the graphs the area with the seam metal, HAZ and the area of the heat deformation effect is specified by the MAE signals of lower amplitudes than those with the base metal. This difference is caused by the formation of the additional barriers resulted by the material stresses, which prevent the jump-like displacement of the furnace walls. The possibility to apply the MAE method for finding the stress state at the WJ control structure threshold is confirmed by the MAE events activity after the procedure of the residual stresses elimination has been introduced. It should be noted, that even if the microstructural inhomogeneity of the metal is revealed, the available residual stresses resulted in the structural factor effect levelling.

Conclusions. The investigations testified, that the MAE method is effective enough for the investigation of the welded elements of the ferromagnetic structures of long-term operation. It is shown, that the grain size of the WJ metal structure effects the MAE signals parameters: the higher dispersion degree, is the higher is the intensity and the amplitudes sum.

According to the results of investigation of the residual stresses it was found, that MAE method is effective (sensitive) to the stress state in the material and is characterized by the decrease of the MAE signals intensity, which makes possible to identify the pipe wall areas, in which elastic deformations and stresses have been initiated during its operation.

References

1. Krechkovs'ka H.V., Yanovs'kyy S.R., Student O.Z., Nykyforchyn H.M. Fraktohrafichni oznaky ekspluatatsiynoyi dehradatsiyi zvarnykh z"yednan' mahistral'nykh naftohoniv, Fiz.-khim. mekhanika materialiv, 2015, vol. 51, no. 2, pp.21 – 27 [in Ukrainian].
2. Shybata M., Ono K. Mahnetomekhanichna akustychna emisiya – novyy metod vymiryuvannya neruynivnoho napruhy, NDT International, 1981, vol. 14, no. 5, pp. 227 – 234.
3. Nazarchuk Z.T., Andreykiv O.Ye., Skal's'kyy V.R. Otsinyuvannya vodnevoyi dehradatsiyi feromahnetykiv u mahnetnomu poli., K.: Nauk. dumka, 2013, 272 p. [in Ukrainian].
4. Mel'guj M.A. Magnitnyj kontrol' mexanicheskix svojstv stalej, Minsk: Nauka i texnika, 1980, 184 p. [in Russsian].
5. Mixeev M.N., Gorkunov E'.S. Magnitnye metody strukturnogo analiza i nerazru-shayushhego kontrolya., M.: Nauka, 1993, 252 p. [in Russsian].
6. Nazarchuk Z.T., Skal's'kyy V.R., Pochaps'kyy Ye.P. Tekhnolohiyi vidboru ta opratsyuvannya nyz'koenerhetychnykh diahnostychnykh syhnaliv., Kyiv, Nauk. dumka, 2014, 304 p. [in Ukrainian].
7. Guyot M., Cagan V. The magneto-acoustic emission (invited), J. Appl. Phys., 1993, vol. 73, no. 10, pp. 5348 – 5353.
8. D. H. L. Ng, C. C. H. Lo, Jakubovics J.P. The effects of demagnetizing and stray fields on magnetoacoustic emission, J. Appl. Phys., 1994, vol. 75, no. 10, pp. 7009 – 7011.
9. D. H. L. Ng, C. C. Yu, C-D. Qin et al. The dependence of magnetoacoustic emission on magnetizing frequency in nickel and mild steel, J. Appl. Phys., 1996, vol. 79, no. 8, pp. 6057 – 6059.
10. Ye. Pochaps'kyy, N. Mel'nyk Otsinyuvannya peremishchen' domennoyi stinky u feromahnetnykh materialakh za diyi zovnishn'oho mahnetnoho polya, Visnyk TNTU, Ternopil', 2015, no.3, vol. 79, pp. 102 – 109 [in Ukrainian].

Список використаної літератури

1. Фрактографічні ознаки експлуатаційної деградації зварних з’єднань магістральних нафтогонів [Текст] / Г.В Кречковська, С.Р. Яновський, О.З. Студент, Г.М. Никифорчин // Фіз.-хім. механіка матеріалів. – 2015. – 51, № 2. – С. 21 – 27.
2. Shibata M., Ono K. Magnetomechanical acoustic emission – a new method for non–destructive stress measurement // NDT International. – 1981. – 14, № 5. – P. 227 – 234.

3. Назарчук, З.Т. Оцінювання водневої деградації феромагнетиків у магнетному полі. [Текст] / З.Т. Назарчук, О.Є. Андрейків, В.Р. Скальський – К.: Наук. думка, 2013. – 272 с.
4. Мельгуй, М.А. Магнитный контроль механических свойств сталей. [Текст] / М.А. Мельгуй – Минск: Наука и техник. 1980. – 184 с.
5. Михеев, М.Н. Магнитные методы структурного анализа и неразру-шающего контроля. [Текст] / М.Н. Михеев, Э.С Горкунов. – М.: Наука, 1993. – 252 с.
6. Назарчук, З.Т. Технології відбору та опрацювання низькоенергетичних діагностичних сигналів. / [Текст] З.Т. Назарчук, В.Р. Скальський, Є.П. Почапський – К.: Наук. думка, 2014. – 304 с.
7. Guyot M. The magneto-acoustic emission (invited) [Text] / M. Guyot, V. Cagan // J. Appl. Phys. – 1993. – 73 (10). – P. 5348 – 5353.
8. Ng D. H. L. The effects of demagnetizing and stray fields on magnetoacoustic emission [Text] / D. H. L. Ng, C. C. H. Lo, J.P. Jakubovics // J. Appl. Phys. – 1994. – 75 (10). – P. 7009 – 7011.
9. The dependence of magnetoacoustic emission on magnetizing frequency in nickel and mild steel [Text] / D. H. L. Ng, C. C. Yu, C-D. Qin et al. // J. Appl. Phys. – 1996. – 79 (8). – P. 6057 – 6059.
10. Почапський, Є.П. Оцінювання переміщень доменної стінки у феромагнетних матеріалах за дії зовнішнього магнетного поля [Текст] / Є. Почапський, Н. Мельник // Вісник ТНТУ. – Тернопіль. – 2015. – 3 (79). – С. 102 – 109.

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ДІАГНОСТУВАННЯ ПОЗДОВЖНІХ ЗВАРНИХ З’ЄДНАНЬ ТРУБ МЕТОДОМ МАГНЕТОПРУЖНОЇ АКУСТИЧНОЇ ЕМІСІЇ

Євген Почапський; Богдан Клим; Мар’ян Рудак; Петро Великий

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***Резюме**. Досліджено мікроструктуру сталі 19Г та 17Г1С труб після довготривалої експлуатації. Встановлено залежність зміни параметрів сигналів магнетопружної акустичної емісії від структури різних зон зварного з'єднання. Досліджено вплив залишкових напружень після зварювання на зміну суми амплітуд сигналів магнетопружної акустичної емісії.*

***Ключові слова**: магнетопружна акустична емісія, трубопровід, зварні з’єднання, мікроструктура, залишкові напруження.*

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